Hay and Baleage Shortcourse 2018

University of Georgia Cooperative Extension
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For more information, visit www.georgiaforages.com.

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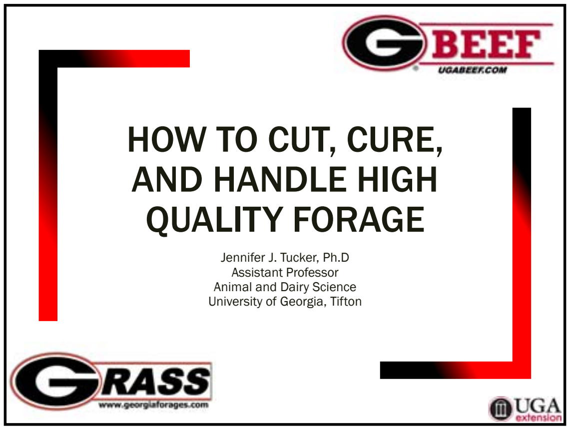
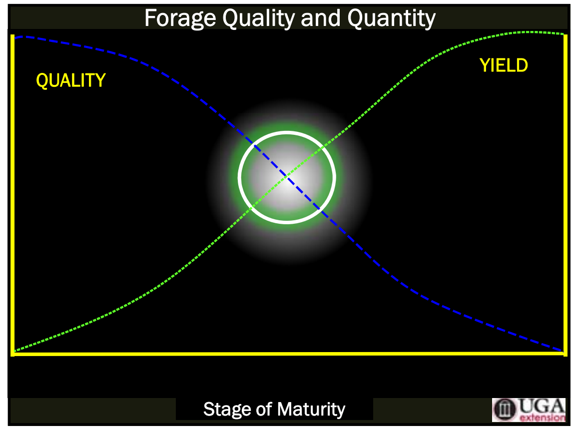
GRASS

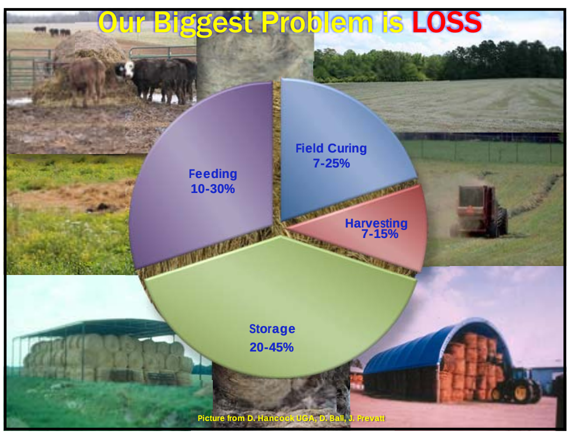
HOW TO CURE AND HANDLE HIGH QUALITY HAY

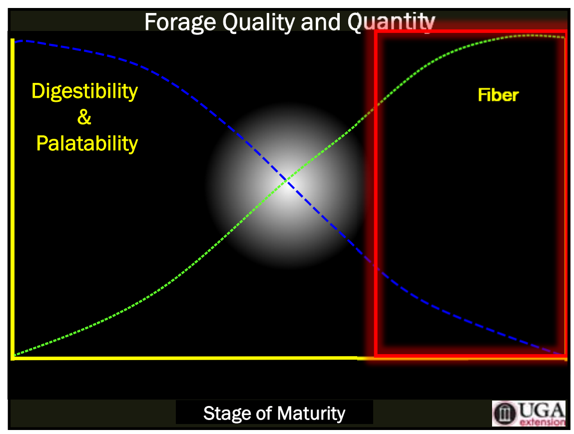
Dr. Jennifer Tucker, Asst. Professor, Animal and Dairy Scientist

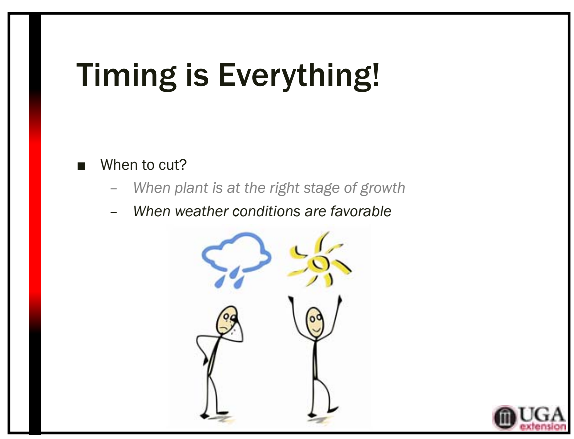
How to Cut, Cure, and Handle Hay











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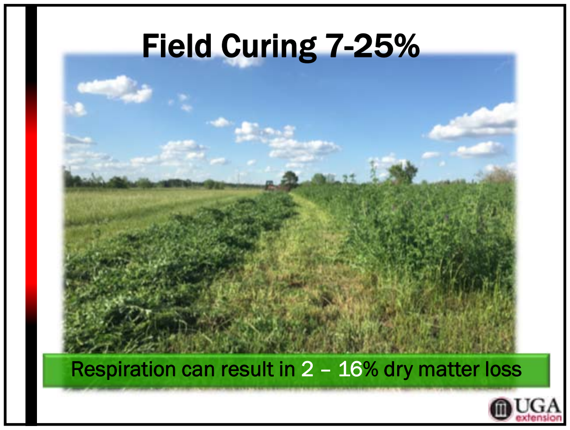
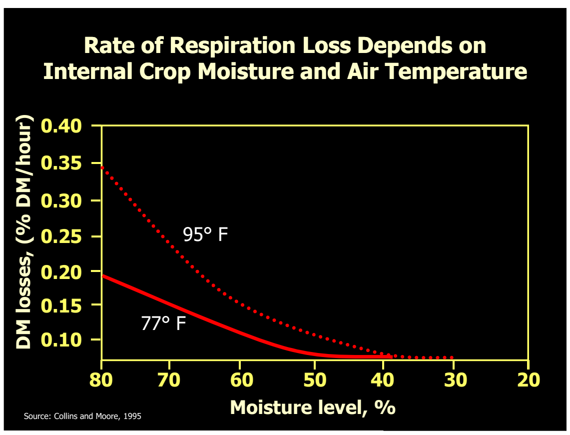


The effect of rain during curing on hay losses[1] .

Loss	Alfalfa			Red Clover		
	No rain	2" rain during curing	3" rain on dry hay	No rain	2" rain during curing	3" rain on dry hay
	(%)					
Leaf loss	8.8	16.4	14.7	10.5	16.8	20.4
Leaching and respiration loss	1.3	27.7	39.1	0.5	32.5	34.7
Total loss	10.0	44.0	53.8	11.0	49.2	55.1

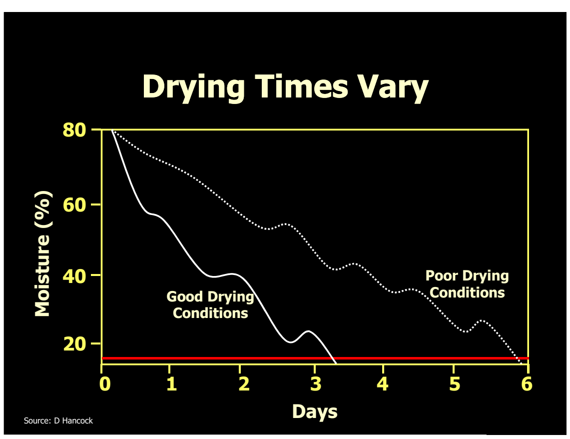
[1] percent of initial dry matter
Source: M. Collins. 1983. Agronomy Journal. 75:523.



Should I cut or should I wait?

- Late hay making can result in extensive loss
  - *Loss in quality and digestibility*
  - *Wilting losses in the swath*
  - *Increased leaf shatter*
- Wilting and shattering losses are always proportionally higher with late-cut than with early-cut forages.

Source: M. Collins, Making and Storing Quality Hay

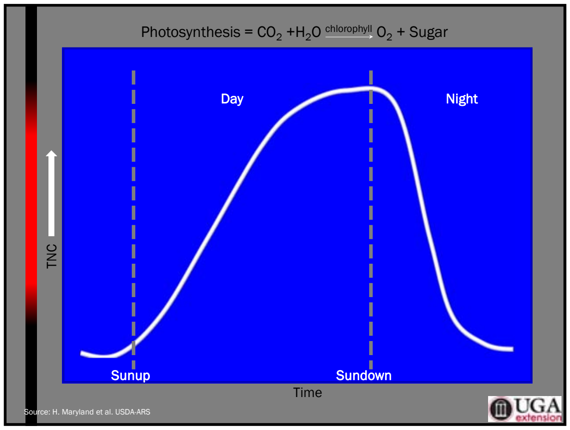


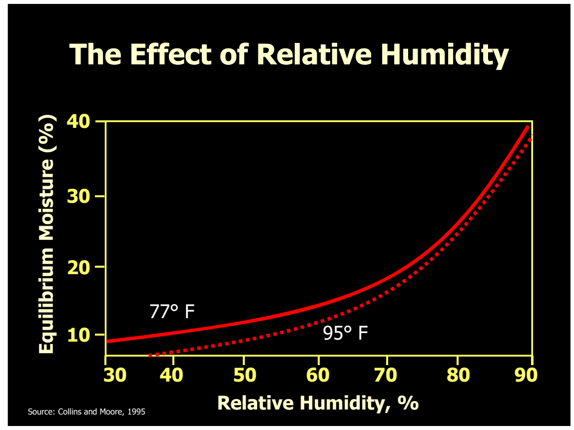
Timing is Everything!

- When to cut?
  - *When plant is at the right stage of growth*
  - *When weather conditions are favorable*
- Morning or evening?

Dr. Jennifer Tucker
Assistant Professor, Animal Scientist

How to Cut, Cure, and Handle Hay



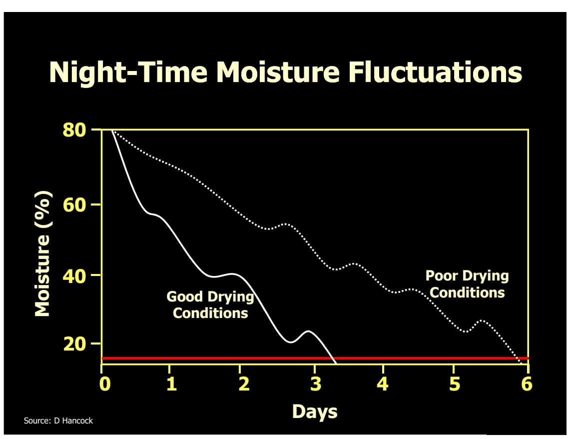


Timing is Everything!

- When to cut?
  - *When plant is at the right stage of growth*
  - *When weather conditions are favorable*
- Morning or evening?
  - *Morning – the forage is wetter but you get a full day of drying time*
  - *Evening – the forage is dryer, but the energy level may be greater due to increased carbohydrate concentrations in the plant material*

Timing is Everything!

- When to cut?
  - *When plant is at the right stage of growth*
  - *When weather conditions are favorable*
- Morning or night?
  - *Morning – the forage is wetter but you get a full day of drying time*
  - *Evening – the forage is dryer, but the energy level may be greater due to increased carbohydrate concentrations in the plant material*
- When to rake, ted, and bale?
  - *When the moisture content is just right!*



To be Timely you need to Be Prepared!

- Have the equipment maintained and ready
  - *It's better to be waiting on the plant, than to be working on a mower when the plant and weather are ready to go!*

Dr. Jennifer Tucker
Assistant Professor, Animal Scientist

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How to Cut, Cure, and Handle Hay

Harvesting 7-15%

- Leaf losses can be high during baling operations (1-15%)
- Losses with conventional balers can range from 8-15%

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Mower Options

- Sickle Cutterbar
  - *10-20% less expense*
  - *Require 30% less hp*
  - *Repairs are less expensive*

- Disk Cutterbar
  - *Faster ground speed*
  - *Cuts through ant hills better*
  - *Maintenance is 20-30% less*
  - *Better if crop is lodged*

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Using hay crimpers or crushers (conditioners)leads to reduced:

- Dry matter loss
- Curing time in the swath
- Exposure to the weather
- Leaf shattering and respiration losses

Crushing Stems (conditioning) at mowing will cause stems to dry at nearly the same rate as leaves!

Source: J. Henning, Making and Storing Quality Hay

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MOWING

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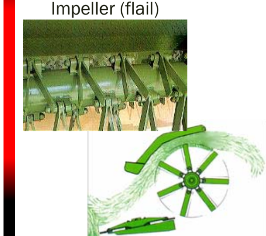
Conditioner Styles

Impeller (flail)



Fine stemmed grass

Roller (crimper)

Thick stemmed grass and Leafy (legumes)

Source: D Hancock

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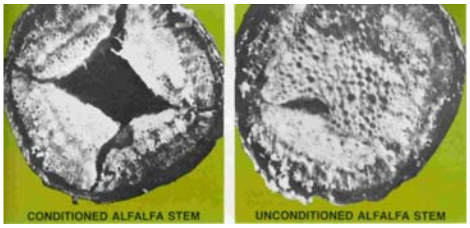
Cross Section of Crop Stem



- Stems have a waxy surface called cutin
- Conditioning should scratch or crack the stem surface for faster drying

Source: D Hancock

RAKING

TEDDING

- Parallel bar rake
  - The lowest amount of hay loss, particularly with legumes.
  - Usually ground drive system.
- Rotary rakes
  - Some are dual function (rake or ted).
- Wheel rakes
  - Operated at a higher speed (saves time)
  - Tend to leave more in the field.

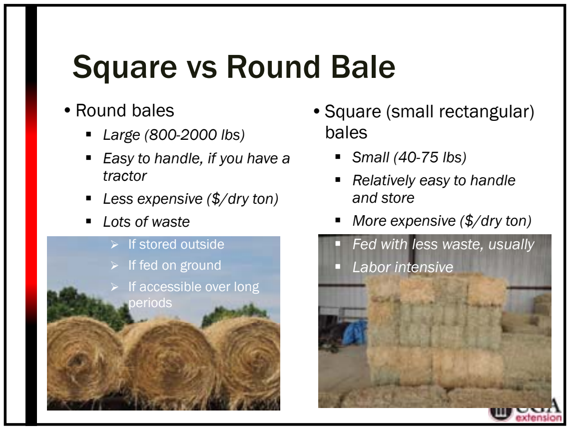
Source: D Hancock

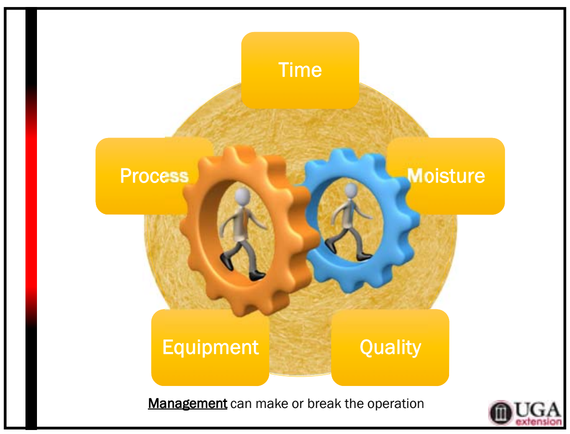
- Increase hay-drying rates by 20-40% (~ 0.5 – 1 day)
- DM Loss: Grasses (<3%) Legumes (7-10% +)
- Breaks up clumps & distributes the crop over the entire area.
  - *Increased sun*
  - *Fluffed for better air movement*
- Initial tedding: w/in 2-4 hrs (clumps break better)
- Additional tedding? May be necessary for grass, probable for alfalfa

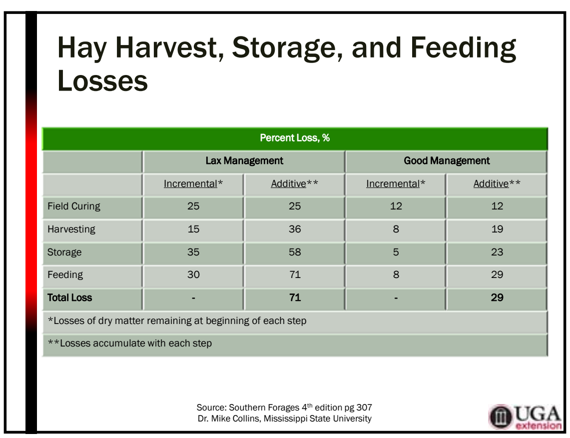
Photo Source: D Hancock and farmingmagazine.com

BALING

How to Cut, Cure, and Handle Hay







Percent Loss, %				
	Lax Management		Good Management	
	Incremental*	Additive**	Incremental*	Additive**
Field Curing	25	25	12	12
Harvesting	15	36	8	19
Storage	35	58	5	23
Feeding	30	71	8	29
Total Loss	-	**71**	-	**29**

*Losses of dry matter remaining at beginning of each step

**Losses accumulate with each step

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How to Cut, Cure, and Handle Hay

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UT Extension

SP437-A

High-quality Hay Production

Gary Bates, Professor, Plant Sciences

When pasture growth is limited, some type of stored feed must be provided to grazing animals. Hay is one of the most versatile stored feeds available because:

1. Accumulated forage from periods of excess growth can be cut for hay, which minimizes waste.
2. It can be stored for long periods of time with little loss in nutritional value if protected from weather.
3. It can be produced and fed in large or small amounts.
4. It can be produced and fed either mechanically or manually.
5. It can supply the nutrient requirements of most classes of livestock.
6. A large number of crops can be used to produce hay.

Since hay is such a widely used stored feed, it is important to understand the factors that influence hay quality and the criteria used to evaluate hay quality. This information can then be used to develop a feeding program that will be the most effective and efficient in meeting each producer's goals.

Importance of Hay Quality

Hay quality is usually measured by the amount and availability of nutrients contained in the hay. The estimation of protein, fiber and digestibility of a hay can all be used to determine quality. The ultimate test of hay quality, however, is animal performance. Quality can be considered satisfactory when animals consuming the hay perform as desired. Three factors which influence animal performance are:

1. **intake**—hay must be palatable if it is to be consumed in adequate quantities to produce the desired performance.
2. **digestibility and nutrient content**—once the hay is eaten, it must be digested and converted to animal products.
3. **toxic factors**—the hay must be free of components that are harmful to the animals.

Factors Affecting Hay Quality

There are many factors that will influence hay quality, some of which can be manipulated by the producer. These are:

A. Plant species
B. Stage of maturity
C. Curing and handling conditions
D. Soil fertility
E. Seed quality

Plant species - The species of forage will have a large impact hay quality. Legumes are generally higher quality than grasses, and cool-season grasses such as tall fescue and orchardgrass are higher quality than warm-season grasses like bermudagrass (Table 1). Within each class there can be a wide range of quality, however. When properly cut, a mixture of a grass and legume usually produces high-quality hay. Perennials such as alfalfa, orchardgrass, timothy, fescue, bermudagrass, etc. are usually more economical as hay crops than annuals, although annuals such as sorghum-sudangrass hybrids, pearl millet, small grains and ryegrass can be used effectively.

Stage of maturity when harvested - As grasses and legumes advance from the vegetative to the reproductive (seed) stage, they become higher in fiber and lower in protein, digestibility and palatability. Forage quality deteriorates rapidly as the forage matures, even though yield continues to increase (Table 2). Within each forage species, the most important factor that affects hay quality and the one where the greatest improvements can be made is stage of maturity. The optimum stage of maturity for harvest of many hay crops is listed in Table 3.

Table 1. Yield, crude protein (CP), and total digestible nutrient (TDN) content of various hay crops[1].

Forage species	Yield (ton/acre)	CP (%)	TDN (%)
alfalfa	3-6	17-22	57-62
orchardgrass	2-5	12-15	55-60
tall fescue	2-4	10-15	55-60
rye	1-4	8-10	50-55
ryegrass	1-4	10-16	56-62
bermudagrass	5-8	10-14	52-58
johnsongrass	2-5	10-14	50-60
pearl millet	2-6	8-12	50-58

[1] dry matter basis
Adapted from: D.M. Ball and co-workers. 1991. Southern Forages.

Table 2. The effect of age of Tifton-44 bermudagrass hay on yield and quality[1].			
Cutting Interval	**Yield**	**Crude Protein**	**Digestibility**
	(lb DM/acre)	(%)	(%)
1 week	8539	19.8	61.8
2 weeks	8603	17.0	62.2
4 weeks	8197	14.1	61.3
8 weeks	13329	9.7	54.3

[1] dry matter basis
Source: W. Monson and G. Burton. 1982. Agronomy Journal. 74:371

Table 3. Recommended stage to harvest various forage crops.	
Forage Species	**Time of Harvest**
alfalfa	Bud stage for first cutting, 1/10 bloom for second and later cuttings. For new spring seedings, allow the first cutting to reach full bloom.
orchardgrass, timothy, tall fescue	Boot to early head stage for first cut, every 4-6 weeks thereafter.
red clover, crimson clover	Early bloom to 1/2 bloom.
wheat, rye, ryegrass, oats, barley	Boot to early head stage.
white clover	Cut at correct stage for companion grass.
sudangrass, sorghum hybrids, pearl millet and johnsongrass	40-inch height or early boot stage, whichever comes first.
bermudagrass	15- to 18-inch height for first cutting, every four weeks thereafter.

Table 4. Effect of stage of maturity at harvest of timothy on hay quality[1], animal intake[1] and milk yield.					
Stage at Harvest	**Crude Protein**	**Acid Detergent Fiber**	**Intake**	**Intake**	**Milk**
	(%)	(%)	(lb DM/day)	(% of body wt)	(lb/day)
late boot	11.3	35.9	33.3	2.84	37.5
late bloom	5.4	42.1	24.3	2.17	20.1

[1] dry matter basis
Source: Vinet and co-workers. 1980. Canadian Journal of Animal Science. 60:511

Table 5. Effect of stage of maturity at harvest on alfalfa hay quality[1].			
Stage at Harvest	**Crude Protein**	**Acid Detergent Fiber**	**Digestibility**
	(%)	(%)	(%)
pre-bloom	21.1	30.2	63.3
early bloom	18.9	33.0	62.4
mid-bloom	14.7	38.0	55.4
full bloom	16.3	45.9	53.2

[1] dry matter basis
Source: Kawas and co-workers. 1990. Journal of Animal Science. 68:4376.

As plant maturity advances, increased fiber levels and decreased crude protein and digestibility result in a drop in dry matter intake and milk production by cows consuming the hay (Tables 4 and 5). The nutrient needs of gestating cows can be met by feeding hay. As more mature hay is used, however, the reduced nutrient content and digestibility of the hay results in the need for an increased level of grain supplementation for cows to maintain their body condition and rebreed after calving.

Curing and handling conditions - After mowing, poor weather and handling conditions can lower hay quality. Rain can cause leaf loss and nutrient leaching from plants during curing (Table 6). Sunlight can reduce Vitamin A content through bleaching. Raking dry, brittle hay can cause excessive leaf loss.

Table 6. The effect of rain during curing on hay losses[1].						
	Alfalfa			Red Clover		
Loss	no rain	2" rain during curing	3" rain on dry hay	no rain	2" rain during curing	3" rain on dry hay
	(%)	(%)	(%)	(%)	(%)	(%)
leaf loss	8.8	16.4	14.7	10.5	16.8	20.4
leaching and respiration loss	1.3	27.7	39.1	0.5	32.5	34.7
total loss	10.0	44.0	53.8	11.0	49.2	55.1

[1] percent of initial dry matter
Source: M. Collins. 1983. Agronomy Journal. 75:523.

Crushing stems (conditioning) at the time of mowing will cause stems to dry at nearly the same rate as leaves. Conditioning has been shown to decrease the drying time of large-stemmed plants approximately one day and result in less leaf and nutrient loss. Plants with an 80 percent moisture content must lose approximately 6,000 pounds of water to produce a ton of hay at 20 percent moisture. Raking while hay is moist (40 percent moisture) and baling before hay is crisp (at 18 percent moisture) will help reduce leaf losses.

Soil fertility - Adequate amounts of lime, nitrogen, phosphate, potash and certain minor elements are needed to produce high yields of hay. Maintaining a high level of fertility will also help to maintain the stand of desirable plants and prevent weed encroachment. A soil test should be used as a guide in determining the amount of fertilizer and lime needed for economical hay production.

High yields of hay remove large amounts of nutrients. Since properly inoculated legume plants are capable of fixing atmospheric nitrogen, mixtures containing more than 30 percent legumes usually do not give economic responses to nitrogen fertilization. With pure grass stands, nitrogen must be added for high levels of production.

Seed quality - Plant certified seed of a recommended variety. This will ensure the use of quality seed of a variety adapted to local conditions. Fall seedings should be made early enough for establishment before cold weather stops or slows growth. Late winter and early spring seedings should be made early enough to provide a vigorous stand which can survive summer drought and weed competition.

Table 7. Score card for visual hay quality evaluation.			
Characteristic	**Description**	**Range**	**Score**
I. Stage of Harvest	1. Before blossom or heading 2. Early blossom or early heading 3. Mid-to-late bloom or head 4. Seed stage	26-30 21-25 16-20 11-15	
II. Leafiness	1. Very leafy 2. Leafy 3. Slightly stemmy 4. Stemmy	26-30 21-25 16-20 11-15	
III. Color	1. Natural green color of crop 2. Light green 3. Yellow to slightly brownish 4. Brown or black	13-15 10-12 7-9 0-6	
IV. Odor	1. Clean - "crop odor" 2. Dusty 3. Moldy - mousey or musty 4. Burnt	13-15 10-12 7-9 0-6	
V. Softness	1. Very soft and pliable 2. Soft 3. Slightly harsh 4. Harsh, brittle	9-10 7-8 5-6 0-4	
		subtotal	
VI. Penalties	1. Trash, weeds, dirt and other foreign material	subtract 0-35	
SCORING	> 90 Excellent hay 80 - 89 Good hay 65 - 79 Fair hay < 65 Poor hay	**TOTAL**	

Clean seed (seed free of weed contamination) is important, especially when planting perennial hay crops. Weeds generally reduce hay quality by adding material lower in palatability and digestibility, while some may be harmful or toxic. Certified seed insures quality.

Evaluating Hay Quality

Chemical evaluation - The most reliable way to determine hay quality is through chemical analysis. The Soil, Plant and Pest Center in Nashville, part of University of Tennessee Extension, can analyze a sample of hay for crude protein, fiber and total digestible nutrients. These results can be used to assess quality and to determine type and amount of supplementation needed for the desired level of animal production. Accuracy depends on obtaining a representative sample, which usually requires the use of a core sampler. Determining hay quality and matching the quality to different classes of livestock based on nutrient requirements can lead to a more efficient forage-livestock program. Contact your local Extension office for more information concerning forage testing.

Visual evaluation - Although not as reliable as forage testing, a visual estimate can be helpful in determining forage quality. A guide for visual evaluation is given in Table 7. Learning what to look for in high quality hay will help in determining when to cut hay, and will give a guide for the relative ranking of hays. High quality hay is early cut, green, soft, leafy, free of foreign material and has a pleasant odor.

Producing high-quality hay should be a goal of each cattle producer. Feeding high-quality hay during periods of reduced pasture growth can result in better weight gain in calves, and better milk production and rebreeding in cows. Feeding high-quality hay can also reduce the level of grain supplementation needed during winter. Cutting hay early, proper fertilization and cutting when the hay will not get wet will allow cattle producers to get higher-quality hay and more efficient use of pastures.

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a U.T. Extension Reminder…

Forage Testing Information

Sampling Information

Results and recommendations are no better than the sample submitted for testing. Please follow the sampling suggestions below for best results.

How much is needed? Approximately 1/2 gallon of sample (forage or grain) should be sent for an adequate test.

How to sample:

Hay – obtain samples from approximately 10 bales. Best samples are obtained with the use of a forage sampling probe. Check with your local Extension office about the availability of these samplers. For square bales, take one core from one end of each bale. For round bales, take a sample from each side of the bales. If grab samples are taken, be sure to obtain a representative sample.

Silage or haylage – if haylage is in round bales, follow the same procedures as for round baled hay. If haylage or silage is chopped, then obtain 2-3 gallons of material from 10-15 places in the silo. For upright silos, run unloader and collect one sample per minute for several minutes. In both situations, mix all of the collected material together, then fill sample bag with this mixture. Be sure to seal bag to ensure correct moisture determination.

Grain – obtain several small samples from different areas of the bin or storage area. Mix as listed above. Commercial feeds should not be submitted.

Mailing Information

1. Seal the plastic bag containing the sample to be tested.
2. Put name and sample number on bag. Sample number is important for identification during the laboratory process, especially when more than one sample is submitted.
3. Be sure the name, address and sample number on information sheet correspond to information on the bag.
4. For each sample to be tested, there is a $10 charge for the basic test. Make check payable to "The University of Tennessee." Place checks and forms in an envelope and mail separately.
5. Submission forms and other information can be found at *www.soilplantandpest.utk.edu*
6. Mail samples to:

Soil, Plant and Pest Center
5201 Marchant Dr.
Nashville, TN 37211-5850
(865) 832-5850

Visit the UT Extension Web site at
http://www.utextension.utk.edu/

07-288 SP437-A -3.5M-7/07 E12-5115-00-001-08

MEASURING THE MOISTURE CONTENT OF FORAGE USING A MICROWAVE OVEN

1. Chop fresh forage into short lengths (< 1 inch) for ease of handling and uniform drying.
2. Weigh out at least 100 grams (3.5 ounces) of chopped forage.
3. Spread forage thinly on a microwave-safe dish and place into microwave. (A cup of water placed in the microwave beside the sample will help prevent the sample from igniting once dry.)
4. Heat for 1-2 minutes and reweigh.
   - If forage is not completely dry, shake and redistribute the sample, and repeat the heating cycle until the sample reaches a stable weight. (Microwaves vary considerably in drying capacity. It is better to dry for short intervals and reweigh until the last two weights are constant, than to overdry and run the risk of burning and damage to oven.) If charring occurs, use the previous weight.
5. Calculate moisture content using the following equation:

$$\% \text{ Moisture Content} = \frac{W1 - W2}{W1}$$

Where: W1 = weight of forage before heating
W2 = weights of forage after heating

Dry matter (DM) is the percentage of forage that is not water. DM equals 100% minus the % Moisture Content.

Adapted from: Southern Forages 4th Edition, Page 303

HAY

Prevention of Hay Fires

by Dr. Don Ball, Extension Agronomist/Professor, Department of Agronomy and Soils, Auburn University, AL 36849.

Every year a few hay producers who have the unfortunate experience of having part or all of their hay destroyed by fire. There is no way to be absolutely certain that all possibility of a fire has been eliminated, but several precautions can be taken that are helpful in reducing the likelihood of a hay fire.

External Source Fires

Decisions pertaining to storage can have a big influence on the likelihood of accidental fires. Bale stackyards should not be located in places where a fire is most likely to occur. For example, they should not be adjacent to a wire fence or under a tree that might attract lightening. Similarly, they should not be at the edge of a grass field that might catch fire and burn. Keeping stackyards away from roads where a careless smoker might toss a cigarette is also a good idea.

It is best to have several bale stackyards rather than just one as this reduces the risk of a wildfire destroying all hay on the farm. The same principle applies to barn storage if one has the option of storing hay in more than one place.

If hay is stored in a barn, it is prudent to eliminate combustible vegetation and trash around the edge of the barn that could cause the structure and its contents to catch fire in the event of a wildfire in the vicinity. Likewise, spraying a nonselective herbicide to kill vegetation around the edge of a bale stackyard makes sense. Posting “No Smoking” signs around a barn is desirable, and use of fireworks in the vicinity of a hay barn or stackyard should never be permitted.

Spontaneous Combustion

Spontaneous combustion can occur in hay if it is baled at too high a moisture level. The general recommendation is that small rectangular bales should be baled at 20% moisture or less and that large round bales should be baled at 18% moisture or less The exception to this is when a hay preservative such as proprionic acid is applied to the hay prior to bailing. When this is done, hay may be safely baled at 25 percent moisture or higher.

Heating of hay is caused by the activity of microorganisms. Dry hay does not heat excessively because it lacks the necessary moisture to support any significant microbial growth. The microorganisms that cause heating are naturally present on forage and they will become active if conditions are suitable.

Spontaneous combustion is more likely to occur in tightly baled hay as opposed to loosely baled hay, and packing newly made bales tightly together in a barn also makes it more difficult for heat to escape. However, there could be danger anytime the recommended moisture levels for baling are exceeded, although if the moisture level is no more than a few percent higher than recommended it is likely that the main negative result will be moldy hay. The higher above recommended levels that the moisture level goes, the greater the likelihood of extreme heating and fire.

Monitoring Bale Temperature

Anytime a producer suspects that there might be an overheating problem, monitoring of hay after baling will be a good idea. If large bales that are ultimately to be stored inside are heating excessively, delaying putting them in the barn for a few weeks may save the hay and a barn. Spacing suspect bales widely to allow heat and moisture to escape (as well as to reduce the likelihood of losing several bales instead of just on in the event one does catch fire) is advisable. Putting green hay against dry hay should always be avoided.

Several types of thermometers can be used to check temperature in hay, including laboratory thermometers, candy thermometers, or thermometers made for monitoring compost. However, it is not a good idea to insert glass thermometer directly in hay because it is likely to break. Spirit filled thermometers or electronic thermometers should be used rather than mercury filled thermometers that could contaminate hay if they break.

Hay temperature can be checked by making a probe. Such a probe can be made from a piece of 2-inch diameter pipe on which one end has been sealed with a sharpened plug. The pipe can then be driven into a stack or large bale of hay followed by lowering of a thermometer into the pipe. If there is concern about a cutting of hay, multiple readings should be taken at various locations and/or in different bales to determine the temperatures throughout the hay.

If a bale contains reasonably uniform moisture and density throughout the bale, the highest temperature is likely to be near the middle of the bale because this is where heat will remain for the longest period of time. Square (rectangular) bales should be probed from the side and round bales should be probed from the end.

A temperature probe should be long enough to reach the middle of the bale (normally 18 to 36 inches, depending on the size and type of bale). Checking every bale usually isn't feasible, so it makes sense to monitor bales that seem most likely to cause a problem. This would be bales that seem to contain the wettest hay.

When hay temperature remains below 120 degrees Fahrenheit it is considered safe. The range between 120 and 140 degrees is considered a caution zone in which the hay should be closely monitored. Even if the hay does not catch fire, heating to this level reduces the nutritional value of the hay. If the temperature rises to 160 or above, a fire is likely.

Research has shown that the maximum heating of hay usually occurs within one week of baling. Three weeks is normally considered the maximum length of time after baling that the highest temperature resulting from microorganism-induced heating would occur. Thus, putting hay into permanent storage after three weeks should be safe.

Sources of Thermometers

Thermometers that are suitable for checking temperature in hay can be found at many locations including farm supply stores, hardware stores, and heating and air conditioning suppliers. In addition, there are numerous catalog or internet sources,

Examples are as follows:

Ever Ready Thermometer Co., Inc
2555 Kerper Blvd.
Dubuque, IA 52001
Phone: (800) 553-0039
Fax: (563) 589-0516
http://www.ertco.com/index.html

Gempler's
P. O. Box 44993
Madison, WI 53744
(800) 382-8473
http://www.gemplers.com

JHL Supply
P. O. Box 720
Fulton, NY 13069
(800) 537-1339
Fax: (315) 592-4796
http://www.hvactool.com/index.php3

Omega Engineering, Inc.
P.O. Box 4047
One Omega Drive
Stamford, CT 06907-0047
(800) 826-6342
http://www.omega.com

Lesman Instrument Co.
215 Wrightwood Ave.
Elmhurst, IL 60126-1112
(800) 953-7626
http://www.lesman.com/index.html

NASCO – Fort Atkinson
901 Janesville Avenue
P.O. Box 901
Fort Atkinson, WI 53538-0901
(800) 558-9595
Fax: (920) 563-8296
http://www.nascofa.com/prod/home

Conclusion

Hay is a commodity that readily burns, and hay fires are costly. Hay production is difficult and stressful enough under the best of circumstances, but it is particularly tragic to see one's hay crop literally go up in smoke. A little knowledge, common sense, and simple precautions can go a long way toward reducing the likelihood of a hay fire.

<< top

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Extension Service
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Forage Management

Ed Rayburn, Extension Forage Agronomist January 2002

PROPER HANDLING AND CURING OF HAY[1]

Hay made from the best-adapted species and fertilized properly can still result in suboptimal forage if not properly handled and cured. Haymaking is an art, and understanding the science behind it can help us become better artists.

Haymaking serves two main purposes:

- To conserve excess forage during the spring flush for use when forage growth is slower or nonexistent.
- To produce a cost-effective, nutritional livestock feed.

This paper will cover the basic tasks in haymaking and some of the management considerations needed to be taken to better achieve these two purposes.

Mowing

The first task is to choose when to start making hay. Forage yield and quality are covered in Hay Quality vs Hay Quantity (Fact Sheet 5817). When high-quality hay is needed, the harvest must start at an early growth stage, such as late boot to very early head in grasses and late bud to early bloom in legumes. In mixed grass-legume stands, the decision for the first cut should be based on the grass since the grasses usually mature earlier than the legume. Aftermath harvests should then be based on the legume growth stage. Where only moderate quality is needed and yield is the primary goal, then take the first cut when the grass is at early head to early bloom stage.

For most livestock farms having different classes of animals, some of which need high-quality forage and some of which can do with lower-quality forage, it is most practical to start harvesting early in the season, realizing that there will usually be enough later-cut, lower-quality hay. Then store the early-cut hay separately from the late-cut and feed the hay to the animals based on forage quality and animal need.

The next question is, should hay be cut early or late in the day? In the last few years, it has been reported that hay should be cut when the sugar and starch or total nonstructural carbohydrate (TNC) is highest in the plant. The TNC content of a plant is at its lowest at sunrise since the plant used carbohydrates for respiration during the night and could not fix sugar through photosynthesis. At sunrise, the plant can start photosynthesis to fix sugar, allowing the TNC concentration to increase through the day and reaching a peak in late afternoon around 6 P.M. (1800 hr) (Fig. 1). It is reported that hay made when the TNC is at the high point results in higher animal forage intake and performance. On the other hand, there is a problem. Cutting hay late in the day results in forage not drying very much before nightfall. During the night, TNC is lost by respiration. This loss increases with forage moisture and air temperature, as shown in Fig. 2. If hay at 70% moisture (700 g/kg) going through a cool 68°F night (20°C) it will lose TNC at a rate of 0.15 % of total DM per hour. However, hay at the same moisture going though a warm 86°F (30°C) night would lose TNC at 0.25% of the dry matter per hour. In the cool environment, the loss is 1.8% units TNC; in the warm environment, the loss is 3.0% units TNC. With a 2.5% daily range in plant TNC (Fig. 1), this means that with cool nights we can get a net gain but on warm nights we get a net loss in hay

[1] Presented at the Virginia Forage and Grassland Council Meeting. January 11, 2001, Verona, Virginia

TNC content. Much greater gains in forage TNC content can be achieved by harvesting hay at an earlier date or by increasing the legume content in the stand.

Figure 1. The time of day that forage is cut affects the amount of sugars and starches, expressed as total nonstructural carbohydrates (TNC), in forage (Smith 1975).

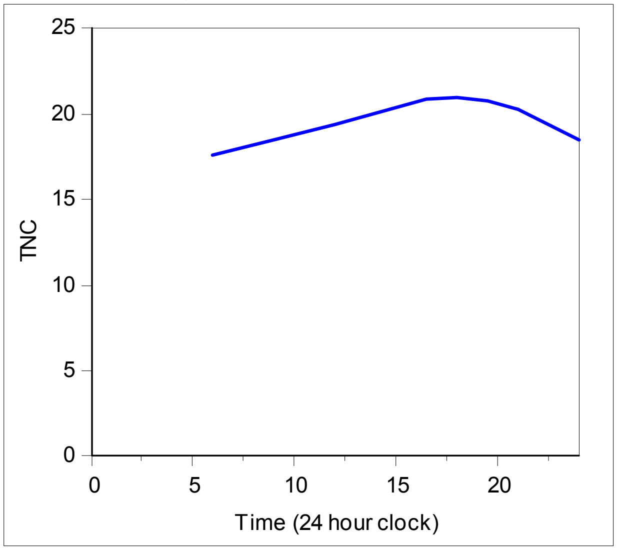
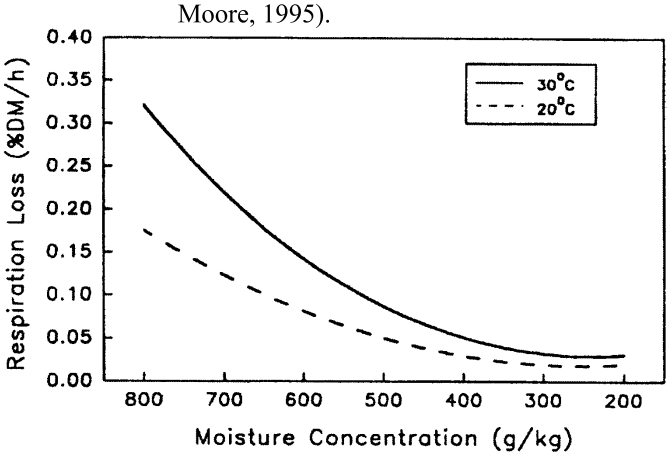


Figure 2. Respiration loss from hay curing in the field is proportional to the forage moisture content and air temperature (Collins and Moore, 1995).



It is practical to start mowing after the dew has dried off. This is about 10 A.M. on hilltops in West Virginia. By this time, the TNC in the hay is on the increase. Also, the dew on the plant's surface will dry quicker if the plant is standing than it will in the swath if cut too early. If harvesting a large acreage for hay, some of what is cut will be later in the day when the TNC is higher. When the weather is warm, the earlier cut hay will dry to a point that reduces the nighttime respiratory loss of TNC.

When mowing to make dry hay, set the mower to make as wide a swath as possible. This exposes more of the forage to the drying effects of the sun and wind.

A few words on what type of mower is "best." A person can cut more acres per hour with less maintenance downtime with a disk mower than a sickle bar mower. A mower-conditioner will crimp hay stems so that the hay dries faster and can be baled sooner than if a mower without conditioning roles is used. However, a new disk mower is more expensive than a sickle bar mower, and a mower conditioner is more expensive than a mower. Which to use comes down to the size of the haying operation, the local economic situation, and the preferences of the owner. When reliable custom operators are available, it is often more practical for the small operation to use their services rather than owning and making the hay on their own.

Tedding

Some resent research on hay tedding implies that it does not allow hay to dry any quicker. When looking at average hay moisture, this may be true. However, the value in tedding is to turn the swath and allow forage that was on the bottom or in clumps to come to the top and dry better, resulting in more uniform drying and reducing wet spots in the hay. On the other hand, if hay is tedded when it is too dry or if it is tedded too often, leaves will be broken off, causing a loss in forage quality and yield. The leaves are the part of the plant with the highest protein and digestibility.

In most cases hay should be tedded once. However, if the mower cannot be set to get an open swath, tedding the day of mowing may be warranted.

Tedding should usually be done the morning after the hay is mown. Tedding in the morning, after the dew is off but while the hay is tough, reduces leaf loss. When the hay's moisture content is above 50%, leaf loss is kept below 5% of dry matter (Fig. 3). Even on the second morning after mowing, the hay will usually be in the 50%-60 % dry matter range, as shown in Fig 4. This is because when the nighttime humidity approaches 90%-100% the equilibrium moisture content of hay approaches 50% (Fig. 5). This means that dry hay gets tough (takes up moisture) when the humidity increases. Those experienced in haymaking have seen this on evenings when they baled later in the day than they wanted.

Figure 3. The effect of forage moisture on dry matter loss during raking of alfalfa hay (Collins and Moore, 1995).

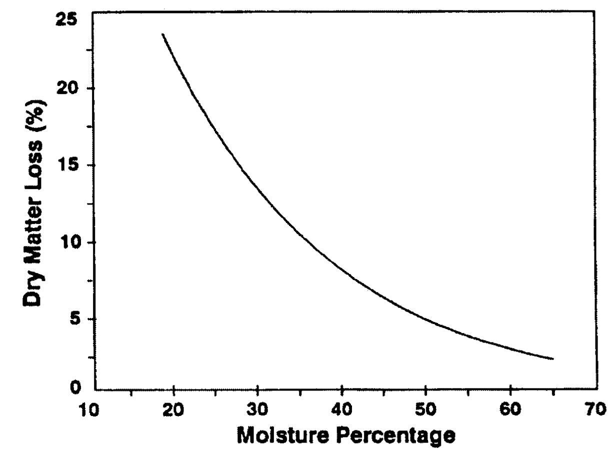
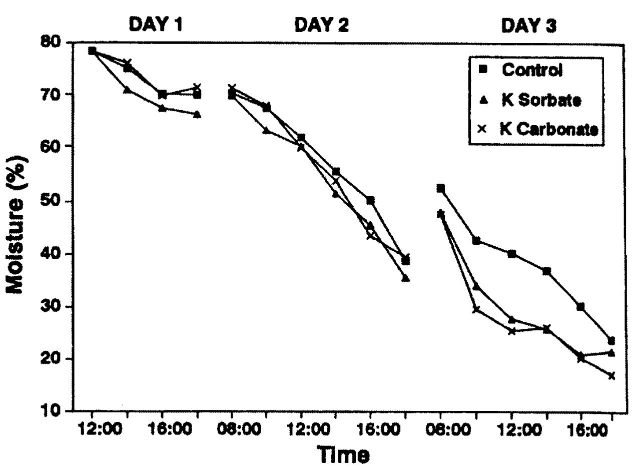
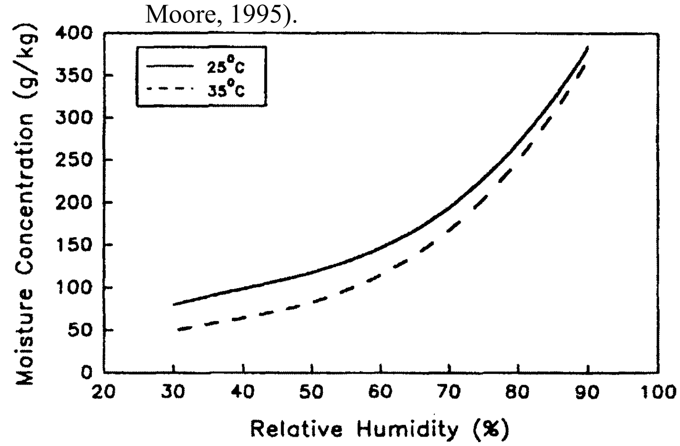


Figure 4. The effect of two drying aids on the loss of moisture from alfalfa during drying (Collins and Moore, 1995).



When purchasing a tedder, look at the total operation cost. A tedder that works two swaths requires half the machinery and labor time to work a field compared to a less expensive, one-swath tedder. Most tedders are light so the tractor size and fuel needed will be little more with the larger tedder.

Figure 5. Equilibrium moisture content of hay is proportional to the relative humidity in the air and the air temperature (Collins and Moore, 1995).



Raking

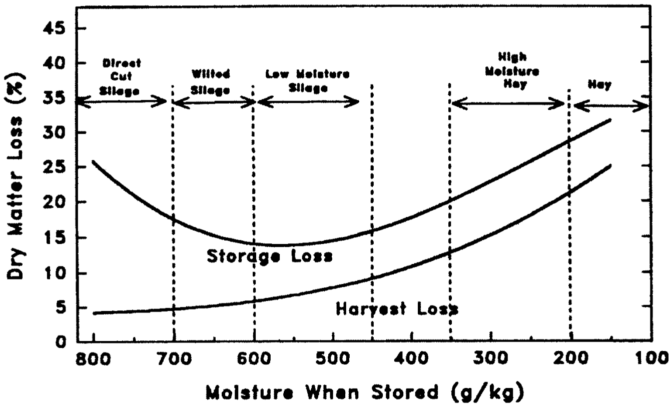
Raking the hay into a windrow allows for increased drying before the hay is baled. There are several new rake technologies that increase the openness of the windrow for drying. It is important to rake in a manner that will minimize leaf loss. The same principles that apply to tedding hold for raking. Raking when the hay is tough but not wet with dew will reduce leaf loss. Also, using rakes that handle the hay more gently or slowing the speed of the rake, if it is working the hay too hard, are ways to reduced leaf loss.

Baling

Making hay crop silage in plastic-wrapped big round bales is very popular. This technique allows adding a relatively low-cost silage option to an operation that already makes large round bales. By making balage, a producer can reduce dry hay losses but may have some silage storage losses if not managing carefully. When hay is baled at higher moistures, leaf loss is reduced. If moisture is too high, storage loss by seepage will occur (Fig 6). This happens even in wrapped bales due to daytime evaporation and nightime condensation when bales are exposed to the sun. In a silo, seepage loss is due to compression by the weight of silage in the upper part of the silo.

If hay is almost dry enough to put up without wrapping, it is too dry to wrap. In this situation, the hay will not ensile properly and harmful bacterial may grow, causing health problems and possible livestock death.

Figure 6. The effect of forage moisture at ensiling or haying on harvest and storage losses (Collins and Moore 1995).



Balage does not increase the quality of forage. Late-cut hay is still late-cut hay. Making balage can reduce the risk of rain damage, but quality hay made as balage still must be harvested at an early maturity stage.

Drying Agents and Preservatives

Drying agents and preservatives are other technologies that should be looked at closely to see if they have economic value. Drying agents are useful on legumes but not on grasses. They allow the water to dry from the legume forage faster, making it possible to bale the hay a few hours sooner (Fig 4). Preservatives allow the hay to be baled at a higher moisture content without molding and spoiling. The practical and economic value of both of these technologies depends on local product availability and cost and on the economics of the hay's planned use.

Conclusion

Hay can be a low-cost, high-quality conserved feed. Proper management is necessary to achieve this. Early harvest of hay containing legume will produce the highest quality hay. Good recycling of manure made from hay feeding and using legume-fixed nitrogen will reduce the cost of hay production by reducing the need for purchased fertilizers. Harvesting at the correct stage of growth and enhancing drying by judicious tedding and raking will help optimize forage quality.

New technologies also can be of great use in forage management. But not all of them will improve the bottom line on all farms. When purchasing technology for haymaking determine the following:

- your livestock's feed requirement,
- the local economic value of improved animal performance,
- the local economic value of increased forage yield,
- the quality and yield of hay being put up now,
- the increase in quality and yield provided by the new technology.

From this, you can determine the likeihood of a new technology increasing your net income or farming satisfaction.

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Moore, L.A. 1962. Grass-legume silage. *IN*. Forages - the science of grassland agriculture. H.D. Hughes, M.E. Heath, D.S. Metcalfe (ed). Second Edition. The Iowa State Univ. Press. Ames, Iowa.

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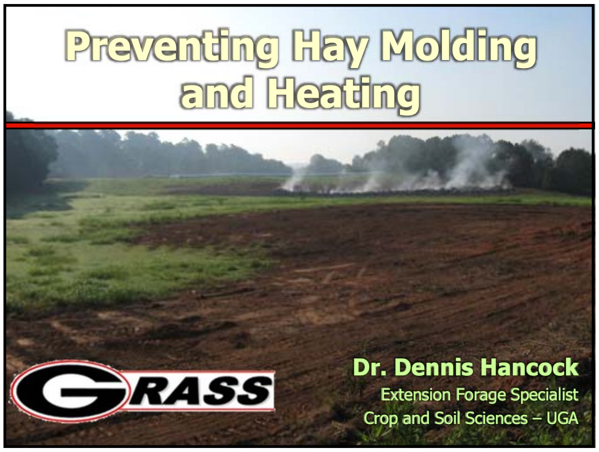
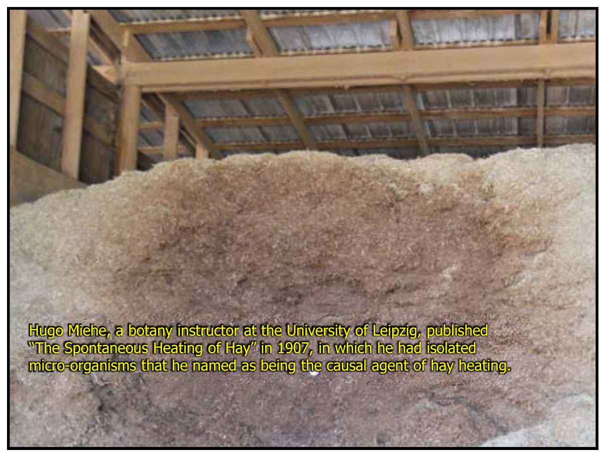
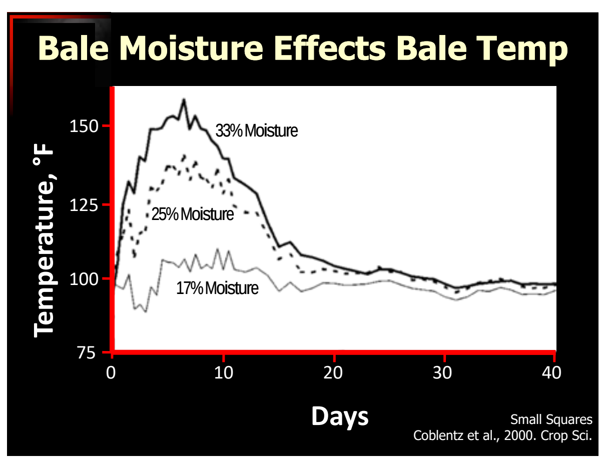
Preventing Hay Molding and Heating

Dr. Dennis Hancock, Extension Forage Agronomist

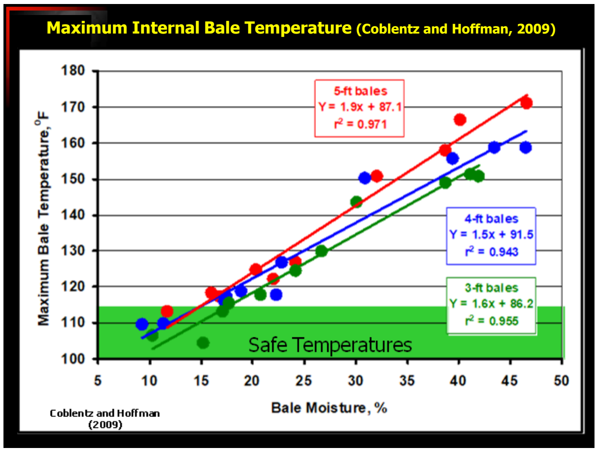
Preventing Hay Molding and Heating

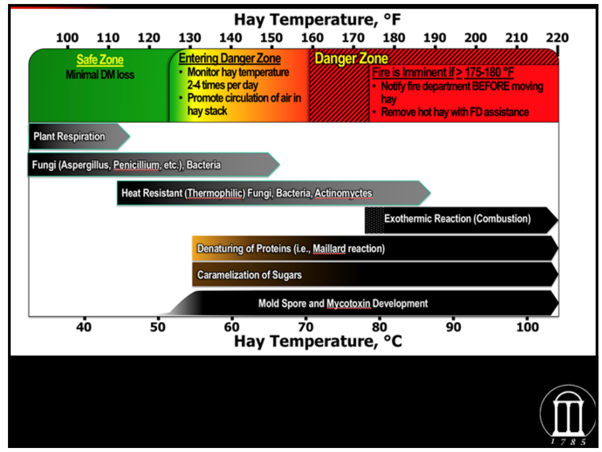


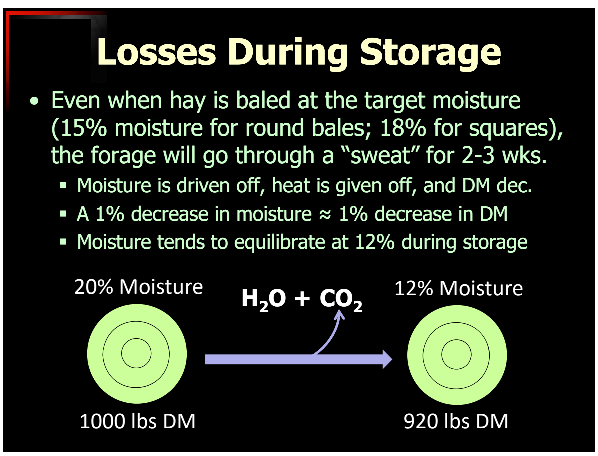


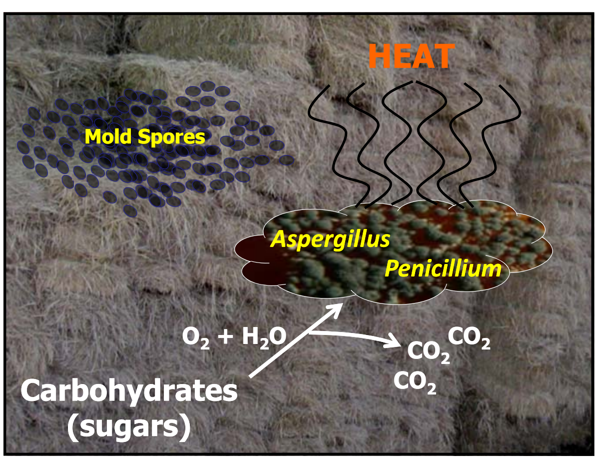


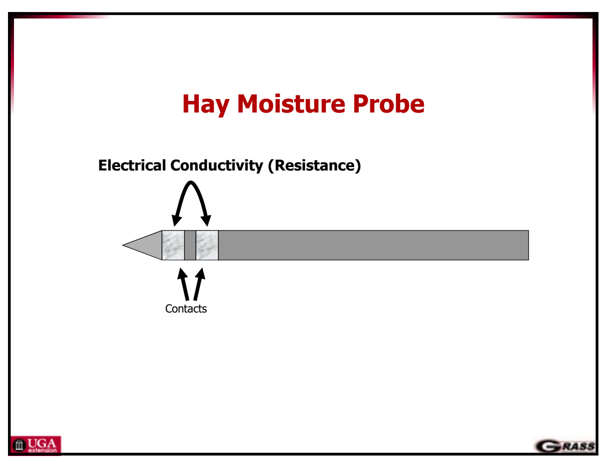
Preventing Hay Molding and Heating



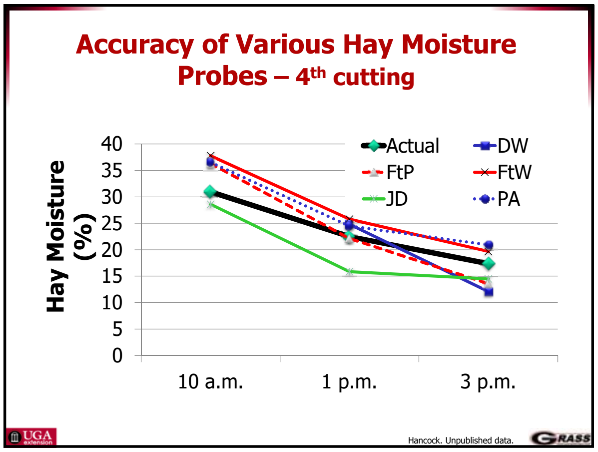


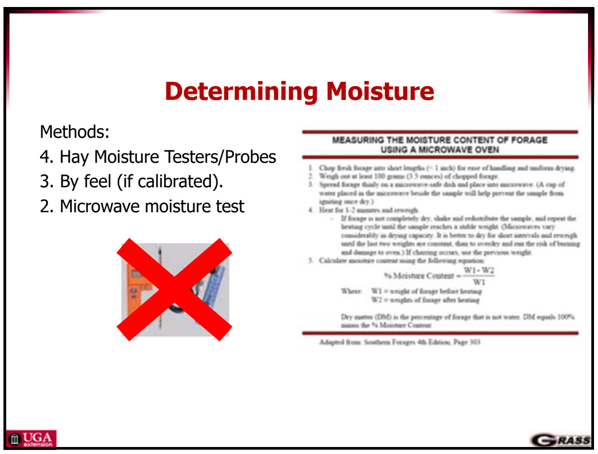


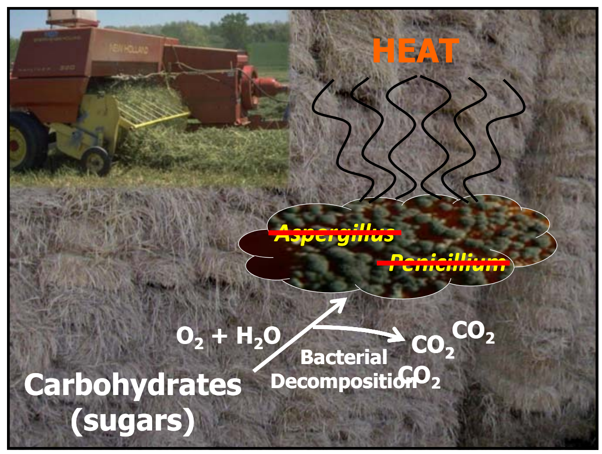


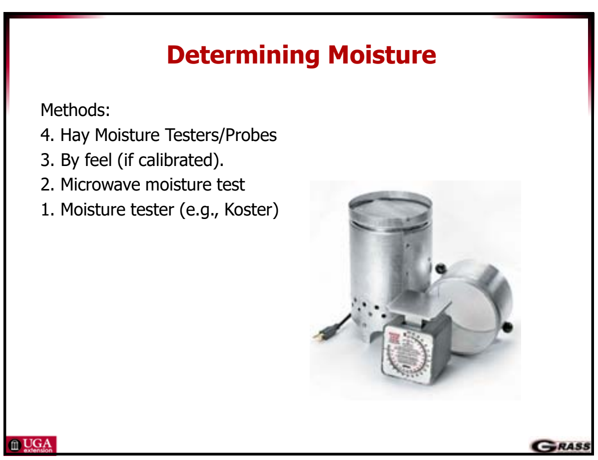


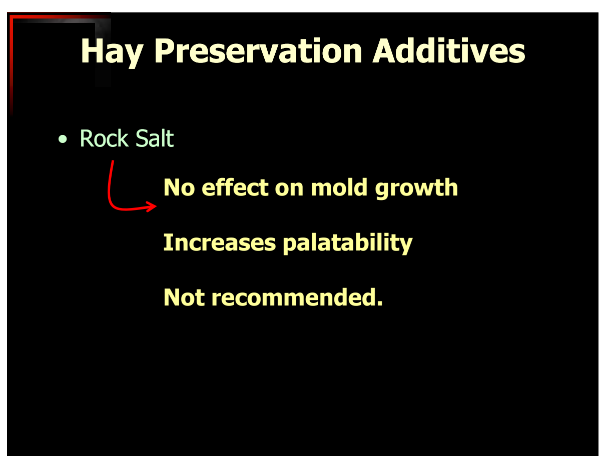
Preventing Hay Molding and Heating











Preventing Hay Molding and Heating

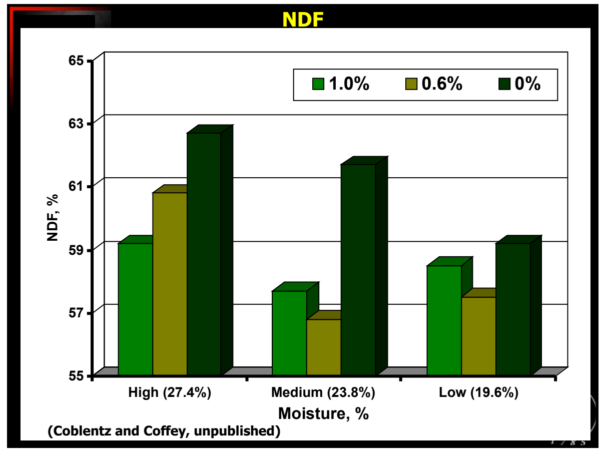
Hay Preservation Additives

- Organic acids
- Buffered acids

Prevents heating, but maintains moist environment for microbial activity.

DM losses often offset DM gains.

Beneficial when moisture is 18 – 25%

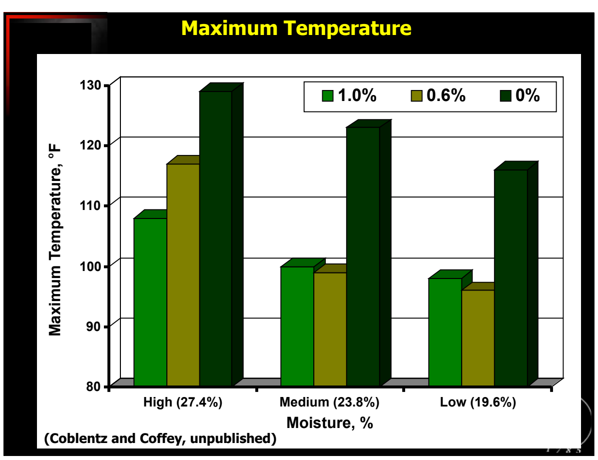


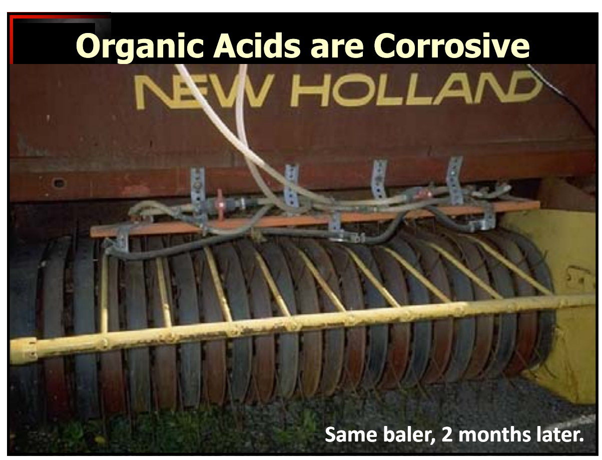
Preservatives

Application of Propionic Acid Preservative[1] to Large Square Bales[2] of Alfalfa/Orchardgrass Hay (Coblentz and Coffey, unpublished)

Group	Moisture	Volume	Wet Weight	Dry Weight	DM Density
	%	*ft³*	*lbs*	*lbs*	*lbs DM/ft³*
High	27.4	40.7	644	467	11.5
Medium	23.8	40.7	626	476	11.8
Low	19.6	42.1	613	494	11.7
SEM	0.80	0.39	9.3	10.4	0.20

[1] Rates: 0, 0.6, or 1.0% of fresh weight.
[2] Large square bales were 3 x 3 x 6 ft.





Preventing Hay Molding and Heating

Hay Preservation Additives

- Bacterial/microbial inoculants

Those tested have no consistently demonstrable effect.

Some **have had inconsistent effects** (some positive, some no change).

Effectiveness in Humid South is questionable (high humidity)

Requires real-time moisture measurement (rate adjustment)

Heat Damaged Forages: Effects on Forage Energy Content

by **Wayne Coblentz, Patrick Hoffman, Dan Undersander**

Introduction

Traditionally, the effect of heat damage within forages has focused on reduced bioavailability of crude protein (**CP**) to ruminant animals as a result of Maillard reactions. The products of these reactions are the result of complex, multi-step pathways. Typically, the initial step of Maillard reactions involves the merging of certain plant carbohydrates (often sugars) with protein (amino acids). The undesirable consequence of this reaction is that forage proteins become less digestible to dairy cows or replacement heifers. However, recent research has shown that losses of energy from heated hays are perhaps more important. This Focus on Forage will highlight new perspectives on energy losses from heated forages.

How is Forage Energy Calculated?

For many years, empirical equations based on a single forage component (often ADF) have been used to predict concentrations of total digestible nutrients (**TDN**). These types of equations are still in limited use today because they are convenient, and require only minimal laboratory inputs; however, their accuracy for specific forages can vary dramatically based on a wide variety of factors, one of which is heat damage. Over the last decade, most public and private forage-testing laboratories have adopted the summative approach for estimating TDN in forage samples (NRC, 2001). The theory behind this approach is relatively simple; laboratories analyze forages and other feedstuffs for a wide range of nutritional components, apply a digestibility coefficient to each, and then sum the products to obtain a TDN value for the forage. This summative concept is summarized below:

TDN = truly digestible nonfiber carbohydrate (**TD-NFC**) + truly digestible crude protein (**TD-CP**) + truly digestible NDF (**TD-NDF**) + [truly digestible fat (**TD-FAT**) x 2.25] – metabolic correction factor.

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In this expression, the metabolic correction factor is based on extensive research and is a numerical constant equal to 7 percentage units of TDN. Typically, concentrations of fat in forages are very low. The most important truly digestible components summed to determine the final estimate of TDN for any forage are TD-NFC, TD-CP, and TD-NDF.

How does spontaneous heating affect truly digestible nonfiber carbohydrate?

Nonfiber carbohydrate (**NFC**) is comprised primarily of plant sugars. In summative equations, the digestibility coefficient applied to NFC is 0.98. In practical terms, this implies that the digestibility of NFC is nearly complete. Therefore, it is critically important to conserve NFC throughout any harvest and storage process. Spontaneous heating occurs in moist hays when either the microflora attached to the hay or still-functioning plant cells oxidize sugars during the process of respiration, yielding carbon dioxide, water, and heat. In research trials, heating is often measured as heating degree days > 86^{o}F (**HDD**), which is a single number that integrates both the magnitude and duration of spontaneous heating during storage. A thorough summary of spontaneous heating in hays, as well as the calculation of HDD is available at: www.uwex.edu/ces/crops/uwforage/HeatDamage-FOF.pdf

Figure 1 illustrates the relationship between the change in TD-NFC during storage (poststorage – prestorage; ΔTD-NFC) and HDD for alfalfa-orchardgrass hays made in large-round bales. To provide a practical perspective, the heating within these bales ranged from no visual evidence of heating to pockets of blackened, charred hay within the interior of the bale. Over this wide range of spontaneous heating, the maximum depression of TDN associated with losses of TD-NFC was about 6.2 percentage units, or about 25% of the original TD-NFC. It also is important to note that much of this response occurred within a rather limited range of heating, indicating that even minor heating is accompanied by a measureable reduction in the energy available from the hay.

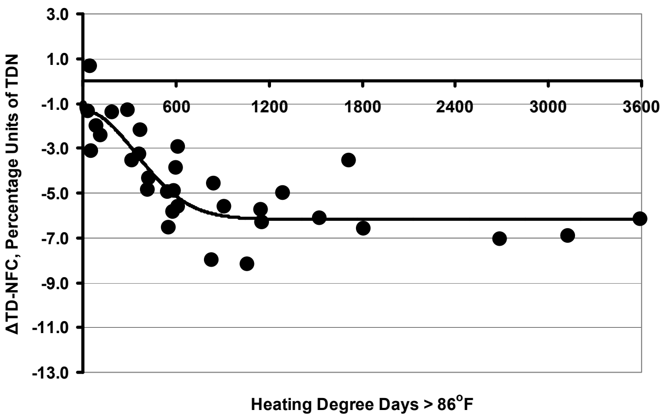

Figure 1. Relationship between the change in TD-NFC (poststorage – prestorage; ΔTD-NFC) and HDD for large-round bales of alfalfa-orchardgrass hay. The mean prestorage TD-NFC was 25.6%, which corresponds generally to ΔTD-NFC = 0 on the y-axis. (Coblentz and Hoffman, 2010)

How does spontaneous heating affect digestible protein?

In the summative model, truly digestible crude protein (**TD-CP**) is estimated from the expression CP x $e^{-1.2 \times [ADICP/CP]}$, where acid-detergent insoluble crude protein (**ADICP**) is used to adjust CP digestibility. The rather complicated multiplier ($e^{-1.2 \times [ADICP/CP]}$) serves as the digestibility coefficient for CP, and approaches 1.0 in unheated, high-quality hays. Oftentimes, it is arbitrarily assigned a value of 0.93 in order to avoid laboratory determination of ADICP, which is both cumbersome and expensive. This is a reasonable approximation for most dairy feeding applications, but it is less acceptable for heated forages. Across the range of heating depicted for alfalfa-orchardgrass hays made in large-round bales (Figure 2), this calculated digestibility coefficient ranged from 0.94 in unheated hays to a low of 0.76 for bales incurring the most severe heating. Overall, the relationship between changes in TD-CP (poststorage – prestorage; ΔTD-CP) and HDD can best be explained as a nonlinear decline in which the maximum depression in severely heated hays was about 2.6 percentage units of TDN.

How does spontaneous heating affect fiber (NDF) digestibility?

Unlike the other component parts of the summative model, truly digestible NDF (**TD-NDF**) can be determined by two distinctly different methods. One approach (**TD-NDF$_{lig}$**) requires inputs of lignin, NDF, and quantification of residual CP in the NDF residue. The main advantages of this method are that it requires only laboratory inputs, and it does not require rumen fluid or a fistulated donor animal. The main

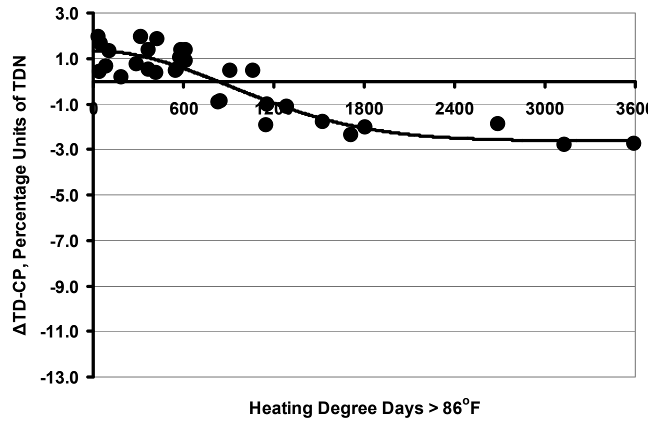

Figure 2. Relationship between the change in TD-CP (poststorage – prestorage; ΔTD-CP) and HDD for large-round bales of alfalfa-orchardgrass hay. The mean prestorage TD-CP was 16.8%, which corresponds generally to ΔTD-CP = 0 on the y-axis. (Coblentz and Hoffman, 2010)

disadvantage is that acid-detergent lignin is challenging to quantify, and its determination has been associated historically with very poor laboratory repeatability. When forages (hay or silage) heat spontaneously, many Maillard reaction products are generated that are recovered as lignin; therefore, concentrations of lignin are associated very closely and positively with HDD. In recent studies (Figure 3), lignin concentrations increased during storage by about 73% in severely heated hays.

An alternative method for determining TD-NDF requires inputs of NDF and a 48-hour in vitro determination of digestible fiber (**NDFD; see** **www.uwex.edu/ces/crops/uwforage/NDFDig.html**). The product of these inputs (**TD-NDF$_{ndfd}$**) often is used as a proxy for the TD-NDF$_{lig}$ method described previously. For our data set of large-round bales of alfalfa-orchardgrass hay, NDFD was poorly related to HDD; in fact, there was no statistical relationship at all if the four most severely heated hays were excluded from the data set (Figure 4). Although estimates of NDFD were largely nonresponsive to spontaneous heating, concentrations of NDF increased sharply in these same hays (Figure 5). It is important to note that concentrations of NDF in hays generally do not increase because more fiber is formed as a consequence of spontaneous heating. Rather, NDF concentrations increase because other (more desirable) forage components, such as plant sugars, are lost through respiration or volatilization.

Side-by-side comparisons of the relationships between TD-NDF and HDD determined by both methods (Figure 6) illustrate several important points:

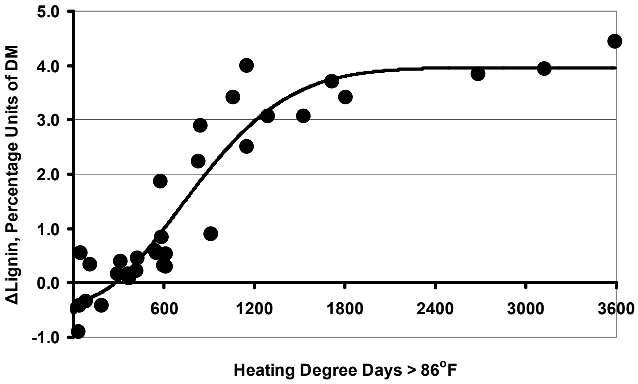

Figure 3. Relationship between the change in concentrations of acid-detergent lignin (poststorage – prestorage; ΔLignin) and HDD for large-round bales of alfalfa-orchardgrass hay. The mean prestorage concentration of lignin was 5.5%, which corresponds generally to ΔLignin = 0 on the y-axis. (Coblentz and Hoffman, 2009)

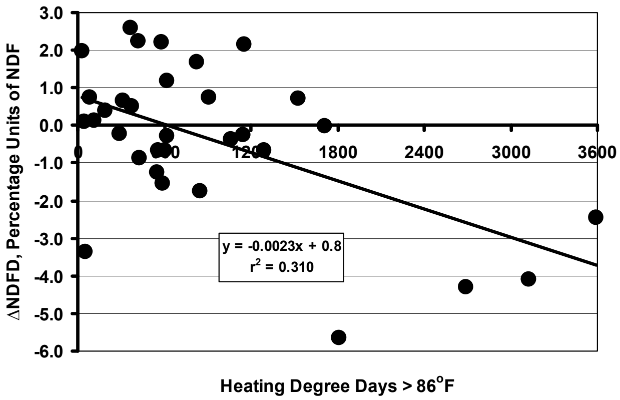

Figure 4. Weak linear relationship between 48-hour NDFD and HDD for large-round bales of alfalfa-orchardgrass hay. The initial concentration of NDFD was 48.1% of NDF, which corresponds to 0 (no change) on the y-axis. (Coblentz and Hoffman, 2009)

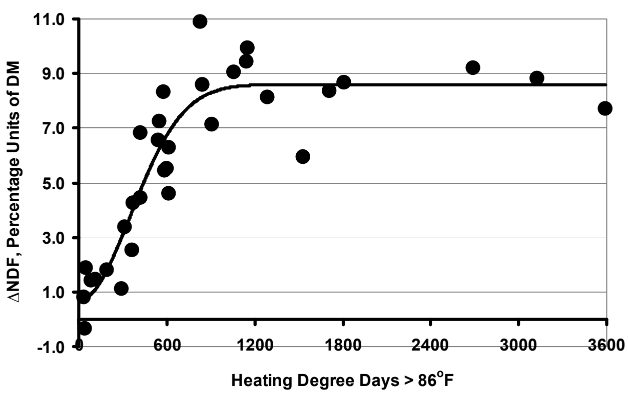

Figure 5. Nonlinear relationship between concentrations of NDF and HDD for large-round bales of alfalfa-orchardgrass hay. The initial concentration of NDF was 46.5%, which corresponds to 0 (no change) on the y-axis. (Coblentz and Hoffman, 2009)

1) There is little difference between the $TD\text{-}NDF_{lig}$ and $TD\text{-}NDF_{ndfd}$ methods for determining TD-NDF when hays are well managed and incur limited heating during storage.

2) In modest to severely heated hays, the $TD\text{-}NDF_{lig}$ method will yield lower estimates of TD-NDF, relative to the $TD\text{-}NDF_{ndfd}$ method, primarily because concentrations of artifact lignin increase sharply in response to heating (Figure 3).

3) Net effects of spontaneous heating on TD-NDF are mildly positive when the $TD\text{-}NDF_{ndfd}$ method is used. This occurs because estimates of NDFD are largely unresponsive to heating (Figure 4), but the overall concentration of forage fiber (NDF) increases sharply (Figure 5) over the same range of heating.

4) The differential between estimates of TD-NDF determined by the $TD\text{-}NDF_{lig}$ and $TD\text{-}NDF_{ndfd}$ methods may be as large as 4 percentage units of TDN in modest to severely heated hays.

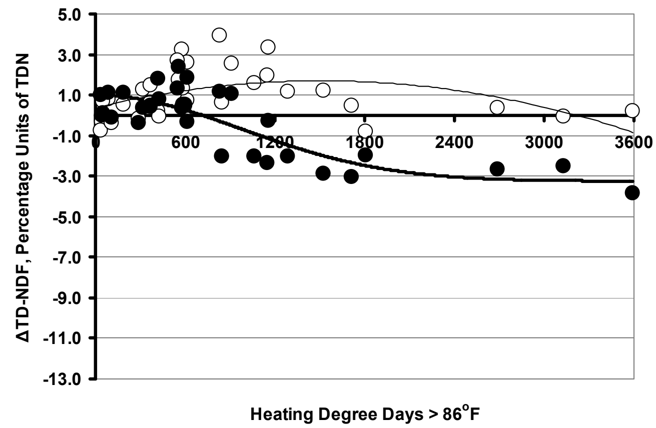

Figure 6. Net contributions of TD-NDF to total TDN estimates for large-round bales of alfalfa-orchardgrass hay. The symbol ● indicates evaluations of TD-NDF were made by the $TD\text{-}NDF_{lig}$ method, while ○ indicates evaluations were made by the $TD\text{-}NDF_{ndfd}$ method for the same hays. The prestorage concentration of TD-NDF was 20.8%, which corresponds generally to 0 (no change) on the y-axis. (Coblentz and Hoffman, 2010)

After quantifying all the components contributing to the total TDN estimate, what are the net effects of spontaneous heating on the total TDN estimate?

For the same set of hay bales discussed throughout this Focus on Forage, net effects of heating on estimates of TDN decreased in curvilinear patterns (Figure 7). In severely heated hays, reductions in TDN reached 9 to 12 percentage units, depending on methodology, which constitutes an enormous energy loss. Roughly 50 to 75% to of this loss was associated specifically with losses of TD-NFC (Figure 1). The effect of heating on TDN content within hays is further compounded because the relationship between TDN and heating is not a steady linear decline. Rather, the effects are somewhat 'front loaded'; in other words, almost all of the losses for TDN are associated with only modest levels of heating. For severely heated hays, there is relatively little additional loss. Finally, the divergent estimates of TD-NDF created by the TD-NDF_{lig} and TD-NDF_{ndfd} analytical approaches are clearly evident in Figure 7; TDN losses determined by the TD-NDF_{lig} method were greater by 2 to 4 percentage units in severely heated hays.

Overall, energy losses from heated hays have often been ignored in the past, with more educational emphasis placed on CP availability. This past emphasis is still important, but it often results in an understatement of the problem. Spontaneous heating becomes an increasingly likely phenomenon as hay packages become larger; associated losses of energy as a result of spontaneous heating are a serious problem at least equal in scope to depressions in CP availability.

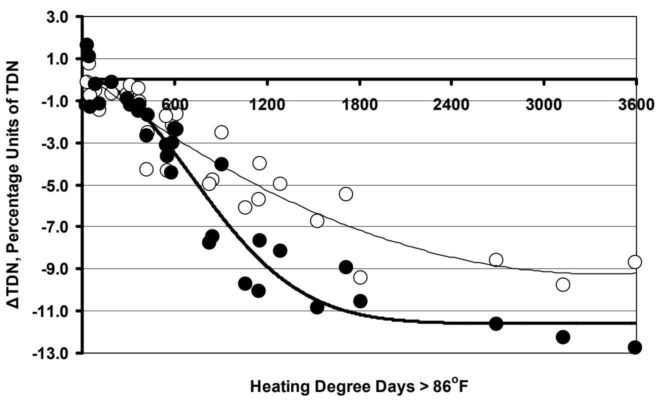

Figure 7. Net effects of spontaneous heating on TDN estimates for large-round bales of alfalfa-orchardgrass hay. The symbol ● indicates that evaluations of TD-NDF were made by the TD-NDF_{lig} method, while ○ indicates use of the TD-NDF_{ndfd} method for the same hays. The prestorage concentration of TDN was 57.8%, which corresponds generally to 0 (no change) on the y-axis. (Coblentz and Hoffman, 2010)

Are there any other analytical issues that are important when analyzing for TDN in heated hays?

One additional consideration is worthy of discussion. The summative model approach described by NRC (2001) specifies that the TD-NDF_{ndfd} method can serve as an alternative or proxy method for estimating TD-NDF_{lig}. Within this context, specified inputs are limited to the concentration of NDF in the forage, as well as the 48-hour in vitro digestibility of that NDF. In practice, there often are questions about whether the NDF concentration should be corrected for any residual CP associated with the forage NDF fraction (often abbreviated as **NDICP**). For unheated, high-quality legume hays, this fraction is relatively small, and this potential error often is either ignored entirely or a standard value based on past research is applied. In contrast, quantification of NDICP is already a required input for the TD-NDF_{lig} method of estimating TD-NDF, although it may be circumvented by similar shortcuts in some laboratories. Recent research suggests that rather large errors in estimates of TD-NDF can occur when 'shortcut' concentrations of NDICP are used for heated hays. All estimates of TD-NDF should be corrected for NDICP if there is any corroborating evidence of heating during storage.

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Heat Damaged Forages: Effects on Forage Quality

by **Wayne Coblentz and Patrick Hoffman**

Introduction

Traditionally, heat damage in forages has been associated primarily with alterations in forage protein quality as a result of Maillard reactions. A Maillard reaction is a heat-induced chemical reaction between protein (amino acids) and sugars. Maillard products produce a range of odors and colors in forages, but generally are poorly characterized nutrients in ruminant nutrition. Terms such as heat-damaged protein, available protein, and acid-detergent insoluble protein have been used to characterize heat damage in forages for decades. Recent research offers new and broader perspectives in regard to the effects of heating on forage quality. This Focus on Forage will highlight new perspectives on how heating effects forage quality.

What Causes Heat Damage?

Standing forages contain an abundance of epiphytic microorganisms such as bacteria, yeast and molds. An epiphyte is simply an organism that grows upon (or attached to) a living plant, and epiphytic bacteria are common on all harvested forages. Epiphytes can be divided into two simple groups, those that require oxygen (aerobic) and those that do not (anaerobic). Anaerobic epiphytic bacteria are in part the class of bacteria that ferment silages. Desirable silage is produced as a result of anaerobic fermentation. When forages are conserved as silage, baleage, or dry hay, air (oxygen) is always entrapped within the crop. In normal silage production, aerobic bacteria, yeast and molds coupled with plant respiration quickly consume all free oxygen and replace it with carbon dioxide initiating anaerobic fermentation.

Dry hay is typically baled at very low moisture contents and aerobic epiphytes are unable to survive. When hay is baled too wet, or conversely when forages are ensiled too dry, a pseudo-fermentation environment exists. The forage contains adequate moisture for aerobic epiphytes (and other external microorganisms) to grow, but excessive oxygen is entrapped within the forage mass extending the aerobic phase over days or even weeks. Under these conditions soluble carbohydrates from the forage are consumed by aerobic microorganisms producing carbon dioxide and heat. Initial heat production produces secondary environments for other types of microrganisms, including thermophilic bacteria, and the temperature within the forage mass can cyclically rise. Some aerobic bacteria, such as Actinomycetes, are thermophilic and can grow at temperatures >120oF. Respiratory activity of microorganisms can cause internal bale temperatures to rise to approximately 160oF; however, as internal bale temperatures reach this level, microbial activity normally ceases. Further temperature increases are largely driven by oxidative (nonenzymatic) reactions that are poorly understood.

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Within any given bale type, the moisture content of the forage at baling has the greatest impact on the severity of heating during storage. This concept is illustrated in Figure 1 for small-rectangular (80 to 100-lb) bales of alfalfa baled over a wide range of moisture contents. In Figure 1, heating is measured as heating degree days >86oF (HDD), which is similar to the growing degree day concept used by agronomists. Generally, HDD integrates the magnitude of the internal bale temperature over the time period during which bale temperatures were elevated. To calculate HDD, 86oF is subtracted from the maximum internal bale temperature for each day of storage. The daily differential is then summed for each day that the difference was > 0. On days the internal bale temperature remained <86oF, a value of 0 HDD is assumed. There are two important concepts illustrated by Figure 1. First, the relationship between moisture content at baling and spontaneous heating is positive and (in this case) linear. Second, the variability of data points around the regression line is quite limited, indicating moisture content at baling is the primary factor driving spontaneous heating.

Another factor impacting the severity of heating in baled hays is the size and/or density of the bale package itself. Generally, heat generation potential of forage DM is independent of bale size; however, larger and/or denser packages contain more DM within each bale. Larger bale packages also have less surface area per unit of forage DM, which impedes heat dissipation. The combined effects of moisture content at baling and bale size are shown in Figure 2, which summarizes heat accumulation within large-round bales of alfalfa–orchardgrass hay packaged in 3, 4, and 5-foot diameter bales. As observed for small-rectangular bales, the HDD accumulated during storage increased with moisture content for each bale diameter. However, as bale diameter increased, large-diameter bales were more likely to exhibit spontaneous heating at relatively low moisture contents (<20%), and accumulate more HDD during storage. Larger-diameter bales also pose an increased risk of spontaneous combustion.

How does heating effect forage quality?

Heat damage in forages is often viewed in binary terms, meaning that the forage is either heat damaged, or it is not heat damaged. In reality, the effects of heating on forage quality are not binary, but are better described as a continuum. Most producers and nutritionists are familiar with the concept of heat-damaged protein (discussed below); however, this is not necessarily the most important negative consequence of spontaneous heating. Figure 3 describes the relationship between concentrations of forage NDF and HDD. Concentrations of NDF increased by as much as 11 percentage units as a result of spontaneous heating, but it is important to note that NDF is not really generated during the heating process. Increases in NDF concentrations occur because cell solubles (most specifically, sugars) are oxidized preferentially during microbial respiration. Fiber components, such as NDF, ADF, and lignin, are generally inert during this process, but their concentrations increase because cell solubles are reduced due to oxidation. This is particularly important because sugars and other cell solubles are essentially 100% digestible, while fiber components are not. As a result, spontaneous heating decreases the energy density (expressed as TDN) of the forage (Figure 4).

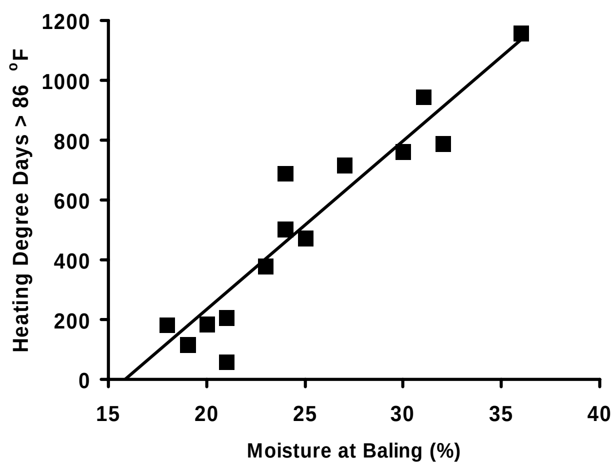

Figure 1. Linear relationship between moisture content at baling and heating degree days accumulated during storage for small-rectangular bales of alfalfa hay.

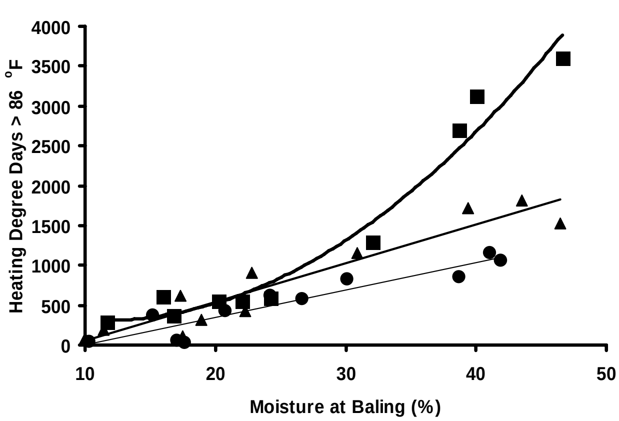

Figure 2. Relationships between moisture content at baling and heating degree days accumulated during storage for large-round bales of alfalfa-orchardgrass hay packaged in 5- (■), 4- (▲), and 3-ft (●) diameter bales in Marshfield, WI.

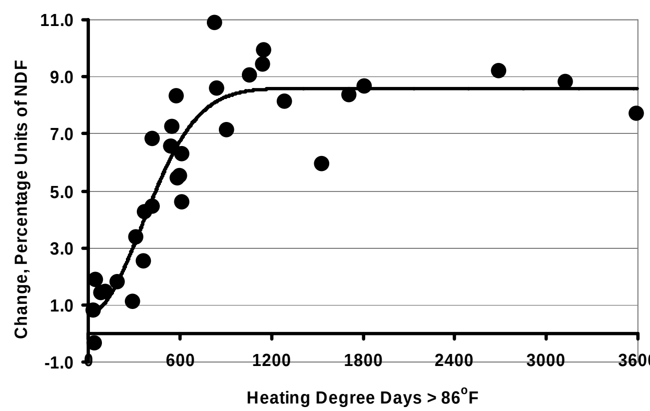

Figure 3. Nonlinear relationship between concentrations of NDF and heating degree days for large-round bales of alfalfa-orchardgrass hay in Marshfield, WI. The initial concentration of NDF, which corresponds to 0 (no change) on the y-axis, was 46.5%.

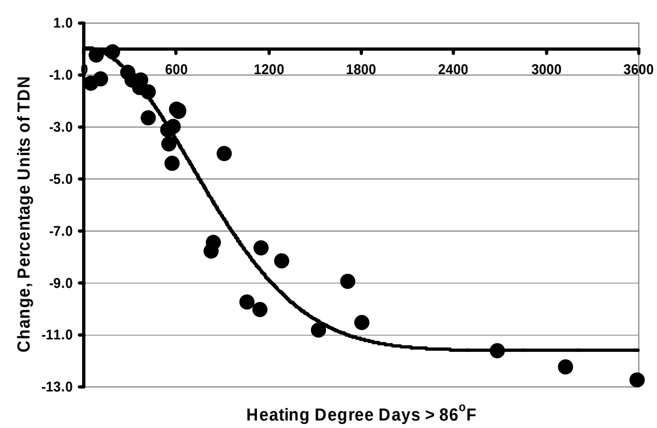

Figure 4. Nonlinear relationship between energy density (TDN) and heating degree days for large-round bales of alfalfa-orchardgrass hay in Marshfield, WI. The initial concentration of TDN, which corresponds to 0 (no change) on the y-axis, was 57.9%.

Many nutritionists hold the view that NDF digestibility is reduced as a result of spontaneous heating. Surprisingly, results from studies suggest NDF digestibility is not significantly altered by heating unless heating is severe enough to cause charring, which appears as black or dark brown pockets within the bale core. When extreme cases of heating are excluded, there is little evidence that NDF digestibility (measured as 48-hour NDFD) and HDD are related statistically (Figure 5).

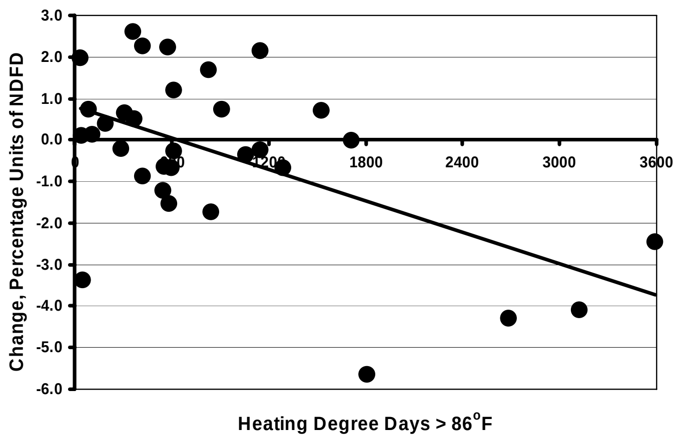

Figure 5. Weak linear relationship between 48-hour NDFD and heating degree days for large-round bales of alfalfa-orchardgrass hay in Marshfield, WI. The initial concentration of NDFD, which corresponds to 0 (no change) on the y-axis, was 48.1%.

How can heating be prevented?

Traditionally, the threshold moisture level for acceptable storage for small-rectangular bales has been about 20%. As larger hay packages become more popular with producers, it is important to reduce this threshold moisture level to limit heating. A good target window for large-round or large-square bales would be 16-18% moisture. It often is easier to attain even lower moisture at baling with grasses, which dehydrate more easily. Although some heating will occur in large hay bales when they are packaged within this range and stored outdoors (Figure 2), the associated effects on forage quality are relatively minor (Figures 3-6).

Air movement around bales will help to dissipate both water and heat; therefore, outdoor storage is somewhat more forgiving. Storage of large hay bales indoors is complicated further because there is little or no air movement around the bales, and spontaneous combustion is quite possible if moisture content is not monitored closely. The 16-18% target baling moisture for large hay packages is a relatively common recommendation; however, outdoor storage also is the

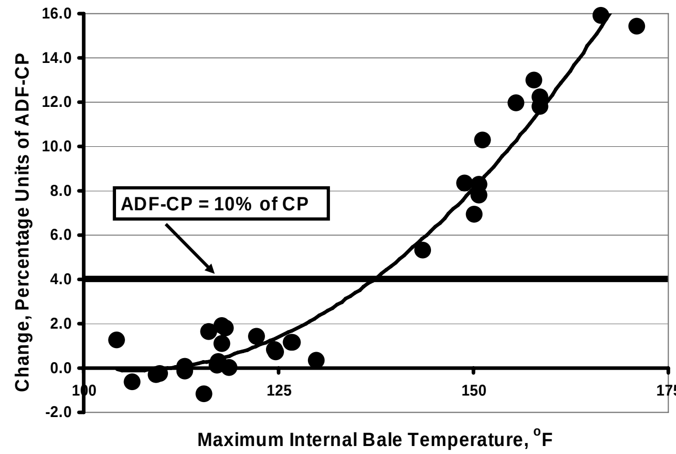

Figure 6. Nonlinear relationship between ADF-CP and maximum internal bale temperature for large-round bales of alfalfa-orchardgrass hay in Marshfield, WI. The initial concentration of ADF-CP was 6.3% of CP, which corresponds to 0 (no change) on the y-axis. Therefore, an increase of approximately 4 percentage units would meet the traditional threshold defining heat damage to forage proteins (10% of CP).

predominant management choice throughout much of the country. Producers storing high-quality bales under roof should consider managing moisture at baling even more conservatively. For legume hays, these issues create a difficult management situation for producers because forage quality also will deteriorate as a result of leaf shatter, and it may not be possible to completely eliminate heating and optimize recovery of leaves in large hay bales without preservatives or by eliminating oxygen by sealing with plastic wrap. More detailed information regarding best management practices and moisture contents for making forages as baled hay, silage or baleage are available at http://www.uwex.edu/ces/crops/teamforage/

Is the laboratory test for heat damaged protein still valid?

Tests for heat-damaged protein in forages are expressed in many ways by commercial forage testing laboratories. Commonly used terms are acid detergent insoluble protein (ADICP), acid detergent fiber crude protein (ADF-CP), acid detergent insoluble nitrogen (ADIN), heat-damaged protein (HDP) and insoluble crude protein (ICP). In general, these measurements represent the same nutrient. In many cases, they are reported as a percentage of total CP, but they also can be reported as a percentage of forage DM. Arguably, the best definition is acid detergent fiber crude protein (ADF-CP) because the actual laboratory test measures the amount of crude protein retained in acid detergent fiber. Historic benchmarks suggest that if this fraction comprises <10.0% of the total forage CP, then minimal heat damage has occurred during storage. It is important to note that all forages contain some ADF-CP; in unheated hays, this probably comprises 4 to 8%

of the total CP. In native (unheated) forms, CP in ADF is largely indigestible within ruminants, but some research suggests that CP in ADF produced as a result of spontaneous heating may have low bioavailabilities. Recent research (Figure 6) indicates that traditional guidelines defining heat-damage to forage proteins are reasonable, but concurrent reductions in energy density may be the most serious consequence of spontaneous heating.

Rain Damage and Spontaneous Heating in Southern Forages Harvested as Hay

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Introduction

One of the most common problems faced by hay producers is how to manage hay production schedules around unfavorable weather. This problem is particularly frustrating throughout the spring and early summer when the probability of rainfall events is high. Inevitability, some wilting forage crops are damaged by unexpected rainfall events each year, and producers often inquire about the effects of unexpected rain damage, and what impact this may have on subsequent animal performance. In truth, the scope of the problem is considerably more complex than direct damage to wilting forage crops via leaching, reactivated respiratory processes, and/or leaf shatter. Common consequences of uncooperative weather also may include: i) spontaneous heating and/or combustion that occurs when producers try to complete baling operations of incompletely wilted forage prior to an oncoming rainfall event; ii) a combination of rain damage and spontaneous heating that may occur with multiple rainfall events or prolonged unstable weather; and iii) excessively mature forage that results from delaying haymaking operations until weather is more favorable. Producers are often unaware or unconcerned about the last consequence, but maturity effects on forage quality can be every bit as severe as spontaneous heating and/or rain damage.

Effects of Maturity on Forage Quality

Generally, the effects of maturity on forage quality are well known to most producers; more than any other factor, the maturity level of the forage at the time of harvest determines the quality of the hay. Generally, the ratio of leaf and stem tissues declines as forages mature. This results in greater concentrations of fiber components, such as NDF, ADF, and lignin, but lower concentrations of CP, digestible dry matter, and energy. Figure 1 illustrates the effect of growth stage on the concentration of NDF for tall fescue forage (Ball et al., 2002). Between the late-boot and soft dough stages of growth, NDF increased by about 12 percentage units from 53 to 65%. A similar response can be expected for other southern forages, such as bermudagrass (Table 1). This is important for several reasons. First, as concentrations of NDF increase, the digestibility (Figure 1) of these same forages decreases concomitantly. Secondly, higher concentrations of NDF are frequently associated with poorer voluntary intakes by livestock consuming forage-based diets. This is especially important when the livestock class consuming the forage has high nutrient demands, such as those of dairy or stocker cattle. Finally, and most importantly, these concepts are important because they illustrate that there is always a cost associated with delaying harvest because of potential rainfall events, and these costs result in a forage of lower nutritional value that will not be consumed as readily by livestock.

Effects of Rainfall on Dry Matter Loss and Forage Quality

Overview. Rainfall applied to wilting forages will leach soluble nutrients (primarily sugars) from hay, resulting in DM loss, increased concentrations of fiber components, and decreased energy density within the forage. Leaching losses are a function of the forage species, the DM content of the forage at the time the rainfall event occurs, the sugar content of the forage, and the number, amount, intensity, and/or duration of the rainfall event or events. Plant sugars are assumed to be 100% digestible; therefore, leaching causes the loss of the most digestible components of the forage. Rain also can reactivate respiration by plant enzyme systems and other microorganisms associated with the forage plants (Rotz and Muck, 1994). This causes additional plant sugars to be consumed, resulting in additional DM loss and further reductions in the nutritional value of the forage. Significant losses of DM also can occur directly as a result of leaf shatter, especially if the hay crop is a legume. In addition, any rainfall during the wilting process may lead to additional tedding and raking operations that result in even more leaf shatter before the forage is dry enough to bale. However, since the production of legume hays is less common in the southeastern US than in many other parts of the country, the concepts of leaf shatter and rain damage to wilting legume forages will not be discussed further.

Losses of DM from Wilting Orchardgrass Forages. Recently, studies conducted at the University of Arkansas evaluated losses of DM and changes in nutritive value for wilting orchardgrass and bermudagrass forages (Scarbrough et al., 2005) damaged by rainfall delivered from a rainfall simulator. From 0 to 76 mm (0 to 3 inches) of simulated rainfall were applied to both forages in single rainfall events in 12.5-mm (0.5-inch) increments. Rainfall was applied to orchardgrass when the moisture content of the forage was very high (67.4%), ideal for baling (15.3%), and excessively dry (4.1%).

Losses of DM for the orchardgrass were low (< 2%) if rainfall occurred when the forage moisture content was high (67.4%), but increased substantially if rainfall occurred when the forage was dry (Table 2). Losses of 10.7% of total plant DM occurred when 76 mm of rainfall were applied to excessively dry (4.1%) forage. At an ideal moisture for baling (15.3%), maximum losses were only slightly lower, reaching 8.8% of DM. Regardless of the moisture content of the forage, DM losses for dry forages increased with the amount of rainfall in curvilinear patterns, but losses were disproportionally large at rainfall increments of 13, 25, and 38 mm, and tended to level off as cumulative rainfall increased beyond these levels.

For bermudagrass (Table 3), rainfall treatments were applied immediately after mowing (76.1%), at the approximate midpoint of the wilting period (40%), and when the forage moisture content was ideal for baling (13.0%). There was essentially no DM loss when the forage was wet, but drier forages lost measurable DM with increased rainfall. Greater losses of DM occur in drier forages because plant cells lose their integrity, and can no longer regulate the movement of soluble compounds in or out of the cell. Unlike orchardgrass, maximum DM losses for bermudagrass were quite limited; the forage that was ideal for baling (13.0%) lost a maximum of 2.1% of total plant DM. Perhaps these differences can be explained on the basis of the sugar content of each grass. Perennial cool-season grasses, such as orchardgrass, have much higher concentrations of water-soluble plant sugars and other compounds than bermudagrass or other warm-season perennial grasses. Therefore, orchardgrass has the potential for more DM loss through leaching. Figure 3 illustrates the comparison of DM losses for bermudagrass and orchardgrass when both forages were wilted to an ideal moisture content for baling; DM losses for orchardgrass were at least four times greater than observed for bermudagrass after the rainfall amount reached 51 mm.

Changes in Nutritive Value for Grasses. The summary of nutritive value for rain-damaged orchardgrass forages (Table 2) demonstrates that relatively wet (67.4%) forage was affected only minimally. Drier forages (4.1 or 15.3% moisture) exhibited more undesirable changes in response to simulated rainfall. Theoretically, fiber components (NDF, ADF, and lignin) are not water soluble; therefore, their concentrations should increase as soluble plant sugars are leached away during the application of simulated rainfall. Generally, our results supported this premise; concentrations of these fiber components increased in curvilinear patterns by as much as 7.8, 9.9, and 3.74 percentage units, respectively,

For bermudagrass (Table 3), changes in nutritive value followed patterns that were similar to those observed for orchardgrass, except that the magnitude of the responses was generally smaller. Maximum increases in NDF, and ADF in response to 76 mm of simulated rainfall were only 2.9 and 2.2 percentage units, respectively, and were observed for forage wilted to 40.0% moisture prior to the rainfall event. For bermudagrass that was dry enough for baling (13.0%), respective increases in NDF and ADF in response to 76 mm of simulated rainfall were only 1.3 and 1.1 percentage units. While the nutritive value of bermudagrass remained relatively stable in response to simulated rainfall, it should not be assumed that rain-damaged forages are as palatable, and they may not be consumed as readily by livestock.

Rainfall Effects on Tall Fescue and Subsequent Intake by Steers

Recently, another series of experiments were completed at the University of Arkansas that assessed the effects of naturally occurring rainfall and subsequent spontaneous heating during storage on the nutritive value of wilting tall fescue forage (Turner et al., 2003), and subsequent effects on voluntary intake and digestibility by growing steers (Turner et al., 2004). Tall fescue was baled at slightly above the recommended moisture content (22.5%), at an ideal moisture for baling (16.4%), and when it was excessively dry (9.9%) without rain damage. In addition, tall fescue was baled at 24.6% moisture after a 23-mm rainfall event, and at 9.3% moisture following three rainfall events totaling 71 mm. The tall fescue was mowed in late-May at the heading stage of growth. At baling, a 23-mm rainfall event increased ($P < 0.01$) the concentration of NDF by 4.9 percentage units compared to all hays baled without rain damage (72.0 vs. 67.1%), while digestibility was suppressed by 1.8 percentage units (63.6 vs. 61.8%). After three rainfall events totaling 71 mm, NDF was further increased ($P < 0.01$) to 76.4%, which was an increase of 8.7 percentage units over hay baled at an ideal 16.4% moisture; however, the associated reduction in digestibility was only 3.2 percentage units. Generally, the effects of a single 23-mm rainfall event were not excessive, especially compared to the rapid changes in nutritive value that may occur as a result of delaying harvest (see Figure 1). However, substantial increases in NDF were observed in hay that was subjected to three rainfall events totaling 71 mm.

After storage, there were few differences in nutritive value between bales that incurred modest spontaneous heating, rain damage, or both (Table 5). This strongly suggests that the practice of baling hay when slightly wet in order to avoid an unexpected shower offers little nutritional (chemical) advantage over waiting to bale until after the rainfall event; however, waiting out the shower will likely require additional raking and tedding operations. Spontaneous heating is highly dependent on the moisture content of the hay. Therefore, producers may have difficulty evaluating what is marginally wet, and the potential for serious depressions in nutritive value as a result of excessive spontaneous heating is quite high.

The voluntary intakes of these fescue hays (Table 6) were identical for hays baled without rain damage, regardless of whether they incurred modest spontaneous heating or not. It is important to note that the levels of spontaneous heating in these hays were very modest because of the relatively low moisture levels (< 25%) at baling, the small rectangular bale packages, and a period of relatively cool weather that occurred within two weeks of baling. More intense heating would be expected if these hays had been packaged as large round bales. Hays that were damaged by rain or rain and modest spontaneous heating were not consumed as well by steers. Depressions ($P = 0.01$) in daily voluntary hay intake, relative to those baled without rain damage, were 0.17% of bodyweight for hay receiving 71 mm of rain prior to baling, and 0.25% of bodyweight for hay receiving a single 23-mm rainfall event coupled with modest spontaneous heating. Therefore, there was about a 10% reduction in voluntary hay intake in any forage damaged by at least one soaking rain. Coefficients of apparent digestibility for DM, OM, and NDF were greater ($P \leq 0.03$) for hays damaged by rainfall events; this may have been related to total tract retention times that were numerically, but not statistically ($P > 0.10$), longer than observed for hays not damaged by rain.

Recommendation

Given the uncertainty of the weather, specific recommendations are difficult. For tall fescue, results of experiments at the University of Arkansas indicate that the damage created by a single rainfall event of approximately 25 mm is not excessive, particularly when compared to the consequences of spontaneous heating, or the rapid negative changes in forage quality that occur when harvest is delayed. This suggests that producers could be more aggressive during the late-spring with fairly limited risk. Orchardgrass and legumes may be more susceptible to rain damage, and may need to be managed more conservatively. In contrast, the quality characteristics of bermudagrass (and likely other perennial warm-season grasses) are only affected minimally by rainfall events; however, this may be less important because weather patterns usually become more stable during summer months. Although there are relatively few studies assessing the impacts of rain damage on voluntary intake of hay by livestock, these studies suggest that a 10% reduction in response to a soaking rain may serve as a good 'rule of thumb' until additional studies provide more information.

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Table 1. Fiber characteristics of ‘Coastal’ bermudagrass (adapted from NRC, 1989).

Stage of growth	CP	NDF	ADF	TDN
	% of DM			
early vegetative	16.0	66	30	61
late vegetative	16.5	70	32	54
15 to 28 days	16.0	74	33	55
29 to 42 days	12.0	76	38	50
43 to 56 days	8.0	78	43	43

Table 2. Effects of crop moisture content and amount of rainfall on the nutritive value of wilting orchardgrass hay. Orchardgrass forage was harvested on 18 June 2001, which was the second harvest of the growing season. Simulated rainfall was applied at a rate of 76 mm/h (adapted from Scarbrough et al., 2005).

Moisture[a]	Amount	DM loss	CP	NDF	ADF	Lignin
%	mm	--------------------------------	---- % of DM ----	----------------------------------		
67.4	0	0	13.2	63.6	35.5	3.36
	13	0.6	13.4	64.0	36.5	3.04
	25	1.2	14.2	64.4	37.0	3.24
	38	1.2	14.3	64.4	37.5	3.87
	51	1.9	13.9	64.9	36.6	4.03
	64	1.6	13.9	64.7	35.0	2.70
	76	1.4	15.2	64.5	34.2	2.71
	Effect[b]	L < 0.01	L < 0.01	L < 0.01	Qu = 0.04	Qu < 0.01
15.3	0	0	13.6	65.0	34.7	2.85
	13	5.7	14.9	68.9	37.4	4.31
	25	5.0	14.5	68.4	39.3	4.62
	38	7.3	14.5	70.1	39.9	4.55
	51	8.3	15.0	70.9	40.3	5.39
	64	8.6	13.9	71.2	42.1	5.43
	76	8.8	14.4	71.3	44.6	6.59
	Effect	Qu = 0.01	Q = 0.04	Qu = 0.02	C < 0.01	C < 0.01
4.1	0	0	13.8	65.2	34.0	3.91
	13	5.8	13.6	69.3	35.3	6.20
	25	7.6	13.4	70.6	36.5	4.87
	38	8.4	14.4	71.2	36.5	5.91
	51	9.1	14.1	71.7	37.5	4.09
	64	10.1	13.9	72.6	37.8	3.87
	76	10.7	14.3	73.0	38.3	4.28
	Effect	L = 0.03	NS	C = 0.05	L < 0.01	C = 0.04

[a] Moisture content of the forage when the simulated rainfall was applied.

[b] Highest order effect of rainfall amount: NS, nonsignificant (P > 0.05); L, linear; Q, quadratic; C, cubic; and Qu, quartic.

Table 3. Effects of crop moisture content and amount of rainfall on the nutritive value of wilting bermudagrass hay. Bermudagrass was harvested on 30 August 2001. Simulated rainfall was applied at a rate of 76 mm/h (adapted from Scarbrough et al., 2005).

Moisture[a]	Amount	DM loss	CP	NDF	ADF	Lignin
%	mm	-------------------------	-------------------------	% of DM	-------------------------	-------------------------
76.1	0	0	15.6	71.8	32.4	3.62
	13	- 1.4	15.8	70.8	30.7	3.08
	25	- 0.6	15.9	71.3	33.0	4.43
	38	- 1.6	15.8	70.7	31.0	2.72
	51	- 1.3	15.2	70.8	31.2	3.15
	64	- 0.7	16.1	71.3	31.3	3.76
	76	0.1	15.6	71.9	36.6	5.77
	Effect[b]	Q = 0.01	NS	Q = 0.01	Qu = 0.05	C = 0.02
40.0	0	0	14.9	71.5	31.0	3.03
	13	1.4	14.9	72.6	32.2	3.70
	25	1.5	15.3	72.7	32.7	3.50
	38	2.3	15.1	73.2	33.1	3.84
	51	1.9	15.4	72.9	32.6	3.45
	64	1.4	15.4	72.6	33.1	3.49
	76	3.8	15.0	74.4	33.2	3.59
	Effect	L < 0.01	NS	L < 0.01	C = 0.05	NS
13.0	0	0	15.3	71.4	31.7	3.32
	13	0.8	15.0	72.0	33.0	3.49
	25	2.0	15.5	72.8	33.5	3.85
	38	2.0	15.3	72.9	33.7	3.72
	51	1.8	15.6	72.7	32.9	3.44
	64	2.1	15.6	72.9	33.8	3.71
	76	1.7	16.6	72.7	32.8	3.44
	Effect	Q < 0.01	Q = 0.04	Q < 0.01	Q < 0.01	Q = 0.01

[a] Moisture content of the forage when the simulated rainfall was applied.
[b] Highest order effect of rainfall amount: NS, nonsignificant (P > 0.05); L, linear; Q, quadratic; C, cubic; and Qu, quartic.

Table 4. Effects of natural rainfall on the nutritive value of endophyte-infected tall fescue hay at baling. Rainfall events were naturally occurring, and bales were packaged as conventional rectangular bales in Fayetteville, AR during May 2000.[a]

Treatment	Crop Moisture at Baling	Total Rainfall Amount	Number of Rainfall Events[b]	CP	ADIN	NDF	ADF	Lignin	Digestibility[c]
	%	mm	no.	% of DM	% of N	------------------------ % of DM ------------------------			
a	22.5	0	0	7.9	7.1	66.3	37.6	4.81	64.1
b	16.4	0	0	8.2	8.3	67.7	38.3	5.12	62.9
c	9.9	0	0	7.9	8.0	67.3	38.1	4.98	63.9
d	24.6	23	1	8.4	7.7	72.0	40.5	5.48	61.8
e	9.3	71	3	8.6	7.8	76.4	42.6	5.52	59.7
Contrasts									
1) one rainfall event (d) vs. no rain (a, b, c)				NS[d]	NS	< 0.01	< 0.01	0.02	0.08
2) multiple rainfall events (e) vs. no rain (a, b, c)				0.09	NS	< 0.01	< 0.01	0.01	< 0.01
3) one rainfall event (d) vs. multiple events (e)				NS	NS	< 0.01	< 0.01	NS	0.09
4) ideal moisture (b) vs. excessively dry (c)				NS	NS	NS	NS	NS	NS

[a] Adapted from Turner et al. (2003).
[b] Number of rainfall events contributing to the total rainfall prior to baling.
[c] Determined by 48-h ruminal incubation in situ.
[d] NS, nonsignificant (P > 0.10)

Table 5. Effects of natural rainfall during wilting and spontaneous heating during storage on the nutritive value of endophyte-infected tall fescue hay. Rainfall events were naturally occurring, and bales were packaged as conventional rectangular bales and stored for approximately six weeks in small stacks at Fayetteville, AR during 2000.[a]

Treatment	Crop Moisture at Baling	Total Rainfall Amount	Number of Rainfall Events[b]	Maximum Internal bale temperature	CP	ADIN	NDF	ADF	Lignin	Digestibility[c]
	%	mm	no.	°C	% of DM	% of N	------------------ % of DM			---------------------
a	22.5	0	0	49.8	8.9	10.4	74.5	43.4	5.89	59.8
b	16.4	0	0	40.0	8.2	6.4	70.5	41.1	6.20	62.9
c	9.9	0	0	42.8	7.9	7.6	68.1	39.7	5.83	63.2
d	24.6	23	1	50.8	8.6	15.5	78.5	44.4	6.47	59.6
e	9.3	71	3	31.4	7.7	13.0	76.0	44.0	6.83	59.7
SEM				1.3	0.44	1.20	0.71	0.51	0.386	0.75
Contrasts										
1) all damaged hays (a, d, e) vs. no damage (b, c)					NS[d]	< 0.01	< 0.01	< 0.01	NS	< 0.01
2) rain damaged (d, e) vs. no rain (a, b, c)					NS	< 0.01	< 0.01	< 0.01	0.06	< 0.01
3) spontaneous heating (a, d) vs. minimal heating (b, c, e)					0.07	0.01	< 0.01	< 0.01	NS	< 0.01
4) spontaneous heating and rain damage (d) vs. heating only (a)					NS	0.02	< 0.01	NS	NS	NS

[a] Adapted from Turner et al. (2003).
[b] Number of rainfall events contributing to the total rainfall prior to baling.
[c] Determined by 48-h ruminal incubation in situ.
[d] NS, nonsignificant (P > 0.10)

Table 6. Effects of natural rainfall during wilting and spontaneous heating during storage on the voluntary intake, in vivo apparent digestibility, and total tract retention time for growing steers consuming endophyte-infected tall fescue hay. Rainfall events were naturally occurring, and bales were packaged as conventional rectangular bales and stored for approximately six weeks in small stacks at Fayetteville, AR during 2000.[a]

				Intake		Digestion Coefficients			
Treatment	Crop Moisture at Baling	Total Rainfall Amount	Maximum Internal bale temperature	Diet	Hay	DM	OM	NDF	Total Tract Retention Time[b]
	%	mm	^{o}C	% of BW		%			h
A	22.5	0	49.8	2.28	2.10	51	53	56	56.5
B	9.9	0	42.8	2.31	2.10	50	52	52	57.6
C	24.6	23	50.8	2.04	1.85	57	60	64	60.9
D	9.3	71	31.4	2.15	1.92	53	56	59	59.2
SEM			1.3	0.057	0.062	1.70	1.63	1.82	3.39
Contrasts									
1) all damaged hays (a, c, d) vs. no damage (b)				0.05	0.09	0.09	0.05	0.01	NS[c]
2) rain damaged (c, d) vs. no rain (a, b)				0.01	0.01	0.03	0.02	0.01	NS
3) spontaneous heating (a, c) vs. minimal heating (b, d)				NS	NS	NS	NS	0.06	NS

[a] Adapted from Turner et al. (2004).
[b] Determined with Yb as an external marker.
[c] NS, nonsignificant ($P > 0.10$).

Figure 1. Relationship between concentrations of NDF and digestibility (%) for KY-31 tall fescue (adapted from Ball et al., 2002). Source: C. S. Hoveland and N. S. Hill, University of Georgia.

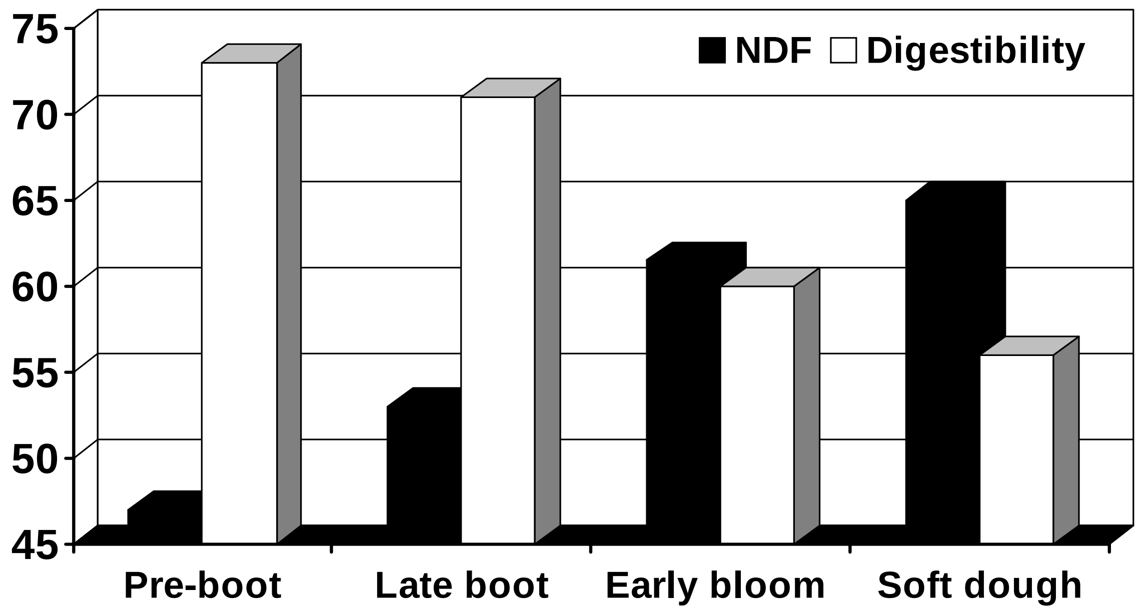
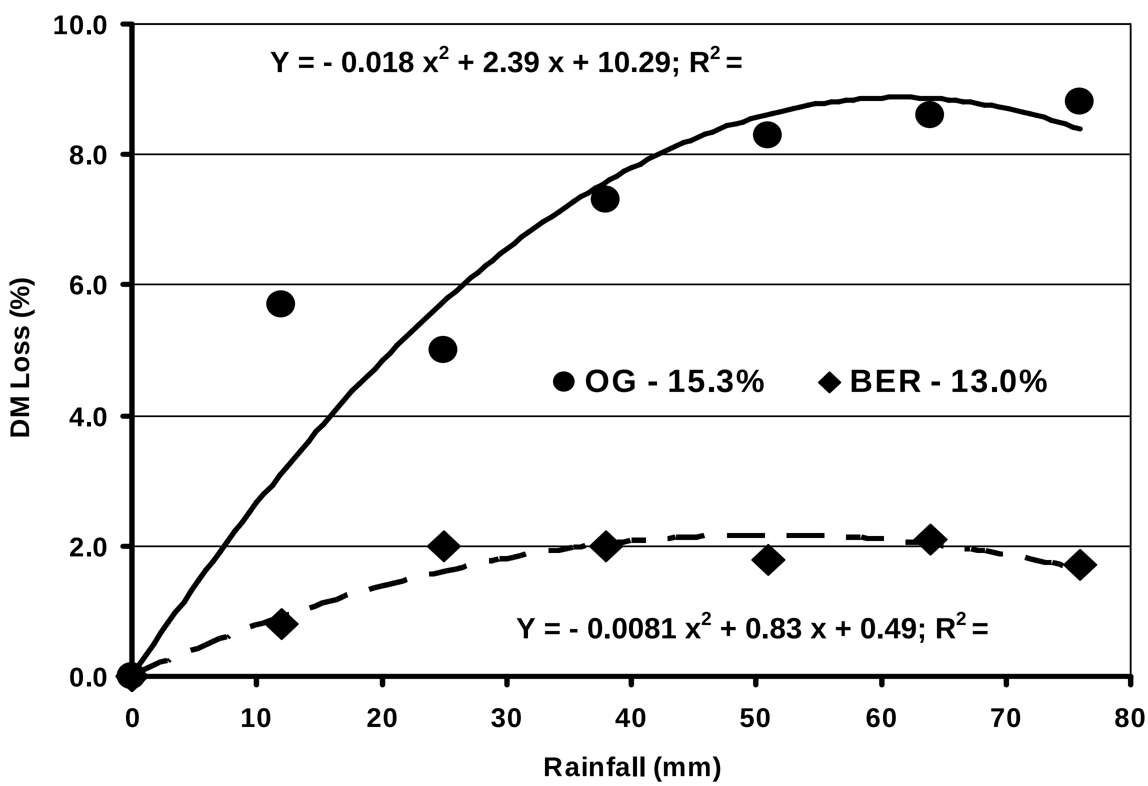


Figure 2. Losses of DM in response to simulated rainfall for vegetative orchardgrass (OG) and bermudagrass (BER) hays damaged by rainfall at ideal moisture concentrations for baling (adapted from Scarbrough et al., 2005).



Hay Storage Systems

Dr. John Worley, Extension Agricultural Engineer

2018 Hay and Baleage Short Courses
Hay Storage Systems

Hay Storage Systems
2018 Hay Shortcourse

John W. Worley

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Alternatives

- Storage
  - Square Bales - Barn
  - Round Bales
    - Field
    - Tarp
    - Barn

HAY LOSS ACCUMULATES WITH EACH STEP

It's not unusual to see total losses of 70% or greater

We will concentrate on the Storage portion

Slide courtesy of Dennis Hancock

Twine vs. Hay Wrap

Storage Alternatives

- Curing
  - Field Dry (15% moisture)
  - Baleage (50-60% moisture)
- Packaging
  - Round Bales
    - Twine
    - Bale (net) Wrap
  - Square Bales
    - Small
    - Large

Permeable Wrap

- Aka "B-Wrap"
- Compare to Gore-tex
- Preserves hay very similar to a barn
- Cost similar to a barn ($7/bale)

Hay Storage Systems

Baleage

- Greater control over harvesting time
- Excellent quality if moisture level right and no leaks
- Reduces Nitrate Levels

Hay Storage – Preserving Quality

- Why build it?
- How to build it
- How to use it

Baleage

- Costs more
- Can cause problems if ensiling isn't successful
- Disposal of Plastic

Hay Barn

- Best choice for long-term storage

Baleage

- Get the moisture level right (50-60%)
- Get tension right and put enough plastic
- Control vegetation (mice and predators)

Small Square Bales

Hay Storage Systems

Hay Barn

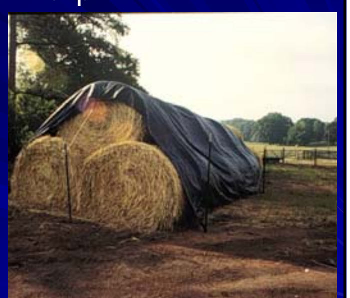
- Enclosed sides –
  - Better Protection (sun and rain)
  - Costs about twice as much
  - Ventilation
  - High-end hay storage
  - Small square bales

Storage Options

Tarped Stacks
Hay Sheds
Hoop Structures

Slide courtesy of Dennis Hancock

Tarp



- Low-cost alternative
- More Labor
- Decreased losses in case of fire

Cost of Owning a Building

- 50 by 100 ft building at $6.00/ square foot ($30,000) (Roof only)

– Depreciation (20 years)	$1500
– Interest (8%)	$1200
– Tax & Ins.	$900
– Annual Repairs	$150
Total Annual Cost	$3750

Uncovered

- Lowest Cost - Greatest Losses - Poorest Quality

Benefits of Covered Storage

- Reduced Dry Matter Loss
- Improved Nutritional Value
- Reduced animal refusal
- Barn can be used for other things when not used for hay (equipment storage)

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Hay Storage Systems

Dry Matter Losses (%)

Study	Ground Stored	Elevated on Pallets	Elevated & Tarped	Tarped Only	Barn Stored
1	65	38	14	na	4
2	50	32	14	na	4
3	30	na	na	10	0

Digestibility and Palatability Also Affected

Size of Bale Affects Losses

- Outer 4 to 6 inches is lost
- Higher percentage of a small bale

Nutritional Losses

Start with 1,000-lb bale at 15% moisture

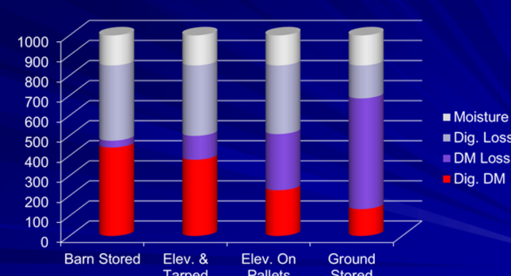
850 lb DM before storage	Ground Stored	Elev. on Pallets	Elev. & Tarped	Barn Stored
DM Loss	65	38	14	4
Digestibility (%)	45	49	52	54
Digestible Matter After Storage	172	258	380	441

Dry Matter Losses (%) As Affected by Bale Size

Bale Diam. (ft.)	Ground Stored	Elevated on Pallets	Elevated & Wrapped	Barn Stored
4	32.4	26.2	14.6	4
5	23.8	17.4	11.4	4
6	19.6	13.4	10.0	4

Digestible Matter After Storage

(1,000-lb Bale)



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Annual Savings on Hay Storage

- Assumptions
  - Hay valued at $80/ton (dry matter) ($34/1,000-lb roll)
  - Hay losses reduced by 30%
  - 50 x 100 building (annual cost - $3750)
  - Storage Capacity - 250 tons (wet basis)
  - Hay stored at 15% moisture

Barn Recommendations

- Build to meet Southern Building code (80 mph wind)
- If possible, orient the long axis east and west on open-sided barns
- Round bale storage should be open, especially at the gable end for ventilation

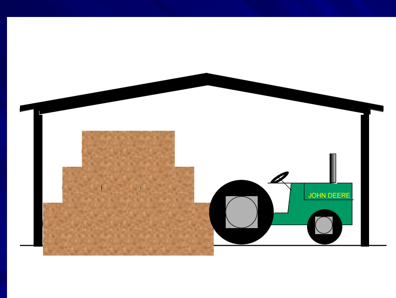
Annual Savings on Hay Storage

- Dry matter saved - 61 tons - - $4880
- Net Savings - - - $1130
- What if?
  - If Digestibility Improved by 9% (Total of 42% Savings) Net Savings - - $3100
  - If Hay worth $90/ton, Net Savings - - $4000

Barn Recommendations

- Stack bales on end to increase capacity
- Make sure the eave height (vertical clearance) of barn is sufficient

If You Build A Barn

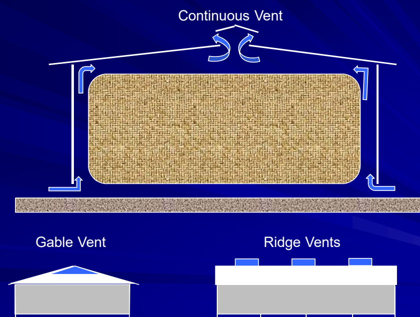


Rot and Rust on Inside Roof?

Hay Storage Systems

Enclosed Gable

How much Ventilation?
(Enclosed Barn)



Water Loss from Curing Hay

- 100 tons of hay stored at 16% moisture
- Dries to 13% moisture
- 3% of 100 tons = 3 tons of water
- = 722 gallons
- Must be removed by ventilation

How much Ventilation?
(Enclosed Barn)

- Larger of the following 2 options:
  - 6” continuous ridge vent
  - 2”/ 10 ft of width
- For a 50-ft wide building -10” Ridge vent (83 sq. ft of ridge/gable opening for 100-ft long building)
- Equal area of opening near bottom of walls (Door can serve as part of vent)

Enclosed Hay Barn

- Typical for small square bales

Flooring for Square Bales

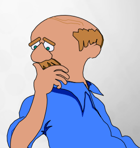
- Floor higher than surrounding soil
- Anything that promotes ventilation under the hay is good (Large rock, pallets, etc.
- Ideal is a raised floor with air underneath (not always practical)
- Bottom layer on edge – primarily to keep twine from rotting, but also helps promote ventilation
- Concrete with vapor barrier underneath and well-drained

Hay Storage Systems

If You Store In the Field

Field Storage Recommendations

- Store on high, well-drained ground
- Store in open, sunny area
- Store in rows with flat edges touching and round edges separated (unless tarped)
- Orient rows North and South
- Orient rows down slope, not across slope



QUESTIONS ?

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Economics of FARM STORAGE BUILDINGS

Levi Russell, Extension economist, and John Worley, Extension engineer

It is widely accepted that storing farm equipment under a shelter is better than storing it outside and that hay stored in a barn is better than hay stored in the field. But how can we determine just how much a farm storage building is worth? The answer is different for every individual operation, but there are some guidelines that will help you make an intelligent decision about whether or not you can afford a building (or afford not to have one).The following is a discussion of the costs and benefits of owning a building, along with some example calculations. In each example, you are given the opportunity to substitute your figures, which might more accurately reflect your local markets and conditions.

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COST OF OWNING A BUILDING

The cost of a building depends on many factors including the amount of side enclosure, type of floor, height, and type of construction. Costs also vary depending on steel and wood prices. For an example calculation, we will use a pre-engineered steel building 50 by 100 feet with 14 foot eave height (vertical clearance). The building is open-sided and has a dirt floor. It would be suitable for storing equipment or hay.

Example: 50′ by 100′ open shed.

			Your Figures
Cost - 5,000 ft^2 of storage @ \$6.00/ft^2.	=	\$30,000	________
Salvage value after use	=	\$0	________
Annual Costs:			
Depreciation (20 years) \$30,000 - 0 / 20 yrs	=	\$1,500	________
Interest (8% of avg. value) \$15,000 x 0.08	=	\$1,200	________
Taxes and Insurance (3%) \$30,000 x 0.03	=	\$900	________
Annual Repairs (.5%) \$30,000 x .005	=	\$150	________
Total Annual Cost		**\$3,750**	________

Depreciation is calculated as the beginning value minus the ending value divided by the useful life. In this example, the structure is assumed to be worth \$0 after 20 years. In all likelihood, it will be worth something. In that case, the actual depreciation will be less. For instance, if the building were worth \$5,000 after 20 years, the actual depreciation would be \$1,250 per year (\$30,000-\$5,000/20 years).

Interest is calculated based on the average value, which is the beginning value plus the ending value divided by two. In this example, ending value is assumed to be \$0 so the average value is merely \$30,000/2. However, if the ending value were \$5,000, the average value would be \$17,500 (\$30,000+\$5,000/2).

Taxes and insurance are location dependent so readers should consult their local tax assessor.

Annual repairs will vary considerably. In many years, there will likely be no repairs. However, in other years repairs could be considerable. Readers are encouraged to calculate a realistic average annual repair estimate or consult with their builder and include that cost as part of the annual expenses.

Instead of using depreciation and interest, some producers may prefer to use annual principal and interest payments. In that case, Table A (found at the end of this publication) may be useful. To use this table, readers find the appropriate payback period and interest rate and multiply the corresponding value by the thousands of dollars financed. For instance, if \$30,000 is financed for 20 years at 8%, the annual payment would be \$3,055.50 (30 X \$101.85).

BENEFITS OF STORING MACHINERY INSIDE

In a nationwide survey (Meador, 1981), farmers were asked about the resale value of their farm equipment at trade-in and whether or not it was stored inside when not in use. The results in Table 1 show that farmers who traded their equipment after five years got significantly more for tractors and other equipment that were stored inside than for equipment stored outside.

Table 1. Increased value of stored equipment at resale after five years (% of resale price)

	5 years	Per year
Tractors	16.5%	3.3%
Planters	22.1%	4.4%
Harvesting Equipment	23.7%	4.7%
Tillage Equipment	10.0%	2.0%

A 3% savings per year on barn-stored equipment is a conservative estimate of storage benefits. Using a resale value of 50% of new cost after five years, we can expect the savings shown in Figure 1 from storing equipment.

Figure 1. Annual Savings for Storage of Selected Equipment

		Your Figures
Two 155-HP Tractors @ $100,000 each	$200,000	
Combine	$325,000	
Cotton Picker	$700,000	
Hay Baler (Round)	$35,000	
Total Equipment Value	**$1,260,000**	
Equipment value after 5 years ($1,260,000 x 50%)	**$630,000**	
Savings of 3% per year ($630,000 x 3%)	**$18,900**	
Net Annual Savings (Annual Savings less Annual Cost of Facilities) ($18,900 - $3,750)	**$15,150**	

The equipment described in the example in Figure 1would only require approximately **1,100** of the **5,000** ft^2 of available space. **Additional savings can be expected from reduced down time.** Deterioration of rubber and plastic parts due to exposure to the sun is a major contributor to breakdowns and increased maintenance time. It has been estimated that barn-stored equipment has less than half the down time of field-stored equipment.

BENEFITS OF BARN HAY STORAGE

A number of studies have been done comparing various storage methods for large round bales of hay. The results varied greatly depending on the weather during the storage period. The kind and quality of hay, tightness and size of bales, and the length of time stored also affect losses. In each test, though, it was clear that a significant amount of dry matter was lost in field-stored hay, and the quality (digestibility) of the remaining hay was lowered. Results of three of these tests (1. Ely, 1984; 2. Collins et al., 1987, and 3. Hoveland et al., 1997) are shown in Table 2. All of these tests were based on a storage period of seven months.

Size of the bale affects losses because typically the outer 4 to 6 inches of the bale is lost, and that outer layer represents a higher portion of a small bale than a large bale. The outer 6 inches of a 4-ft diameter bale represents about 44% of the bale while the same outer 6 inches of a 6-ft diameter bale represents 31% of the bale.

The effect of increased digestibility in barn-stored hay was studied in experiment 1 and shown at the bottom of Table 2. This effect is greater than it initially appears from the figures in Table 2. If we start with a 1,000-lb bale at 85% dry matter and 54% digestibility, we have (1000 x 85%) = 850 lb of dry matter and (850 x 54%) = 459 lb of digestible hay. If that bale is stored on the ground, losing 30% of its dry matter and lowering the digestibility to 45%, we now have (850 x 70%) = 595 lb of dry matter and (595 x 45%) = 268 lb of digestible hay. This represents a loss of 42% of digestible hay. The actual savings on hay storage depends on the value of the hay, the length of storage, and the weather during the storage period.

Table 2. Storage and handling losses for large round hay bales

Study	Ground Stored	Elevated on Pallets	Elevated & Tarped	Tarped Only	Barn Stored
Dry Matter and Handling Loss (%)					
1	65	38	14	n/a	4
2	50	32	14	n/a	4
3	30	n/a	n/a	10	0
Digestibility (%)					
1	45	49	52	n/a	54

Figure 2 shows a conservative example of the benefits of barn storage. The example does not include the benefits of using the building for other purposes when it's not needed for hay storage. Should you store all of your hay in a barn? Not necessarily. Hay harvested late in the season and fed early in the winter would have much lower loss than hay stored over a longer period. One strategy would be to store early hay in a barn, mid-summer hay under tarps, and late hay in the open (if barns and tarps are all full).

Figure 2. Benefits of Barn-Stored Hay

Use the following:	**Your Figures**
1. Hay valued at **$80/ton** of dry matter (equivalent to $34/1000-lb roll)	_________ ($/ton)
2. Dry matter losses reduced by **30%** over ground storage	_________ (% reduced dry matter loss)
3. Digestibility decreases from 54% to 45%, yielding a total effective loss of **42%** of digestible hay (see previous example).	_________ (% digestible hay loss)
4. Building is 50' by 100' with annual cost of $3,750.	_________ (Annual building cost)
5. Bales are 5' diameter by 4', weigh 1,000 lb, and are stacked 3 high (on end) so 500 bales or **250 tons** can be stored in the barn.	_________ (Total tons stored)
6. Hay stored at 85% moisture content	_________ (% moisture content)
Hay Storage Savings:	
7. Total dry matter stored 250 x 85% = 212 tons	_________ (#5 x #6)
8. Dry matter saved 212 tons x 30% = 64 tons	_________ (#7 x #2)
9. 64 tons @ $80/ton = $5,120	_________ (#8 x #1)
10. Net annual savings $4,800 - $3,750 = $1,050	_________ (#9 - #4)
If we include savings due to increased digestibility:	
11. 42% x 212 tons x $80/ton = $7,123	_________ (#3 x #7 x #1)
12. Net annual savings $6,678 – $3,750 = $2,928	_________ (#11 - #4)
If hay is worth $90/dry ton ($38/1,000-lb roll):	
13. 42% x 212 tons x $90/ton = **$8,014**	_________ (#3 x #7 x $90)
14. Net annual savings $8,014 - $3,750 = $4,264	_________ (#13 - #4)

GENERAL RECOMMENDATIONS

1. **Open-sided barns** should generally be oriented with the long axis east and west to minimize the amount of sun intrusion into the building.

2. **If only one side** of the barn is open, it should be facing away from prevailing wind (generally South), to minimize rain being blown into the barn.

3. **All buildings** should meet Southern Building Code requirements.

4. **Sidewalls add protection** to both equipment and hay, but add significantly to the cost of the building. You should get a bid on different types of buildings and do your own analysis using the guidelines in this publication.

5. **Buildings for hay storage** should be as open as possible in the gable ends (peak of the roof) to allow moisture to escape as the hay dries while in the barn. Other-wise, condensation and rust will occur on the inside of the roof. Ridge vents should also be considered in large barns. 100 tons of hay will give off about 5,000 lb of water during curing, and this must be removed by ventilation.

6. **More large round hay bales** can be stored in a barn by stacking the bales on their (flat) end rather than on their (round) side. This can be done with a 4-foot front-end-loader fork. It does, however, take a little more time and effort than storing on the side.

7. **Make sure the eave height** (vertical clearance) of your barn is high enough to fit your needs (usually at least 14 feet.) Nothing is more frustrating than realizing that one more foot of ceiling height would allow you to put another layer of hay bales in the barn or that your barn is one foot too short for the new combine.

Table A. Annual Payments per $1,000 Borrowed for Various Payback Periods and Interest Rates

Number of Years	Interest Rate				
	4.00%	6.00%	8.00%	10.00%	12.00%
1	$1,040.00	$1,060.00	$1,080.00	$1,100.00	$1,120.00
2	$530.20	$545.44	$560.77	$576.19	$591.70
3	$360.35	$374.11	$388.03	$402.11	$416.35
4	$275.49	$288.59	$301.92	$315.47	$329.23
5	$224.63	$237.40	$250.46	$263.80	$277.41
6	$190.76	$203.36	$216.32	$229.61	$243.23
7	$166.61	$179.14	$192.07	$205.41	$219.12
8	$148.53	$161.04	$174.01	$187.44	$201.30
9	$134.49	$147.02	$160.08	$173.64	$187.68
10	$123.29	$135.87	$149.03	$162.75	$176.98
11	$114.15	$126.79	$140.08	$153.96	$168.42
12	$106.55	$119.28	$132.70	$146.76	$161.44
13	$100.14	$112.96	$126.52	$140.78	$155.68
14	$94.67	$107.58	$121.30	$135.75	$150.87
15	$89.94	$102.96	$116.83	$131.47	$146.82
16	$85.82	$98.95	$112.98	$127.82	$143.39
17	$82.20	$95.44	$109.63	$124.66	$140.46
18	$78.99	$92.36	$106.70	$121.93	$137.94
19	$76.14	$89.62	$104.13	$119.55	$135.76
20	$73.58	$87.18	$101.85	$117.46	$133.88
25	$64.01	$78.23	$93.68	$110.17	$127.50
30	$57.83	$72.65	$88.83	$106.08	$124.14
35	$53.58	$68.97	$85.80	$103.69	$122.32
40	$50.52	$66.46	$83.86	$102.26	$121.30

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Hay for Horses: Figuring Out What Horse Owners Want

Dr. Kylee Duberstein, Asst. Professor and Equine Specialist

2018 Hay and Baleage Short Courses
Hay for Horses

Selecting Appropriate Hay for Horses

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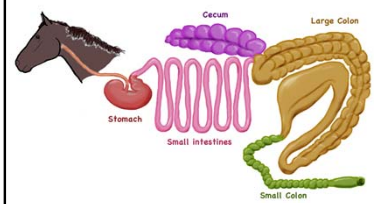
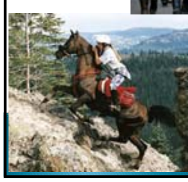
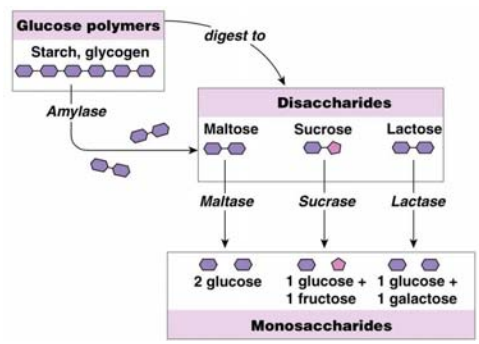
Horse GI anatomy



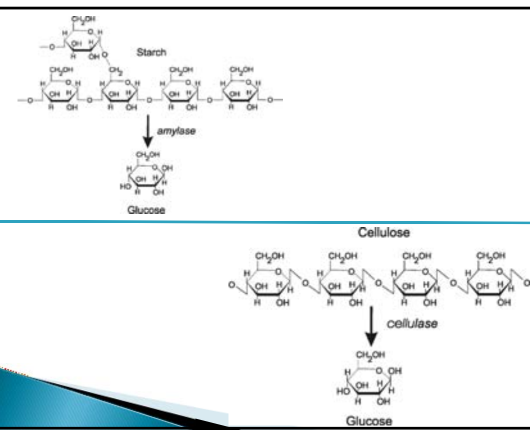
Unique demands of the horse industry....





Know what your clientele wants!

- What types of hay do they feed?
- Square vs. Round bales
- Forage test
- Sensory properties
- Delivery and storage
- Cost



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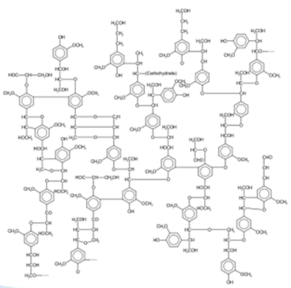
Hay for Horses

An example of a lignin structure…



What do horse owners feed?

- Grass hay
  - Bermudagrass
    - Coastal vs. other hybrids
    - The colic dilema
  - Timothy, Orchardgrass
  - Tall fescue—endophyte contamination
  - Ryegrass—problematic for sugar sensitive horses
- Legumes
  - Alfalfa
  - Perennial peanut
  - Red clover—slobbers
  - Lespedeza

Forage Quality Determined by:

- Digestibility
  - Maturity—stage when harvested
  - Moisture content
  - Stem to leaf ratio (more leaves=better quality)
- Free of dust, weeds, mold
- Storage for horses

Comparison of bermudagrass hybrids

Table 1a.
Summary of the characteristics of the primary vegetatively propagated (sprigged) bermudagrasses in Georgia.

Variety	Overall Rating	Yield*	Digestibility**	Winter Hardiness	Persistence	Leaf Spot Resistance
Alicia (Alecia)	★★½	100	P	G	P	P
Coastal	★★★½	100	F	G	G	E
Coastcross II	★★★★½	135	E	G	ND	ND
Russell	★★★★½	130	G	E	E	G
Tifton 44	★★★★	90	G	E	G	E
Tifton 78	★★★	120	E	F	F	E
Tifton 85	★★★★★	135	E	F	E	E

Ratings: E = Excellent, G = Good, F = Fair, P = Poor.
* Yields are expressed as a percent of yields from Coastal.
** Based on *in vitro* dry matter digestibility.
ND Insufficient data exists to accurately estimate these parameters. Coastcross II remains a relatively new variety and has not yet been evaluated as rigorously as other hybrids.

Selecting a forage bermudagrass variety. UGA Cooperative Extension. Dennis W. Hancock, Norman R. Edwards, T. Wade Green, Deron M. Rehberg.

What goes wrong with performance horses??

Colic

Ulcers

Molds and fungi in forages

- Horses can be very sensitive to molds
  - Storage is very important
- Tall fescue
  - Endophyte produces ergovaline—reproductive problems
- Sweet clover
  - Moldy plants produce dicumerol
- Red clover
  - Rhizoctonia leguminicola
  - Slaframine

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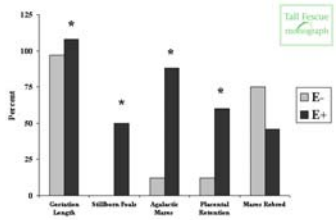
Hay for Horses

Fescue Toxicosis



Comparison of the effects of E+ and E– tall fescues on gestation length, foal mortality, agalactia, incidence of placental retention, and rebreeding response in mares (adapted from Monroe et al., 1988). Stars indicate significant difference between treatments ($P < 0.05$).

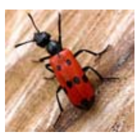
Fribourg, H. A., D. B. Hannaway, and C. P. West (ed.) 2009. Tall Fescue for the Twenty-first Century. Agron. Monog. 53. ASA, CSSA, SSSA. Madison, WI. 540 pp. Also (http://forages.oregonstate.edu/tallfescuemonograph).

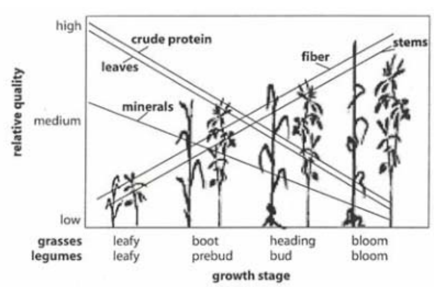
Forage analysis to determine hay quality!

- DE most important; ADF, NDF
- Protein
  - Good quality grasses: 10-16% CP on DM basis
  - Good quality legumes: 18-22% CP on DM basis
- Also should include % moisture
  - No less than 10% (leaf shattering)
  - No more than 15-18% (mold, combustion)
- Minerals, esp. Ca, P

Other forage contaminants

- Blister beetles
  - Cantharidin
  - Alfalfa
  - ¼"X 3/4"
  - Cutting of hay





http://animal.ifas.ufl.edu/extension/equine/documents/2006EquineInstit/SelectingHay.pdf

Nitrate Toxicity

- Urea
  - NPN
  - Digestion in rumen vs. stomach/small intestine
    - Conversion to CO_2 and ammonia
  - Toxicity: 0.3-0.5 g/ lethal 1-1.5 g/kg; horses 4 g/kg
- Forage nitrate accumulation
  - Sudan grasses, Johnsongrass, Bermudagrass, Tall Fescue, Ryegrass, Pearl Millet, Crabgrass
  - Higher concentration following heavy fertilization
  - <4500 ppm dry forage safe
    - Horses may tolerate closer to 10,000 ppm

Hay Market Task Force Classifications

Quality Standard	Crude Protein	ADF (Acid Detergent Fiber)	NDF (Neutral Detergent Fiber)	RFV (Relative Feed Value)
Prime	>19%	<31%	<40%	>151
1	17-19%	31-35%	40-46%	151-125
2	14-16%	36-40%	47-53%	124-103
3	11-13%	41-42%	54-60%	102-87
4	8-10%	43-45%	61-65%	86-75
5	<8%	>45%	>65%	<75

<u>**Additional considerations:**</u>

DE less than 0.75 Mcal/lb are not suitable for horses
ADF greater than 45% are not very digestible to horses
NDF greater than 65% are not readily eaten by horses

ADF less than 31% considered excellent
NDF less than 40% considered excellent

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Hay for Horses

How do different hays rank?

Table 1: Typical nutrient content of hays fed to horses (as-fed basis)*

Hay Variety	Digestible Energy (Mcal/lb)	Acid Detergent Fiber (%)	Crude Protein (%)	Calcium (%)	Phosphorus (%)
Alfalfa	0.8 to 1.1	24 to 34	15 to 22	0.9 to 1.5	0.2 to 0.3
Perennial peanut	0.8 to 1.0	28 to 38	10 to 15	0.9 to 1.5	0.2 to 0.3
Orchardgrass	0.7 to 1.0	30 to 40	7 to 11	0.3 to 0.5	0.2 to 0.3
Timothy	0.6 to 1.0	30 to 40	6 to 11	0.3 to 0.5	0.2 to 0.3
Bermudagrass	0.7 to 1.0	28 to 38	6 to 11	0.3 to 0.5	0.15 to 0.3
Grass/legume mix hay	0.8 to 1.0	27 to 36	12 to 18	0.8 to 1.2	0.2 to 0.3

Source: Dairy One, Feed Composition Laboratory

How to determine value?

- Need to determine:
  - Cost of hay/pound
  - Mcal of DE/$
- Example 1
  - 50 lb bale of bermudagrass that costs $5.00
  - $5.00/50 lbs = $0.10/lb
- If that bale of hay had 0.80 Mcal DE/lb
  - .80 Mcal DE/lb X 1 lb/$0.10 = 8 Mcal DE/$1.00
- Example 2
  - What about a bale of alfalfa that costs $10.00/bale and has 1.00 Mcal DE?
  - $10.00/50 lbs = $0.20/lb
  - 1 Mcal DE/lb X 1 lb/$0.20 = 5 Mcal DE/ $1.00

Different hays for different horses?

Table 3: Guidelines for Matching Hay to the Horse

Horse	Type of Hay	Visual Characteristics*	Laboratory Characteristics	
			Crude Protein	ADF
Weanlings Lactating mares	Early- to Mid- Maturity Legume hays or Grass/legume Mix hays	Leafy Fine stemmed Few seed heads/flowers	> 14%	< 34%
Performance Yearlings 2-year-olds	Mid- Maturity Grass or Legume hays or Grass/legume Mix hays	Leafy Medium-fine stems Small, soft seed heads, small flowers on legumes	12 – 16 %	30 – 36%
Recreation use or idle horses	Mid- to Late-Maturity Grass hays Late- Maturity Grass/legume Mix	Medium stems Large, soft seed heads, flowers on legumes	8 – 12%	37 – 40 %
Overweight	Late- Maturity Grass hays	Thick, coarse stems Large, brittle seed heads	7 – 10%	> 40%

All hay should be clean-smelling and free from molds, weeds and trash; avoid excessive rain damaged hay.

http://animal.ifas.ufl.edu/extension/equine/documents/2006EquineInstit/SelectingHay.pdf

Carbohydrate testing

- NSC vs ESC vs WSC
- WSC
  - Simple sugars, disaccharides, oligosaccharides, and some polysaccharides
  - Includes fructans
  - Glycemic response depends on % of fructans
- ESC
  - Subset of WSC
  - Includes sugars, disacharides, oligosaccharides and some fructans
  - Typically induces high glycemic response
- NSC
  - WSC+starch

How to estimate digestible energy…

- DE (kcal/kg DM) = 2,118 + 12.18 (CP%) – 9.37 (ADF %) –3.83 (hemicellulose %) + 47.18 (fat %) + 20.35 (NSC) – 26.3 (ash %)
- DE(kcal/kg) = 255 + 3660 x TDN

Average sugar, starch, and non-structural CHOs

FEEDSTUFF	SUGAR	STARCH	NSC
Oat hay	16.0%	6.3%	22.3%
Alfalfa hay	8.9%	2.5%	11.4%
Bermudagrass hay	7.5%	6.1%	13.6%
Grass hay	11.1%	2.9%	13.8%
Beet pulp	10.7%	1.4%	12.1%
Oats	6.3%	44.4%	50.7%
Corn	3.7%	70.3%	74.0%
Wheat middlings	10.1%	26.2%	36.3%
Soybean meal	14.3%	2.1%	16.4%

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- http://www2.ca.uky.edu/agc/pubs/id/id146/id146.htm
- http://animalscience.tamu.edu/files/2012/04/equine-selection-usage-hay-processed-roughage11.pdf

Climate Outlook and Implications for the Hay Market

Dr. Pam Knox, Extension Climatologist

Climate Outlook & Implications

Climate Outlook and Implications for the Hay Market

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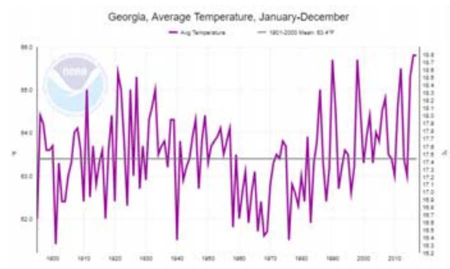
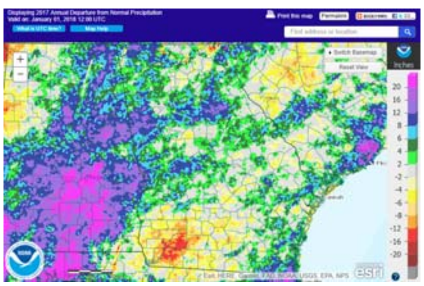
2017 was tied with 2016 for the warmest year on record in Georgia



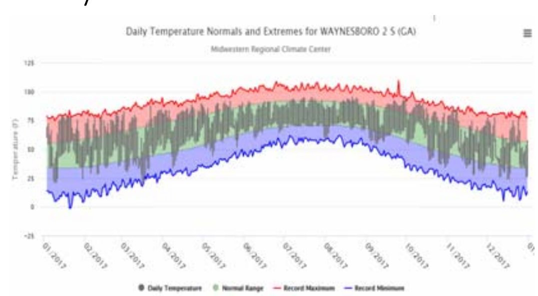
https://www.ncdc.noaa.gov/cag

A Look Back at 2017-Precipitation



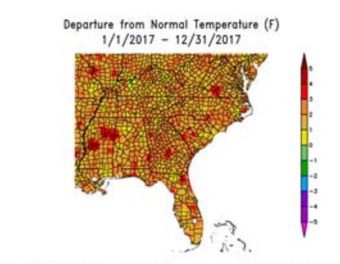
http://water.weather.gov/precip/

Waynesboro in 2017



http://mrcc.isws.illinois.edu/CLIMATE/Station/Monthly/StnNormsExtremesChart.jsp

A Look Back at 2017-Temperature



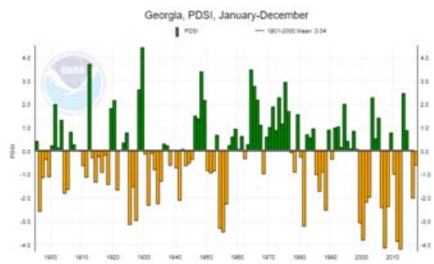
https://hprcc.unl.edu/maps.php?map=ACISClimateMaps

No long-term trend in Georgia's precipitation

https://www.ncdc.noaa.gov/cag

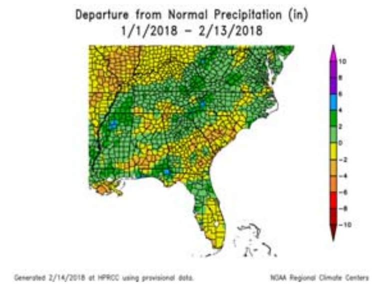
2018 Hay and Baleage Short Courses
Climate Outlook & Implications

Droughts are getting longer and more frequent



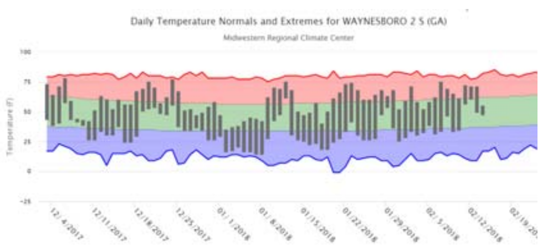
https://www.ncdc.noaa.gov/cag

Where are we now?



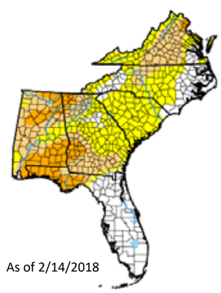
https://hprcc.unl.edu/maps.php?map=ACISClimateMaps

Where are we now in 2018?



http://mrcc.isws.illinois.edu/CLIMATE/Station/Monthly/StnNormsExtremesChart.jsp

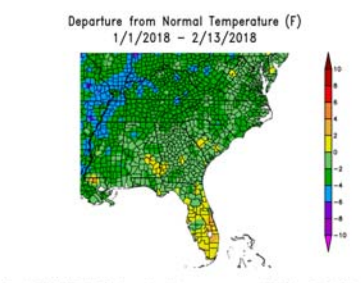
Where are we now?



As of 2/14/2018

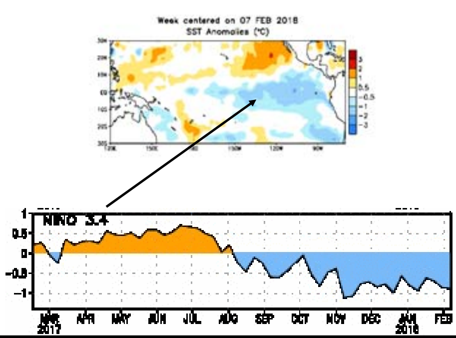
http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?Southeast

Where are we now?



https://hprcc.unl.edu/maps.php?map=ACISClimateMaps

La Niña is at peak and will decline



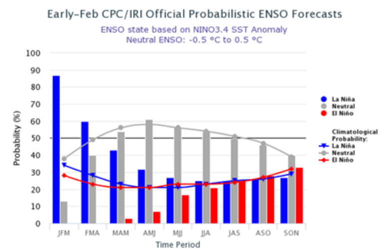
Dr. Pam Knox
Extension Climatologist

UGA extension

2018 Hay and Baleage Short Courses

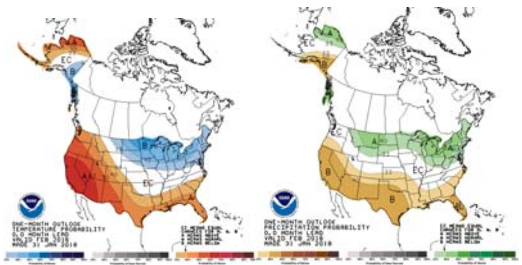
Climate Outlook & Implications

La Niña is expected to be done by mid-spring



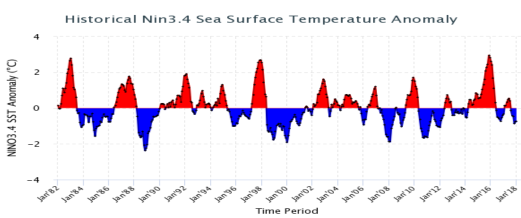
https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current-2/

Outlook for February 2018



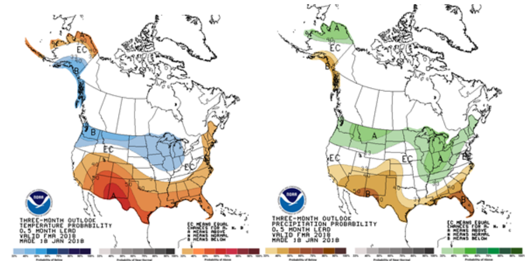
http://www.cpc.noaa.gov/products/predictions/30day/

Recent research shows that in the 2nd year of a "double-dip" La Niña, parts of the Southeast may be drier than the first year (esp. TN Valley)



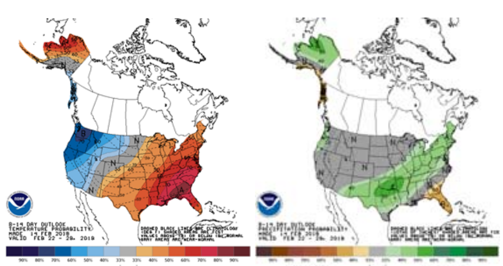
https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current-2/

Outlook for February-April 2018



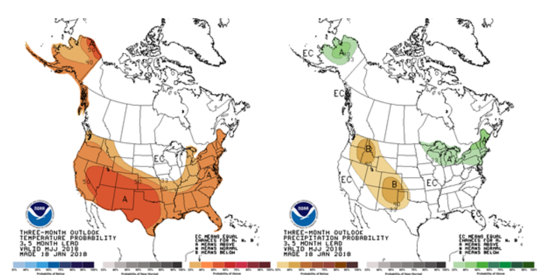
http://www.cpc.noaa.gov/products/predictions/long_range/

Outlook for days 8-14



http://www.cpc.noaa.gov/

Outlook for May-July 2018



http://www.cpc.noaa.gov/products/predictions/long_range/

Dr. Pam Knox
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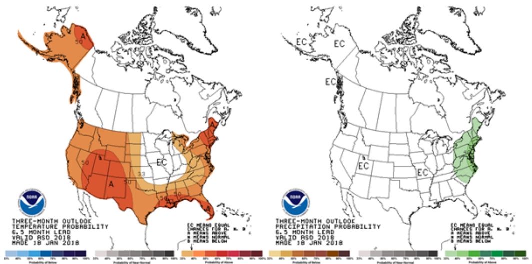
Climate Outlook & Implications

Outlook for August-October 2018

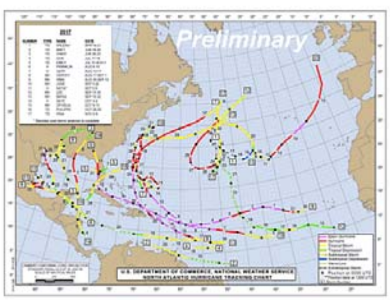


http://www.cpc.noaa.gov/products/predictions/long_range/

What it means for hay and forage

- Take advantage of spring moisture to get pastures established
- Be prepared for dry conditions starting in early to mid-summer reducing yields and increasing pests
- Keep an eye on the tropics from June on to make sure you avoid big rain events for drying

What about the tropics?



https://www.nhc.noaa.gov/data/tcr/

Thank you!

Pam Knox
pknox@uga.edu
706-310-3467 office
706-621-1970 cell
http://blog.extension.uga.edu/climate

On the CASE...
Climate and Agriculture in the South East

Forecast for 2018 Growing Season

- Dry conditions will decrease short-term
- We could see a return to colder conditions in March
- Drought is likely to return this summer
- Atlantic tropical season will be active again, but we don't know where the storms will go

Dr. Pam Knox
Extension Climatologist

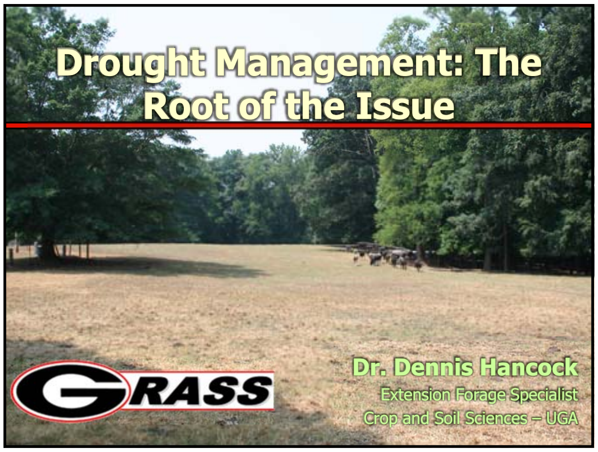
UGA extension

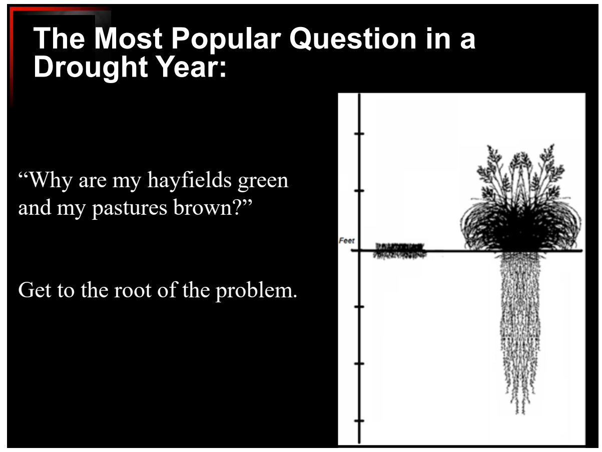
Drought Management: The Root of the Issue

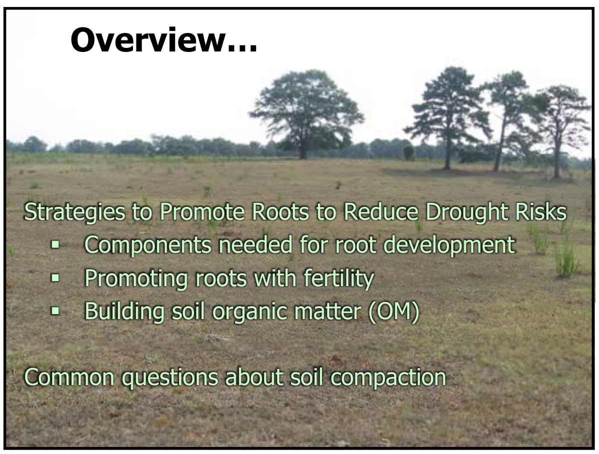
Dr. Dennis Hancock, Extension Forage Agronomist

2018 Hay and Baleage Short Courses

Drought Management: Root of the Issue





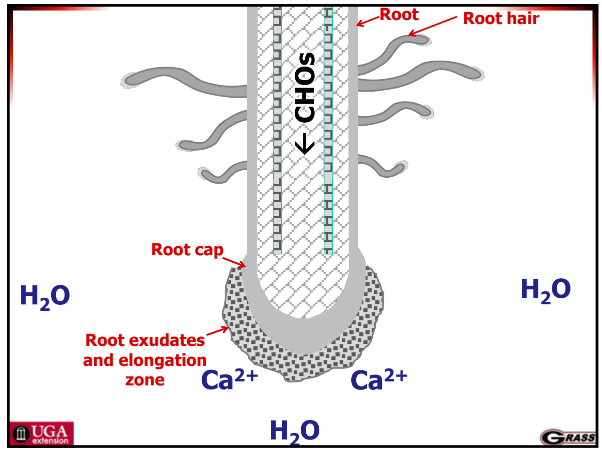


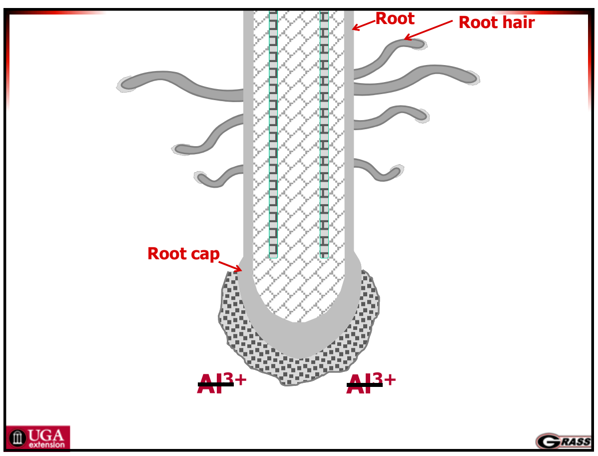
Drought Tolerance

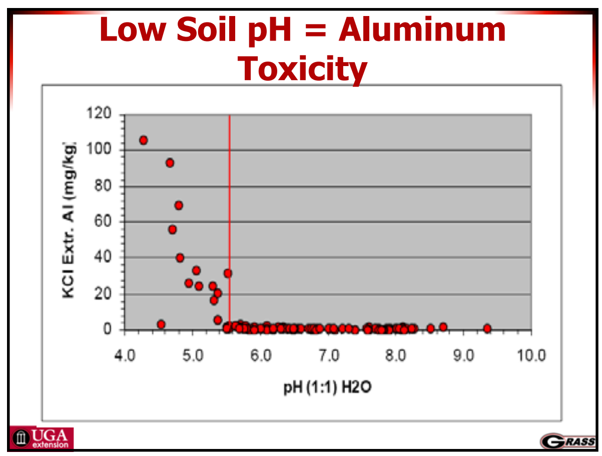
Species	Water Use Efficiency	Max. Root Depth
	DM lbs/inch	inches
Coastal Bermudagrass	1646	78
Pensacola Bahiagrass	1194	79
Tall Fescue	1064	48
Ladino Clover	480	38
Red Clover	436	45

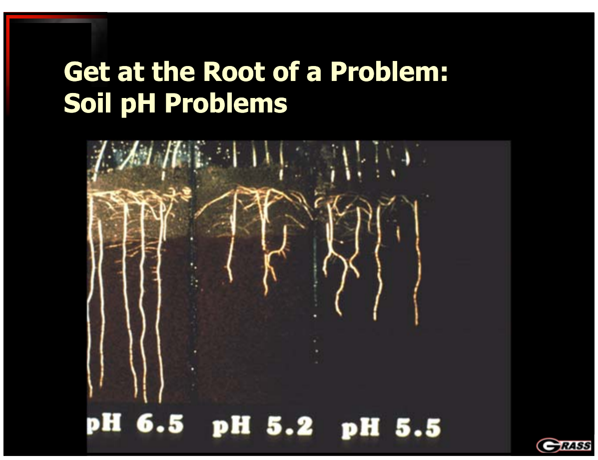
From: Southern Forages, as adapted from Doss et al. (1960; 1962; 1963)

Drought Management: Root of the Issue



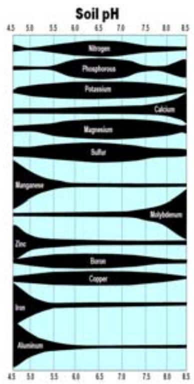






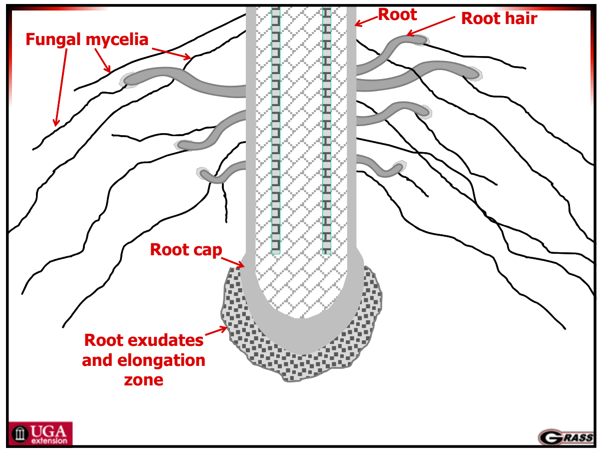
Drought Management: Root of the Issue

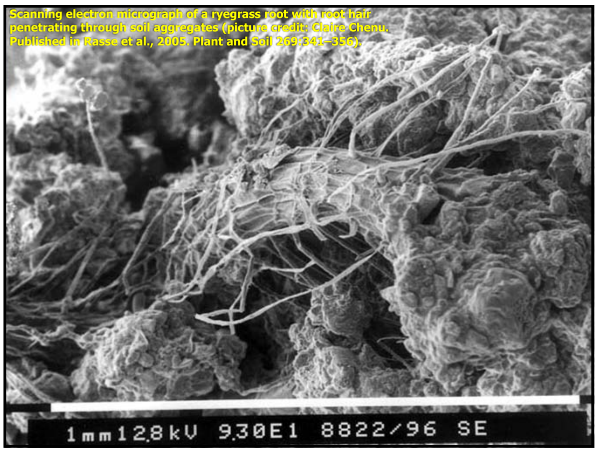
How Soil pH Affects Availability of Plant Nutrients



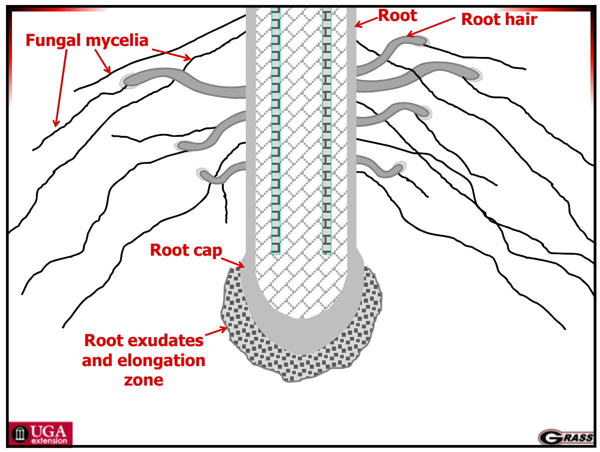
The difference of a soil pH of 5.6 vs. 6.2:

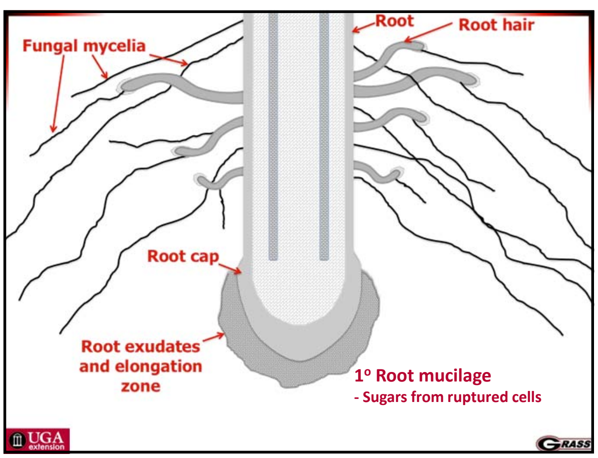
Nutrient	Amt. Used Annually (Lbs/acre)	Unit Price ($/lb)	Dec. in Efficiency	Value of Decrease ($/acre)

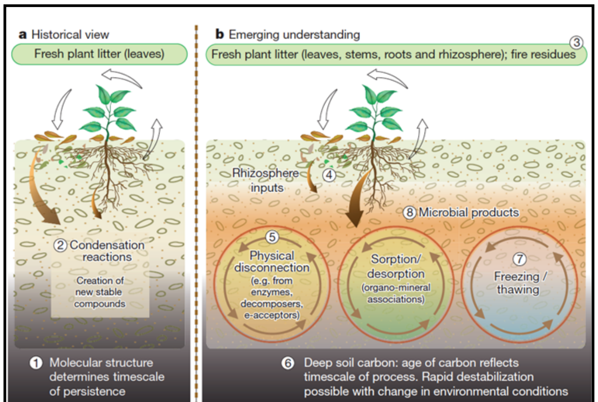




Scanning electron micrograph of a ryegrass root with root hair penetrating through soil aggregates (picture credit: Claire Chenu. Published in Rasse et al., 2005. Plant and Soil 269:341–356).

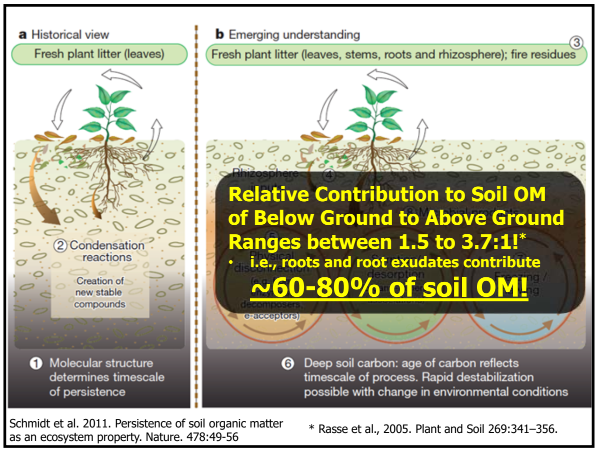


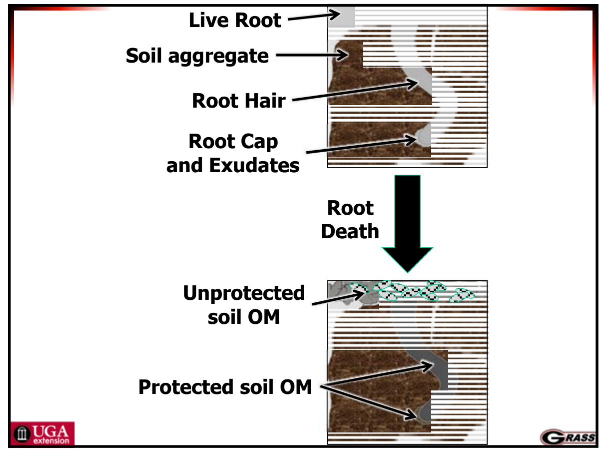


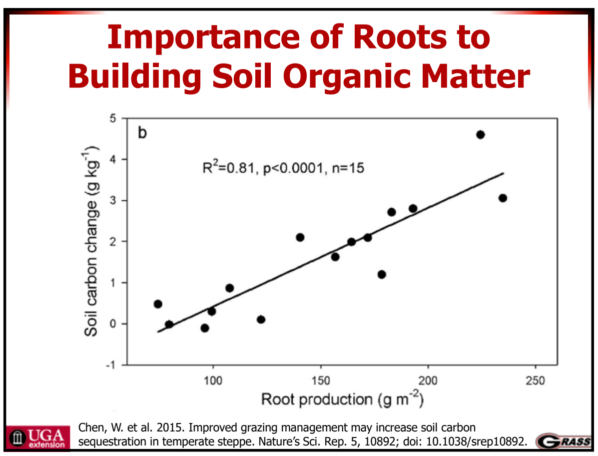


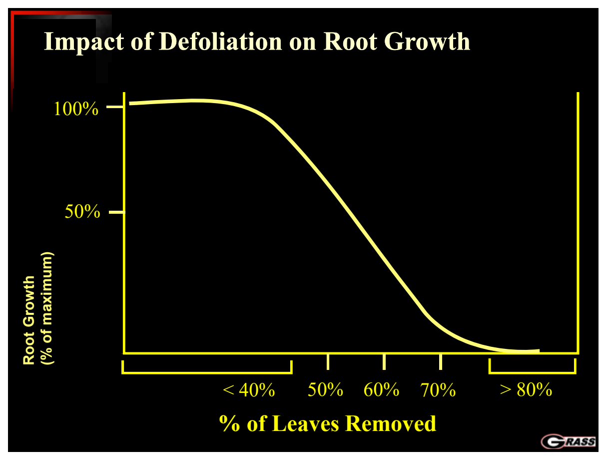
Schmidt et al. 2011. Persistence of soil organic matter as an ecosystem property. Nature. 478:49-56

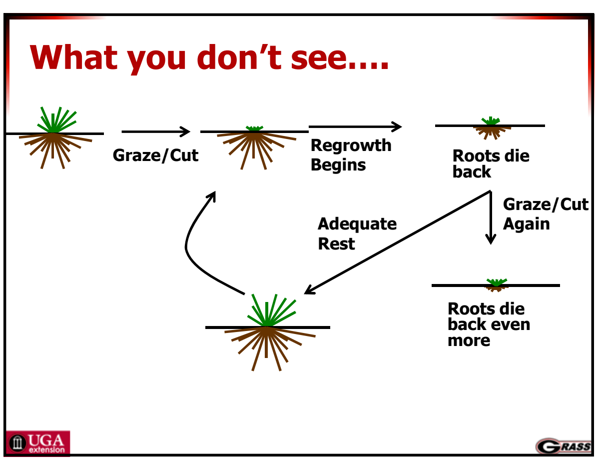
Drought Management: Root of the Issue











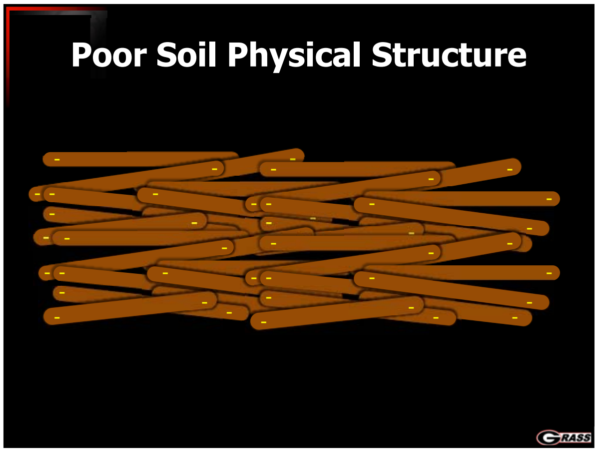
Drought Management: Root of the Issue

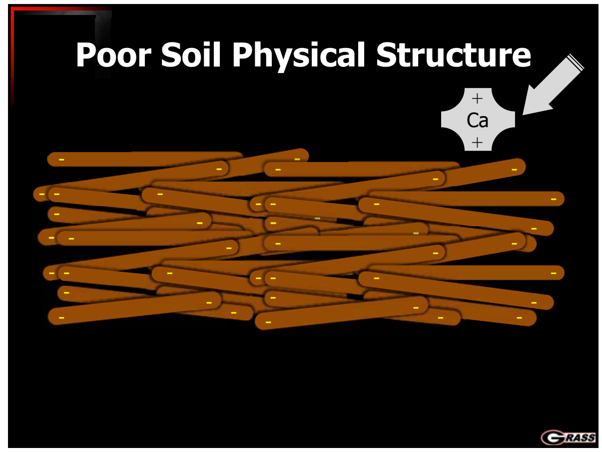
Pasture Aeration Treatment –
Mississippi State Univ. 1993; Bahiagrass

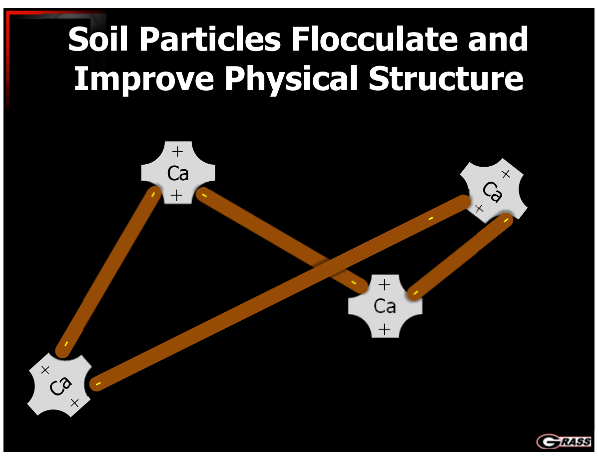
	Bahiagrass Yields	Penetrometer Strain (July)
	lbs of DM/ac	*lb/in²*
Rolling Spike		
Shank Renovator		
Disk		
Deep Chisel (10")		
Control		
LSD(0.05)	866	28

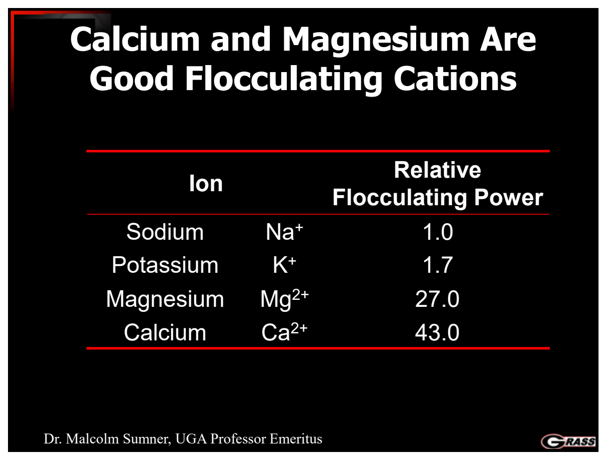
Hayfield Aeration
MSU 1994-95; Bermudagrass

	Coastal, Brown Loam Branch		Tifton 78, Coastal Plain		Alicia, White Sands	
	1994	1995	1994	1995	1994	1995
			lbs DM/acre			
Control						
Spring						
Summer						
Spring + Summer						
$LSD_{(0.05)}$						









Ion		Relative Flocculating Power
Sodium	Na^{+}	1.0
Potassium	K^{+}	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

Problem Insects and What to Do About Them

Dr. Will Hudson, Extension Entomologist

Problem Insects in Hayfields

Hayfield Pests: The Worst of the Worst

Will Hudson
Extension Entomologist
University of Georgia

- BSM Damage

Bermudagrass stem maggot
Atherigona reversura

- First found in Georgia in 2010
- Now found throughout range of Bermudagrass
- Maggot chews stem at the first node, killing the last 2 leaves

- Heavy BSM Damage

Photo by S. Carlson

- Bermudagrass stem maggot

Photo by L. Wiggins

Photo by S. Carlson

BSM Management

- Check finer-textured varieties before harvest
- If there is noticeable damage, plan to treat 10-14 days after cutting
- Pyrethroids work, no preference for which
- Unirrigated fields may require a second treatment if regrowth is slow

Dr. Will Hudson
Extension Entomolgist

Problem Insects in Hayfields

BSM Management

For middle GA, the July cutting is usually the first to show damage. Damage may appear in June farther south.

In UGA trials, a single application has been effective for irrigated fields. Without irrigation, slower regrowth may mean a second application 10-14 days after the first.

Once the grass is 6"-8" tall, it may be more practical to cut and protect the regrowth if damage is heavy.

If the field next door is mowed, the flies will move!

ARMYWORMS

- SYMPTOMS: GRASS BLADES EATEN
- THRESHOLD: VARIES WITH SIZE AND WEATHER
- TREATMENT: CONFIRM, PYRETHROIDS, SEVIN, OR DIMILIN
- DIAMIDES ARE GOLD STANDARD ($$$)
  - Prevathon, Besiege

Armyworms

Which Insecticide?

- How early?
  - The earlier they show up, the more treatments you are likely to make
- How much hay do you have/need?
  - In good years, late cuttings may not be eaten
- How much do you want to spend?
  - Pyrethroids are cheap, but repeated applications add up.
    - If you treat more than 2-3 times, you've spent more than the diamide

FALL ARMYWORMS

- ADULTS - MOTH
- EGGS LAID IN MASS
- GENERATION - 28 DAYS
- OVERWINTERS IN FL.
- DRY SUMMERS OFTEN WORSE

Fire Ant Biology

- Colony life begins with a mating swarm
- Mated queens dig or find a spot to construct a cell in the earth, then lay first eggs
- Developing larvae are fed by queen
- Once the first workers become adults, foraging begins
- First reproductive produced >6 months after the new queen initiates the colony

Dr. Will Hudson
Extension Entomolgist

Problem Insects in Hayfields

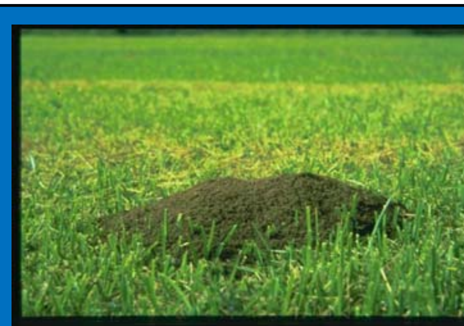
Fire Ant Facts

7 Years – life span of a fire ant queen

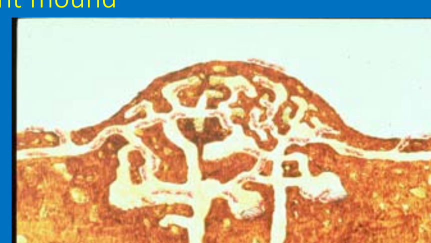
60-90 days – life span of fire ant worker

400,000 – possible number of workers in a mature colony

1,000 – number of eggs a fire ant queen may lay in a day



Fire ant mound



- foraging occurs between 72°F and 96°F
- Thermoregulation within the mound

Dr. Will Hudson
Extension Entomolgist

Problem Insects in Hayfields

Fire Ant Control

- 2-step program
  - Baits twice per year
  - Mound treatments for established colonies
  - The best approach, if area is large enough
- Broadcast/contact treatments
  - Quick results
  - Effective for small areas or short time
  - More expensive than baits

Fire ant treatment methods: Chemical Control

- Some commonly used contact insecticides:

acephate	Orthene, other names
botanicals	
carbaryl	Sevin, other names
fipronil	Chipco Choice, TopChoice,
inorganic compounds	Boric acid, diatomaceous earth
pyrethoids	Talstar, etc.
spinosad	Conserve, Greenlight, others

Fire Ant Control Options

- Baits
  - Cheap - $20-$30/acre
  - Slow – 3-8 weeks for control
  - The best option for large areas
- Broadcast/Contact
  - Quick
  - Provide a few weeks – a year of control
  - Price varies from <$10 to >$200 per acre

Natural Control

Fire ant treatment methods: BAITS

- Some commonly used **baits**:

avermectin	Ascend, Clinch, Varsity
fipronil	Maxforce FC
hydramethylnon	Amdro, AmdroPro, SiegePro, Combat, MaxForce, Probait, Raid
indoxycarb	Advion, Spectracide, Real-Kill
insect growth regulators (fenoxycarb, methoprene, pyriproxyfen)	Award, Logic, Extinguish, Distance
spinosad	Greenlight, Safer, Conserve
hydramethylnon+methoprene	Extinguish

Dr. Will Hudson
Extension Entomolgist

Fire Ant Quarantine and Hay Transport
Summarized by David Buntin, Univ. of Georgia
March 15, 2011

The red imported fire ant (*Solenopsis invicta*) was accidentally introduced around Mobile, Alabama in the early 1930's. The ant has spread throughout the southern United States and is also present in southern California. The fire ant is regulated by a federal quarantine regulating movement of certain agricultural materials outside of a quarantine area. The U.S. Department of Agriculture, Animal Plant health Inspection Service (USDA-APHIS) and various state agencies (such as the Georgia Department of Agriculture) have authority to enforce the quarantine. The map below shows the quarantine area as of October 2009. Recently, concerns about the spread of the imported fire ant have prompted the USDA-APHIS to be more restrictive on the transport of hay and crop straw out of quarantine areas. The following information items some recent conversations with state and federal officials on this subject.

Quarantine Rules

• Only hay and crop straw are regulated. Pine straw if not specifically listed in the quarantine regulations. Other products are also regulated including turf and ornamental nursery potted plant. Full details are here:
http://www.aphis.usda.gov/plant_health/plant_pest_info/fireants/index.shtml.

• Hay and crop straw can be shipped anywhere within the quarantine area (see map) without a permit, which includes all of the states of Georgia, South Carolina, Alabama, Mississippi, and Florida and parts of surrounding state (for current map of the quarantined area, visit: http://www.aphis.usda.gov/plant_health/plant_pest_info/fireants/downloads/fireant.pdf).

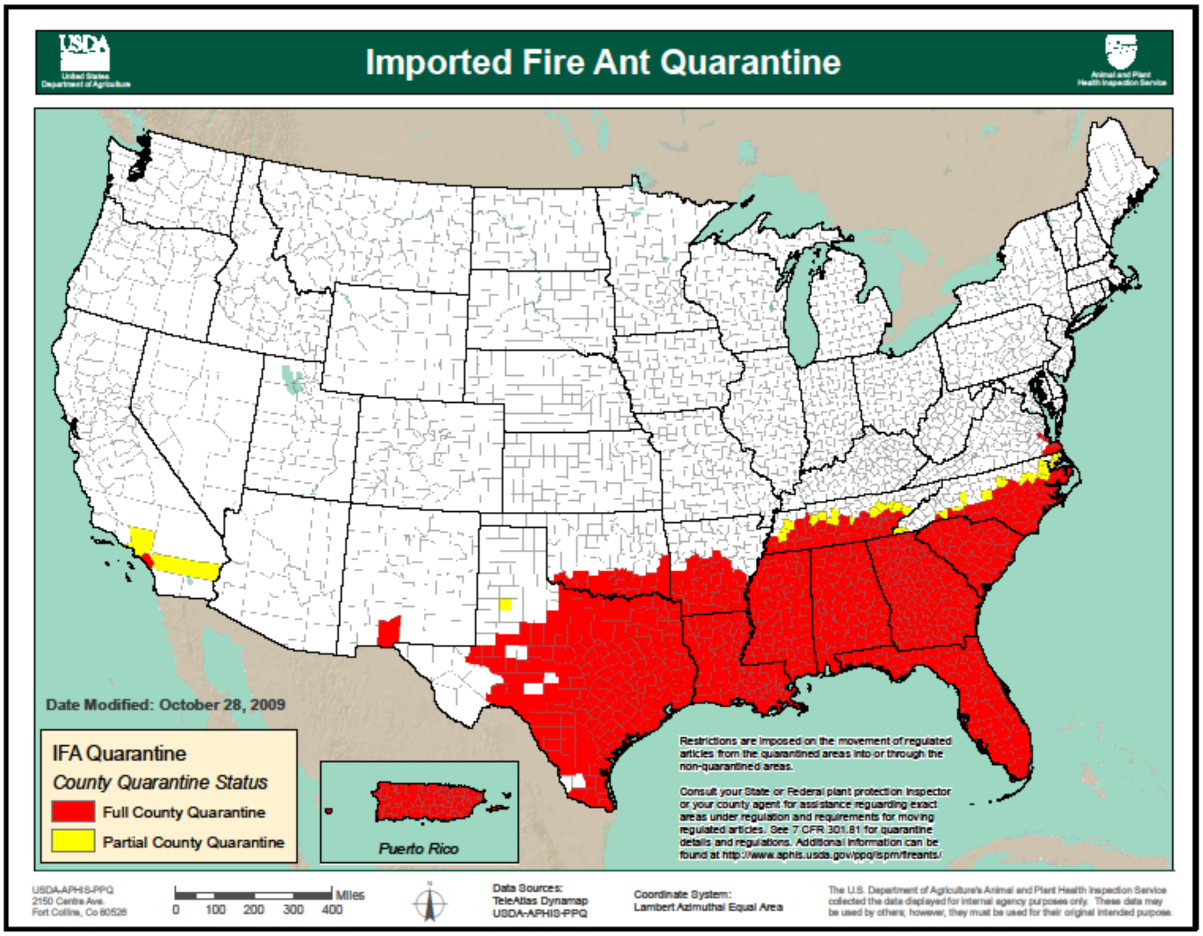
• For shipping outside the area, a shipping permit or stamp may be required by the state outside the quarantine area. In Georgia, for a one-time shipment, a farmer can call the Georgia Dept of Agriculture (Division of Plant Industry - Plant Protection). An inspector will inspect their operation and issue a fire ant stamp for shipment. For farmers or brokers that want to ship out of quarantine area routinely, they can meet with the Dept of Agriculture and arrange for a long-term compliance agreement for multiple shipments.

Best Management Practices

• Hay should be picked up and stored as soon as possible after baling. Hay can remain in the field after baling for a short period of time before it is picked up and moved into a storage barn. The term 'short time' is not defined in the regulations but a one or two days is acceptable, but the bales should not lay out much longer due to the risk of infestation.

• If stacked bales are stored under enclosure such as an open pole barn, the bottom layer of hay must remain in the quarantined area, everything else may move.

• There currently are no insecticide treatments for directly treating stored hay to remove fire ants in hay and straw. However treatment of the area around the storage site with an insecticide registered for fire ant control, such as insecticide bait products, is acceptable to reduce the risk of infestation. Products must be applied according to label directions and should not be applied directly to the stored hay or straw.



Managing BERMUDAGRASS STEM MAGGOTS

Lisa L. Baxter | *Post-Doctoral Research Associate, Department of Crop and Soil Sciences*

Dennis W. Hancock | *State Forage Extension Specialist, Department of Crop and Soil Sciences*

Will G. Hudson | *Extension Entomologist, Department of Entomology*

Bill Anderson | *Plant Geneticist, United States Department of Agriculture's Agricultural Research Service, Coastal Plain Experiment Station*

Jennifer J. Tucker | *Assistant Professor, Department of Animal and Dairy Sciences*

UGA extension

In the summer of 2010, bermudagrass (*Cynodon dactylon* (L.) Pers.) hay producers in Georgia counties (Jeff Davis, Irwin, Pierce, and Tift) began noticing a "bronzing" of their hay fields, generating damage similar to that of severe drought- or frost-damaged bermudagrass (Figure 1A). The bronzing was the result of chlorosis and necrosis in the top two to three leaves of the plant (Figure 1B). The damaged leaves could easily be pulled from the sheath, and the end inside the sheath either showed evidence of insect damage or obvious decay (Figure 1C). The collected larvae were grown out and allowed to pupate and mature. The resulting adults were subsequently identified as *Atherigona reversura* Villeneuve (Diptera: Muscidae), now commonly known as the bermudagrass stem maggot (BSM).

Figure 1A. "Bronzing" of bermudagrass hay fields as a result of bermudagrass stem maggot damage. *Photo by Will Hudson.*

Figure 1B. The bronzing is the result of damage done at the uppermost node that results in the deterioration of the top two to three leaves of the plant. *Photo by Lisa Baxter.*

Figure 1C. The damaged leaves can easily be pulled from the sheath and the end inside the sheath shows evidence of insect damage or obvious decay. *Photo by Lisa Baxter.*

The BSM is believed to be native to Southeast Asia, which is where it was first discovered. Since the 2010 discovery in southern Georgia, the BSM has spread throughout the Southeast, damaging bermudagrass turfgrass, hayfields, and pastures as far north as North Carolina and Kentucky and as far west as Texas.

Yield Losses

In general, each *Atherigona* species has its own preferred host. Though it may be found on or around other grass species, *A. reversura* has only been found to damage bermudagrass and stargrass (*C. nlemfuensis*) in the United States.

The larva of BSM bores into the pseudostem, the stem-like structure made up of leaf sheathes, where it macerates the vascular tissue. It feeds on the sap and microbial soup that it creates from the macerated tissue. This feeding occurs outward from the last node of the plant, which cuts off water and sap flow to and from the top two to three leaves. The amount of yield loss caused by this feeding depends upon the stage of growth wherein the damage occurs.

If the damage occurs once the bermudagrass is nearing harvest, the loss of those top two to three leaves may reduce the yield by less than 10% for that cutting. However, if the damage occurs during the early stages of regrowth, affecting less than 6 inches (15 centimeters) of new growth, yield losses can be severe. Yield losses in excess of 80% have been reported in bermudagrass hayfields in the later part of the season.

Since bermudagrass is grown for hay and pasture—around 300,000 and 3 million acres, respectively, in Georgia alone—on so many acres across the Southeast, the economic impact of the BSM is substantial. Conservatively, a total yield loss of up to 3 tons/acre (6,700 kg/ha) could be expected in a typical bermudagrass hayfield in south Georgia if the BSM was left untreated. Depending on the quality and market for this forage, a loss of 3 tons/acre could represent an economic loss of over $600/acre ($1,500/ha). Preliminary research has shown that BSM damage decreased relative feed quality (RFQ) of late-season bermudagrass hay by 7% on average. This decrease was attributed to lower total digestible nutrients (TDN) and slightly lower dry matter intake (DMI). Crude protein (CP) actually increased in the damaged bermudagrass, but this was a function of dilution of desirable carbohydrates. This would be similar to the phenomenon seen in weathered hay such that CP is actually higher in the outer edges of the hay bale where desirable carbohydrates have leached out of the bale while the nitrogen remains.

Growth Stages

Like other species in the Muscidae family, the adult stage of the BSM is a fly. The BSM fly is easier to find and identify than the larva or pupae because it occurs outside of the pseudostem and has distinct coloration (Figure 2). They have transparent wings, a gray thorax, and a yellow abdomen with at least one pair of black spots. Adult BSMs are about 1/8 inch (around 3.0 to 3.5 millimeters) in length. The females are typically larger than the males. The female abdomen is longer, more pointed, and curves under the fly's body. In contrast, the male's abdomen is shorter and more rounded. The proportion of female to males in a population varies from field to field and, perhaps, with the season. Data collected to date indicate that the females outnumber the males by an average of 4.6 to 1. However, this ratio has been observed to vary from 2:1 to 10:1.

The BSM female has the potential to lay a large number of eggs. Figure 3 shows the two ovaries of the female's reproductive tract. Within each ovary, there are approximately 15 to 18 ovarioles. Each ovariole is capable of producing an oocyte (egg).

The larvae are white, cylindrical, and about 1/8 inch (3 millimeters) long when fully grown (Figure 4A). As they mature, their color gradually darkens to a tan or brown. The larvae also have mouth hooks that are barely visible to the naked eye. It is presumed that these mouth hooks enable the BSM to macerate the walls of the pseudostem. The metamorphosis of the BSM larvae into the adult fly occurs in a puparium, a rigid outer shell covering the pupae, that is orange to dark red and barrel-shaped, similar to that of other *Atherigona* species.

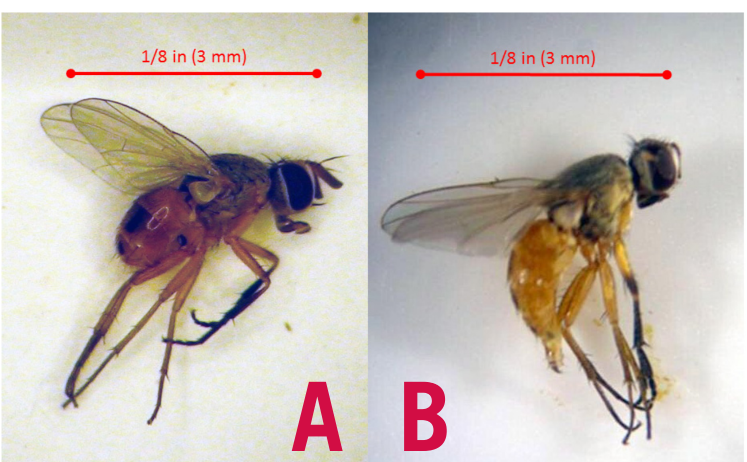


Figure 2. The adult male (A) and female (B) bermudagrass stem maggot fly. *Photo by Lisa Baxter.*

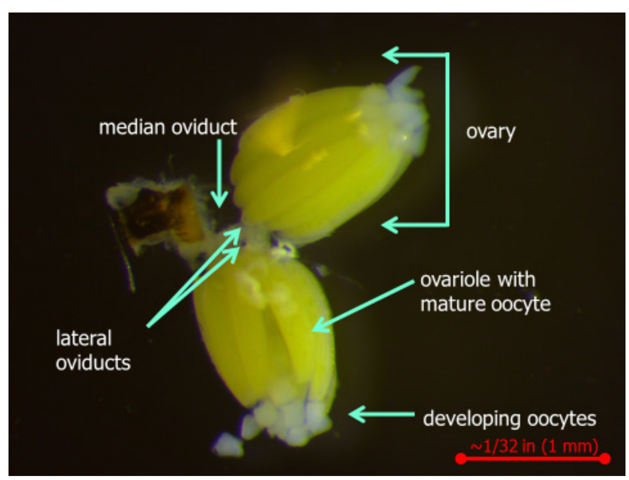


Figure 3. The reproductive tract of a female bermudagrass stem maggot fly. *Photo by Lisa Baxter.*

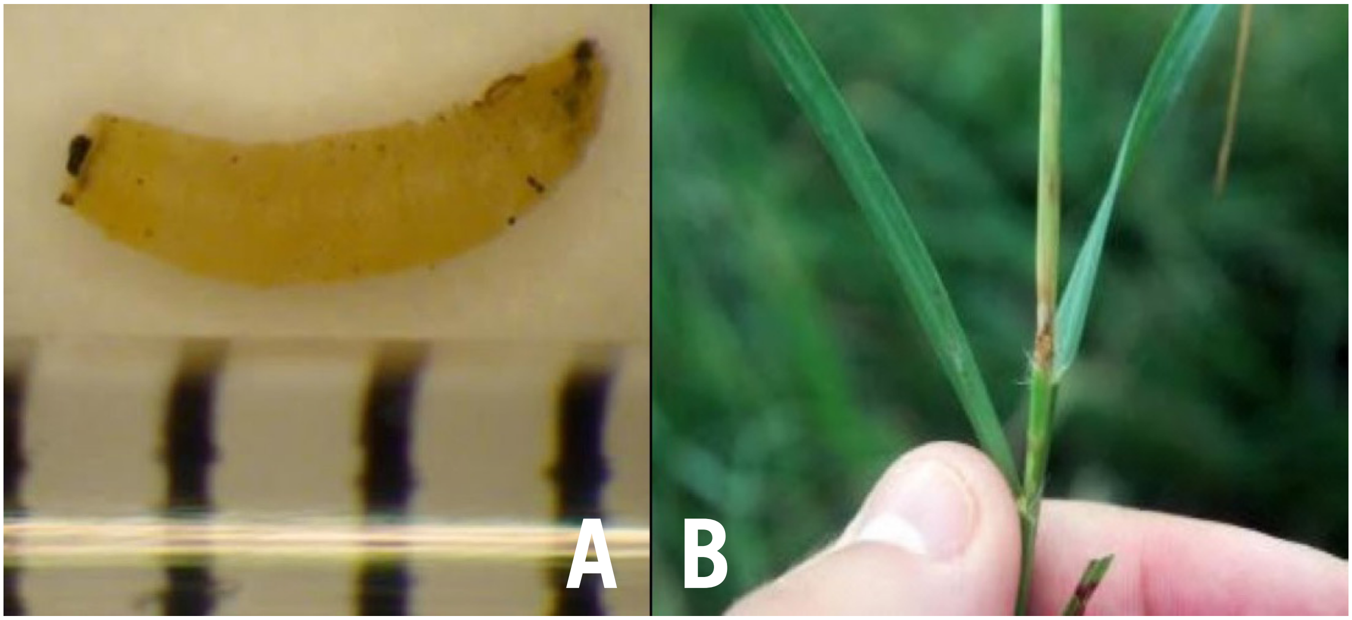


Figure 4. Larvae (A) of the bermudagrass stem maggot are approximately 1/8 inch (3 millimeters) long. After feeding, the larva bores through the pseudostem leaving behind an exit hole (B). *Photo by Lisa Baxter.*

Life Cycle

A better understanding of the bermudagrass stem maggot's life cycle and biology has emerged as research on the timing of these biological phases continues. The life cycle begins with the BSM fly laying an egg on a bermudagrass leaf. The larva emerges approximately two to three days post-oviposition, or after eggs are laid, and slips or bores into the central whorl of the pseudostem. Once in the pseudostem, it begins to macerate the vascular tissue at the first node it encounters.

The lack of sap flow causes the top two to three leaves to become chlorotic, or yellowed due to insufficient clorophyll. Within one to two days after feeding begins, the first signs of damage are observed, and the affected leaves soon become completely chlorotic or necrotic (prematurely dying). Between the time when chlorosis is first observed and complete leaf senescence, or deterioration, the larva exits the stem (Figure 4B) and moves to the soil for pupation. The metamorphosis occurs in an orange-colored puparium over the course of 7 to 10 days and culminates with the emergence of the adult fly.

It has also been shown that when the pseudostem is cut (with a hay mower or grazed, for example), any viable larvae will exit the stem and move to the soil to pupate. As a result, adult flies begin to emerge in a sizeable flush 7 to 10 days after cutting. These findings have helped refine the timing for insecticide applications for suppressing adult populations during the first two to three weeks following a cutting (see the "Chemical Control" paragraph in the "Mitigation Strategies" section).

Adult flies live for approximately 18 to 20 days when kept in enclosures and provided sugar water. Actual adult life spans are estimated to be 14 to 21 days. Based on these observations, we believe the complete life cycle of the BSM to be three to four weeks long with multiple offspring being produced by the fly during its adulthood.

The degree to which the BSM overwinters in the Southeast remains unclear. We have observed that populations increase progressively from south to north, with high populations developing as early as mid-June in central Florida, early July in south Georgia, mid-July in central Georgia, and late July in north Georgia and points further north. This would indicate that overwintering success is, at a minimum, much better in more southern climes. Nonetheless, we have collected flies as early as February near Valdosta, Georgia, and mid-May near Athens, Georgia, so we presume they have at least some ability to overwinter at these latitudes.

Assessing BSM Populations

The orange, barrel-shaped puparium of the BSM may be found just under the soil surface when the insect is pupating. However, finding puparia in the soil has proven too challenging for a practical assessment of BSM populations. Consequently, no protocols have been developed to search for the pupae in a damaged field's soil.

Finding the larva is only slightly less challenging, as it requires dissecting pseudostems as soon as they show the first signs of chlorosis in response to BSM damage. If the pseudostem shows extensive damage, then it is likely the larva has already left the pseudostem to pupate. Pseudostems may be carefully dissected using a sharp knife or razor blade, splitting the stem until the center of the shoot is revealed. Because of the small size of the larva, it is best to work over a solid, dark-colored surface so that the larva is not lost during the procedure.

Producers can use sticky traps or sweep nets to collect and identify the BSM fly in the field relatively easily (Figure 5). However, they tend to stay down in the forage canopy and rarely fly higher than 18 inches (0.5 meter) above the canopy. To date, sticky traps have only been useful in alerting one to the presence of the BSM because fly counts on sticky trap cards have not yet been observed to be correlated with fly populations. Sweep net estimates have been found to be relatively accurate predictors of actual fly populations in the field (Figure 6). Correlating fly populations to actual yield loss has proven much more challenging than simply catching and counting flies. The amount of damage is not merely a function of fly populations because a number of other factors also can influence yield loss. These include, but are not limited to, bermudagrass variety, timing of the infestation, number and proximity of bermudagrass fields near the field in question, timing of when those neighboring fields were last cut, amount of disease present in the crop, and the amount of fertilization added to the crop.

Figure 5. Sticky traps (A) and sweep nets (B) can be used to catch flies. After dumping the catch from 10 sweeps with the net in a collapsible observation cage (C), one can estimate the number of insects collected (D).

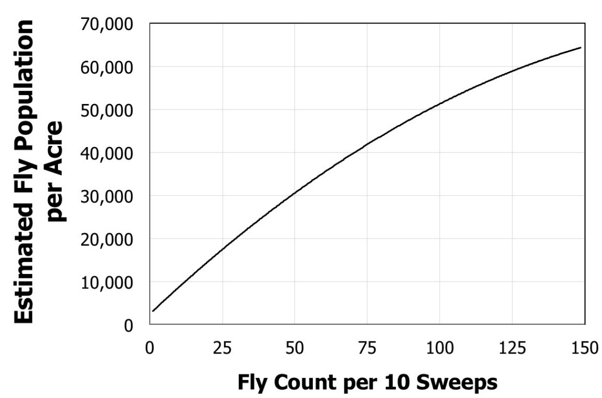


Figure 6. Estimated fly population per acre predicted from the number of flies counted per 10 sweeps with a sweep net.

Varietal Differences

Research into damage by the BSM has shown that varieties that produce finer leaves or pseudostems and/or produce more pseudostems per square foot (or square meter) tend to be more susceptible to damage and yield loss. In general, the coarse-textured varieties of stargrass (*Cynodon nlemfuensis* Vanderyst) and hybrids of bermudagrass and stargrass (cv. 'Tifton 85', 'Coastcross-I', and 'Coastcross-II') are less susceptible to BSM damage. While these varieties have fewer tillers, proportionately fewer of those tillers are damaged. Cultivars with a higher number of shoots also tend to have a smaller shoot diameter, narrower leaves, and a lighter green color. These plant characteristics create a denser forage canopy, which seems to attract the BSM (Figure 7).

Consequently, some varieties of bermudagrass are more susceptible to damage by the BSM than are others. Table 1 reports the common yield loss observed in research trials conducted by the University of Georgia and the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) in Tifton, Georgia, as well as observations made by UGA Extension agents and bermudagrass producers in Georgia. Though substantial yield loss can certainly be possible in the less susceptible varieties, performance is generally greater. Ongoing plant breeding efforts at the USDA-ARS in Tifton have shown progress in developing more varieties that are high yielding and high quality, while exhibiting more tolerance to the BSM. Until then, producers should choose the most tolerant variety that is recommended for their area.

Figure 7. Hybrids of bermudagrass with stargrass (left), such as 'Tifton 85,' 'Coastcross-I,' and 'Coastcross-II,' result in fewer tillers per unit area, larger tillers, and less canopy thickness compared to bermudagrass cultivars (right). *Photo by Lisa Baxter.*

Variety	Typical Range in Yield Loss Observations (%)
Sprigged	
Alicia	30-60*
Coastal	15-30*
Coastcross II	0-15*
Russell	20-40*
Tifton 44	15-30
Tifton 85	0-20*
Seeded	
Common	30-60*
Various seeded	30-60

Table 1. Varieties of bermudagrass differ in the amount of yield loss typical observed in harvests made after the second cutting.

Range observed in yield trials comparing treated and untreated plots.

Timing of Infestation

When BSM damage occurs near the end of a regrowth cycle (within 2.5 to 3 weeks after the previous cutting or grazing), the yield loss is usually less than 10%. However, a bermudagrass crop damaged at an early stage of regrowth (e.g., 6 to 8 inches or 15 to 20 centimeters) is unlikely to further develop. Bermudagrass is very intolerant of shade, especially in regards to producing new tillers or pseudostems. When the top of a 6-to-8-inch-tall crop (15 to 20 centimeters) is damaged and left in the field, it will cast enough shade to slow or stop new pseudostem emergence. Thus, the crop growth slows or ceases. If the crop is damaged at this point, it is crucial to remove the damaged grass to enable new growth to occur.

Infestation timing is also related to the number and proximity of bermudagrass fields near the field in question and the timing of when those neighboring fields were last cut. Experience has shown that bermudagrass fields surrounded by forest or row crops tend to be less susceptible to damage. Fields of bermudagrass that are large or near large fields are most susceptible. Whenever these neighboring fields are harvested, the flies in those fields will often move into fields with bermudagrass that can sustain the population. This buildup of BSM population on a field that is just a few days into a regrowth cycle can result in heavy damage and yield losses. Consequently, producers should be aware of the harvest schedule of neighboring fields and take action to control the BSM when damage is likely.

Growth Conditions Influence Damage

Increased BSM damage is frequently associated with fields suffering from heavy disease pressure or bermudagrass stands receiving high rates of nitrogen (N) and low rates of potassium (K) fertilizer. It is still unclear why these conditions are associated with increased BSM damage. A balanced soil fertility program minimizes the risk of disease and ensures a healthy stand.

Mitigation Strategies

As with any pest, one should employ an integrated pest management strategy that exploits biological, cultural, physical, and/or chemical control measures. Although *Atherigona* populations are unlikely to be fully controlled (much less eradicated), taking an approach that integrates these control measures will reduce economic damage.

Biological Control – Since it is a non-native species, none of the BSM's natural predators are present in the Southeast, to our knowledge. It is presumed, however, that some insect and spider species present in bermudagrass pastures and hayfields would prey on the BSM. However, the extent and significance of this predation on controlling the BSM population is unknown. Thus, the most successful tool for biological control is to choose a variety that is tolerant or less susceptible to BSM damage. As discussed in the section entitled "Varietal Differences," bermudagrass producers should choose varieties that are the least susceptible among the bermudagrass varieties recommended for their area.

Cultural Control – Bermudagrass stands that are managed to minimize disease pressure and fertilized with a balance of nutrients are generally less susceptible to BSM damage. Interseeding alfalfa into bermudagrass has substantially reduced or eliminated BSM damage in bermudagrass hayfields. This practice, which has benefits beyond eliminating BSM damage (e.g., reducing or eliminating N fertilization needs, lowering fertilizer costs, increasing forage quality), should be strongly considered whenever a bermudagrass stand proves to be prone to damage.

Physical Control – Properly timed bermudagrass harvests can minimize the yield losses from the BSM. If signs of BSM damage occur near the end of a regrowth cycle (within 2.5 to 3 weeks after cutting or grazing), the producer should harvest or graze the field as soon as conditions become favorable. Once a stand that is 6 to 8 inches (15 to 20 centimeters) or taller has been damaged by BSM feeding, the only option is to cut and/or graze the stand to a height of 3 to 4 inches (7.5 to 10 centimeters) and encourage regrowth to occur. It is better to cut the field extremely early and accept the loss than to have a low-yielding, severely damaged crop that harbors a large fly population and leads to a further buildup.

Ideally, the infected material would be removed from the field to prevent shading of any regrowth. The larvae do not appear to remain in cut stems. Within hours of cutting, larvae will exit damaged stems and travel to the soil. Flies in fields that have been harvested escape to field margins and neighboring bermudagrass fields. Prompt applications of chemical controls in fields following the harvest of a neighboring field can greatly reduce the risk of BSM damage.

Chemical Control – Chemical control of the BSM larva is challenging because it is inside the pseudostem. Consequently, an insecticide with systemic activity would be needed to prevent larval feeding. However, none of the systemic insecticides currently approved for use in pastures or hay crops are labeled for (or effective at) controlling the BSM. Consult your county Extension agent for specific pesticide recommendations.

The BSM fly is the target of chemical suppression efforts. A broad spectrum insecticide timed when large numbers of adult flies are present provides the most suppression. Suppression of the BSM fly can be challenging because the flies are mobile. In our experience, the flies do not fly very high (usually less than 18 inches, or 0.5 meters, above the canopy) nor very far (no more than 10 feet, or 3 m) in any single instance of flight, even after being disturbed. Therefore, normal spray boom heights should be effective for chemical applications for BSM control. However, it is also important to understand the limits of a chemical application in canopy penetration. In our experience, the BSM flies tend to remain deep in the canopy except to move from one location to another or in response to a disturbance. Applications that do not penetrate the canopy may have limited success. It would be ideal to apply the insecticide in a volume of water in excess of 12 to 15 gallons/acre (112 to 140 L/ha) to ensure adequate canopy penetration.

Suppressing the BSM can be effective when a recommended rate of an insecticide is applied after the bermudagrass has begun to regrow (7 to 10 days after cutting) following an affected harvest. A second application can be made 7 to 10 days later to suppress any flies that have emerged or arrived since the last application. This second application is usually only necessary when neighboring fields were harvested after the first application, the crop growth cycle has been extended due to dry weather, or a forecast of rain suggests that the hay harvest may be delayed. Chemical actions should be taken if there is a known history of BSM damage to the bermudagrass and the expense of the application(s) is justified by the forage yield saved. An individual application usually costs $2 to $3/acre ($5 to $7.50/ha) for the insecticide and $5 to $10/acre ($12 to $25/ha) for application. If the bermudagrass forage is valued at $100/ton ($90/metric ton), a corresponding yield savings of approximately 200 lbs DM/acre (225 kg DM/ha) would be necessary to warrant this investment. In July and August, bermudagrass hayfields may produce up to 6,000 lbs DM/acre (6,725 kg DM/ha) at a single cutting, so applications at this time of year are more likely to result in an economic benefit. Because bermudagrass yields in September or October may only be 1,500 to 2,000 lbs DM/acre (1,700 to 2,250 kg DM/ha), fall insecticide applications are much less likely to result in a return on that investment.

Based on our current observations, BSM populations are not high enough to warrant chemical suppression prior to the first bermudagrass hay cutting (or equivalent timing if the crop is to be grazed) and population buildup may not occur until late into the regrowth cycle for the second cutting for the central latitudes of the Southeast U.S. or the third cutting for more northern areas where bermudagrass is grown.

Insecticide Resistance – Overuse of pesticides of a single mode of action to combat a pest that is capable of producing a large number of offspring is likely to eventually result in a buildup of resistance to that pesticide's mode of action. Care should be taken to avoid using insecticides too frequently and extensively and occasionally changing the mode of action used.

Much remains unanswered about the BSM. Additional research is needed to identify economic thresholds and alternative pesticides that differ in their mode of action. The current information provides producers basic management and suppression techniques, but much more research is needed to assist producers in making informed decisions about options for BSM management.

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ALABAMA COOPERATIVE Extension SYSTEM

ANR-1019

ALABAMA A&M AND AUBURN UNIVERSITIES

MANAGEMENT OF Fall Armyworm in Pastures and Hayfields

The fall armyworm, *Spodoptera frugiperda,* is a chronic pest in the Southeast. The caterpillars feed on a variety of forage crops, but seem to prefer lush, green, well-fertilized bermudagrass. Other forage grasses which are hosts for fall armyworm are bahiagrass, pearl millet, sorghum-sudan hybrids, tall fescue, and various winter annuals including ryegrass, rye, wheat, and oats. More than 60 plants have been reported as hosts of the fall armyworm, including corn, alfalfa, cotton, soybeans, and most vegetable crops.

Seasonal Occurrence

As the name indicates, fall armyworms are most numerous in late summer or early fall. Usually, reports of fall armyworm damage begin to come in during late July or early August. First reports are usually from southern Alabama. There are three or more generations of fall armyworm each year. Occasionally, severe outbreaks occur as early as mid-April.

Fall armyworms are susceptible to cold, and are unable to survive even the mildest winters in Alabama. Each year, fall armyworm moths, carried by air currents, make their way from southern Florida and Central and South America. The size and timing of the initial moth flights are two factors that influence the outbreak potential of this pest.

Droughty conditions are favorable for the fall armyworm.

Behavior Patterns

The fall armyworm is in the same insect family *(Noctuidae)* as cutworms and other armyworms. Fall armyworm caterpillars damage grass by chewing plant tissue.

Fall armyworms are typically most active early in the morning, late in the afternoon or in early evening, but on taller, unmowed grass, they can be observed feeding on foliage throughout the day. On closely grazed or recently mowed hayfields, fall armyworm larvae spend the warmer hours of the day deep in the sod.

Fall armyworm damage often seems to appear "overnight." Young armyworms don't eat much. Almost all the damage is caused by the oldest caterpillars which eat more than all the other ages put together (See Figure 1). Therefore, an infestation may have been present but not detected because of the small size of the caterpillars.

Another reason for the sudden appearance of this insect is that the larger fall armyworms will sometimes "march into" (quickly invade) an uninfested area in search of food once an adjacent field has been defoliated. Large armyworms frequently disappear almost as suddenly as they appeared, either burrowing into the ground to pupate or moving on in search of food.

Damage

Fall armyworm damage may vary in appearance and severity according to the type of grass and management practices. In closely grazed fields, the grass may seem to thin out and develop brown spots similar to those sometimes seen on golf courses (See Figure 2). These spots look burned or browned out. This appearance is the result of grass plants rapidly dehydrating after fall armyworm larvae have chewed off the tender

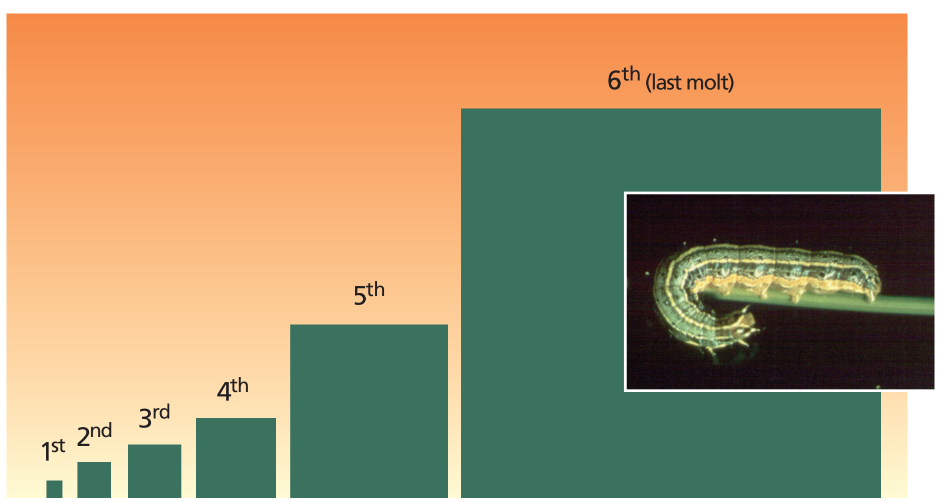

Figure 1. Relative amounts of food eaten by a fall armyworm caterpillar during each growth stage.

Figure 2. Fall armyworm damage on closely mowed grass. Note brown patches resembling drought damage.

foliage. For this reason, fall armyworm damage often resembles drought damage.

In hayfields or in pastures where there has been substantial growth accumulation, virtually all tender green material may be removed, leaving only tough stems a few inches long protruding from the soil surface (See Figure 3). Brown patches appear in the field and can rapidly increase in size.

Established, healthy, bermudagrass is rarely killed by fall armyworms, but the complete defoliation caused by a severe infestation weakens plants and deprives livestock of pasture or a hay producer of a hay cutting.

Fall armyworm damage on newly established grasses including winter annuals, tall fescue, or orchardgrass can be an even more serious situation. Seedlings of these fall-seeded plants are small when populations of fall armyworm are at seasonal highs. These crops can be severely stunted or killed if fall armyworms feed too far down on these plants.

Figure 3. Fall armyworm damage in a hayfield. Caterpillars have eaten the tender, green portions of the grass, leaving jagged leaf edges and tough leaf bases.

Description and Life Cycle

Adult. The adult fall armyworm is an ash-gray moth with a wing-span of about 1½ inches. The front wings are mottled and have white or light gray spots near the tips. The back wings are white with a narrow, smoky-brown edge. Moths become active at twilight and feed on nectar. They have an average life span of 2 to 3 weeks.

Eggs. The female moths lay eggs at night in masses of up to several hundred on light-colored surfaces, such as fence rails, tree trunks, and the underside of tree limbs. The eggs are light gray and covered with grayish fuzz from the female's body. These masses darken with age, and the eggs hatch within 2 to 4 days. All the eggs within a mass hatch at about the same time.

Larvae (caterpillars). The tiny, light-colored, black-headed larvae spin down to the ground on silken webs and begin to feed. As they grow, their bodies darken and noticeable stripes appear. When fully grown, larvae may be up to 1½ inches long and vary in color from light green to almost black with several stripes along the body (See Figure 4). The "face" is marked with a light-colored inverted "Y." Just behind the head, on the back of the caterpillar, you will see three thin white stripes running the length of the next segment. Sometimes these lines extend along the length of the caterpillar, as seen in Figure 4. There are usually small dark spots on the top side of each segment of the body. On the next-to-last segment, these spots are arranged like the corner points of a square (See Figure 5).

Pupae. Development from egg to fully grown larva requires about 2 to 3 weeks. At this point, larvae burrow into the soil and form pupae. The moths emerge in about 10 to 14 days.

Management Tips for Perennial Grass Pastures and Hayfields

Fall armyworm damage is most likely to occur from August through October when populations are at seasonal highs. During periods of drought, it is not uncommon to receive the first reports of damage in July. Natural enemies of the armyworm are less effective during drought years.

Damage from armyworms seems to come in "waves," about a month apart. This is because moth activity and egg laying peak periodically even though there is substantial overlap between generations. Fields damaged by fall armyworm should be closely monitored for the rest of the season to determine whether further treatment is required. Two weeks after damage has occurred, start checking for small caterpillars.

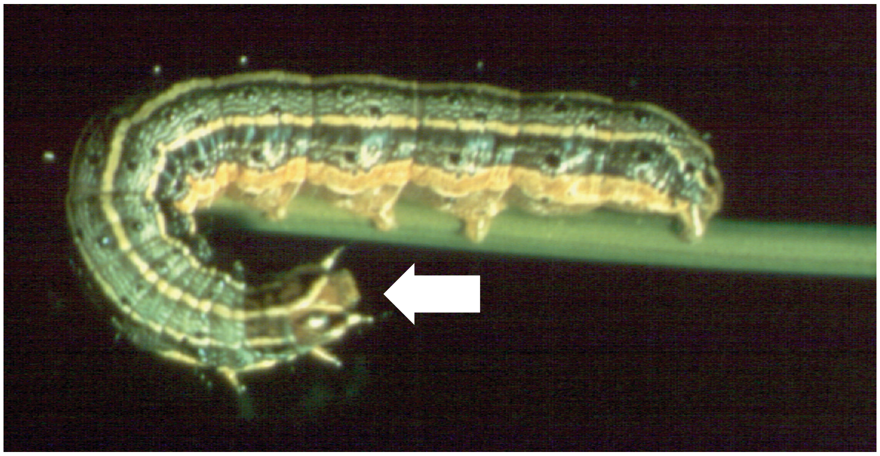

Figure 4. Fully grown fall armyworm larva. Note inverted "Y" on the head capsule and the three white stripes just behind the head.

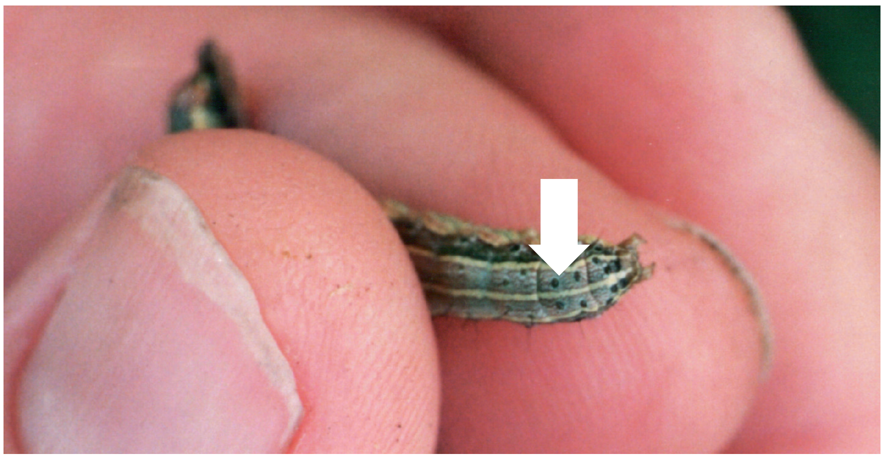

Figure 5. Fully grown fall armyworm larva. Note set of four dots on the end of the abdomen.

Because moths prefer light-colored surfaces on which to lay eggs, check these first. In pastures and hayfields, fence rails, fence posts, and tree limbs are favored egg-laying sites.

If a hayfield has been heavily damaged, fertilize as recommended to allow for another hay crop. Badly damaged pastures may need to be "rested." If possible, restrict grazing on badly damaged pastures until the grass has regrown.

Scouting. Scouting pastures and hayfields can help detect fall armyworm infestations before they cause economic damage. An easily detectable sign of armyworms is the presence of flocks of birds (especially cattle egrets) feeding in pastures or hay fields. Closely examine areas where birds are congregating.

In established pastures or hayfields, check in and around areas with dead grass or where birds are congregating. If no caterpillars are seen on the grass, look in the thatch at the base of the plants for larvae and green pellets of frass (larval excrement) about the size of bahiagrass seeds. If available, use an insect net to "sweep" the grass in early morning or late afternoon to check for the presence of young fall armyworms. In fields wet with dew, you can find caterpillars stuck on tires of vehicles that have been driven through an infested field.

Treatment Threshold. The decision to treat for fall armyworms depends on the stage of the armyworms and the intended use of the forage. A population of 3 or more fall armyworms per square foot is a reasonable treatment threshold.

As with other pests, timing is important. If infestations are detected too late, the damage may already have been done.

If necessary, treat with insecticides at the right time. Small fall armyworms are much easier to kill than larger ones. Some products will not control large larvae at all. If you check an area properly, you can determine the extent of an infestation, and spot-treat.

Frequently, mowing is the best option for salvaging a hay crop. When this approach is taken it may be possible to avoid using an insecticide.

Insecticidal Control. If control is necessary on perennial grass pastures and hayfields, numerous insecticides may be effective (see Table 1). Pay close attention to grazing and harvest restrictions. Note that methomyl is registered for use only on bermudagrass.

- Apply insecticides early or late in the day, because fall armyworm larvae are most active at these times.
- Apply sprays by ground in a minimum of 30 to 40 gallons of water per acre, or by air in a minimum of 3 to 5 gallons of water per acre. Control of larvae longer than ¾ inch may be poor. Control of larvae in tall or thick stands of grass may also be poor. If possible graze the affected area before treating.

Additional Information

You can obtain more information from your county Extension office. Look in your telephone book under your county's name to find the number.

For the most up-to-date control recommendations on pastures and hayfields, small grains, corn, and other crops, check the annually updated Extension publication ANR-0500-A, *Alabama Pest Management Handbook, Volume 1,* available from your county Extension office or online at http://www.aces.edu/pubs/docs/A/ANR-0500-A.

Table 1. Suggestions for Control of Fall Armyworm in Perennial Grass Pastures and Hayfields

Insecticide and Formulation	Rate[1]	Signal Word/Use Restrictions[3]	Minimum Days from Last Application to Harvest or Grazing	Comments
beta-cyfluthrin Baythroid XL	0.02 to 0.22 lb ai/A 2.6 to 2.8 fl oz/A	Warning/ Restricted Use	0	
carbaryl[2] Sevin XLR Plus	1.0 to 1.5 lb ai/A 1.0 to 1.5 qt/A	Caution	14 (harvest or grazing)	
cyfluthrin Tombstone Helios	0.025 to 0.03 lb ai/A 1.6 to 1.9 fl oz/A	Warning/ Restricted Use	0	Use higher rate for heavy population and larger caterpillars.
diflubenzuron[2] Dimilin 2L	0.12 lb ai/A 2 fl oz/A	Caution/ Restricted Use	1 (hay), 0 (grazing)	Apply before armyworms are ½ inch long because caterpillars keep eating until their next molt. For maximum control apply at first sign of egg hatch.
lambda-cythalothrin[2] Karate with Zeon Technology	0.02 to 0.03 lb ai/A 1.28 to 1.92 fl oz/A	Warning/ Restricted Use	7 (hay), 0 (grazing)	Use higher rate for heavy populations, larger caterpillars, or dense foliage.
methomyl[2] Lannate LV 2.4	0.22 to 0.9 lb ai/A 0.75 to 3 pt/A	Danger: Poison/ Restricted Use	3 (hay), 7 (grazing)	Use only on bermudagrass. Use higher rate for heavy populations and larger caterpillars.
methoxyfenozide Intrepid 2F	0.06 to 0.12 lb ai/A 4 to 8 fl oz/A	Caution	7 (hay), 0 (grazing)	Use higher rate for heavier infestations or dense foliage. Larvae stop feeding almost immediately but may take several days to die.
methyl parathion[2] Cheminova Methyl 4EC	0.75 lb ai/A 1.5 pt/A	Danger: Poison/ Restricted Use	15 (harvest or grazing)	Will not control large caterpillars. No residual activity.
rynaxypyr Coragen	0.045 to 0.065 lb ai/A 3.5 to 5 fl oz/A	No Signal Word	0	Larvae become paralyzed soon after eating the foliage then die in 1 to 3 days.
spinosad[2] Tracer SC	0.03 to 0.06 lb ai/A 1 to 2 fl oz/A	Caution	3 (hay), 0 (grazing)	Do not allow cattle to graze until the foliage has dried. Use higher rate for heavy populations and larger caterpillars.
zeta-cypermethrin[2] Mustang Max	0.0175 to 0.025 lb ai/A 2.8 to 4 fl oz/A	Warning/ Restricted Use	0 (harvest or grazing)	Use higher rate for heavy populations and larger caterpillars.

[1]Amounts listed are for the formulated product, unless otherwise indicated by ai, which is the amount of active ingredient per acre.
[2]Other products containing this active ingredient may be available.
[3]Signal words describe the acute (short-term) toxicity of the product. Products with no signal word or with the word "caution" are the lowest in toxicity.

ALABAMA COOPERATIVE Extension SYSTEM

ANR-1019

Kathy L. Flanders, *Extension Entomologist,* Associate Professor, Entomology and Plant Pathology; **Donald M. Ball,** *Extension Agronomist,* Professor, Agronomy and Soils; and **Patricia P. Cobb,** Professor Emerita, all with Auburn University

Photographs by Patricia Cobb, John French, and Kathy Flanders.

Use pesticides only according to the directions on the label. Follow all directions, precautions, and restrictions that are listed. Do not use pesticides on plants that are not listed on the label.

The pesticide rates in this publication are recommended only if they are registered with the Environmental Protection Agency and the Alabama Department of Agriculture and Industries. If a registration is changed or canceled, the rate listed here is no longer recommended. Before you apply any pesticide, check with your county Extension agent for the latest information.

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

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ALFALFA: ALFALFA INSECT CONTROL

David Buntin, Research/Extension Entomologist

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	LBS ACTIVE PER ACRE	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
At-Planting Pests Cutworms, grubs, wireworms	*chlorpyrifos* Lorsban 15G Smartbox	1B	6.7 lb	1	24 H/ 21 D	Apply in-furrow at planting for suppression of target pests. Do not cut or graze within 21 days after application. Make only 1 application/year.
	SEED TREATMENT: *thiamethoxam* Cruiser 5FS alfalfa	4A	0.001 mg (ai)/ seed		12 H/ –	
Alfalfa weevil (Hay production)	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	Alfalfa weevil infestations can normally be found from mid-February until after the 1st cutting. Scout 1-2 times/week during this period by randomly pulling 30 whole stems from throughout the field. Place stems in a plastic bucket and dislodge larvae by vigorously flailing the stems against the sides of the bucket. Count the number of larvae. Use plant height to determine your treatment level where: Stem Height (inches) — Larvae per stem 3-8 — 0.5 9-14 — 1 15 or more — 1.5 Do not treat solely on weevil numbers. Wait until you have damage on about 30% of the terminals before you consider spraying. For sweep net sampling, treat if 20 or more larvae/sweep are present. All weevil sprays should be made with ground equipment with a minimum of 10 gal/A **Grazing Alfalfa Pastures:** Products and rates listed in the table for grazing alfalfa have grazing restrictions of 0 days. Several products listed in the hay section have a 7 day grazing restriction. The reduced rate of permethrin may be less effective in controlling larvae than rates recommended for hay production. **NOTE:** Chlorpyrifos products may cause injury to young, rapid growing foliage but normally does not affect yield. Do not tank mix with other pesticides unless previously shown to not cause injury. HIGHLY TOXIC TO BEES.
	beta-cyfluthrin Baythroid XL 1.0 EC	3A	1.6-2.8 fl oz	0.0125-0.022	12 H/ 7 D	
	cyfluthrin Tombstone 2	3A	1.6-2.8 fl oz	0.025-0.044	12 H/ 7 D	
	chlorpyrifos Lorsban Adv, Chlorfos, Chlorpyrifos, other brands 4E	1B	1-2 pt	0.5-1	24 H/ 14 D at 1 pt 21 D at 2 pt	
	indoxacarb Steward 1.25 SC	22	6.7-11.3 fl oz	0.065-0.11	12 H/ 7 D	
	gamma-cyhalothrin Declare 1.25 EC Proaxis 0.5 EC	3A	1.02-1.54 fl oz 2.56-3.28 fl oz	0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1 EC	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 7 D	
	methomyl Lannate, other brands 2.4 LV Lannate 90 SP	1A	3 pt 1 lb	0.90 0.90	48 H/ 7 D	
	permethrin Permethrin 3.2EC, other brands	3A	8 fl oz	0.2	12 H/ 14 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 fl oz	0.014-0.025	12 H/ 3 D	
Alfalfa weevil (Grazing alfalfa) Products and rates listed have grazing restrictions of 0-3 days.	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	
	gamma-cyhalothrin Declare 1.25 Proaxis 0.5	3A	1.02-1.54 fl oz 2.56-3.84 fl oz	0.01-0.015 0.01-0.015	12 H/ 1 D Forage	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1 EC	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 1 D Forage	
	permethrin Permethrin 3.2EC, other brands	3A	4 fl oz	0.1	12 H/ 0 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 fl oz	0.14-0.025	12 H/ 3 D	

ALFALFA INSECT CONTROL

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	LBS ACTIVE PER ACRE	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
Aphids	*chlorpyrifos* Lorsban Adv, Chlorfos, Chlorpyrifos, other brands 4E	1B	1-2 pt	0.5-1	24 H/ 14 D at 1 pt 21 D at 2 pt	In Georgia, especially in the Coastal Plain area, aphids can be extremely abundant without causing economic damage. Some varieties are resistant to aphids. Treat aphids as listed below based on average number per stem at a given stem height. If alfalfa is near the time of cutting consider cutting earlier and treating the stubble if aphids remain after cutting. Stem Height (inches) — Aphids per Stem 10-15 — 40-50 16-20 — 60-80 21+ — 100-120 **NOTE:** Chlorpyrifos products may cause injury to young rapid growing foliage but normally does not affect yield. Do not tank mix with other pesticides unless previously shown to not cause injury. HIGHLY TOXIC TO BEES.
	dimethoate Dimethoate 4EC, 400 Dimethoate 2.67EC	1B	0.5-1 pt 0.75-1.5 pt	0.25-0.5 0.25-0.5	12 H/ 10 D	
	flupyradifurone Sivanto prime	4D	7-14 fl oz	0.09-0.14	12 H/ 7 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	1.02-1.54 fl oz 2.56-3.84 fl oz	0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 7 D	
	malathion Malathion 5EC, 57EC, Malathion 8EC	1B	1.5-2 pt 1-1.25 pt	0.94-1.25 0.94-1.25	12 H/ 0 D	
	permethrin Permethrin 3.2EC, other brands	3A	8 fl oz	0.2	12 H/ 14 D	
Cutworms and Armyworms (True armyworm, Fall armyworm, Beet armyworm, Yellowstriped armyworm)	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	**ARMYWORMS ON SOIL SURFACE:** Treat when any of these armyworm pests or combination of pests are found at an average of 2-3/sq ft. **CUTWORMS:** Several species. Treat if 3 or more cutworms/sq ft. In standing alfalfa use enough pressure and water for spray penetration to the ground. If near cutting, consider cutting early and treating stubble if infestation remains. Cutworms often will congregate under windrowed hay. **CARBARYL NOTE:** Do not apply when crop is wet. Carbaryl may bleach tender foliage. Do not apply this product to target crops or weeds in bloom. **NOTE:** Baythroid and Tombstone for small armyworm larvae only.
	beta-cyfluthrin Baythroid XL 1.0EC	3A	1.6-2.8 fl oz	0.0125-0.022	12 H/ 7 D	
	carbaryl Sevin XLR Plus, 4F	1A	1-1.5 qt	1-1.5	12 H/ 7 D	
	chlorantraniliprole Coragen 1.67SC Prevathon 0.43 (armyworms only)	28	3.5-5 fl oz 14-20 fl oz	0.047-0.09 0.047-0.09	4 H/ 0 D	
	cyfluthrin Tombstone 2	3A	1.6-2.8 fl oz	0.025-0.044	12 H/ 7 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	1.02-1.54 fl oz 2.56-3.84 fl oz	0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 7 D	
	methomyl Lannate, Annihilate 2.4 LV Lannate 90SP	1A	3 pt 1 lb	0.90 0.90	48 H/ 7 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	2.24-4 fl oz	0.14-0.025	12 H/ 3 D	

ALFALFA INSECT CONTROL

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	LBS ACTIVE PER ACRE	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
Blister beetles	*carbaryl* Sevin XLR Plus, 4F, other brands	1A	 0.5-1 qt	0.5-1	12 H/ 7 D	Treat when 2 beetles/sq ft are found. Beetles tend to aggregate on the weedy margins of fields. Blister beetles bailed up in hay are toxic to livestock, especially horses. **CARBARYL NOTE:** Do not apply when crop is wet. Carbaryl may bleach tender foliage. Do not apply this product to target crops or weeds in bloom.
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	 1.02-1.54 fl oz 2.56-3.84 fl oz	 0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.28-1.92 fl oz 2.56-3.84 fl oz	 0.02-0.03 0.02-0.03	12 H/ 7 D	
Clover root curculio, Lesser clover leaf weevil, Sweet clover weevil (Adults only)	*gamma cyhalothrin* Declare 1.25 Proaxis 0.5	3A	 1.02-1.54 fl oz 2.56-3.84 fl oz	 0.01-0.015 0.01-0.015	12 H/ 7 D	**CLOVER ROOT CURCULIO, SWEET CLOVER WEEVIL:** Damage is caused by larvae in soil feeding on roots and root nodules. No effective control for larvae in soil. Adults feed on foliage causing notches in leaves. Products listed may reduce adult populations.
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.28-1.92 fl oz 2.56-3.84 fl oz	 0.02-0.03 0.02-0.03	12 H/ 7 D	
Foliage feeding caterpillars: Green cloverworm and/ or Velvetbean caterpillar and/or Alfalfa Webworm and/ or Alfalfa caterpillar and/or Alfalfa looper	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	 2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	**FOLIAGE FEEDING CATERPILLARS:** For alfalfa caterpillar, green cloverworm, velvetbean caterpillar, alfalfa webworm, and foliage inhabiting armyworms, treat when any of these pests or combinations of pests are found at an average of 2 or more 1/2" long larvae per plant OR defoliation exceeds 10%. **CARBARYL NOTE:** Do not apply when crop is wet. Carbaryl may bleach tender foliage. Do not apply this product to target crops or weeds in bloom.
	beta-cyfluthrin Baythroid XL 1.0EC	3A	 1.6-2.8 fl oz	0.0125-0.022	12 H/ 7 D	
	carbaryl Sevin XLR Plus, 4F, other brands	1A	 0.5-1 qt	0.5-1	12 H/ 7 D	
	chlorantraniliprole Coragen 1.67SC Prevathon 0.43	28	 3.5-5 fl oz 14-20 fl oz	 0.047-0.09 0.047-0.09	4 H/ 0 D	
	cyfluthrin Tombstone 2	3A	 1.6-2.8 fl oz	0.025-0.044	12 H/ 7 D	
	indoxacarb Steward 1.25 SC	22	 6.7-11.3 fl oz	0.065-0.11	12 H/ 7 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	 1.02-1.54 fl oz 2.56-3.84 fl oz	 0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.28-1.92 fl oz 2.56-3.84 fl oz	 0.02-0.03 0.02-0.03	12 H/ 7 D	
	methomyl Lannate, Annihilate 2.4 LV Lannate 90 SP	1A	 3 pt 1 lb	 0.90 0.90	48 H/ 7 D	
	permethrin Permethrin 3.2EC, other brands	3A	 8 fl oz	0.2	12 H/ 14 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	 2.24-4 fl oz	0.14-0.025	12 H/ 3 D	

ALFALFA INSECT CONTROL

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	LBS ACTIVE PER ACRE	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
Grasshoppers	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	Treat when heavy grasshopper infestations are causing excess defoliation. Grasshoppers often invade fields from adjacent weedy areas; border treatments are sometimes appropriate. **NOTE:** Chlorpyrifos products may cause injury to young rapid growing foliage but normally does not affect yield. Do not tank mix with other pesticides unless previously shown to not cause injury. HIGHLY TOXIC TO BEES.
	beta-cyfluthrin Baythroid XL 1EC	3A	2-2.8 fl oz	0.0155-0.022	12 H/ 7 D	
	chlorpyrifos Lorsban Adv, Chlorfos, Chlorpyrifos, other brands 4E	1B	1 pt	0.5	24 H/ 14 D at 1 pt	
	cyfluthrin Tombstone 2	3A	2-2.8 fl oz	0.031-0.044	12 H/ 7 D	
	dimethoate Dimethoate 4EC, 400 Dimethoate 2.67EC	1B	 0.5-1 pt 0.75-1.5 pt	 0.25-0.5 0.25-0.5	12 H/ 10 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	 1.02-1.54 fl oz 2.56-3.84 fl oz	 0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.28-1.92 fl oz 2.56-3.84 fl oz	 0.02-0.03 0.02-0.03	12 H/ 7 D	
	malathion Malathion 5EC, 57EC Malathion 8EC	1B	 1.5-2 pt 1-1.25 pt	 0.94-1.25 0.94-1.25	12 H/ 0 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	2.8-4 fl oz	0.0175-0.025	12 H/ 3 D	
Leafhoppers (potato leafhopper, aster leafhopper)	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	Potato leafhopper feeding generally causes V-shaped yellow leaf discoloration that reduces yield. Treat when sweep net samples show leafhopper numbers for a given stem height exceed the following levels: Stem Height (inches) — Hoppers per sweep 3-7 — 0.5 8-10 — 1 11-14 — 2 14+ — 4 or cut hay early **NOTE:** Chlorpyrifos products may cause injury to young rapid growing foliage but normally does not affect yield.
	beta-cyfluthrin Baythroid XL 1EC	3A	1.6-2.8 fl oz	0.0125-0.022	12 H/ 7 D	
	cyfluthrin Tombstone 2	3A	1.6 fl oz	0.013	12 H/ 7 D	
	dimethoate Dimethoate 4EC, 400 Dimethoate 2.67EC	1B	 0.5-1 pt 0.75-1.5 pt	 0.25-0.5 0.25-0.5	12 H/ 10 D	
	flupyradifurone Sivanto prime	4D	7-14 fl oz	0.09-0.14	12 H/ 7 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	 1.02-1.54 fl oz 2.56-3.84 fl oz	 0.01-0.015 0.01-0.015	12 H/ 7 D	

ALFALFA INSECT CONTROL

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	LBS ACTIVE PER ACRE	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
Leafhoppers (potato leafhopper, aster leafhopper) *(continued)*	*lambda cyhalothrin* Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 7 D	
	permethrin Permethrin 3.2EC, other brands	3A	8 fl oz	0.2	12 H/ 14 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	2.24-4 fl oz	0.014-0.025	12 H/ 3 D	
Mites	*dimethoate* Dimethoate 4EC, 400 Dimethoate 2.67EC	1B	1 pt 1.5 pt	0.5 0.5	12 H/ 10 D	**Mite control may be difficult.** Treat if mites are causing leaf discoloration over large areas of the field. If near cutting, consider cutting early and treating stubble if infestation remains. Apply by ground with 15 or more gal/A. Warrior II Zeon and Declare are for suppression only.
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	1.54 fl oz 3.84 fl oz	0.015 0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.92 fl oz 3.84 fl oz	0.03 0.03	12 H/ 7 D	
Threecornered alfalfa hopper	*alpha-cypermethrin* Fastac, other brands 0.83 EC	3A	2.2-3.8 fl oz	0.012-0.025	12 H/ 3 D	Treat when adults and/or nymphs are found on 10% of seedling alfalfa plants or if adults or nymphs are girdling and killing 10% of the lateral stems in a field. **CARBARYL NOTE:** Do not apply when crop is wet. Carbaryl may bleach tender foliage. Do not apply this product to target crops or weeds in bloom.
	beta-cyfluthrin Baythroid XL 1.0EC	3A	1.6-2.8 fl oz	0.0125-0.022	12 H/ 7 D	
	carbaryl Sevin XLR Plus, 4F, other brands	1A	1 qt	1	12 H/ 7 D	
	cyfluthrin Tombstone 2	3A	1.6-2.8 fl oz	0.025-0.044	12 H/ 7 D	
	gamma cyhalothrin Declare 1.25 Proaxis 0.5	3A	1.02-1.54 fl oz 2.56-3.84 fl oz	0.01-0.015 0.01-0.015	12 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.28-1.92 fl oz 2.56-3.84 fl oz	0.02-0.03 0.02-0.03	12 H/ 7 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	2.24-4 fl oz	0.014-0.025	12 H/ 3 D	

Premixed or Co-Packed Insecticides: Products listed are available as premixes or co-packages of two insecticide active ingredients. User should check mixture labels for active ingredient, specific use rates, target pests, and precautions.

BRAND NAME (ACTIVE INGREDIENTS)	RANGE OF FORMULATION RATES
Besiege *(lambda cyhalothrin, chlorantraniliprole)*	5-9 fl oz/A
Cobalt Advanced *(chlorpyrifos, gamma-cyhalothrin)*	13-42 fl oz/A
Stallion *(chlorpyrifos, zeta-cypermethrin)*	5-11.75 fl oz/A

CLOVER: CLOVER INSECT CONTROL

Other than alfalfa, including arrowleaf, crimson, red, white, and other clovers

Will Hudson, Extension Entomologist, and David Buntin, Research Entomologist

PEST	INSECTICIDE	MOA	AMOUNT PER ACRE	REI/PHI (Hours or Days)
Alfalfa weevil, Clover weevil, Lesser clover leaf weevil, Clover head weevil	*carbaryl* Sevin, other brands 4.0	1A	1.0-1.5 qt	12 H/ 7 D
	malathion Malathion 8EC, other brands	1B	1.0-1.25 pt	12 H/ 0 D
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 oz	12 H/ 3 D
Aphids	*malathion* Malathion 8EC, other brands	1B	15-20 fl oz	12 H/ 0 D
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 oz	12 H/ 3 D
Caterpillars (armyworm, cutworms, green cloverworm, velvetbean, yellowstriped armyworm)	*carbaryl* Sevin, other brands 4.0	1A	1.0-1.5 qt	12 H/ 7 D
	chlorantraniliprole Coragen 1.67SC Prevathon 0.43	28	 3.5-5 fl oz 14-20 fl oz	4 H/ 0 D
	methoxyfenozide Intrepid 2F	18	4-8 fl oz	4 H/ Forage 0 D Hay 7 D
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 oz	12 H/ 3 D
Grasshoppers, Striped ground crickets	*carbaryl* Sevin, other brands 4.0	1A	1.0-1.5 qt	12 H/ 7 D
	malathion Malathion 8EC, other brands	1B	1.0-1.25 pt	12 H/ 0 D
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.8-4 fl oz	12 H/ 3 D
Green June beetle larvae	*carbaryl* Sevin, other brands 4.0	1A	1.0-1.5 qt	12 H/ 7 D
Leafhoppers	*carbaryl* Sevin, other brands 4.0	1A	1.0-1.5 qt	12 H/ 7D
	malathion Malathion 8EC, other brands	1B	1.0-1.25 pt	12 H/ 0 D
	zeta-cypermethrin Mustang Maxx, Respect 0.8 EC	3A	2.24-4 oz	12 H/ 3 D

REMARKS AND PRECAUTIONS

CAUTION BEE HAZARD: Clovers are either dependent upon or benefited by insect pollination, primarily by bees. They are an important source of honey and pollen for bees, including honey bees. **Do not apply these insecticides to clover fields when clover or weeds in clover fields are flowering.**

WHEN TO TREAT FOR INSECTS IN CLOVER PASTURES

FOLIAGE FEEDING CATERPILLARS (armyworm, alfalfa caterpillar, beet armyworm, corn earworm, cutworms, green cloverworm, fall armyworm, velvetbean caterpillar, yellowstriped armyworm)**:** Treat when populations of any (or any combination) of these insects exceed 3 larvae (1/2” long or larger)/sq ft.

ALFALFA WEEVIL: Treat when larvae and/or adults are damaging 50% of the leaves or buds.

APHIDS: Treat if infestations appear to be causing excessive leaf discoloration.

CLOVER LEAF WEEVIL: Treat when 50% of the plants have leaf feeding damage from larvae and/or adult weevils.

GRASSHOPPERS: Treat when heavy populations are causing excessive defoliation.

LEAFHOPPERS: Treat when heavy populations are causing leaf discoloration over large areas of the field.

LESSER CLOVERLEAF WEEVIL: Treat when 10% or more of the buds or seed heads are infested with larvae or when the adults are damaging the leaves and stems on 50% of the plants.

STRIPED GROUND CRICKETS: Treat when 10% of the seedling-stand has been lost and crickets are still present. If crop is not being monitored closely, treat preventively after seeding but before seedlings emerge.

NOTE: Coragen/Prevathon: 0 day PHI. No more than 4 applications per crop; no more than 0.2 lb ai oz/A/crop.

EC – emulsifiable concentrate, SP – soluble powder, S – sprayable powder, EL – emulsifiable liquid, WP – wettable powder
Numbers following liquid formulations indicate lb ai/gal; those following solids indicate % ai.

PERENNIAL GRASS: PERENNIAL GRASS INSECT CONTROL

Including bermudagrasses, bahiagrasses, fescues, and other perennial pasture grasses

Will Hudson, Extension Entomologist, and David Buntin, Research Entomologist

PEST	MATERIAL AND FORMULATION[1]	MOA	AMOUNT PER ACRE	REMARKS AND PRECAUTIONS
Bahiagrass borer, billbug larvae, white grubs, whitefringed beetle larvae				No effective insecticides labeled for control of these insect s in pastures. If practical, rotate fields to crops where preplant or at-planting insecticides can be used to control these insects. **Exception:** Deep turning of infested pastures usually reduces bahiagrass borer populations to the point that bahiagrass or other grasses can be reseeded into the pasture.
Bermudagrass Stem Maggot	Various pyrethroids *(zeta-cypermethrin, cyfluthrin, lambda-cyhalothrin, etc)*	3A	Lowest label rate	Apply 7-10 days after cutting if significant damage was noted.
Chinch bug	Mow or burn.			See below.
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	
Cutworms	Materials applied for armyworms will give helpful control.			
Armyworm, Caterpillars, Fall armyworm, Striped Grass Looper	*carbaryl* Sevin SL, Sevin 4F Others	1A	1-1.5 qt	
	chlorantraniliprole Prevathon	28	14-20 oz	
	chlorantraniliprole + lambda-cyhalothrin Besiege	3 + 28	6-10 fl oz	
	cyfluthrin Baythroid XL	3A	2.6-2.8	
	diflubenzuron Dimilin 2L	15	1-2 oz	
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
	methoxyfenozide Intrepid 2F	18	4-8 oz	
	spinosad Tracer	5	1-2 oz	
	methomyl Lannate 2.4 LV, 90SP *(Use methomyl on bermudagrass only.)*	1A	1-2 pt 0.25-0.5 lb	
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	

WHEN TO TREAT FOR INSECTS IN PERENNIAL-GRASS PASTURES

FOLIAGE FEEDING CATERPILLARS (armyworm, fall armyworm, mocis grassworms, sod webworms, yellowstriped armyworm)**:** Treat when larval populations of these insects (any one or any combination) exceed 3 larvae (1/2" long or larger) per square foot.

APHIDS: Treat if heavy infestations are causing leaf discoloration over large areas of the field.

CHINCH BUGS: Treat if populations are causing grass leaves to wilt over large areas of the field.

CUTWORMS, FLEA BEETLES, GRASSHOPPERS: Treat if heavy populations appear to be defoliating grass excessively.

FIRE ANTS: Treat in pastures where heavy livestock birthing will occur. In hay pastures, treat when mounds are so numerous they interfere with haying operations.

GREEN JUNE BEETLE LARVAE: Treat when populations average 1 larva/sq yd.

LEAFHOPPERS: Treat if heavy infestations are causing the grass to appear off-color or unthrifty.

SPITTLEBUGS: Treat when 1 or more adult spittlebug is found per square foot.

THRIPS: Treat if heavy infestations are causing discolorations and damage over large areas of the field.

PESTICIDE USE PRECAUTIONS

Apply any of the pesticides listed in this table with aerial or ground equipment as label directs. Where a range of rates is given for a material, use the low rate on low-growth grass or small larvae and the high rate on dense grass growth or large larvae.

Amdro: 7 day PHI for hay. Okay for grazing.

Baythroid: 0 day PHI for hay and grazing, see label for other restrictions.

carbaryl (Sevin, etc.): Do not graze or cut for hay for 14 days after application.

cypermethrin (Mustang Maxx): 0 day PHI for hay or forage; Do not apply more than 0.10 lb/A/ season.

diflubenzuron (Dimilin): 0 day for grazing; 1 day PHI for hay; no more than 2 oz/cutting.

PERENNIAL GRASS INSECT CONTROL

PEST	MATERIAL AND FORMULATION	MOA	AMOUNT PER ACRE	REMARKS AND PRECAUTIONS
Fire ants	*hydramethylnon* Amdro	20A	1-1.5 lb	**PESTICIDE USE PRECAUTIONS** Apply any of the pesticides listed in this table with aerial or ground equipment as label directs. Where a range of rates is given for a material, use the low rate on low-growth grass or small larvae and the high rate on dense grass growth or large larvae. **Intrepid:** 0 day grazing interval, 7 day PHI for hay. One application per cutting. **Warrior II Zeon:** 0 day grazing restriction, 7 day PHI for hay, see label for application restrictions. **methomyl:** Do not cut for hay within 3 days, or graze or feed treated crop within 7 days of last application. Do not apply more than 0.9 lb ai/A/crop. Do not make more than 4 applications per crop. **spinosad (Tracer):** Do not harvest hay or fodder for 3 days. Do not graze until spray has dried. Do not apply more than 6 oz/season. **Besiege and Prevathon (chlorantraniliprole):** 0 day PHI for forage or grazing; 7 day PHI for hay.
	methoprene Extinguish	7A		
	spinosad Justice	5	mound treatment only	
Flea beetles	*Carbaryl* as applied for armyworm may give helpful control.			
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
Grasshoppers	*malathion* 8EC		20 fl oz	
	cyfluthrin Baythroid XL	3A	2.6-2.8	
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
	carbaryl Sevin 4L	1A	1-1.5 qt	
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	
Green June beetle larvae	*carbaryl* Sevin 4L	1A	1-1.5 qt	
	lambda-cyhalothrin + chlorantraniliprole Besiege	28 + 3A	5-9 oz	
Leafhoppers	*lambda-cyhalothrin* Warrior II Zeon	3A	1.28-1.92 oz	
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	

PERENNIAL GRASS INSECT CONTROL

PEST	MATERIAL AND FORMULATION[1]	MOA	AMOUNT PER ACRE	REMARKS AND PRECAUTIONS
Mole crickets	No economically effective materials currently labeled.			
Sod webworms	*carbaryl* Sevin SL Sevin 4F others	1A	 1.25 lb 2 lb	
	diflubenzuron Dimilin 2L	15	1-2 oz	
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
Spittlebug adults	*carbaryl* (Sevin) as applied for armyworm may give helpful control. (Control of immatures may require cut and burn approach.)			
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	

[1] Abbreviations used are: EC=emulsifiable concentrate, M=microencapsulated material, SP=soluble powder, L=liquid, S=sprayable powder, WP=wettable powder. Numbers following liquid formulations indicate lbs active ingredient per gallon; those following solids indicate percent active ingredient.

TEMPORARY GRAZING: TEMPORARY SUMMER GRAZING INSECT CONTROL

Millets, sudan grass, sorghum-sudan hybrids

Will Hudson, Extension Entomologist, and David Buntin Research/Extension Entomologist

PEST	MATERIAL AND FORMULATION[1]	MOA	AMOUNT PER ACRE	REI/PHI (Hours/Days)
Aphids	*malathion* 8EC	1B	15-20 fl oz	12 H
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	12 H
	fupyradifurone Sivanto	4D	4-10 oz	12 H
Armyworm, Fall Armyworm, Cutworms, Yellowstriped armyworm	*carbaryl* Sevin, others	1A	See label. Many formulations available.	12 H
	lambda-cyhalothrin Warrior II Zeon	3A	1.28-1.92 oz	12 H
	chlorpyrifos Lorsban 4E	1B	1-2 pt	24 H
	spinosad Tracer, others	5	1.5-3 oz	4 H
	zeta-cypermethrin Mustang Maxx	3A	4 oz	12 H
Chinch bug	*beta-cyfluthrin* Baythroid XL	3A	See label. Rates vary by forage species	12 H
	chlorpyrifos Lorsban 4E	1B	1-2 pt	24 H
	zeta-cypermethrin Mustang Maxx	3A	4 oz	12 H
Corn earworm	*beta-cyfluthrin* Baythroid XL	3A	See label. Rates vary by forage species	12 H
	The materials listed for armyworm give control.			
Flea beetles	*carbaryl* Sevin as applied for armyworm may give helpful control.			
Grasshoppers	*carbaryl* Sevin, others	1A	See label. Many formulations available.	12 H
	malathion 8EC	1B	15-20 fl oz	12 H
	zeta-cypermethrin Mustang Maxx	3A	2.24-4 oz	12 H
	beta-cyfluthrin Baythroid XL	3A	See label. Rates vary by forage species	12 H
Green June beetle larvae	*carbaryl* Sevin, others	1A	See label. Many formulations available.	12 H

REMARKS AND PRECAUTIONS

WHEN TO TREAT FOR INSECTS IN FORAGE GRASSES

FOLIAGE FEEDING CATERPILLARS: (armyworm, beet armyworm, cutworms, fall armyworm, yellowstriped armyworm): Treat for any one or any combination of these insects when they are causing excessive defoliation.

APHIDS: Treat for corn leaf aphid if heavy infestations are causing leaves to dry and die over large areas of a field. Treat for greenbug or yellow sugarcane aphid if populations of these aphids are killing 3 or more leaves per plant.

"BUDWORMS" (usually fall armyworm and corn earworm): Treat when more than 50% of the plants are infested with larvae.

CHINCH BUG: Treat if bugs become numerous and wilting leaves are noticed.

EUROPEAN CORN BORER: If plants are heavily infested (central growing shoots dying or breaking over on a high percentage of the plants), salvage crop by grazing or cutting for fodder.

FLEA BEETLES, GRASSHOPPERS: Treat if heavy populations are causing excessive foliage loss.

GREEN JUNE BEETLE LARVAE: Treat when populations average 5 grubs/sq yd.

PESTICIDE USE PRECAUTIONS

Apply any of the materials listed in this table with aerial or ground equipment as label directs. Where a range of rates is given for a material, use the low rate on small plants or small larvae and the high rate on larger plants or larger larvae.

carbaryl (Sevin): 14 day grazing and harvest interval.

chlorpyrifos (Lorsban): Check label for grazing and crop restrictions.

cypermethrin (Mustang Maxx): 0 day PHI for sorghum, 45 day PHI for millets for forage.

lambda-cyhalothrin (Warrior II Zeon): 0 day grazing interval, 7 day harvest interval.

malathion: Apply as needed up to day of grazing or harvest for hay.

methomyl: 3-day harvest interval. Do not apply more than twice per crop. Do not apply more than 0.9 lb/A/crop. Not labelled on millet or sweet sorghum

spinosad (Tracer): Not labeled on all millets. Do not apply within 7 days of grain harvest or 14 days of forage harvest.

flupyradifurone (Sivanto): Millet rate is 7-10 oz/acre.

CAUTION: Check labels carefully. Labeling varies, and not all formulations of these materials can be used on forage grasses. [1] Abbreviations used are: EC–emulsifiable concentrate, SP–soluble powder, S–sprayable powder, WP–wettable powder. Numbers following liquid formulations indicate lb ai/gal; those following solids indicate percent active ingredient.

TEMPORARY WINTER GRAZING INSECT CONTROL

Rye, oats, wheat and ryegrass

David Buntin, Research/Extension Entomologist

PEST	MATERIAL AND FORMULATION[1]	MOA	AMOUNT OF FORMULATION PER ACRE	LB ACTIVE INGREDIENT PER ACRE	REI/ PHI GRAZING (Hours or Days)	REMARKS AND PRECAUTIONS
Aphids	**SEED TREATMENTS**					Treat for aphids if large numbers occur and cause leaves to dry and die over large areas. Bird cherry oat aphids also can infect wheat and oats with barley yellow dwarf disease which may reduce later forage growth. **NOTE:** Gaucho and Attendant are not labeled for use on ryegrass. Gaucho XT, Cruiser and NipsIt Inside also contain fungicides **NOTE:** Cruiser 5FS is available as a commercial seed treatment. Rate of CruiserMaxx Cereals and Cruiser Maxx Vibrance alone is too low for effective aphid control. **NOTE:** Seed treatments listed are not labeled for use on ryegrass. **NOTE:** Warrior II Zeon will replace Karate Zeon. **NOTE:** Transform wheat, triticale and barley only.
	clothianidin NipsIt Inside	4A	0.75-1.79 fl oz/100 lb seed	–	12 H/ – Not listed	
	imidacloprid Gaucho 600, Attendant 600, Axcess Gaucho XT Enhance AW	4A	0.8 fl oz/100 lb seed 3.4 fl oz/100 lb seed 4 fl oz/100 lb	0.03 lb/100 lb seed 0.03 lb/100 lb seed 0.05 lb/100 lb seed	12 H/ 45 D	
	thiamethoxam Cruiser 5FS Ceral Maxx Vibrance plus Cruiser 5FS	4A	0.75-1.33 fl oz/100 lb seed 5 fl oz/100 lb seed 5-10 fl oz/100 lb seed	0.03-0.05 0.04 lb/100 lb seed (total)	12 H/ 45 D	
	FOLIAR TREATMENTS					
	beta-cyfluthrin Baythroid XL (1)	3A	1.8-2.4 fl oz	0.014-0.019	12 H/ 3 D	
	gamma cyhalothrin Declare (1.25) Proaxis (0.5)	3A	1.54 fl oz 3.84 oz	0.015 0.015	24 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	1.92 fl oz 3.84 fl oz	0.03 0.03	24 H/ 7 D	
	malathion Malathion 57EC, 5EC Malathion 8EC	1B	1.5 pt 1 pt	0.94 1	12 H/ 7 D	
	sulfoxaflor Transform 50WG	4C	0.75-1.5 oz	0.023-0.046	24 H/ 7 D	
Armyworm True armyworm Fall armyworm, Beet armyworm, Yellowstriped armyworm	*alpha-cypermethrin* Fastac 0.83EC	3A	3.2-3.8 fl oz	0.020-0.025	24 H/ 14 D	True armyworm usually infests wheat in late winter and spring at the boot/head stage. Treat when larval numbers exceed 4 larvae per square foot before pollen shed and 8 larvae per square foot after pollen shed. Fall armyworm, beet armyworm, yellowstriped armyworm and cutworm infestations usually occur in fall on seedling plants. Treat when larval populations of any one or any combination of these insects exceed 3 larvae (1/2” long or larger)/sq ft. **NOTE:** Dimilin is only for small larvae, will not kill large larvae.
	beta-cyfluthrin Baythroid XL 1	3A	1.8-2.4 fl oz	0.014-0.019	12 H/ 3 D	
	cyfluthrin (wheat only) Tombstone Tombstone Helios 2.0	3A	1.8-2.4 fl oz	0.028-0.038	12 H/ 3 D	
	chlorantraniliprole Coragen 1.67SC Prevathon (0.43)	28	3.5-5 fl oz 14-20 fl oz	0.045-0.065 0.047-0.067	4 H/ 14 D	
	diflubenzuron Dimilin 2L	15	2 fl oz	0.5	12 H / 0 D	

TEMPORARY WINTER GRAZING INSECT CONTROL
Rye, oats, wheat and ryegrass

PEST	MATERIAL AND FORMULATION[1]	MOA	AMOUNT OF FORMULATION PER ACRE	LB ACTIVE INGREDIENT PER ACRE	REI/ PHI GRAZING (Hours or Days)	REMARKS AND PRECAUTIONS
Armyworm True armyworm Fall armyworm, Beet armyworm, Yellowstriped armyworm *(continued)*	*gamma cyhalothrin* Declare (1.25) Proaxis (0.5)	3A	 1.28-1.54 fl oz 3.2-3.84 fl oz	 0.0125-0.015 0.0125-0.015	24 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.6-1.92 fl oz 3.2-3.84 fl oz	 0.025-0.03 0.025-0.03	24 H/ 7 D	
	methomyl Annihilate LV	1A	 0.75-1.5 pt	 0.225-0.45	48 H/ 7 D	
	spinosad Blackhawk (36%)	5	 1.7-3.4 oz	 0.038-0.075	4 H/ 3 D	
	spinetoram Radiant 1SC	5	 3-5 fl oz	 0.0234-0.0469	4 H/ 3 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	 3.2 fl oz	 0.02-0.025	12 H/ 14 D	
Grasshoppers	*beta-cyfluthrin* Baythroid XL 1EC	3A	 1.8-2.4 fl oz	 0.014-0.019	12 H/ 3 D	Treat when grasshoppers are causing excessive defoliation.
	gamma cyhalothrin Declare (1.25)	3A	 0.77-1.54 fl oz	 0.0075-0.015	24 H/ 7 D	
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.28-1.92 fl oz 2.56-3.84 fl oz	 0.02-0.03 0.02-0.03	24 H/ 7 D	
	malathion Malathion 57EC, 5EC Malathion 8EC	1B	 1.5 pt 1-1.25 pt	 0.94 1.0-1.25	12 H/ 7 D	
	zeta-cypermethrin Mustang Maxx, Respect 0.8EC	3A	 3.2 fl oz	0.02-0.025	12 H/ 14 D	
Lesser cornstalk borer						No feasible chemical control available. Seed treatments applied for aphid control may provide useful suppression.
Winter grain mite	*gamma cyhalothrin* Declare (1.25) Proaxis (0.5)	3A	 1.54 fl oz 3.84 fl oz	 0.015 0.015	24 H/ 7 D	Treat when mites are present and plants are stunted and discolored. Infestations are usually associated with application of cattle manure or chicken litter.
	lambda cyhalothrin Warrior II Zeon 2.08 Silencer, Lambda, other brands 1	3A	 1.92 fl oz 3.84 fl oz	 0.03 0.03	24 H/ 7 D	

***PHI: Harvest intervals listed are for grazing. See product label for hay and grain PHI.**

Problem Weeds and What to Do About Them

Dr. Patrick McCullough, Extension Weed Scientist

Problem Pasture Weeds

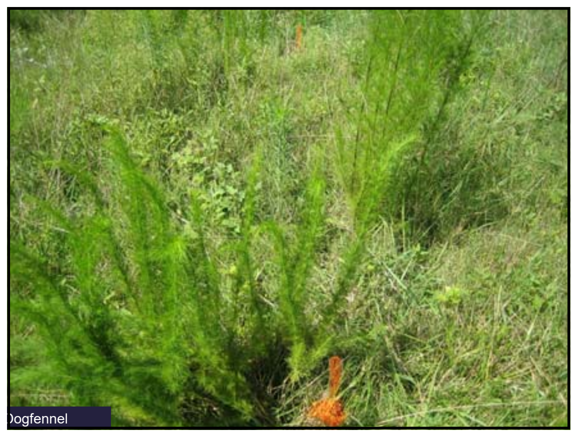
Problem Weeds and What to Do About Them

Patrick McCullough, Ph.D.

University of Georgia

Early Detection of New Weeds

- Identify the weed species
  - Weed ID books
  - Consult with county extension office
- Select control options
  - Easier to control prior to population spreading
  - Mechanical or physical removal often possible
- Review growing conditions and management practices
  - Modifications can reduce spread and growth of weeds
  - Promote competition of the pasture grasses



Dr. Patrick McCullough
Extension Weed Scientist

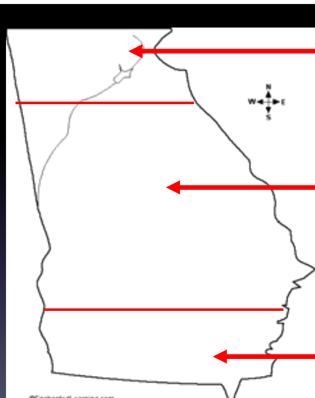
Problem Pasture Weeds

Restrictions

- Do not exceed 4.2 qt/a per year
- Do not apply to mixed stands of grasses with legumes (other than alfalfa)
- There is no pre-harvest or pre-grazing interval restriction
- Mixed stands of grasses and alfalfa may be grazed or harvested 14 or more days after applications

Annual Grassy Weed Control
(Crabgrass, Sandbur, Foxtails, Goosegrass)

- Bermudagrass
  - Consider tank-mixtures of Pastora + Prowl H_2O
  - Sequential treatments or tank-mixtures
- Bahiagrass
  - No POST herbicides for crabgrass, Prowl timing is critical
- Tall fescue
  - Prowl H_2O treatments
  - Facet (quinclorac) + Prowl H_2O for crabgrass and annual foxtails



March 1 to April 1

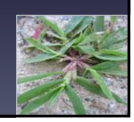
March 1 to 20

January 1 to March 1

Annual Grassy Weed Control
(Crabgrass, Sandbur, Foxtails, Goosegrass)

Bermudagrass

- Preemergence control critical
  - Prowl H2O (pendimethalin) at 3.1 to 4.2 qt/acre
  - Apply when soil temps are in low 50's
- Postemergence control
  - Pastora: 1 to 1.5 oz/acre (early-POST)
  - Impose: 4 to 8 oz/acre (early to late POST)



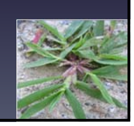
Extending the Length of Annual Weed Control

- Apply split applications 6-8 weeks apart
  - Split in between cuttings
- For example, Prowl H_2O at 4.2 qts/acre
  - **In March**, apply 2.1 qts /acre
  - **In mid-June**, apply 2.1 qts/acre

Annual Grassy Weed Control
(Crabgrass, Sandbur, Foxtails, Goosegrass)

Bermudagrass

- Pastora
  - May be applied 7 days after cutting
  - Does not have haying restrictions
  - Little to no reductions in yield after treatments
- Impose
  - More injurious than Pastora on bermudagrass
  - Can reduce initial yield up to 50%
  - 7 day cutting restriction



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UGA extension

Problem Pasture Weeds

Annual Grassy Weed Control
(Crabgrass, Sandbur, Foxtails, Goosegrass)

- Bahiagrass
  - Prowl applications (PRE control)
- Tall fescue
  - Facet as an early POST treatment (64 oz/acre)
  - Does not control goosegrass or sandbur
  - Promote stand density in early spring

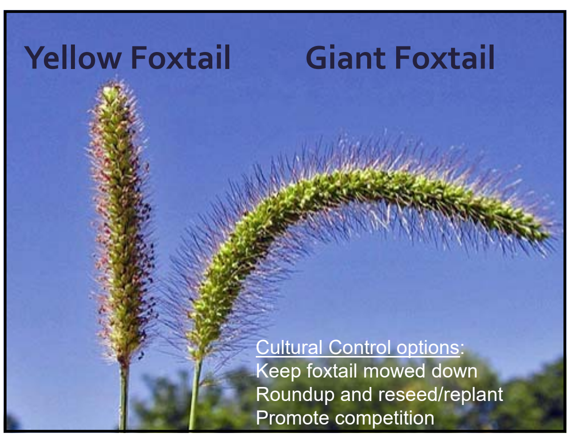
Green and Yellow Foxtail Control

Common Name	Trade Name	Control
imazapic	Impose*	G
imazamox	Raptor	F-G
imazethapyr	Pursuit	G
nicosulfuron + metsulfuron	Pastora	F-G
pendimethalin (PRE)	Prowl	F
sethoxydim	Poast*	E

*Grazing restrictions

Pre-Plant Weed Control

- Bermudagrass
  - Diuron: applied before sprigging in summer
  - Must be applied pre-plant, may stunt growth
  - Not labeled for grazed pastures
- Alfalfa (may have yield reduced in first year)
  - EPTC (Eptam): 3.5 pt/acre
  - Benefin (Balan): 2 lb/acre
- Other species
  - No pre-plant options
  - Consider glyphosate or paraquat prior to planting to control seedlings



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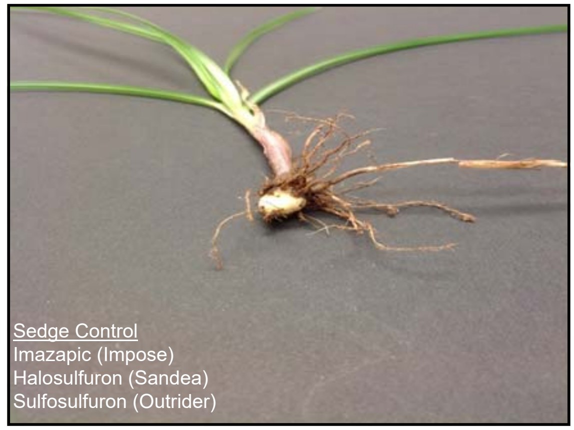
Problem Pasture Weeds



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Problem Pasture Weeds

Horsenettle Control

Common Name	Trade Name	Control
2,4-D	various	P
2,4-D + dicamba	Weedmaster	F
2,4-D + picloram	Grazon P + D	G-E
2,4-D + triclopyr	Crossbow	P-F
aminopyralid	Milestone	E
aminopyralid + 2,4-D	GrazonNext	E
dicamba	Banvel, Clarity	G
metsulfuron	Cimaron, others	P
metsulfuron + chlorsulfuron	Cimarron Plus	P-F
metsulfuron + 2,4-D + dicamba	Cimarron Max	P-F
picloram + fluroxypyr	Surmount	E
triclopyr	Remedy	F

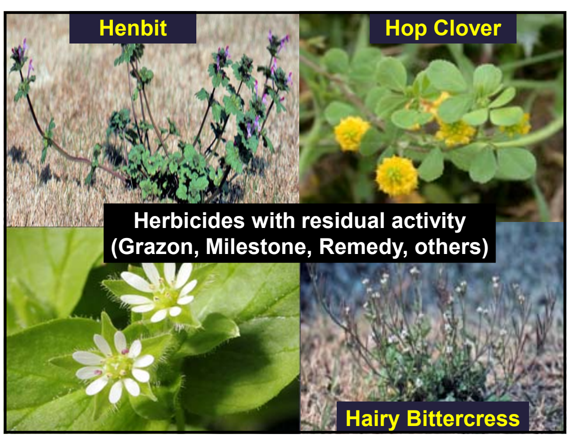
Plant Back Concerns for Fall

Grasses

- GrazonNext – 15 days prior to planting
- Chaparral – 30 days prior to planting
- PastureGard – day of planting
- Pastora - 4 months

Legumes (examples)

- 2,4-D – 3 to 4 weeks
- PastureGard – 1 month
- GrazonNext – bioassay recommended
- Chaparral – bioassay recommended
- Milestone – bioassay recommended
- Pastora – 12 months



Vaseygrass

Control in pastures:

Imazapic (Impose)

Pastora (nicosulfuron + metsulfuron)

sethoxydim

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Extension Weed Scientist

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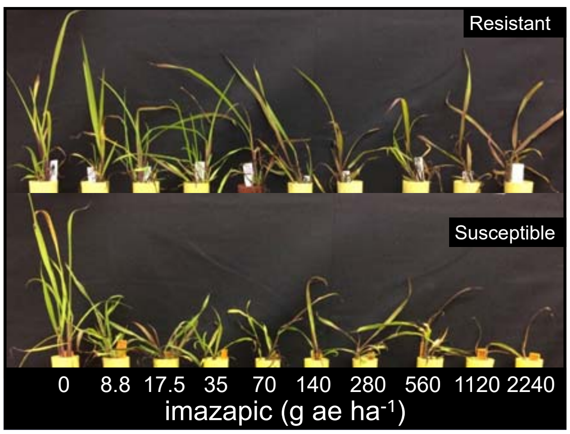
Problem Pasture Weeds

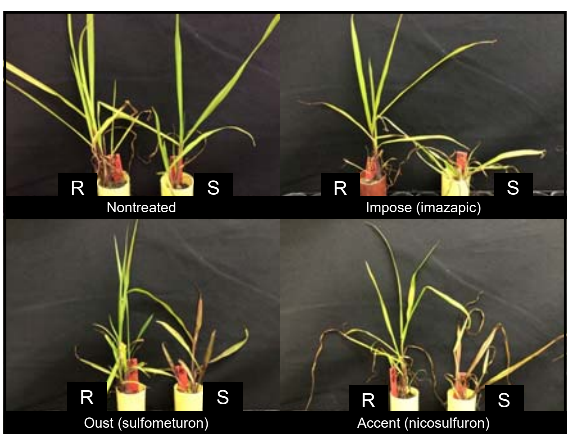
Vaseygrass Control in Pastures

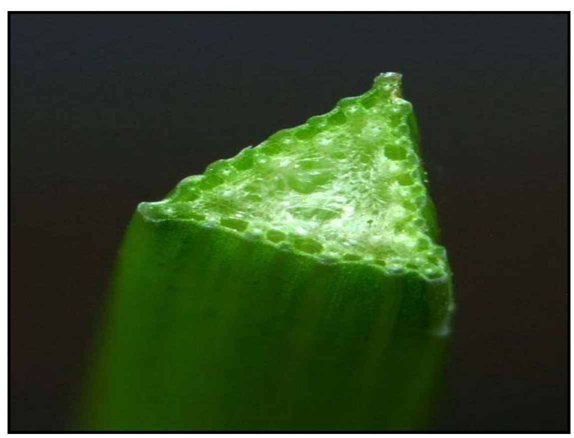
WSSA Group	Common Name	Trade Name
1	sethoxydim	Poast, others
2	nicosulfuron + metsulfuron	Pastora
2	imazapic	Impose
9	glyphosate	various

Vaseygrass Control Options

- Control considerations
  - Make treatments when plants are about 18" or smaller
  - Mowing will suppress growth and enhance control from herbicides
  - Use high quality adjuvant with vaseygrass herbicides
- Fall vs. spring
  - Spring treatments will suppress populations
  - Fall is best time of year for long-term control



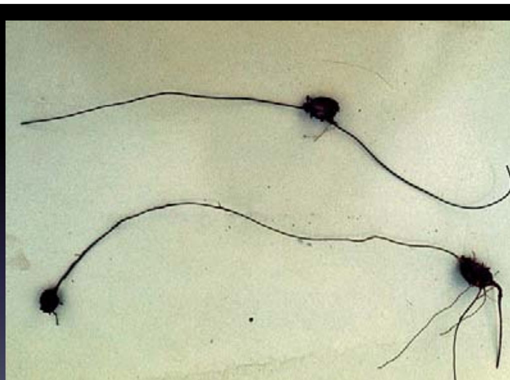


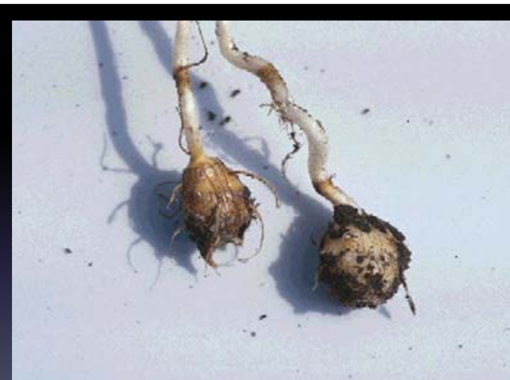


Dr. Patrick McCullough
Extension Weed Scientist

UGA extension

Problem Pasture Weeds





Terminal tubers

Sedge Control in Pastures

- Cultural
  - Reduce moisture, improve drainage
  - Early detection is critical
- Chemical
  - Bermudagrass and bahiagrass: Outrider, Impose, Sandea
  - Perennial peanut: Impose
  - Other species: no control options available
  - Consider fall applications for controlling perennial sedges

Yellow Nutsedge

Ryegrass (*Lolium* spp.)

- Transition out overseeded ryegrass in bermudagrass
  - Competitive growth in spring
  - Causes thinning of pasture grasses in early summer
- Hayfields
  - Increases maintenance costs
  - Yield losses
  - Establishment of summer weeds

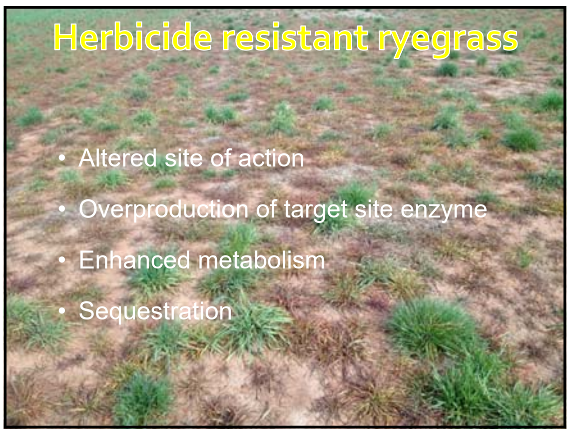
Dr. Patrick McCullough
Extension Weed Scientist

UGA extension

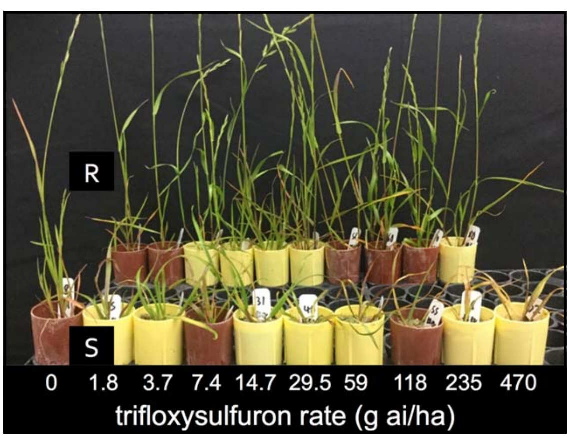
Problem Pasture Weeds

Popular Herbicides For Ryegrass Control

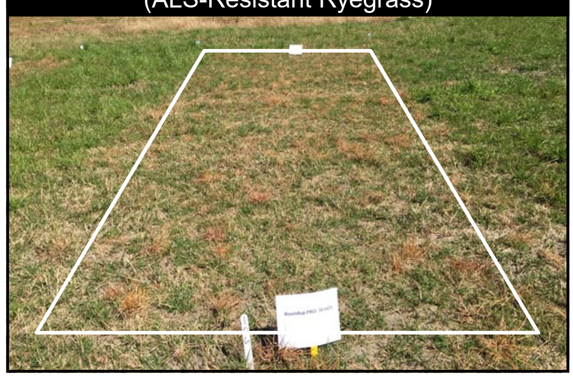
WSSA Group	Common Name	Trade Name
1	sethoxydim	Poast, others
2	metsulfuron	Cimarron, others
2	nicosulfuron + metsulfuron	Pastora
2	imazapic	Impose
9	glyphosate	Roundup, others



Pastora at 1.25 oz/acre in February
(ALS-Resistant Ryegrass)



Roundup Pro at 16 oz/acre in February
(ALS-Resistant Ryegrass)



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Pastora + Roundup Pro in February
(ALS-Resistant Ryegrass)

Questions

Ryegrass Control

Bermudagrass

- Fall timings
  - Pastora at 1 to 1.25 oz/acre in November/December
  - Impose (Imazapic) at 4 to 6 oz/acre
  - Metsulfuron (60%) at 0.3 to 0.5 oz/acre (erratic control)
- Winter timings
  - Pastora at 1 to 1.5 oz/acre + glyphosate at moderate rates (8 to 12 oz/acre of 4 lb ai/gal product)

Ryegrass Control

- Perennial peanut
  - Sethoxydim (Poast)
  - Impose (Imazapic)
- Bahiagrass
  - Prowl (preemergence)
- Tall fescue
  - Prowl (preemergence)

ALFALFA WEED CONTROL

Patrick E. McCullough, Extension Agronomist – Weed Science

HERBICIDE	MOA	BROADCAST RATE PER ACRE: AMOUNT OF FORMULATION	BROADCAST RATE PER ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
PREPLANT INCORPORATED					
benefin Balan 60DF		2 lb	1.2		Incorporate 2-3” deep before planting for grass control. EPTC may provide better broad-spectrum weed control. Some epinastic injury to alfalfa usually occurs from EPTC; however, injury is normally temporary. Do not use if grain or grass crop is to be planted with alfalfa. Research has shown significant injury as stand reduction from Balan. Injury would be expected to be less when used on fall than on spring planted alfalfa. The yield of the first cutting may be reduced when treated with Balan.
EPTC Eptam 7 lb/gal		3.5 pt	3.1		
trifluralin Treflan 4 lb/gal		1	0.5		TREFLAN HFP has a supplemental label for weed control in seedling alfalfa during establishment. Proper incorporation is critical (refer to Treflan HFP label), since severe crop damage and stunting can result. Some stand reduction and stunting of alfalfa may occur with TREFLAN HFP, but reduced weed competition will allow establishment of a quality stand.
POSTEMERGENCE SEEDLING ALFALFA					
2-4,DB Butyrac 200 Butoxone 1.75 lb/gal		2-3 qt 4.3-6.5 pt	1-1.5 0.9-1.4		Apply in fall or spring after alfalfa has 2-4 trifoliate leaves. Controls emerged annual broadleaf weeds less than 3” tall. Do not graze or cut for hay for 60 days after application. Rainfall or irrigation within 7-10 days after treatment may cause injury. DO NOT add wetting agents or surfactants to the spray solution.
bromoxynil Buctril 2L		1.5 pt	0.375		Apply to seedling alfalfa that has a minimum of 4 trifoliolate leaves. Spray winter annual broadleaf weeds that do not exceed the 4-leaf stage or 2” in height, or have rosettes greater than 1.5” in diameter. DO NOT apply when temperatures exceed 70°F at and 3 days after application or unacceptable crop injury may occur. DO NOT add a surfactant or crop oil. DO NOT cut for feed or graze spring treated alfalfa for 30 days after application. DO NOT cut for feed or graze fall or winter treated alfalfa for 60 days after application.
imazethapyr Pursuit 70DG Pursuit 2EC		1.08-2.16 oz 3-6 fl oz	0.047-0.094		Apply to seedling alfalfa with a minimum of 2 trifoliate leaves and when weeds are 1-3” tall or before rosette forming weeds exceed 3” in diameter. Pursuit requires a 1 hour rain free period. Pursuit may cause a temporary reduction in height or slight leaf yellowing. DO NOT feed, graze, or harvest alfalfa for 30 days after application. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1.25% v/v to the spray solution. If replanting is necessary in a field treated with Pursuit, do not plant alfalfa for 4 months following the application of Pursuit.
glyphosate Roundup WeatherMax 5.5 lb/gal		22-44 fl oz	0.95-1.9		**USE ONLY ON ALFALFA VARIETIES DESIGNATED AS CONTAINING A ROUNDUP READY (RR) GENE.** Apply from alfalfa emergence up to 5 days before cutting hay. May be applied at any alfalfa growth stage. Due to alfalfa biology and breeding constraints, up to 10% of seedlings may not contain the Roundup Ready gene and will be killed by glyphosate. To eliminate undesirable stand gaps during seedling establishment, apply Roundup WeatherMax at the low rate at or before the 3-4 trifoliate leaf stage of alfalfa. Sequential applications may be made as needed (allow a minimum of 7 days between applications) but do not exceed 4.1 qt/A/year. Remove livestock before application and wait 5 days after the last application before grazing, cutting for silage or hay harvest. Glyphosate will control most weed species, including dodder. Weeds that are not effectively controlled by a single application of glyphosate include: hemp sesbania, bermudagrass, yellow nutsedge, tropical spiderwort, greenbrier species, cutleaf eveningprimrose, Carolina geranium, maypop passionflower and trumpetcreeper. Repeat applications, or other appropriate herbicides, will be needed to control this group of weeds. Other brands of glyphosate may be used on Roundup Ready alfalfa, if the specific brand label lists this use.

HERBICIDE	MOA	BROADCAST RATE PER ACRE AMOUNT OF FORMULATION	POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
POSTEMERGENCE SEEDLING ALFALFA					
imazamox Raptor 1 lb/gal		4-6 fl oz	0.031-0.047		Apply to seedling alfalfa with a minimum of 2 trifoliate leaves and when weeds are 1-3" tall. Raptor requires a 1-hour rain-free period. A temporary growth reduction may occur after application. DO NOT feed, graze, or harvest alfalfa for 20 days after application. A maximum total of 6 fl oz/A may be applied per season. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1-2% v/v to the spray solution. If replanting is necessary in a field treated with Raptor, do not plant alfalfa for 4 months following the application of Raptor.
pendimethalin Prowl H2O 3.8 lb/gal		1.1-2.1 pt	0.5-1		Apply to seedling alfalfa before annual weed emergence and after alfalfa has developed 2 trifoliolate leaves Applications should be made before alfalfa exceeds 6" in height. Pendimethalin will provide good to excellent preemergence control of annual grasses and some annual broadleaf weeds. Do not cut for hay or graze for 28 days after an application.
pronamide Kerb 50W		1-1.5 lb	0.5-0.75		Spray preemergence or early postemergence for control of winter annual weeds after the alfalfa has reached the trifoliolate leaf stage. Do not graze or cut for hay for 120 days after treatment.
sethoxydim Poast 1.5 lb/gal Poast Plus Sethoxydim E-Pro Sethoxydim G-Pro 1 lb/gal		1-1.5 pt 1.5-2.25 pt 1.5-2.25 pt 1.5-2.25 pt	0.19-0.3		Apply low rate with 2 pt of crop oil concentrate/A for control of annual grasses up to 8" tall (varies with species). Use high rate if rhizome johnsongrass is to be controlled, followed by a second application to regrowth or new plants. Do not apply to grass or alfalfa under stress. Apply before the grass has been cut. Do not apply sethoxydim products within 7 days of feeding, grazing or harvesting undried forage, or within 14 days of cutting for dry hay.
clethodim Select Max 0.97 lb/gal Intensity One 0.97 lb/gal TapOut 0.97 lb/gal Shadow 2 lb/gal Arrow 2 lb/gal		9-32 fl oz 6-16 fl oz 6-16 fl oz	0.07-0.24 0.09-0.25 0.09-0.25		Clethodim will provide excellent control of annual and perennial grasses, but will not control broadleaf weeds or sedges. Use the low rate on annual grasses, and the high rate on perennial grasses (see label). Select Max and Intensity One require the addition of a nonionic surfactant at 0.25% v/v. For Shadow and Arrow use only a crop oil concentrate at 1% v/v. Use a nonionic surfactant or crop oil concentrate with TapOut. Clethodim may be tank-mixed with 2,4-DB; however, the risk of temporary injury to alfalfa will increase. Clethodim may also be tank-mixed with Pursuit and Raptor. Do not cut for hay or graze for 15 days after an application of clethodim.
POSTEMERGENCE SEEDLING – ALFALFA (BETWEEN CUTTINGS)					
paraquat Firestorm 3 lb/gal Gramoxone Inteon 2 lb/gal		0.7 pt 1 pt	0.25		Apply to small emerged annual grass and broadleaf weeds in first year alfalfa immediately after removing hay between cuttings. Do not treat more than 5 days after cutting. Add a nonionic surfactant at 1 pt/100 gal of water. Do not make more than 2 applications during the growing season. Apply in 20-40 gal of water/A. Weeds much beyond the seedling stage and stubble of those cut off during harvest will be less affected by the treatment. Do not graze, cut or harvest within 30 days of application.

ALFALFA WEED CONTROL

HERBICIDE	MOA	BROADCAST RATE PER ACRE: AMOUNT OF FORMULATION	BROADCAST RATE PER ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
POSTEMERGENCE – ESTABLISHED DORMANT ALFALFA (SECOND YEAR & OLDER)					
metribuzin Sencor 4L Sencor 75DF Metribuzin 75 DF		12 fl oz 8 oz 8 oz	0.375		See label for weeds controlled at different rates and for precautions related to soil textures. Spray dormant alfalfa, established 1 year or longer, after frost in fall or preferably in late winter before alfalfa begins spring growth while weeds are small. Provides preemergence and early postemergence weed control when surfactant is added. Do not use these treatments on alfalfa-grass mixtures. Do not use Sencor, Metribuzin or Velpar on sands. The higher rate of Velpar may cause crop damage. Do not graze or cut for hay within 28 days after Sencor or Metribuzin treatment. Do not graze or cut for hay within 30 days after Velpar treatment. Do not tank-mix any of these herbicides.
hexazinone Velpar 2L Velpar 75 DF		2-3 pt 8-12 oz	0.5-0.75 0.5-0.75		
pronamide Kerb 50W		1-1.5 lb	0.5-0.75		Apply in January at lower rate for most annual winter grasses, except higher rate for annual ryegrass or orchardgrass. Do no graze or cut for hay for 120 days after treatment. Provides preemergence and early postemergence control. Do not tank mix with other herbicides.
paraquat Firestorm 3 lb/gal Gramoxone Inteon 2 lb/gal		0.7-1.3 pt 1-2 pt	0.25-0.5		Apply during the winter months when established alfalfa is dormant. **DO NOT** apply dormant treatments to seedling alfalfa less than 6 months old. Controls Italian ryegrass (less than 6" tall), chick weed and most other winter annual weeds. Green alfalfa foliage present at time of application will become necrotic (brown). **DO NOT** apply after the initiation of new spring growth. Add a nonionic surfactant at 1 pt/100 gal of spray solution. **DO NOT** graze or harvest within 42 days of application. Make only 1 application per season.
PREEMERGENCE – ESTABLISHED ALFALFA					
norflurazon Solicam 80DF		1.25-2.5 lb	1-2		Apply to established alfalfa in spring or early fall for the control of annual grasses and annual broadleaf weeds such as tropic croton and prickly sida. May be applied to dormant and actively-growing alfalfa. Apply to actively-growing alfalfa following hay removal to ensure spray penetration to the soil surface. DO NOT apply to seedling alfalfa earlier than 5 months after emergence. DO NOT apply Solicam within 28 days of harvest. Use the low rate on sandy soils. Solicam may be tank-mixed with Gramoxone Extra, Poast, Pursuit, Kerb, Sencor, Lexone and 2,4-DB. For 16 months following application rotate only to cotton, soybeans or peanuts.
pendimethalin Prowl H2O 3.8 lb/gal		1.1-4.2 qt	1.05-4		Pendimethalin will provide good to excellent preemergence control of annual grasses and some annual broadleaf weeds. In established alfalfa (defined as alfalfa that was planted in fall or spring and has gone through a first cutting/mowing), Prowl H2O may be applied in the fall after the last cutting, during winter dormancy or in the spring before alfalfa regrowth is 6". Prowl H2O must be applied before crabgrass or other annual grasses germinate. Prowl H2O has no pre-harvest or pre-grazing interval restriction.
flumioxazin Chateau 51 WDG		4 oz	0.13		Flumioxazin will provide good to excellent preemergence control of annual grasses and some annual broadleaf weeds. Apply in the fall or spring months before weed emergence. Do not apply to alfalfa with more than 6" of new growth or significant injury can occur. Do not cut for hay or graze for 25 days after an application of flumioxazin.
POSTEMERGENCE – ESTABLISHED ALFALFA					
2,4-DB Butyrac 200 Butoxone 1.75 lb/gal		2-3 qt 4.3-6.5 pt	1-1.5 0.9-1.4		Spray established dormant or non-dormant alfalfa in late fall through spring for control of emerged weeds that emerge in the fall and over winter in the rosette stage. Do not graze or cut for hay within 30 days after treatment. Overhead irrigation or rainfall within a few days after use may wash chemical into the root zone, possibly causing some twisting of stems and malformation of leaves. Do not add wetting agents or surfactants to the spray mix.

HERBICIDE	MOA	BROADCAST RATE PER ACRE		REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
		AMOUNT OF FORMULATION	POUNDS ACTIVE INGREDIENT		
POSTEMERGENCE – ESTABLISHED ALFALFA *(continued)*					
halosulfuron Sandea 75WG		0.67-1 oz	0.03-0.045		Controls annual and perennial broadleaf weeds and sedges in established alfalfa. It is recommended to make an application as soon as possible after removal of hay. Application of Sandea to alfalfa where re-growth exceeds 6" will result in greater yield reduction. Do not apply more than 2 oz/A/12 month period. Apply to sedges 6-10" tall. Applications are recommended with a non-ionic surfactant at 0.25% vol/vol. For best results, do not graze or mow for 2 weeks before or after application.
imazethapyr Pursuit 70DG Pursuit 2EC		1.08-2.16 oz 3-6 fl oz	0.047-0.094		Apply to established alfalfa in the fall, or in the spring to dormant or semi-dormant alfalfa. Spring treatments should be made before excessive alfalfa growth (less than 3" of new growth) to reduce spray interference. Apply when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. DO NOT feed, graze, or harvest alfalfa for 30 days after application. Add a nonionic surfactant at 0E.25% v/v or a crop oil concentrate at 1.25% v/v to the spray solution. If replanting is necessary in a field treated with Pursuit, do not plant alfalfa for 4 months following the application of Pursuit.
imazamox Raptor 1 lb/gal		4-6 fl oz	0.031-0.047		Apply to established alfalfa in the fall, or in the spring to dormant or semi-dormant alfalfa. Spring treatments should be made before excessive alfalfa growth (less than 3" of new growth) to reduce spray interference. Apply when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. Raptor requires a 1 hour rain free period. A temporary growth reduction may occur after application. DO NOT feed, graze, or harvest alfalfa for 20 days after application. A maximum total of 6 fl oz/A/season may be applied. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1-2% v/v to the spray solution. If replanting is necessary in a field treated with Raptor, do not plant alfalfa for 4 months following its application.
glyphosate Roundup WeatherMax 5.5 lb/gal		44 fl oz	1.9		**USE ONLY ON ALFALFA VARIETIES DESIGNATED AS CONTAINING A ROUNDUP READY (RR) GENE.** May be applied at any alfalfa growth stage. Sequential applications may be made as needed (allow a minimum of 7 days between applications) but do not exceed 4.1 qt/A/year. Remove livestock before application and wait 5 days after the last application before grazing, cutting for silage or hay harvest. Glyphosate will control most weed species, including dodder. Weeds that are not effectively controlled by a single application of glyphosate include: hemp sesbania, bermudagrass, yellow nutsedge, tropical spiderwort, greenbrier species, cutleaf eveningprimrose, Carolina geranium, maypop passionflower and trumpetcreeper. Repeat applications, or other appropriate herbicides, will be needed to control this group of weeds. Other brands of glyphosate may be used on Roundup Ready alfalfa, if the specific brand label lists this use.
sethoxydim Poast 1.5 lb/gal Poast Plus Sethoxydim E-Pro Sethoxydim G-Pro 1 lb/gal		1-1.5 pt 1.5-2.25 pt 1.5-2.25 pt 1.5-2.25 pt	0.19-0.3		Apply low rate with 2 pt of crop oil concentrate/A for control of annual grasses up to 8" tall (varies with species). Use high rate if rhizome johnsongrass is to be controlled, followed by a second application to regrowth or new plants. Do not apply to grass or alfalfa under stress. Apply before the grass has been cut. Do not apply sethoxydim products within 7 days of feeding, grazing or harvesting undried forage, or within 14 days of cutting for dry hay.

ALFALFA WEED CONTROL

HERBICIDE	MOA	BROADCAST RATE PER ACRE: AMOUNT OF FORMULATION	BROADCAST RATE PER ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
POSTEMERGENCE ESTABLISHED – ALFALFA (BETWEEN CUTTINGS)					
clethodim Select Max 0.97 lb/gal Intensity One 0.97 lb/gal TapOut 0.97 lb/gal Shadow 2 lb/gal Arrow 2 lb/gal		9-32 fl oz 6-16 fl oz 6-16 fl oz	0.07-0.24 0.09-0.25 0.09-0.25		Clethodim will provide excellent control of annual and perennial grasses, but will not control broadleaf weeds or sedges. Use the low rate on annual grasses, and the high rate on perennial grasses (see label). Select Max and Intensity One require the addition of a nonionic surfactant at 0.25% v/v. For Shadow and Arrow use only a crop oil concentrate at 1% v/v. Use a nonionic surfactant or crop oil concentrate with TapOut. Clethodim may be tank-mixed with 2,4-DB; however, the risk of temporary injury to alfalfa will increase. Clethodim may also be tank-mixed with Pursuit and Raptor. Do not cut for hay or graze for 15 days after an application of clethodim.
imazethapyr Pursuit 70DG		1.08-2.16 oz	0.047-0.094		Apply as a between cut treatment. Remove hay from the field and apply before excessive alfalfa regrowth. Apply when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. DO NOT feed, graze, or harvest alfalfa for 30 days after application. A maximum total of 2.16 oz/A/year of Pursuit may be applied. Add a nonionic surfactant at 0.2 5% v/v or a crop oil concentrate at 1.25% v/v to the spray solution. If replanting is necessary in a field treated with Pursuit, do not plant alfalfa for 4 months following its application. Do not apply more than 1.44 oz during the last year of the stand.
imazamox Raptor 1 lb/gal		4-6 fl oz	0.031-0.047		Apply as a between cut treatment. Remove hay from the field and apply before excessive alfalfa regrowth. Apply when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. Raptor requires a 1-hour rain-free period. A temporary growth reduction may occur after application. DO NOT feed, graze, or harvest alfalfa for 20 days after application. A maximum total of 6 fl oz/A may be applied per season. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1-2% v/v to the spray solution. If replanting is necessary in a field treated with Raptor, do not plant alfalfa for 4 months following its application.
paraquat Firestorm 3 lb/gal Gramoxone Inteon 2 lb/gal		0.7 pt 1 pt	0.25		Apply to established stands (at least one year old) immediately after alfalfa has been removed for silage or hay. Do not treat more than 5 days after cutting. Add surfactant at 1 pt/100 gal of spray mix. DO NOT graze, cut or harvest within 30 days of application. Make 1-3 applications as needed during the cutting season. Apply in 20-40 gals of water/A. Weeds much beyond the seedling stage and stubble of those cut off during harvest will be less affected by the treatment.
pendimethalin Prowl H2O 3.8 lb/gal		1.1-4.2 qt	1.05-4		Apply as a between cut treatment before annual weeds emerge. Pendimethalin will provide good to excellent preemergence control of annual grasses and some annual broadleaf weeds. Do not cut for hay or graze for 28 days after an application of 2.1 qt/A or less. If Prowl H2O is applied at more than 2.1 qt/A, the grazing and haying restriction is 50 days.
flumioxazin Chateau 51 WDG		4 oz	0.13		Apply as a between cut treatment for preemergence control of annual grasses and some annual broadleaf weeds. Application should be made as soon as possible after hay harvest to minimize injury to alfalfa. Do not apply to alfalfa with more than 6" of new growth or significant injury can occur. Do not cut for hay or graze for 25 days after an application of flumioxazin.

CLOVER WEED CONTROL

(Including arrowleaf, crimson, red, white, and other clovers)

Patrick E. McCullough, Extension Agronomist – Weed Science

HERBICIDE	BROADCAST RATE/ACRE AMOUNT OF FORMULATION	BROADCAST RATE/ACRE POUNDS ACTIVE INGREDIENT	REMARKS AND PRECAUTIONS
PREPLANT INCORPORATED			
EPTC Eptam	3.5 pt	3.1	For winter annual grass and some broadleaf weed control, incorporate 2-3" deep before planting. Do not use on white Dutch clover. Do not use if a grass or grain crop is to be planted with the clover.
benefin Balan 60DF	2 lb	1.2	May be used on alsike, ladino, and red clover. For winter annual grass and some broadleaf weed control, incorporate 2-3" deep before planting. Do not use if a grass or grain crop is to be planted with the clover.
POSTEMERGENCE – Seedling Clovers			
imazethapyr Pursuit 2EC	3-6 fl oz	0.047-0.094	Apply to seedling clover with a minimum of two trifoliate leaves and when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. Pursuit requires a 1 hour rain-free period. Pursuit may cause a temporary reduction in height or slight leaf yellowing. DO NOT feed, graze, or harvest clover for 30 days after application. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1.25% v/v to the spray solution. If replanting is necessary in a field treated with Pursuit, do not plant alfalfa for 4 months following the application of Pursuit.
pronamide KERB 50W	1-1.5 lb	0.5-0.75	For preemergence control of winter annual weeds, spray prior to weed emergence in November or December. Do not graze or cut for hay for 120 days after treatment. In fall-seeded clovers, applications should be made after clover has reached the first trifoliate leaf stage. In spring seedings, applications should be delayed until the following fall or early winter.
sethoxydim Poast 1.5 lb/gal Poast Plus Sethoxydim E-Pro Sethoxydim G-Pro 1 lb/gal	 1-1.5 pt 1.5-2.25 pt 1.5-2.25 pt 1.5-2.25 pt	 0.19-0.3	Apply with crop oil concentrate at 2 pt/A to control annual and perennial grasses. Use the high rate for johnsongrass and bermudagrass. Do not apply to grasses growing under drought-stressed conditions. Apply to annual grasses less than 8" tall. Do not apply within 7 days of feeding, grazing, or harvesting undried forage, or within 20 days of cutting for dry hay.
POSTEMERGENCE – Established Clovers			
imazethapyr Pursuit 2EC	3-6 fl oz	0.047-0.094	Apply to clover with a minimum of two trifoliate leaves and when weeds are 1-3" tall or before rosette forming weeds exceed 3" in diameter. Pursuit requires a 1-hour rain-free period. Pursuit may cause a temporary reduction in height or slight leaf yellowing. DO NOT feed, graze, or harvest clover for 30 days after application. Add a nonionic surfactant at 0.25% v/v or a crop oil concentrate at 1.25% v/v to the spray solution. If replanting is necessary in a field treated with Pursuit, do not plant alfalfa for 4 months following the application of Pursuit.

[1] **Abbreviations used are:** EC – emulsifiable concentrate SP – soluble powder S – sprayable powder EL – emulsifiable liquid WP – wettable powder	Numbers following liquid formulations indicate lb active ingredient per gallon; those following solids indicate percent active ingredient

CLOVER WEED CONTROL

(Including arrowleaf, crimson, red, white, and other clovers)

HERBICIDE	BROADCAST RATE/ACRE		REMARKS AND PRECAUTIONS
	AMOUNT OF FORMULATION	POUNDS ACTIVE INGREDIENT	
POSTEMERGENCE - Established Clovers			
sethoxydim Poast 1.5 lb/gal Poast Plus Sethoxydim E-Pro Sethoxydim G-Pro 1 lb/gal	1-1.5 pt 1.5-2.25 pt 1.5-2.25 pt 1.5-2.25 pt	0.19-0.3	Apply with crop oil concentrate at 2 pt/A to control annual and perennial grasses. Use the high rate for johnsongrass and bermudagrass. Do not apply to grasses growing under drought-stressed conditions. Apply to annual grasses less than 8" tall. Do not apply within 7 days of feeding, grazing, or harvesting undried forage, or within 20 days of cutting for dry hay.
pronamide KERB 50W	1-1.5 lb	0.5-0.75	Controls winter annual grasses and some broadleaf weeds in clovers, birdsfoot trefoil and crown vetch. Apply from November through February. DO NOT graze or harvest for hay for 120 days after application. KERB is a restricted use herbicide.

[1] **Abbreviations used are:** EC – emulsifiable concentrate SP – soluble powder S – sprayable powder EL – emulsifiable liquid WP – wettable powder	Numbers following liquid formulations indicate lb active ingredient per gallon; those following solids indicate percent active ingredient

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

(Including bermudagrasses, bahiagrasses, fescues, and other perennial pasture grasses)

Patrick E. McCullough, Extension Agronomist – Weed Science

HERBICIDE	MOA	BROADCAST RATE/ACRE		REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
		AMOUNT OF FORMULATION	POUNDS ACTIVE INGREDIENT		
NEWLY SPRIGGED BERMUDAGRASS					
diuron Direx 4 L Diuron 4L Diuron 4L Diuron 80	7	0.8-2.4 qt 0.8-2.4 qt 0.8-2.4 qt 1-3 lb	0.8-2.4 lb	12 H	Preemergence applications of diuron provide fair to good control of crabgrass, crowfootgrass and goosegrass. Also provides residual control of certain annual broadleaf weeds. Diuron should be applied immediately after sprigging before weeds emerge. Bermuda sprigs should be planted 2” deep to lessen chance of injury. Emerged bermuda at the time of treatment may be temporarily injured. Do not graze or feed treated foliage for 70 days after diuron application. Diuron is not labeled in established forage bermudagrass.
2,4-D Esteron 99C 4 lb/gal 2,4-D LV 4 Ester 2,4-D LV 6 Ester	4	1-2 qt 1-2 qt 1.3-3 pt	1-2	12 H	Apply to emerged broadleaf weeds 3-4” tall. Provides poor preemergence control of crabgrass. Refer to specific herbicide label for use information.
2,4-D + *dicamba* WeedMaster 2.87 + 1 lb/gal	4 + 4	2-4 pt	0.72 + 0.25 to 1.44 + 0.5	48 H	Apply 7-10 days after sprigging for the postemergence control of seedling broadleaf and grass weeds. Reduced control will occur if weeds are taller than 1”, or if weed seed germination occurs 10 or more days after application. Do not graze lactating dairy animals within 7 days of application. There is no grazing restriction after an application for non-lactating animals. Do not graze meat animals in treated areas within 30 days of slaughter. Do not cut for hay within 37 days of treatment.
ESTABLISHED DORMANT BERMUDAGRASS					
paraquat Firestorm 3 lb gal Gramoxone Inteon 2 lb/gal	22	0.7-1.3 pt 1-2 pt	0.25-0.5	12 H 24 H	Apply in 20-30 gallons of water in late winter or early spring (probably in February or March) before bermudagrass begins spring green-up. Add 1 pt non-ionic surfactant/100 gal spray mix. Do not pasture or mow for hay until 40 days after treatment.
glyphosate Roundup PowerMax Roundup Original Max Roundup Weather Max 5.5 lb/gal	9	8-11 fl oz	0.34-0.47	4 H	Apply in mid-late winter months to bermudagrass pastures and hayfields for the control of little barley, cheat, and to suppress annual Italian ryegrass. Apply before new growth appears in the spring. Bermudagrass that is not dormant at the time of application may show a slight (2-4 week) delay in green-up. There is no grazing or hay restriction for any type of livestock.

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

HERBICIDE	MOA	BROADCAST RATE/ACRE AMOUNT OF FORMULATION	 POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES					
2,4-D various trade names 4 lb/gal	4	1-2 qt	1-2	See label	Apply to weeds 2-4” tall. Use low rates for small weeds, high rates for larger weeds. Apply low volatile esters from October through March. Apply only non-volatile AMINE or ACID formulations from late March through September. Do not graze lactating dairy animals for 14 days after treatment, or cut for hay for all types of livestock for 30 days after treatment. (Grazing and haying restrictions may vary—refer to product label). If thistles are present, apply while they are in the rosette stage of growth.
2,4-D (mixed amines) Hi-Dep 3.8 lb/gal	4	1-2 qt	0.95-1.9	48 H	Hi-Dep consists of dimethylamine and diethanolamine salts of 2,4-D formulated for low spray volume applications. DO NOT graze dairy cattle for 7 days after application. DO NOT cut for hay for 30 days after applications.
dicamba Banvel 4 lb/gal	4	1-3 pt	0.5-1.5	24 H	Controls a wide range of broadleaf weeds. There are no grazing restrictions for animals other than lactating dairy animals. Restrict grazing for lactating dairy animals as follows: **Days Before Grazing Days Before Hay Harvest** Up to 1 pint 7 37 Up to l quart 21 51 Up to 2 quarts 40 70
Clarity 4 lb/gal		1-3 pt			Remove meat animals from treated areas 30 days prior to slaughter. If thistles are present, apply while they are in the rosette stage of growth. This treatment will severely injure or kill clovers and alfalfa.
Xtendimax 2.9 lb/gal		11-44 fl oz	0.25-1 lb		Controls numerous annual and perennial broadleaf weeds. Rates above 44 oz/A are permitted only for spot treatments that do not exceed more than 1000 sq ft of treated area per acre. Do not broadcast apply more than 44 fl oz/A. Grass grown for hay requires a 7 D waiting period between application and harvest. Do not graze lactating dairy animals for 7 and 21 days after treatments of 22 and 44 oz/A, respectively. Do not feed hay that was harvested before 37 and 51 days after treatments of 22 and 44 oz/A, respectively, to lactating dairy animals. See label for grazing and haying restrictions following spot applications. Do not exceed a total of 88 fl oz/A/year.
carfentrazone Aim EW 1.9 lb/gal Aim EC 2 lb/gal	14	1-2 fl oz 1-2 fl oz	0.015-0.03 0.016-0.031	12H	Controls numerous annual broadleaf weeds less than 3” tall. Carfentrazone does not control weedy grasses or sedges. Apply with a nonionic surfactant at 0.25% v/v, or a crop oil concentrate at 1% v/v. For most weeds, carfentrazone is tank-mixed with other registered grass pasture and hay field herbicides. Combining carfentrazone with other herbicides often increases overall control and speed of control. There are no grazing or haying restrictions for any type of livestock for carfentrazone.
2,4-D + *dicamba* Weedmaster 2.87 lb + 1 lb/gal Outlaw 1.45 + 1.1 lb/gal	4 + 4	2-4 pt 2-4 pt	0.72 + 0.25-1.44 + 0.5 0.36 + 0.27-0.72 + 0.55	48 H	For control of a broad spectrum of weeds, apply in late spring or early summer to annual or perennial broadleaf weeds before flowering. Do not graze lactating dairy animals within 7 days. There is no restriction between application and grazing for non-lactating animals. Do not cut for hay within 37 days after treatment. Do not graze meat animals in treated areas within 30 days of slaughter. If thistles are present, apply while they are in the rosette stage of growth. For horsenettle, use the high rate. Weedmaster and Outlaw will severely injure or kill clovers or alfalfa.

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
2,4-D + *picloram* Grazon P+D GunSlinger HiredHand 2 lb + 0.54 lb/gal	4 + 4	2-4 pt	0.5 + 0.13-1 + 0.26	48 H	Controls annual and perennial broadleaf weeds. Use only in PERMANENT GRASS PASTURES AND HAYFIELDS. 2,4-D + picloram may also be applied at 4 pt/A or less to permanent pastures that will be seeded with cool-season grasses (ryegrass, tall fescue). Delay planting for 21 days after application. Small grains should not be planted in treated areas for 60 days after application. For permanent pastures that have been over seeded with small grains or ryegrass, do not apply at rates in excess of 1.5 pt/A and until over seeded ryegrass or small grains are well-established and at the tillering stage of growth. Clover seeding restrictions are as follows: fall-seeding is permitted if Grazon P+D at 2 pt/A or less is applied no later than June (4 month plant back). Spring (February-March) seeding is permitted the following spring for Grazon P+D at 2-3pt/A if applied no later than September 15 the previous year. The Gunslinger label indicates that legume establishment may not be successful if done within 12 months of application. 2,4-D + picloram may be used at 1.5 pt/A after establishment of newly sprigged bermudagrass once stolons have reached 6” in length. This herbicide is not recommended for use in rotational systems that use broadleaf crops or in temporary summer or winter grazing grass systems unless temporary grass is seeded into a permanent pasture. Do not graze lactating dairy animals on treated areas within 7 days after application. There are no grazing restrictions for non-lactating dairy animals, horses, sheep, goats and other types of livestock. Do not harvest grass cut for hay from treated areas for 30 days. Do not use hay from treated areas for composting or mulching of susceptible broadleaf crops. Withdraw meat animals from treated forage at least 3 days before slaughter. Do not transfer livestock from treated areas, or from 2,4-D + picloram-treated hay feeding areas to broadleaf crop areas without first allowing livestock to graze for 7 days on an untreated grass pasture. Do not store or feed 2,4-D + picloram treated hay on fields that will be planted to broadleaf crops. Do not use manure from livestock grazing on 2,4-D + picloram treated areas on gardens, broadleaf crops or orchards. 2,4-D + picloram will injure or kill legumes such as clovers and alfalfa. Restricted Use Herbicide.
picloram + *fluroxypyr* Surmount 1.2 + 0.96 lb/gal	4 + 4	1.5-6 pt	0.22 + 0.18 to 0.9 + 0.72	12 H	Controls a wide range of herbaceous and woody broadleaf plants. Use 1.5-2 pt/A for herbaceous broadleaf weeds. Use 3-6 pt/A for woody brush and trees. Use only in PERMANENT GRASS PASTURES AND HAYFIELDS. This herbicide is not recommended for use in rotational systems that use broadleaf crops or in temporary summer or winter grazing grass systems unless temporary grass is seeded into a permanent pasture. Do not graze lactating dairy animals on treated areas within 14 days after application. There are no grazing restrictions for non-lactating dairy animals, horses, sheep, goats and other types of livestock. Do not harvest grass cut for hay from treated areas for 7 days. Do not use hay from treated areas for composting or mulching of susceptible broadleaf crops. Withdraw meat animals from treated forage at least 3 days before slaughter. Do not transfer livestock from treated areas, or from Surmount treated hay feeding areas to broadleaf crop areas without first allowing livestock to graze for 7 days on an untreated grass pasture. Do not store or feed Surmount treated hay on fields that will be planted to broadleaf crops. Do not use manure from livestock grazing on Surmount treated areas on gardens, broad leaf crops or orchards. Surmount will injure or kill legumes such as clovers and alfalfa. New legume plantings may not be successful if seeded within 1 year of application. Restricted Use Herbicide.

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
triclopyr + *fluroxypyr* PastureGard 1.5 + 0.5 lb/gal	4 + 4	1.5-8 pt	0.3 + 0.1 to 1.5 + 0.5	12 H	Controls a wide range of herbaceous and woody broadleaf plants. Use 1.5-3 pt/A for herbaceous broadleaf weeds. Use 2-8 pt/A for woody brush and trees. Do not graze lactating dairy animals on treated areas during the growing season following application. There are no grazing restrictions for non-lactating dairy animals, horses, sheep, goats and other types of livestock. Do not harvest grass cut for hay from treated areas for 14 days. Withdraw meat animals from treated forage at least 3 days before slaughter. Legumes may be planted 30 days after application. Do not reseed forage grasses for 21 days after application.
aminopyralid Milestone 2 lb/gal		4-7 fl oz	0.06-0.11	48 H	Apply to permanent grass pastures and hayfields. Controls numerous annual and perennial broadleaf weeds. Particularly effective for the control of horsenettle and tropical soda apple. There are no grazing or haying restrictions for Milestone for any type of livestock. Do not transfer livestock from treated pastures, or from Milestone treated hay feeding areas, to broad leaf crop areas without first allowing livestock to graze for 3 days on an untreated grass pasture. Do not store Milestone treated hay on fields that will be planted to broadleaf crops. Do not use manure from livestock grazing on Milestone treated areas on gardens, broadleaf crops or orchards. Milestone will injure or kill legumes such as clovers and alfalfa. Do not plant legumes or broadleaf crops until a field bioassay has shown that the aminopyralid concentration in the soil will not injure broadleaf crops (see label for instructions on conducting field bioassay).
aminopyralid + *2,4-D* ForeFront GrazonNext 0.33 + 2.67 lb/gal	+ 4	1.5-2.6 pt	0.06 + 0.5 to 0.11 + 0.9	48 H	Apply to permanent grass pastures and hayfields. Controls numerous annual and perennial broadleaf weeds. Particularly effective for the control of horsenettle and tropical soda apple. Controls a wider spectrum of weed species than Milestone. There are no grazing restrictions for ForeFront and GrazonNext for any type of livestock. Do not harvest for hay within 7 days of application (all types of livestock). Do not transfer livestock from treated pastures, or from ForeFront or GrazonNext treated hay feeding areas, to broadleaf crop areas without first allowing livestock to graze for 3 days on an untreated grass pasture. Do not store or feed ForeFront or GrazonNext treated hay on fields that will be planted to broadleaf crops. Do not use manure from livestock grazing on ForeFront or Grazon Next treated areas on gardens, broadleaf crops or orchards. ForeFront and GrazonNext will injure or kill legumes such as clovers and alfalfa. Do not plant legumes or broadleaf crops until a field bioassay has shown that the aminopyralid concentration in the soil will not injure broadleaf crops (see label for instructions on conducting field bioassay).

HERBICIDE	MOA	BROADCAST RATE/ACRE AMOUNT OF FORMULATION	BROADCAST RATE/ACRE POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
aminopyralid + *metsulfuron* Chaparral DF 0.62 + 0.0945 lb/lb	+ 2	1.5-3 oz	0.06 + 0.0009 to 0.12 + 0.018	48 H	Apply to permanent grass pastures and hayfields. Bermudagrass should be established for 60 days and tall fescue for 2 years prior to use. Apply with 0.25% v/v nonionic surfactant/100 gal of spray mix. Controls numerous annual and perennial broadleaf weeds—particularly effective for the control of horsenettle and tropical soda apple. Also, controls 'Pensacola' bahiagrass. Controls a wider spectrum of weed species than Milestone. There are no grazing or haying restrictions for Chaparral for any type of livestock. Do not transfer livestock from treated pastures, or from Chaparral treated hay feeding areas to broad leaf crop areas without firs t allowing livestock to graze for 3 days on an untreated grass pasture. Do not store or feed Chaparral treated hay on fields that will be planted to broadleaf crops. Do not use manure from livestock grazing on Chaparral treated areas on gardens, broadleaf crops or orchards. Chaparral will injure or kill legumes such as clovers and alfalfa. Do not plant legumes or broadleaf crops until a field bioassay has shown that the aminopyralid concentration in the soil that will not injure broadleaf crops (see label for instructions on conducting field bioassay). On tall fescue, applications in the early spring may suppress seedhead production and reduce hay yield. To minimize injury to tall fescue: a) tank-mix 2,4-D; b) use the lowest recommended rate for the target weeds; c) use a 1/16 to 1/8% v/v surfactant concentration; d) make applications in the late spring or fall months after 5-6" of new growth has occurred; and e) do not add a surfactant when applied with liquid N.
2,4-D + *triclopyr* Crossbow 2 lb + 1 lb/gal	4 + 4	1-6 qt			Apply to established grass pastures for control of broadleaf weeds and woody plants. Woody plant control requires 6 qt/A or higher rate. Desirable forage broadleaf plants such as clover or alfalfa may be killed if sprayed. Grazing and haying restrictions**: Grazing or harvesting of green forage: (1) Lactating dairy animals**—2 gal/A or less; Do not graze or harvest green forage from treated area for 14 days after treatment. Greater than 2-4 gal/A: Do not graze or harvest green forage until next growing season. **(2) Other livestock**—2 gal/A or less: No grazing restrictions. Greater than 2-4 gal/A: Do not graze or harvest green forage from treated areas for 14 days after treatment. Note: If less than 25% of a grazed area is treated, there is no grazing restriction. **Haying (harvesting of dried forage): (1) Lactating dairy animals:** Do not harvest hay until next growing season. **(2) Other livestock:** Two gal/A or less: Do not harvest hay for 7 days after treatment. Greater than 2-4 gal/A: Do not harvest hay for 14 days after treatment.
triclopyr + *clopyralid* Redeem 2.25 lb + 0.75 lb/gal	4 + 4	1.5-4 pt	0.38-1.12 + 0.14-0.38	48 H	Apply for control of broadleaf weeds. Use 2.5-4 pt/A to control dogfennel, spiny amaranth and horsenettle. Desirable forage broadleaf plants such as clover or alfalfa may be killed if sprayed. Do not apply to newly-seeded or sprigged grasses until they are well established as evidenced by tillering, development of a secondary root system and vigorous growth. Grazing and haying restrictions: **Grazing or harvesting of green forage: (1) Lactating dairy animals**—Do not graze or harvest green forage from treated area for 14 days after treatment. **(2) Other livestock**—No grazing restrictions. **Haying (harvesting of dried forage): (1) Lactating dairy animals:** Do not harvest hay until next growing season. **(2) Other livestock:** Do not harvest hay for 7 days after treatment.

HERBICIDE	MOA	BROADCAST RATE/ACRE AMOUNT OF FORMULATION	BROADCAST RATE/ACRE POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
imazapic Impose Panoramic 2 lb/gal	2	4-8 fl oz	0.063-0.125	12 H	Apply to established bermudagrass. Do not apply to other forage grass species. Provides postemergence control of crabgrass, sandbur, broadleaf signalgrass, johnsongrass, vaseygrass, nutsedge and certain other weeds. This herbicide does not control pricklypear cactus, dallisgrass and goosegrass. Apply in late spring to mid-summer after bermudagrass has reached 100% green-up growth stage. Do not apply during spring transition or to dormant bermudagrass. Imazapic is not recommended on newly sprigged or seedling bermudagrass during the grow-in period. Research has shown that imazapic will moderately injure (yellowing of bermudagrass foliage), and suppress bermudagrass growth for 20-40 days after application. Additionally, bermudagrass hay yields may be reduced 30-50% at the first hay harvest (usually 30 days) following application. Imazapic should not be applied unless a bermudagrass yield reduction is acceptable. No bermudagrass hay yield reduction has been observed at the 2nd, 3rd and 4th hay harvest following an application at 4 fl oz/A. Add a nonionic surfactant (preferred) at 0.25% v/v or methylated seed oil at 1.5-2 pt/A to the spray mix. The use of 2-3 pt/A of 28% N, 32% N, 10-34-0 or ammonium sulfate in combination with the recommended rate of surfactant may increase control. Liquid fertilizer may be used as the sole spray carrier for imazapic, but control may be reduced. Do not add a surfactant or methylated seed oil if liquid fertilizer is used as the sole spray carrier. Annual ryegrass may be seeded 60 days after application. There is no grazing restriction for imazapic for any type of livestock. Do not cut for hay for 7 days after application.
halosulfuron Sandea 75WG	2	0.67-1.33 oz	0.03-0.06	12 H	Controls annual and perennial broadleaf weeds and sedges in established grass pastures and hayfields. Growers must delay hay harvesting for 37 days after application. It is recommended to make an application as soon as possible after removal of hay. No more than 2 applications or 1.33 oz/A of product by weight (0.062 lb ai/A)/12 month period. Apply to sedges 6-10" tall. There is no pre-grazing interval for lactating and non-lactating animals in grass pastures. Applications are recommended with a non-ionic surfactant at 0.25% vol/vol. For best results, do not graze or mow for 2 weeks before or after application.
sulfosulfuron OutRider 75DF	2	1.33 oz	0.062	12 H	Recommended for the control of emerged johnsongrass and sedge species in bermudagrass and bahiagrass forage systems. DO NOT use OutRider on other forage grass species such as tall fescue. OutRider does not control annual grasses such as crabgrass and sandbur, or perennial grasses such as dallisgrass and vaseygrass. Apply to johnsongrass from a minimum of 18" tall to the heading stage. Apply to sedges 6-10" tall. Add a nonionic surfactant at 0.25% v/v. OutRider may be tank-mixed with other pasture herbicides; however, amine formulations may reduce johnsongrass control. Grazing may occur immediately before or after application; however, control may be reduced by grazing of johnsongrass foliage. For best results, do not graze or mow for 2 weeks before or after application.
pendimethalin Prowl H_2O 3.8 lb/gal	3	3.1-4.2 qt	3-4	24 H	Provides preemergence control of annual grasses such as crabgrass and sandbur and some annual broadleaf weeds. Prowl H_2O is labeled for established bahiagrass, bermudagrass, orchardgrass, tall fescue, and other perennial grasses. Applications to newly sprigged bermudagrass, tall fescue, bahiagrass and other perennial forage grasses are not recommended. Apply Prowl H_2O in the late winter and early spring. In most areas of Georgia, this would be February through early March. Prowl H_2O has no pre-harvest or pre-grazing interval restriction. Split applications are permitted between cuttings for bermudagrass and other labeled warm-season species that were initially treated in late winter. Prowl H_2O may be tank-mixed with other herbicides registered for use on forage bermudagrass.

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
triclopyr Remedy 4 lb/gal Vastlan 4 lb/gal	4	1-2 pt	0.5-1	12 H	Apply to established grass pastures for control of broadleaf weeds and brush. Triclopyr may be tank-mixed with 2,4-D for broader spectrum weed control and control of sensitive woody species. Desirable forage broadleaf plants such as clover or alfalfa may be killed if sprayed. Applications at air temperatures > 85°F. may cause moderate to severe bermudagrass injury for 2-3 weeks. Grazing restrictions: **Grazing or harvesting green forage: (1) Lactating dairy animals:**2 qt/A or less: do not graze or harvest green forage from treated areafor 14 days after treatment. **(2) Other livestock:** 2 qt/A or less: no grazing restrictions. **Haying restriction): (1) Lactating dairy animals:** Do not harvest hay until the next growing season. **(2) Other livestock:** 2 qt/A or less: Do not harvest hay for 7 days after treatment. **Slaughter Restrictions:** Withdraw livestock from grazing on treated grass or consumption of treated hay at least 3 days before slaughter.
glyphosate Roundup PowerMax 5.5 lb/gal supplemental label	9	10 fl oz	0.43	4 H	Apply after the first bermudagrass cutting when bermudagrass has not yet initiated regrowth. Controls crabgrass, field sandbur, seedling johnsongrass and most annual grasses. Applications made after regrowth has begun will damage bermuda grass. DO NOT graze or cut for hay for 28 days after application. Make only 1 application per year. DO NOT make an application after the first cutting if the field has previously received a glyphosate application during the winter months.
diflufenzopyr + *dicamba* Overdrive 76.4% DF 0.2 lb + 0.5 lb/gal	19 + 4	4-8 oz	0.05 + 0.125 to 0.1 + 0.25	24 H	Controls annual and perennial broadleaf weeds. Add a nonionic surfactant at 0.25% v/ v or methylated seed oil at 2 pt/A to the spray mix. Diflufenzopyr has been shown t o improve t he activity of “auxin-like” herbicides such as triclopyr, clopyralid and picloram. May be tank-mixed with Grazon P+D, Remedy, Redeem, 2,4-D and Cimarron to increase spectrum of weed species controlled. Overdrive is rainfast within 4 hours after application. DO NOT plant any rotational crop within 30 days of an Overdrive application. There are no grazing or haying restrictions for Overdrive for any type of livestock.
metsulfuron Metsulfuron 60EG Patriot 60DF	2	0.1-0.4 oz	0.004-0.015	4 H	Apply to established bermudagrass for the control of ‘Pensacola’ bahiagrass and certain broadleaf weeds. Bermudagrass should be established for 60 days and tall fescue for 2 years prior to use. Apply 1 pt-1 qt nonionic surfactant/100 gal of spray mix. On tall fescue, applications in the early spring may suppress seedhead production and reduce hay yield. To minimize injury to tall fescue: a) tank-mix 2,4-D with metsulfuron; b) use the lowest recommended rate for the target weeds; c) use a 1/16-1/8% v/v surfactant concentration; d) make application s in the late spring or fall months; e) do not exceed 0.2 oz/A and; f) do not add a surfactant when applied with liquid N. Metsulfuron tank-mixes with liquid fertilizer are not recommended for ‘Pensacola’ bahiagrass control. Not effective for the control of ‘Common’ and ‘Argentine’ bahiagrass. Spot treatments of metsulfuron at 1 oz/100 gal of water may be used for the control of multi flora rose and blackberry. Pasture legumes will be severely injured or killed by metsulfuron. There is no grazing or haying restriction for metsulfuron. Metsulfuron may be tank-mixed with Grazon P+D, Banvel, 2,4-D, Weedmaster, Milestone, ForeFront and Remedy or purchased as a co-pack product with 2,4-D + dicamba.

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
metsulfuron 48% + *chlorsulfuron* 15% Cimarron Plus 63 DF	2 + 2	0.125-1.25 oz	0.004-0.04 + 0.001-0.01		Apply to established bermudagrass for the control of 'Pensacola' bahiagrass and certain broadleaf weeds. Bermudagrass should be established for 60 days and tall fescue for 2 years prior to use. Apply 1 pt-1 qt nonionic surfactant/100 gal of spray mix. On tall fescue, applications in the early spring may suppress seedhead production and reduce hay yield. To minimize injury to tall fescue: a) do not use more than 0.5 oz product/A; b) use the lowest recommended rate for the target weeds; c) use 1/16-1/8% v/v surfactant concentration; d) make applications in the late spring or fall months; e) do not exceed 0.3 oz product/A and; f) do not add a surfactant when applied with liquid N. Cimarron Plus tank-mixes with liquid fertilizer are not recommended for 'Pensacola' bahiagrass control. Not effective for the control of Common and Argentine bahiagrass. Pasture legumes will be severely injured or killed by Cimarron Plus. There are no grazing or haying restrictions for Cimarron Plus. Cimarron Plus may be tank-mixed with Grazon P+D, Banvel, 2,4-D, Weedmaster and Remedy.
metsulfuron 60 DF + *2,4-D* + *dicamba* 2.9 + 1 lb/gal Cimarron Max		0.25 oz + 1 pt	0.009 + 0.4 + 0.125	4 H	Cimarron Max is a 2 part (co-pack) product used for annual and perennial broadleaf weed control in bermudagrass pastures. Also controls Pensacola bahiagrass. Bermudagrass should be established for 60 days and tall fescue for 2 years prior to use. Apply 1 pt-1 qt nonionic surfactant/100 gal of spray mix. On tall fescue only, applications in the early spring may suppress seedhead production and reduce hay yield. To minimize injury to tall fescue: a) use the lowest recommended rate for the target weeds; b) use 1/16-1/8% v/v surfactant concentration; c) make applications in the late spring or fall months; and, d) do not add a surfactant when applied with liquid N. Cimarron Max tank-mixes with liquid fertilizer are not recommended for 'Pensacola' bahiagrass control. Not effective for the control of Common and Argentine bahiagrass. Pasture legumes will be severely injured or killed by Cimarron Max. There is no grazing restriction for non-lactating animals for Cimarron Max. The grazing restriction for lactating dairy animals is 7 days. Do not harvest for hay for 37 days after treatment. Remove meat animals from treated areas 30 days prior to slaughter.
chlorsulfuron Telar 75DF	2	0.25-1 oz	0.012-0.047	4 H	Controls many broadleaf weeds such as blackberry, pigweeds, and wild radish. Not effective for the control of horsenettle and common ragweed. May be used at rates up to 0.5 oz/A in tall fescue. In bermudagrass and bahiagrass rates as high as 1 oz/A may be used. Add a nonionic surfactant at 0.25% v/v to the spray mix. Chlorsulfuron has no grazing or haying restriction for any type of livestock.
nicosulfuron 56.2% + *metsulfuron* 15.0% Pastora 71.2 WDG	2 + 2	1-1.5 oz	0.035 to 0.053 + 0.009 to 0.014	4 H	Pastora is recommended only for use on bermudagrass that has been established for 1 year. Pastora can temporarily injure (yellowing, stunting) bermudagrass. Injury can be decreased by using Pastora during bermudagrass winter dormancy, during green-up with less than 2" of new growth and within 7 days after cutting for hay. Applications at other times may reduce bermudagrass production. Pastora is not recommended for use during bermudagrass "grow-in" from sprigs or seed. Applications to tall fescue, bahiagrass, overseeded winter annual forage grasses and other perennial forage grasses are not labeled. This herbicide has shown good to excellent control of sandbur, Texas panicum, fall panicum, broadleaf signalgrass and barnyardgrass less than 2" tall. Correct application timing is critical for control of annual grasses. Pastora has also shown excellent activity on Italian ryegrass, johnsongrass and Pensacola bahiagrass when treated as per label directions. Pastora at 1oz/A applied twice also has good activity on vaseygrass (see supplemental label). Broadleaf weeds controlled by Pastora include bitter sneezeweed, buttercup, chickweed sp., Carolina geranium, curly dock, dogfennel, henbit, horseweed, musk thistle, smartweed sp., and wild garlic. A nonionic surfactant at 0.25% v/v is the preferred adjuvant for Pastora. This herbicide has no grazing or haying restriction for any type of livestock

WEED CONTROL IN GRASS PASTURES AND HAYFIELDS

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
ESTABLISHED FORAGE GRASSES *(continued)*					
quinclorac Facet L 1.5 lb/gal		12-64 fl oz	0.14-0.75 lb		May be used to control seedling broadleaf weeds and annual grasses, including crabgrass, annual foxtails, and signalgrass that is 0-2" in height in bermudagrass, fescue, orchardgrass, and overseeded ryegrass. Apply with 2 pt/A of crop oil concentrate or methylated seed oil to enhance efficacy. Do not cut for hay within 7 days after treatment. There is no grazing restriction following applications. Do not apply more than a total of 64 fl oz/A/year.
POSTEMERGENCE - Spot or Wiper Applications					
glyphosate Roundup WeatherMax 5.5 lb/gal Roundup Original 4 lb/gal	9	Rate varies with species and application	Rate varies with species and application	4 H	Glyphosate may be applied in wiper applicators to weeds emerged above the forage grass, or applied as a spot treatment. Further applications may be made in the same area at 30-day intervals. Forage grasses, alfalfa, or clover coming in contact with the glyphosate will be injured or killed. Remove domestic livestock before application and wait 7 days after application before grazing livestock or harvesting. Other brands of glyphosate may also be labeled for this use.
tebuthiuron Spike 20P 20% pellet	7	See label			Spike 20P pellets may be applied as a spot treatment in perennial summer grass pastures for control of individual trees or scattered stands of brush. Apply 0.75 oz/100 sq ft of soil surface over the root systems of clumps of brush. Apply in early spring. Stands of cool season grasses such as fescue may be reduced by Spike application. Applications to or near pine trees will cause injury or death of the tree. Do not cut for hay for 1 year after application. Grazing is allowed after application if 20 lb/A or less is used.
MIXTURES - Grass-Lespedeza, Grass-Clover					
2,4-D amine 4 lb/gal	4	0.5-1 pt	0.25-0.5	48 H	Apply only 1 treatment/year to perennial clovers. 2,4-D amine will cause slight to moderate injury to legumes. Refer to specific herbicide label for use information.
CONVERSION TO FUNGUS-FREE FESCUE					
paraquat Firestorm 3 lb gal Gramoxone Inteon 2 lb/gal	22	0.7-1.3 pt 1-2 pt	0.25-0.5	12 H 24 H	Apply paraquat in the fall to actively growing, endophyte-infected fescue 2-3 weeks prior to planting endophyte-free fescue. Apply paraquat again at planting. Apply in 20-40 gal of water/A. Always add surfactant when using paraquat. DO NOT graze the new planting for 60 days or until the new growth is 6" tall.
glyphosate RoundupWeatherMax Roundup Original Max Roundup PowerMax 5.5 lb/gal	9	See remarks	See remarks	4 H	Apply in the fall at 22 fl oz/A to endophyte-infected fescue 3-4 weeks prior to planting endophyte-free fescue. Tall fescue should have 6-12" of new growth before the first application. Apply again at planting at 11 fl oz/A. This treatment provides some suppression of common bermudagrass also. There is no waiting period between application and grazing if total application rate is less than 2 qt/A. Other brands of glyphosate may also be labeled for this use.

PERENNIAL PEANUT WEED CONTROL

Patrick E. McCullough, Extension Agronomist – Weed Science

HERBICIDE	MOA	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REI/PHI (Hours or Days)	REMARKS AND PRECAUTIONS
POSTEMERGENCE					
2,4-D amine Weed Killer EPA Reg. No. 1386-43 -72693	4	1 pt	0.5	48 H	For control of many annual broadleaf species such as Mexican tea (Jerusalem oak), pigweeds, cutleaf eveningprimrose, etc. Can be applied any time during the season as long as the 30 day restriction on hay cutting is observed. May lead to slight yield decrease in "Florigraze", but "Arbrook" is more tolerant. Mixing 8 fl oz of 2,4-D amine Weed Killer with 4 fl oz of Impose has been found to be an effective combination. 2,4-D amine Weed Killer (Universal Crop Production Alliance, LLC) is the product that has been officially approved for use. Use this particular product rather than other non-approved 2,4-D herbicides.
imazapic Impose 2.0 lb/gal	2	4 fl oz	0.063	12 H	Impose is effective on crabgrass, nutsedges, johnsongrass, and numerous broadleaf weeds. Add a surfactant at 0.25% v/v to the spray mix. There are no grazing restrictions for this herbicide. DO NOT cut for hay for 7 days after application. Other herbicides with the same active ingredient such as "Cadre" cannot be legally applied to perennial peanuts.
clethodim Select Max 0.97 lb/gal Intensity One 0.97 lb/gal TapOut 0.97 lb/gal	1	9-32 fl oz	0.07-0.24	24 H	Clethodim will provide excellent control of annual and perennial grasses, but will not control broadleaf weeds or sedges. Use the low rate on annual grasses, and the high rate on perennial grasses (see label). Select Max and Intensity One require the addition of a nonionic surfactant at 0.25% v/v. For Shadow and Arrow use only a crop oil concentrate at 1% v/v. Use a nonionic surfactant or crop oil concentrate with Tapout. Do not cut for hay or graze for 40 days after an application of clethodim.
Shadow 2 lb/gal		6-16 fl oz	0.09-0.25		
Arrow 2 lb/gal		6-16 fl oz	0.09-0.25		

NOTE: The Georgia Department of Agriculture has ruled that the above herbicides may be legally applied to perennial peanuts. This crop is classified as a forage. Additionally, the site of application is classified as a pasture or hay field. DO NOT apply 2,4-D amine to peanuts being grown for seed or nuts. Perennial peanuts are not listed on the 2,4-D amine label. Users are advised that in the event of poor weed control, adverse crop injury, or any other issues that might arise, the manufacturers of 2,4-D amine may not warrant the application. Thus, while an application of these herbicides is legal, the end user assumes all responsibility with issues associated with an application. The University of Florida has conducted numerous experiments with these herbicides; however, there has been only limited testing of 2,4-D amine at 0.5 lb ai/A on perennial peanut in Georgia. End users are advised to evaluate the use of 2,4-D amine on a limited basis, and then make a decision if spraying an entire field is advisable.

TEMPORARY SUMMER GRAZING WEED CONTROL

(Millets, sudan grass, sorghum-sudan hybrids)

Patrick E. McCullough, Extension Agronomist-Weed Science

HERBICIDE	BROADCAST RATE/ACRE AMOUNT OF FORMULATION	 POUNDS ACTIVE INGREDIENT	REMARKS AND PRECAUTIONS
TEMPORARY SUMMER GRAZING CROPS-Millets, Sorghum, Sudan Hybrids, etc.			
2,4-D various trade names 4 lb/gal	1 pt	0.5	Apply to emerged broadleaf weeds when crop is 8-12" tall. Do not graze lactating dairy animals for 14 days after treatment, or cut for hay for all types of livestock for 30 days after treatment. (Grazing and haying restrictions may vary-refer to product label). Refer to specific herbicide label for use restrictions. A 2,4-D formulation labeled on millet is Formula 40.
2,4-D + *dicamba* Weedmaster 2.9 lb + 1 lb/gal Outlaw 1.45 + 1.1 lb/gal	1-2 pt 1-2 pt	0.36 + 0.125 to 0.72 + 0.25 0.18 + 0.14 to 0.36 + 0.27	Apply to emerged broadleaf weeds when crop is 8-12" tall. Do not graze lactating dairy animals within 7 days. There is no restriction between application and grazing for non-lactating animals. Do not cut for hay within 37 days after treatment. Do not graze meat animals in treated areas within 30 days of slaughter. Weedmaster and Outlaw will severely injure or kill clovers or alfalfa.
dicamba Xtendimax 2.9 lb/gal	11-22 fl oz	0.25-0.5 lb	May be applied for controlling annual and perennial broadleaf weeds to forage sorghum, sudangrass and other grasses used for temporary grazing. Do not broadcast apply more than 22 fl oz/A. Grass grown for hay requires a 7 D wait period between application and harvest. Do not graze lactating dairy animals for 7 days after treatments. Do not feed hay to lactating dairy animals harvested before 37 days after treatments.
FORAGE SORGHUM			
metolachlor Dual 8E	1.5-2 pt	1.5-2	Apply after planting seed treated with Concep or Screen seed protectant. Apply before crop and weeds emerge.
FORAGE SORGHUM AND SORGHUM-SUDAN			
atrazine 80W atrazine 4L atrazine 90DG various trade names	1.5 lb 1.2 qt 1.3 lb	1.2	Apply with 1 gal/A of emulsifiable oil or 1 qt/A of crop oil concentrate after sorghum reaches the 3-leaf growth stage but before it exceeds 12" in height. Controls broadleaf weeds 2-3" tall and newly emerged (l-leaf) annual grasses. DO NOT apply with fluid fertilizers or when sorghum is under stress from cold, wet weather, poor fertility or other factors, or when sorghum is wet and tender from a recent rainfall. DO NOT graze or feed treated forage for 21 days after application.

TEMPORARY WINTER GRAZING WEED CONTROL

Patrick E. McCullough, Extension Agronomist – Weed Science

HERBICIDE	BROADCAST RATE/ACRE: AMOUNT OF FORMULATION	BROADCAST RATE/ACRE: POUNDS ACTIVE INGREDIENT	REMARKS AND PRECAUTIONS
TEMPORARY WINTER GRAZING CROPS-Small Grains, Ryegrass			
2,4-D various trade names 4 lb/gal *dicamba* Banvel 4 lb/gal	1 pt-1 qt 0.5 pt	0.5-1 0.25	Apply in December, January or February to control swinecress, blessed thistle, wild garlic, curly dock and similar winter weeds after small grain tillering but before jointing. Grazing restrictions may vary among the different 2,4-D products. Several 2,4-D labels restrict grazing for dairy animals or meat animals being finished for slaughter for 14 days after treatment. For Banvel, restrict grazing for lactating dairy animals for 7 days after treatment and remove meat animals from treated areas 30 days prior to slaughter. For Banvel, there is no waiting period between treatment and grazing for non-lactating animals. Refer to specific herbicide label for additional use information.
2,4-D + *dicamba* Weedmaster 2.9 lb + 1 lb/gal Outlaw 1.45 + 1.1 lb/gal	1 pt to 2 pt 1 pt to 2 pt	0.36 + 0.125 to 0.72 + 0.25 0.18 + 0.14 to 0.36 + 0.27	Apply to emerged broadleaf weeds when crop has 2-4 tillers. Do not graze lactating dairy animals within 7 days. There is no restriction between application and grazing for non-lactating animals. Do not cut for hay within 37 days after treatment. Do not graze meat animals in treated areas within 30 days of slaughter. Weedmaster and Outlaw will severely injure or kill clovers or alfalfa.
dicamba Xtendimax 2.9 lb/gal	11-22 fl oz	0.25-0.5 lb	May be applied to rye, ryegrass, wheat, and other grasses for controlling annual and perennial broadleaf weeds. Do not broadcast apply more than 22 fl oz/A. Grass grown for hay requires a 7 D wait period between application and harvest. Do not graze lactating dairy animals for 7 days after treatments. Do not feed hay harvested before 37 days after treatments to lactating dairy animals.
thifensulfuron-methyl + *tribenuron-methyl* Harmony Extra SG with TotalSol 50 SG	0.45-0.9 oz	0.0094 to 0.0188 + 0.0047 to 0.0094	Apply after two-leaf stage of wheat, barley, triticale and oats but prior to flag leaf being visible. Harmony Extra SG is not recommended for use on ryegrass or rye. Most winter annuals can be controlled with 0.45-0.6 oz/A; however, 0.75-0.9 oz/A is recommended for controlling wild garlic or small wild radish. Add 1 qt of nonionic surfactant per 100 gal of spray solution. For best results, apply when weeds are in the 2-4 leaf stage, temperatures are above 50° F, and not drought stressed. Wild garlic should be less than 12” tall and should have 2-4” of new growth. Liquid nitrogen may be used as the carrier. When using nitrogen as the carrier, reduce surfactant rate to 0.5-1 pt/100 gal of solution (wheat burn may still be noted). May also tank mix Harmony Extra SG with 0.25-0.375 lb ai/A of 2,4-D or MCPA for improved control of wild radish. Do not use surfactant if Harmony Extra SG and 2,4-D or MCPA are applied in nitrogen. Do not graze within 7 days of application. This grazing restriction applies to all types of livestock. Allow at least 30 days between application and feeding of hay from treated areas to livestock.
SUPPRESSION OF BERMUDAGRASS OR BAHIAGRASS SODS			
paraquat Gramoxone Inteon 3 lb/gal	1-2 pt	0.25-0.5	Apply in early fall to sod not more than 3” tall, just prior to or at the time of seeding clovers or winter grasses. Add surfactant according to label directions.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

Patrick E. McCullough, Extension Agronomist – Weed Science

Not all herbicides are labeled for use on all forage crops. Refer to the recommendations shown for a specific herbicide or refer to the herbicide label.

TIME OF APPLICATION	PPI	PPI	PRE	PRE	PRE	POST	POST
	benefin (Balan)	EPTC (Eptam)	Chateau	Kerb	Prowl	2,4-D	2,4-DB
amaranth, spiny	G	G	E	P	F-G	F-G	F-G
bahiagrass	P	P	P	P	P	P	P
bermudagrass	P	P	P	P	P	P	P
bitter sneezeweed	P	P		P		E	G
blackberry	P	P		P	P	P	P
bracken fern	P	P		P	P	P	P
briars (Smilax)	P	P		P	P	P	P
broomsedge	P	P		P	P	P	P
buttercup	P	P		P	P	E	F
camphorweed	P	P		P	P	P	P
chickweed	F	E	E	G	F	P	P
crabgrass	E	G	G	F	G	P-F	
crotalaria, showy	P	P	G	P	P	G	
cudweed	P	P		P		F	
curly dock	P	P	G	P	P	F	P
dallisgrass	P	P	P	P	P	P	P
dandelion	P	E	G	P	P	E	G
dodder	P	P		E		P	P
dogbane, hemp	P	P			P	P-F	P
dogfennel	P	P		P	P	F	P
evening primrose	F	F-G	E	P		E	G
foxtails, green & yellow	G	G	F	P	F	P	P
gallberry	P	P		P	P	G	P
goldenrod	P	P		P	P	F	P

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

[1] Seedling johnsongrass only.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

Not all herbicides are labeled for use on all forage crops. Refer to the recommendations shown for a specific herbicide or refer to the herbicide label.

TIME OF APPLICATION	PPI	PPI	PRE	PRE	PRE	POST	POST
	benefin (Balan)	**EPTC (Eptam)**	**Chateau**	**Kerb**	**Prowl**	**2,4-D**	**2,4-DB**
henbit	F	G	E	P	F-G	P	P
honeysuckle	P	P		P	P	E	P
horsenettle	P	P		P	P	P	P
horseweed	P	P	G-E	P	P	G	P
Italian ryegrass	G	E		G		P	P
johnsongrass	G[1]	G[1]		P	G[1]	P	P
kudzu	P	P		P	P	P-F	P
Lespedeza, Sericea	P	P			P	P	P
little barley	G	G		E		P	P
maypop passion flower	P	P		P	P	P	P
mayweed				P		F	P
nettle, stinging	P	P		P	P	P	P
nutsedge	P	F	P	P	P	P	P
palmetto	P	P		P	P	P	P
perilla mint	P	P			P	P-F	
persimmon	P	P		P	P	P	P
pigweed species	G	G	E		F-G	G-E	G
plantain(s)	P	G	F	F	P	G-E	F
pokeweed, common	P	P		P	P	G	G
prickly pear	P	P		P	P	P	P
ragweed, common	P	P	G-E	P	P	E	G
red sorrel	P	P		P	P	P	P
rush species	P	P		P	P	G	P
sandbur	E	G		P	G	P	P
shepherdspurse	P	G	E	G	F	E	G
sicklepod	P	F	P	P	P	G	F
sida, arrowleaf & prickly	P	P	G-E	P	P	G	P
smartweed(s)	P	P	F	P	P	F	F

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WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

Not all herbicides are labeled for use on all forage crops. Refer to the recommendations shown for a specific herbicide or refer to the herbicide label.

TIME OF APPLICATION	PPI	PPI	PRE	PRE	PRE	POST	POST
	benefin (Balan)	EPTC (Eptam)	Chateau	Kerb	Prowl	2,4-D	2,4-DB
smutgrass	P	P		P	P	P	P
swinecress	P	G		F		E	F
Texas panicum	G-E	G		P	F-G	P	P
thistles	P	P		P	P	E	F
tropical soda apple	P	P		P	P	P	P
vaseygrass	P	P		P	P	P	P
vervain, blue							
Virginia pepperweed	P	G		P	P-F	G	E
wax myrtle	P	P		P	P	G	P
wild cherry	P	P		P	P	E	P
wild garlic	P	P	P	P	P	G-E	P
wild plum	P	P		P	P	E	P
wild radish	P	P-F	G-E	P	P	G	P
wild rose	P	P		P	P	G	P
wooly croton	P	P		P	P	G	P

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WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	bromoxynil (Buctril)	**Chaparral**	**Cimarron Max**	**Cimarron Plus**	**Crossbow**	**dicamba (Banvel, Clarity)**	**ForeFront, Grazon Next**	**Grazon P+D**
amaranth, spiny	P	E	E	E		G-E	E	G-E
bahiagrass	P	G	F-G	G	P	P	P	P
bermudagrass	P	P	P	P	P	P	P	P
bitter sneezeweed		E	E	E	E	E	E	E
blackberry	P	G-E	F	E	G	F	P	F
bracken fern			G		G	G		F
briars (Smilax)	P				P	F		
broomsedge	P		P	P	P	P	P	P
buttercup		G-E	E	E	E	P	E	E
camphorweed		G		G			G	G-E
chickweed	F	E	E	E	F	G	G	P
crabgrass	P		P	P	P	P	P	P
crotalaria, showy		G				G	G	E
cudweed	P	G	G	G	E	E	G-E	G
curly dock		G-E	G-E	G-E	G	E	G-E	G-E
dallisgrass	P		P	P	P	P	P	P
dandelion	P				E	E	G-E	E
dodder					P	P		
dogbane, hemp		P	P	P	F-G	F	P	F
dogfennel	P	P-F	G-E	F-G	E	E	F	G-E
evening primrose		G	G	G	E	E	E	E
foxtails, green & yellow	P		P	P	P	P	P	P

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

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WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	bromoxynil (Buctril)	Chaparral	Cimarron Max	Cimarron Plus	Crossbow	dicamba (Banvel, Clarity)	ForeFront, Grazon Next	Grazon P+D
gallberry	P				E	E		
goldenrod	P	P	G-E	P	G	G	G	G
henbit	F	G-E	E	E	E	G	F	P-F
honeysuckle	P				E	E		F
horsenettle	P	G-E	F	P-F	P-F	G	E	G-E
horseweed	P	G-E	E	F	G	E	E	E
Italian ryegrass	P		P-F	P-F	P	P	P	P
johnsongrass	P		P	P	P	P	P	P
kudzu	P	G	P-F	P-F	F-G	G	G	F
lespedeza, Sericea	P	P	F-G	G-E	P-F	P		P
little barley	P				P	P		P
maypop passion flower		P	P	P			P	P-F
mayweed	P		G	G	G	E	G-E	G-E
nettle, stinging		G-E	F-G	F-G	F-G	P	G	E
nutsedge	P		P	P	P	P	P	P
palmetto	P	P	P	P		F		
perilla mint					F-G	F-G		F-G
persimmon	P				G	E		P
pigweed species	F	G-E	E	E	E	E	E	E
plantain(s)	P	G-E	E	E	G	F	G	F-G
pokeweed, common	P	P		P	G	G	G	F
prickly pear	P	P	P	P		F	P	F-G

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

[1] Seedling johnsongrass only.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	bromoxynil (Buctril)	Chaparral	Cimarron Max	Cimarron Plus	Crossbow	dicamba (Banvel, Clarity)	ForeFront, Grazon Next	Grazon P+D
ragweed, common	G	G-E	G	G	E	E	E	E
red sorrel		E	G	G-E	E	G	E	
rush species	P	P	P	P	F-G	P		
sandbur	P		P	P	P	P	P	P
shepherdspurse	G				E	E	E	E
sicklepod		G	G	G	E	E	E	E
sida, arrowleaf & prickly	P		G	G	P-F	G	E	E
smartweed(s)	G	G-E	E	E	G-E	G	E	E
smutgrass	P		P	P	P	P	P	P
swinecress	E					E	E	E
Texas panicum	P			P	P	P	P	P
thistles	P	E	G-E	F-G	E	G	E	E
tropical soda apple	P	G-E	P	P	F	F-G	G-E	G-E
vaseygrass	P		P	P	P	P	P	P
vervain, blue							G	G
Virginia pepperweed	G					E	G	E
wax myrtle	P	P				E		
wild cherry	P					P	E	
wild garlic	P	G	G-E	G-E		F	F	F
wild plum	P					E	E	
wild radish	F-G	G-E	G-E	G-E	E	E	E	
wild rose	P	G	F	F	E	E	F	F
wooly croton	P	G-E	G-E	G	E	E	E	E

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WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	hexazinone (Velpar)	imazamox (Raptor)	imazapic (Impose)	imazethapyr (Pursuit)	metribuzin (Sencor)	Metsulfuron	Milestone	paraquat
amaranth, spiny	F-G	F-G	G	F-G	P-F	E	G	F-G
bahiagrass	P		G-E		P	G	P	P
bermudagrass	P	P	P	P	P	P	P	P
bitter sneezeweed						E	G-E	
blackberry	F				P	G	G	P
bracken fern	F					G	G	P
briars (Smilax)	F				P			P
broomsedge	P	P	P	P	P	P	P	P
buttercup	G				G	E	G-E	G
camphorweed				P		G		P
chickweed	E	G		F	E	P	F	E
crabgrass	P	F	F-G	F	F	P	P	F
crotalaria, showy								
cudweed						G	E	G
curly dock	P-F	P-F		P-F		E	E	P
dallisgrass			P		P	P	P	P
dandelion	E	F-G		P-F	G	G-E	P	G
dodder								G-E
dogbane, hemp							P	
dogfennel						P-F	P	P
evening primrose	E				G	G	E	P-F
foxtails, green & yellow	P-F	G	F-G	G	P	P	P	F
gallberry	P				P			P

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	hexazinone (Velpar)	imazamox (Raptor)	imazapic (Impose)	imazethapyr (Pursuit)	metribuzin (Sencor)	Metsulfuron	Milestone	paraquat
goldenrod						G-E	G	P
henbit	G-E	F		F	G	E	F-G	G
honeysuckle					P			P
horsenettle		P	P	P	P	P	E	P
horseweed	F	P	P	P	P	F	E	P
Italian ryegrass	G	G	F	P	P	P		G
johnsongrass	P	F	F-G	P	P	P	P	P
kudzu			P	P	P	P-F	F-G	P
lespedeza, Sericea						G-E		P
little barley	E				P	P	P	G-E
maypop passionflower		P		P	P	P	P	P
mayweed	F-G					G		E
nettle, stinging						F-G	E	
nutsedge	P	P-F	G	F	P	P	P	P
palmetto	P		P		P	P	P	P
perilla mint							P	
persimmon	F				P		P	P
pigweed species	G	G-E	G-E	G-E	G	E	E	G
plantain(s)	F-G	P		P	P	E	P	P
pokeweed, common						P	F	
prickly pear	P				P	P	P	P
ragweed, common	F	F	F	F	G	G	E	G
red sorrel						E		P-F

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

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	hexazinone (Velpar)	imazamox (Raptor)	imazapic (Impose)	imazethapyr (Pursuit)	metribuzin (Sencor)	Metsulfuron	Milestone	paraquat
rush species		P	P	P		P		P
sandbur			G-E		F	P	P	G
shepherdspurse	E	E	E	E	E	G	P	G
sicklepod			G		F	G	P	F-G
sida, arrowleaf & prickly		P-F		P-F	F	F	P	P
smartweed(s)	F-G	G-E		G-E		E	E	E
smutgrass	G-E	P	P	P	P	P	P	P
swinecress	E	G	E		E		P	E
Texas panicum	P		P-F		P-F	P	P	G
thistles	E	P		P	G	F	E	G
tropical soda apple	F		P		P	P	E	P
vaseygrass			F		P	P	P	P
vervain, blue							F	
Virginia pepperweed	E	G		G	G		P	G
wax myrtle	P				P			P
wild cherry	E				P			P
wild garlic					P	G	P	E
wild plum	E	P	P	P	P			P
wild radish	E	G-E	E	G-E	E	G-E	P	P
wild rose		P	P	P	P	G	F	P
wooly croton	P	P		P	P	G	E	P

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	Pastora	PastureGard	Redeem	sethoxydim (Poast)	Spike	Surmount	Triclopyr (Remedy)	Weedmaster
amaranth, spiny	G-E	P-F	P	P		G-E		E
bahiagrass		P	P	F		P	P	P
bermudagrass	P	P	P	F-G		P	P	P
bitter sneezeweed	G-E	E	E	P	E	E	E	E
blackberry		G	G-E	P	G	G	G-E	P-F
bracken fern		F	P	P	G	F	G	
briars (Smilax)		G	P	P	G	F	P	F
broomsedge	P	P	P	P		P	P	P
buttercup	E	F	E	P	G	G	E	E
camphorweed		E		P		E	E	P
chickweed	E	E	G	P	E	G-E	F	F
crabgrass	F	P	P	G-E		P	P	P
crotalaria, showy		E				E	E	G
cudweed		G	E	P		G	E	G
curly dock	G-E	F	E	P		G	E	E
dallisgrass		P	P	P		P	P	P
dandelion	G	G-E	G	P	G	E	E	E
dodder		P	P	P			P	P
dogbane, hemp		F-G	P	P		G	F	F
dogfennel	P	E	E		G	E	E	G
evening primrose	F	G		P	G	E	E	E
foxtails, green & yellow	F-G	P	P	E		P	P	P
gallberry		E	G	P			E	G

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	Pastora	PastureGard	Redeem	sethoxydim (Poast)	Spike	Surmount	Triclopyr (Remedy)	Weedmaster
gallberry		E	G	P			E	G
goldenrod	G	G	E	P		G	G	E
henbit	E	G-E	G	P	G	G	F	P
honeysuckle		P	P	P	G	G	P	E
horsenettle	P	P-F	F	P	F	E	P-F	F
horseweed		G	G	P		E	G	E
Italian ryegrass	G-E	P	P	E		P	P	P
johnsongrass	G-E	P	P	G		P	P	P
kudzu		G	G-E	P	P	F	G-E	F
lespedeza, Sericea		E					G-E	P
little barley		P	P	F		P	P	P
maypop passion flower		F		P				P
mayweed	G-E	G	E	P	E	G-E	G	G
nettle, stinging		E	F	P		G	G-E	F
nutsedge	P	P	P	P		P	P	P
palmetto		G	P	P	F	P	F	P
perilla mint		F		P		F	F-G	F-G
persimmon		G-F	P	P		G	F	F
pigweed species	G-E	G	G	P		G	E	E
plantain(s)	F	F	P	P		F	F	G-E
pokeweed, common		P	P	P		G	P	G
prickly pear		F	P	P		E	G[2]	P

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

[2] For prickly pear cactus use 20% v/v Remedy plus 80% diesel fuel. Apply only as a spot treatment, as this treatment will severely injure desirable grasses.

[3] Apply in spring after full spring greenup of vaseygrass, or after hay harvest.

WEED RESPONSE TO HERBICIDES USED IN PASTURE, HAY AND FORAGE CROPS

TIME OF APPLICATION	POSTEMERGENCE							
	Pastora	PastureGard	Redeem	sethoxydim (Poast)	Spike	Surmount	Triclopyr (Remedy)	Weedmaster
ragweed, common		E	E	P		E	E	E
red sorrel		F	F-G	P		E	E	P-F
rush species		P	P	P		P	F	
sandbur	G-E	P	P	G		P	P	P
shepherdspurse		G	G	P	G	G	E	E
sicklepod	E	G	G	P		E	E	E
sida, arrowleaf & prickly		F	P	P		E	P	E
smartweed(s)	G			P				G
smutgrass		P	P	P		P	P	P
swinecress		G	G	P		G	G	E
Texas panicum	G-E	P	P	E		P	P	P
thistles	G	G	E	P		G-E	F-G	G
tropical soda apple	P	G	P	P	P	E	G	F
vaseygrass	F[3]	P	P	P		P	P	P
vervain, blue						E		
Virginia pepperweed		G		P			P	E
wax myrtle		G		P	F			G
wild cherry		G	F	P		G	E	E
wild garlic		F		P		P		G
wild plum		G	P	P	G	G		P
wild radish	G-E	G	F	P		E	E	E
wild rose		E	P	P	G	E	E	E
wooly croton	E	F	F	P		E	G	E

Key: E – Excellent; G – Good; F – Fair; P – Poor Control; A blank space indicates weed response is not known.

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The Uptake, Mode of Action, and Fate of Herbicides Used in Hayfields

Dr. Tim Grey, Professor and Research Weed Scientist

Uptake, MOA, & Fate of Herbicides



The Uptake, Mode of Action, and Fate of Herbicides Used in Hayfields

T.L. Grey
University of Georgia

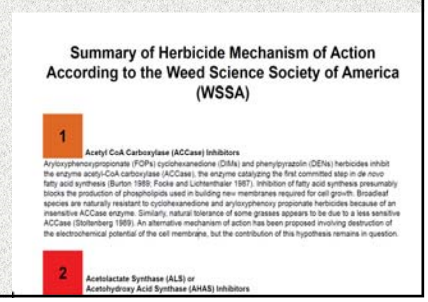
Mode of Action

- **Primary Mechanism of Action**: plant processes affected by lowest phytotoxic dose of herbicide.
- **Secondary Mechanism of Action**: other plant processes affected by herbicide.

Mode of Action - Terminology

- Mode of Action:
  - How a particular herbicide acts on a plant
  - Response of plant to phytotoxic effects of the herbicide
  - How the plant responds to the herbicide

- Description of MOA
- http://www.wssa.net/Weeds/Resistance/WSSA-Mechanism-of-Action.pdf



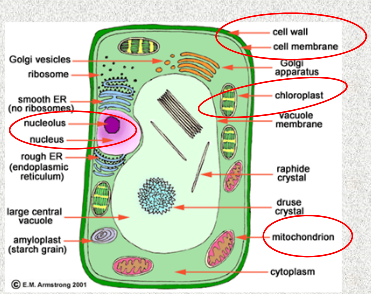
Summary of Herbicide Mechanism of Action According to the Weed Science Society of America (WSSA)

1 Acetyl CoA Carboxylase (ACCase) Inhibitors

Aryloxyphenoxypropionate (FOPs) cyclohexanedione (DIMs) and phenylpyrazolin (DENs) herbicides inhibit the enzyme acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in de novo fatty acid synthesis (Burton 1989; Focke and Lichtenthaler 1987). Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth. Broadleaf species are naturally resistant to cyclohexanedione and aryloxyphenoxy propionate herbicides because of an insensitive ACCase enzyme. Similarly, natural tolerance of some grasses appears to be due to a less sensitive ACCase (Stoltenberg 1989). An alternative mechanism of action has been proposed involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

2 Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) Inhibitors

Plant target Sites



Herbicide Mode of Action - WSSA

- Group herbicides by plant processes affected:
  - Acetyl CoA Carboxylase Inhibitors (1) – sethoxydim
  - Amino acid synthesis inhibitors (2) – SU's, IMI's
  - Microtubule assembly inhibition (3) - pendimethalin
  - Photosynthetic inhibitors (5, 6, 7, 22) – diuron, paraquat, metribuzin
  - EPSP synthesis (9) - glyphosate
  - PPO (14) - flumioxazin

Dr. Timothy Grey
Weed Scientist

GRASS

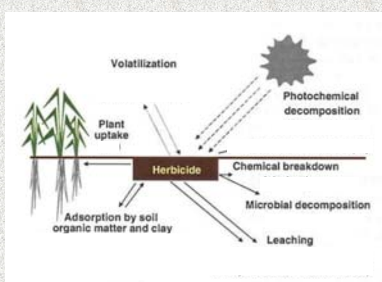
Question

- What happens to herbicides?
- How do these and other herbicides dissipate when applied?
- Limited information in forages
- We know the properties

2 - Amino acid inhibitors

- essential building blocks for plant growth and function
- unlike animals, plants make their own
- amino acids are the primary components of proteins and nucleic acids
- proteins are generally storage proteins or enzymes

Environmental fate



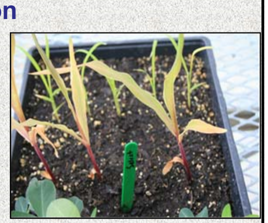
2 - Amino Acid Inhibitors

- generally target a specific enzyme
  - Some block vital steps in the formation of amino acids- proteins, enzymes
  - branched chain amino acid inhibitors
    - Leucine, Isoleucine, Valine
- dependent on plant growth for activity
  - better growth - better control, slow death
- systemic herbicides
- Soil activity
  - None (imazamox)
  - Some (Metsulfuron, nicosulfuron)
  - Long activity – (imazapic)

1 – ACCase

Acetyl CoA Carboxylase Inhibitors

- Grass herbicides that we use in legumes many times
- Inhibit lipid production
- POST applied
- FOPS & DIMS
- sethoxydim
- Poast
- Resistance issues!!!
- No to low residual



Imazethapyr - imazapic

johnsongrass

Ivyleaf morningglory

Dr. Timothy Grey
Weed Scientist

Uptake, MOA, & Fate of Herbicides

ALS Inhibitors

- Imidazolinones
  - Imazapic (Impose)
  - Imazamox (Raptor)
  - Imzethapyr (Pursuit)
- Sulonylureas
  - sulfosulfuron
  - Nicosulfuron + metsulfuron (Pastora)
  - Many others

SU facts

- Most all are formulated as WP or DG
- Photolysis minor
- Volatilization minor
- Can move upward even when they were not previously detected
  - via capillary soil water flow

Organic matter & clay

- Positive correlation between sorption & organic matter content
  - OM increase, sorption increase
- Alkaline soils with low OM
  - SU degrade slowly
- Sulfosulfuron, chlorsulfuron reported
- Clay mineral sorption – varies from none to some

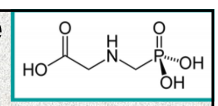
Conclusions

- ↑ soil pH ↑ SU persistence
- ↑ temperature ↑ soil dissipation
- ↑ soil OM content ↓ plant availability
- Low use rates combined with factors above
- Low leaching potential

Leaching

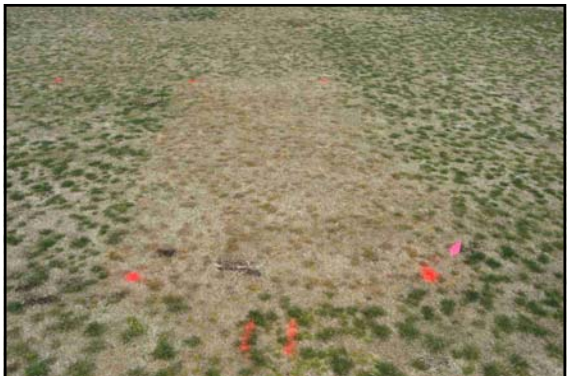
- SU herbicides can be mobile in soil
  - Experiments have demonstrated
- R_f values from 0.21 to 0.9
  - Chlorsulfuron
  - Metsulfuron
  - Sulfometuron
- Primarily dependent on soil type & characteristics – pH, OM, etc.
- Never been a major concern low rates

9 – EPSP synthase Glyphosate



- broadspectrum postemergence weed control
- glyphosate labeled in multitude of areas
- extensively translocated throughout the plant, extremely stable in plant
- blocks synthesis of aromatic amino acids
- Very good for perennial species
- Weeds: Nonselective
- Used in renovation and dormant bermudagrass
- Dissipation via adsorption & microbial

Dr. Timothy Grey
Weed Scientist



Roundup 32 oz, 19 DAT

Microtubule growth Inhibition

- *benefin* - PPI or PRE with irrigation
  - Balan
- *pendimethalin* – PRE
  - Prowl
- soil applied - annual grasses and certain broadleaf weeds
- vary in volatility and photodegradation
- prevent both root and shoot growth, inhibit cell division (mitosis)
- Very effective on small seeded weeds
- Plants cannot take up water-nutrients - starve

3, 15, 23 Microtubule growth Inhibition

- plants grow by making new cells
  - process of cell division, mitosis
- plants are particularly susceptible as emerging seedlings
  - both shoot and roots
- newly forming roots can be susceptible at most stages of plant growth

Microtubule growth Inhibition

Microtubule growth Inhibition

- most growth inhibition herbicides are soil applied and generally affect seedling weeds
- most interfere w/ mitosis (mitotic poisons)
- others appear to prevent lipid (cell membrane) production
- some prevent cell wall formation
- soil active, little movement once absorbed

4 – PGRs (plant growth regulators)

- *2,4-D, 2,4-DB, dicamba and more…….*
- BL weed control for a variety of crops (corn, pastures, legumes) and noncropland
- Cotton & tomato very sensitive – ppb range
- foliar & root uptake- extensive translocation
- interferes with nucleic acid (DNA and RNA) and protein synthesis; cells undergo rapid uncontrolled division and elongation

Uptake, MOA, & Fate of Herbicides

Synthetic Auxin Injury to Broadleaf Weeds

14 - PROTOX Inhibitors

- Biological activity
  - Mode of action - PPO or PROTOX inhibitors, contact action
  - require light for activity
  - Selectivity – metabolism

4- Benzoic Acids

- *dicam*… …res (broa…
- poste… …some soil a…
- readil… …g tips
- interf… …protein synthesis - leading to rapid, uncontrolled growth (similar to phenoxys)

14 - PROTOX Inhibitors

- PRE & POST applied
- Depends on the chemistry
  - Flumioxazin (Chateau)
  - Carfentrazone (Aim)
- Flumioxazin – residual, rate dependent
- Carfentrazone no residual activity

Growth Regulator Herbicides

- Phenoxys
  - 2,4-D
- Benzoics
  - dicamba
- Pyridines
  - clopyralid
  - triclopyr
  - fluroxypyr

fomesafen

Tomato

Ivyleaf morningglory

Dr. Timothy Grey
Weed Scientist

Uptake, MOA, & Fate of Herbicides

5, 6, 7, 22 Photosynthesis inhibitors


Metribuzin

Herbicide chemistry

- Water solubility is important
  - Table salt 360 g/L = 3 lb/gal water
- Glyphosate (K+ formulation)
  - 10.5 g/L = 0.1 lb/gal water
- Paraquat
  - 620 g/L = 5.2 lb/gal water

Photosynthesis inhibitors

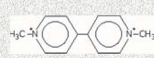
- Biological activity
  - Photosynthesis (PS I & II) inhibitors
  - readily absorbed by plant roots and translocated to leaves via transpiration stream
  - Selectivity based on metabolism
- Dissipation
  - Microbial
  - Hydrolysis
  - Soil & OM absorption
- pH affects availability, increase pH, increase activity
  - Metribuzin, WSSA Group 5

Herbicide chemistry

pH and temperature effects

- Water solubility is important
  - Table salt 360 g/L = 3 lb/gal water
- **Metsulfuron –** Patriot, multiple formulations
  - pH 5.0 - 0.55 g/L = 0.0046 lb/gal water
  - pH 7.0 – 2.8 g/L = 0.023 lb/gal water
  - pH 9.0 - 213 g/L = 1.78 lb/gal water 350x
- Carfentrazone
  - 68 F – 12 g/L = 0.1 lb/gal water
  - 86 F – 23 g/L = 0.2 lb/gal water 2x

22- paraquat



Soybean

Corn

Herbicide chemistry

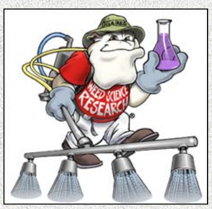
- Water solubility is important
  - Table salt 360 g/L = 3 lb/gal water
- Flumioxazin –
  - 0.00179 g/L = 0.000015 lb/gal
    - Low water solubility can lead to issues…..
    - Tank cleanout!!!

Dr. Timothy Grey
Weed Scientist

Main points

- Pesticides have to go somewhere!
- Break down can be rapid in the environment
  - Depends on pesticide molecule chemistry:
    - Volatility
    - Solubility
    - Stability (resistance to photolysis, hydrolysis, etc.)
  - Depends on the environment (moisture, heat)
  - Depends on application method (granule, spray)
- Leaching
  - Need to move into treated soil
  - Do not want to move into ground water

Thank you



The University of Georgia
College of Agricultural & Environmental Sciences

Question????

Herbicide Resistance: A Growing Issue for Hay Producers

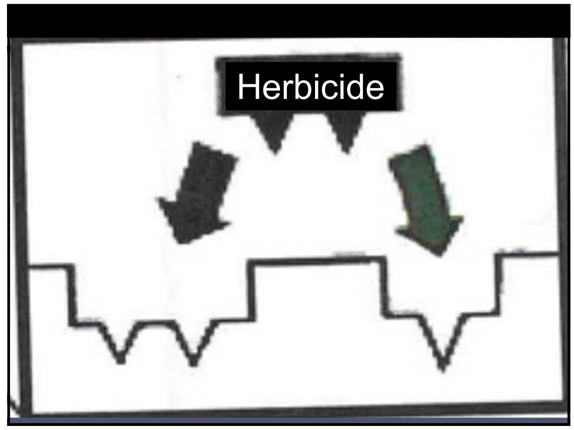
Dr. Patrick McCullough, Extension Weed Scientist

Herbicide Resistance: A Growing Issue

Herbicide Resistance: A Growing Issue for Hay Producers

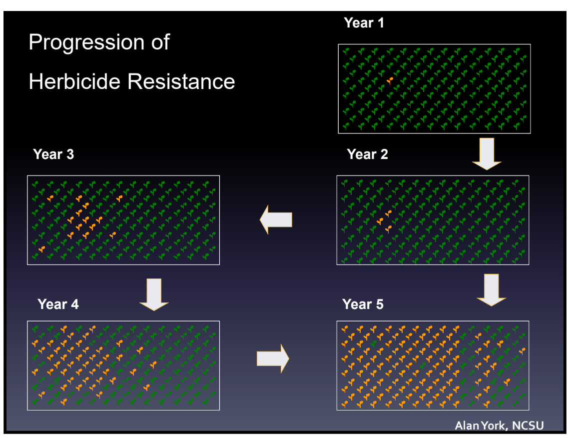
Patrick McCullough, Ph.D.

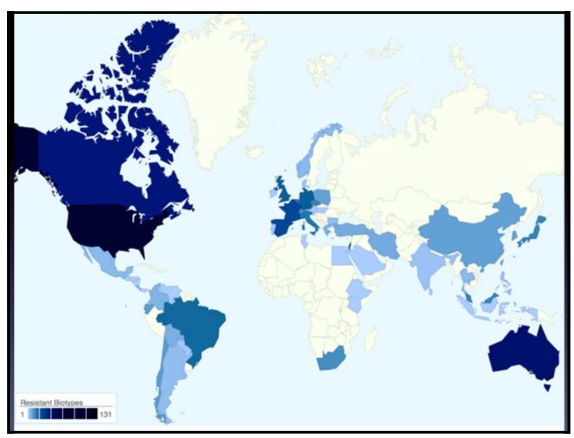
University of Georgia



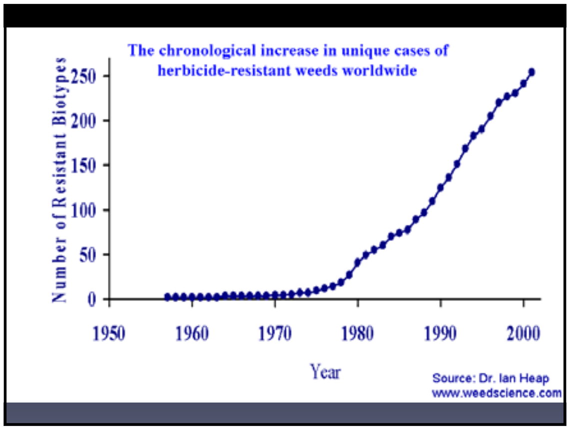
Why Are Plants Resistant to Herbicides?

- Altered site of action
- Overproduction of target site enzyme
- Enhanced metabolism
- Sequestration

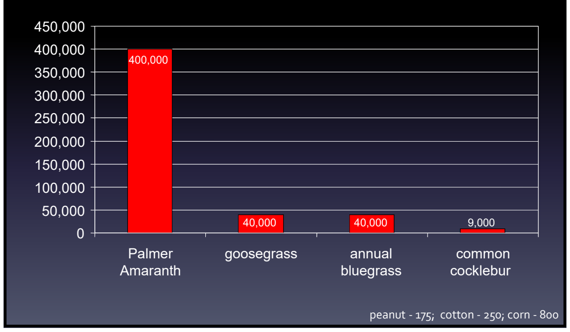




Herbicide Resistance: A Growing Issue

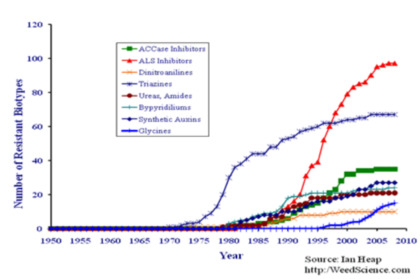


Average Number of Seed per Plant



Herbicide Resistant Weeds

By Mode of Action



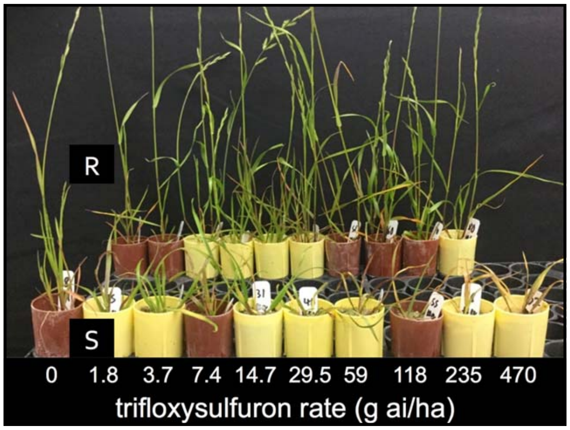
Italian Ryegrass Control in Hayfields

WSSA Group	Common Name	Trade Name
1	sethoxydim	Poast, others
2	metsulfuron	Cimarron
2	nicosulfuron + metsulfuron	Pastora
2	imazapic	Impose
9	glyphosate	various

Dr. Patrick McCullough
Extension Weed Scientist

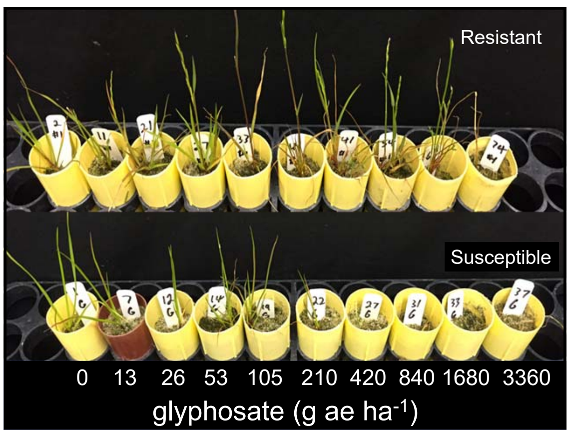
UGA extension

Herbicide Resistance: A Growing Issue



Ryegrass Resistance

- Resistant to:
  - Glyphosate, ALS inhibitors (Pastora, Impose)
- Mechanism
  - Target site susceptibility
- Alternatives
  - Sethoxydim
  - Prowl (PRE control)



Vaseygrass

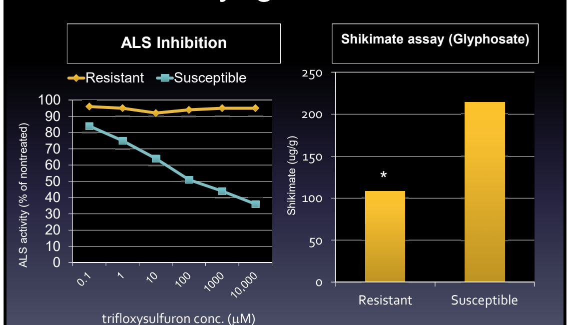
Control in pastures:

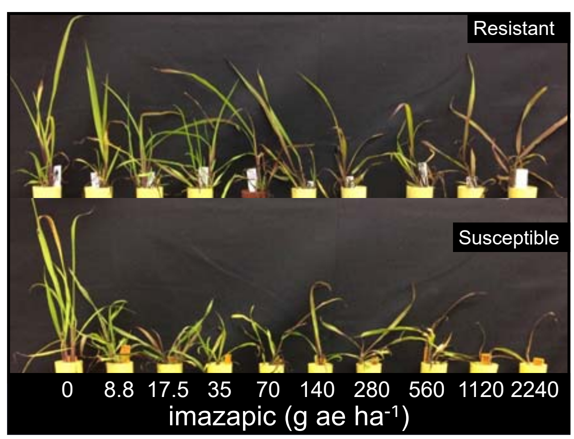
Imazapic (Impose)

Pastora (nicosulfuron + metsulfuron)

sethoxydim

Basis for Ryegrass Resistance





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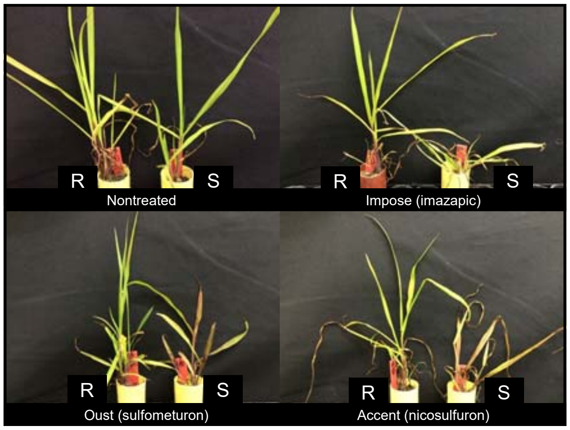
Extension Weed Scientist

UGA extension

Herbicide Resistance: A Growing Issue



Vaseygrass Control in Hayfields

WSSA Group	Common Name	Trade Name
1	sethoxydim	Poast, others
2	nicosulfuron + metsulfuron	Pastora
2	imazapic	Impose
9	glyphosate	various

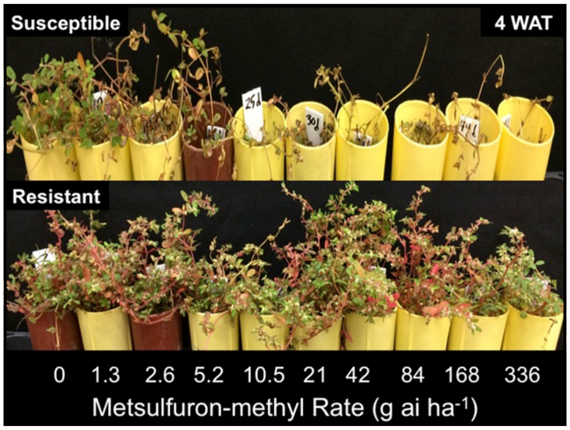
ALS-Resistant Vaseygrass

- Resistance was greater than 80x of the susceptible biotype
- Target site inhibition
  - ALS enzyme activity was not inhibited
- Glyphosate or sethoxydim will control it

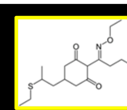
Cimarron at 0.25 oz/acre + NIS (1 WAT)

Resistant Susceptible

Herbicide Resistance: A Growing Issue



sethoxydim

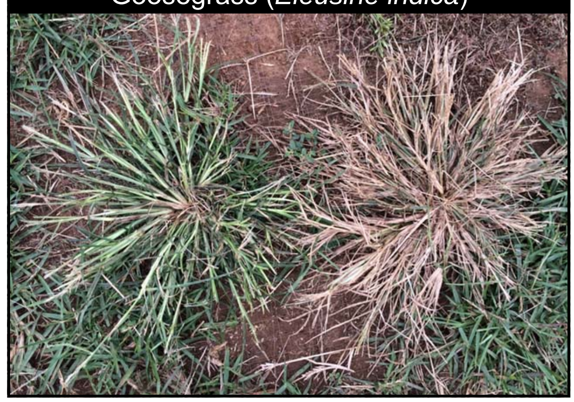


- Characteristics
  - Trade names: Segment, Poast, others
  - Mechanism of action: ACCase inhibitor
- Postemergence control of grassy weeds
  - Crabgrass, goosegrass, crowsfootgrass, bermudagrass, others
- Advantages for weed control in Georgia
  - Efficacy for selective weed control

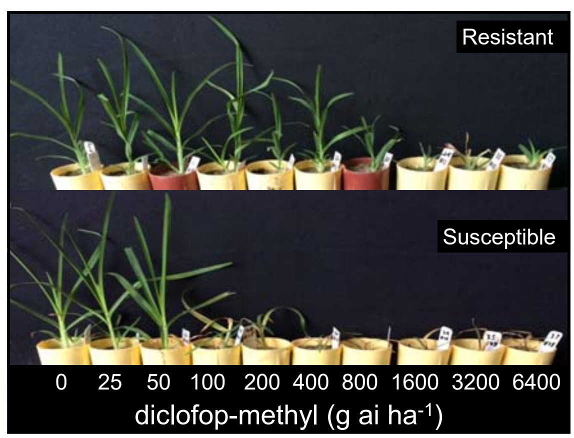
Metsulfuron Resistant Spurge

- Gene mutation that confers resistance to all ALS inhibitors
- Alternatives to control
  - Dicamba, triclopyr, others

Goosegrass (*Eleusine indica*)



Sethoxydim Resistance in Crabgrass and Goosegrass



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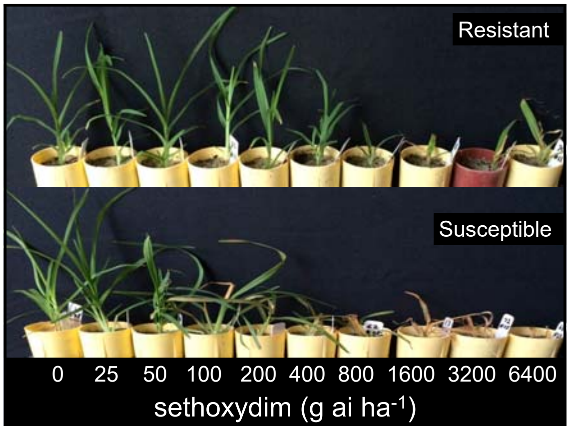
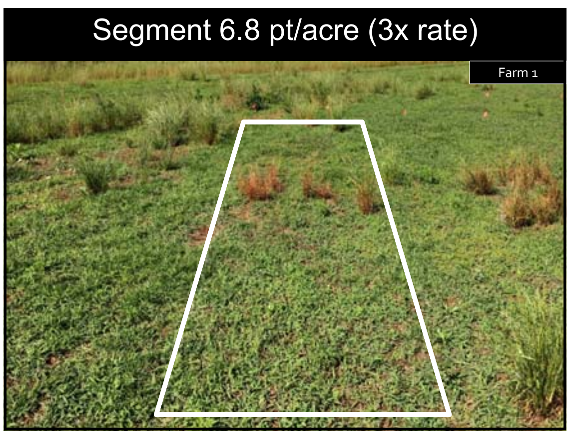
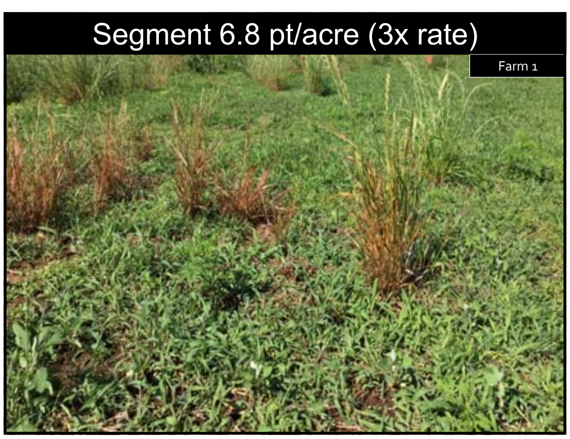
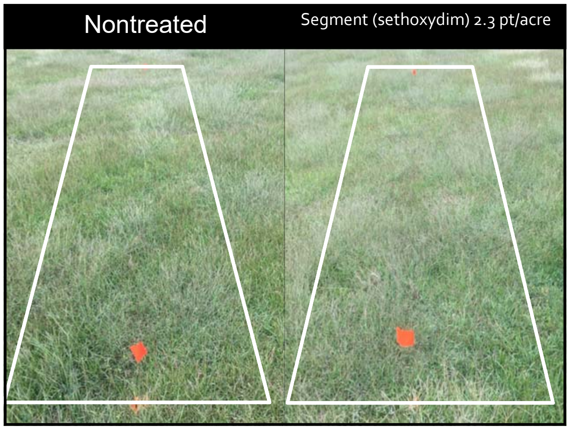
Herbicide Resistance: A Growing Issue

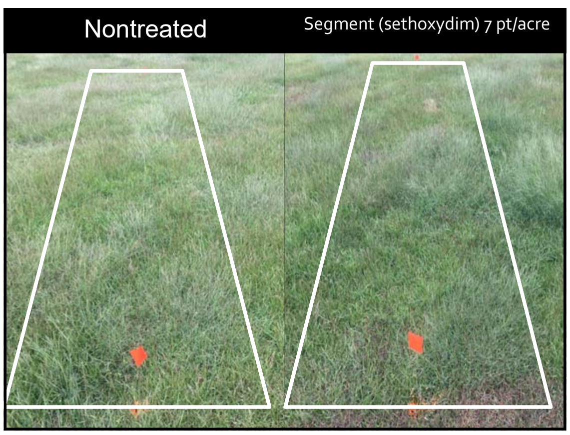






Herbicide Resistance: A Growing Issue





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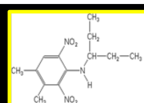
Herbicide Resistance: A Growing Issue

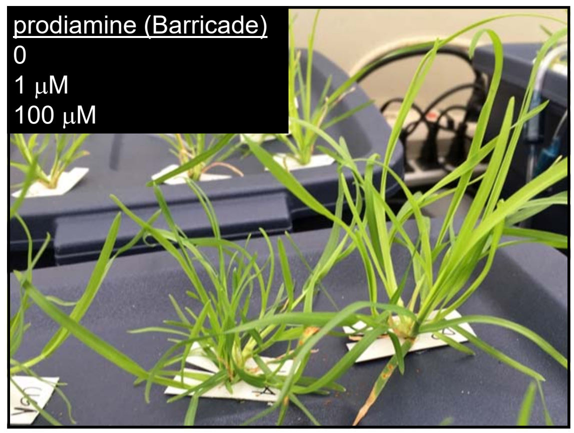
Crabgrass and Goosegrass Control in Hayfields

WSSA Group	Common Name	Trade Name
1	clethodim	Select
	sethoxydim	Poast, others
2	nicosulfuron + metsulfuron	Pastora
	imazapic	Impose
9	glyphosate	various

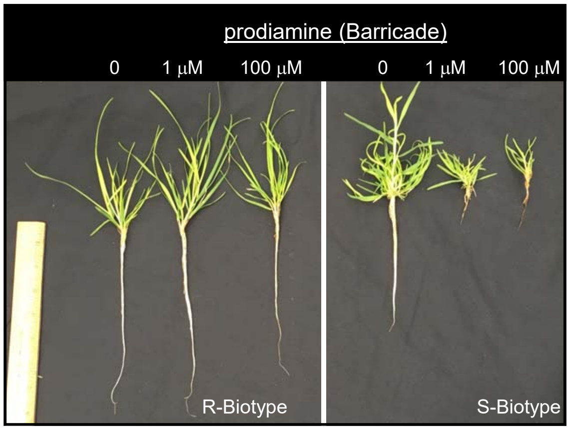
pendimethalin



- Trade Name: Prowl H_2O (3.8SL)
  - Family: Dinitroaniline
  - Mode of action: Mitosis inhibition
- Applications: 1.1 to 4.2 qt/acre
- Maximum Use: 4.2 qt/acre per year
- Use in perennial grass pastures

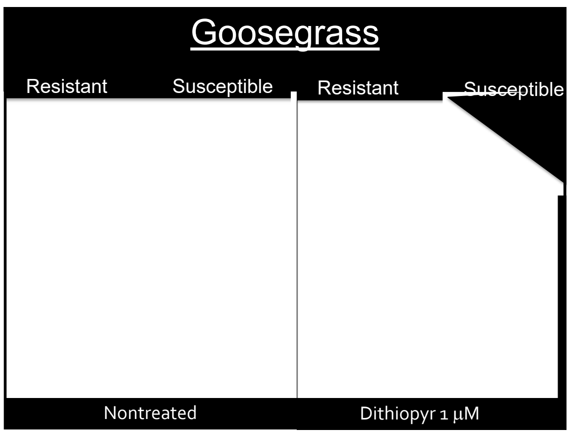


Herbicide Resistance: A Growing Issue



ALS-Resistant Sedge

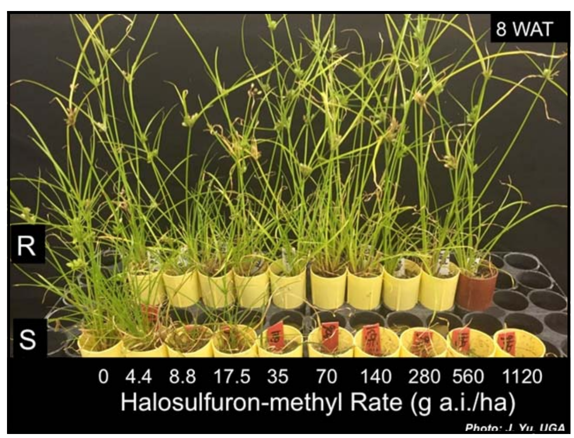
- Populations identified in 2014
  - Sedges were not controlled after a Sedgehammer (halosulfuron) application
  - History of exclusive halosulfuron use for over 15 years
- Halosulfuron (Sedgehammer, Sandea, Prosedge, others)
  - Widely used in turf and ornamentals for sedge control
  - Resistance had not been reported in turfgrass systems



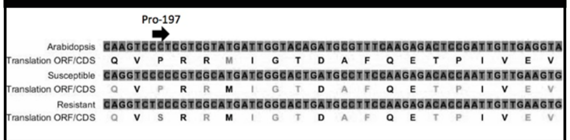
Annual sedge
(*Cyperus compressus*)

Implications for Hayfields

- Bermudagrass, bahiagrass, and alfalfa
  - Prowl H_2O is the only PRE herbicide labeled
  - Exclusive use will lead to selection pressure for resistant biotypes
- Other pasture species
  - No PRE herbicides available



Gene Sequencing for the ALS Enzyme
(McElroy, Auburn University)



ALS-Resistant Annual Sedge Control

Sedgehammer 1.3 oz/acre +NIS | Outrider 1.3 oz/acre + NIS

Sedgehammer (halosulfuron) at 1.3 oz/acre

ALS-Resistant Annual Sedge Control

Dismiss 12 oz/acre +NIS | Basagran 2 pt/acre + NIS

Sedgehammer (halosulfuron) at 1.3 oz/acre

Herbicides for Sedge Control in Hayfield

WSSA Group	Common Name	Trade Name
2	imazapic	Impose
	halosulfuron	Sandea
	sulfosulfuron	Outrider
9	glyphosate	various

Herbicide Resistance: A Growing Issue

2,4-D Resistance

- First case from turf confirmed in Indiana
  - Buckhorn plantain (Patton et al. 2017)
  - Cemetery treated with 2,4-D exclusively
- Suspect plantain resistance
  - Segregation in your population
  - Need higher 2,4-D rates to control
  - Rule out other causes of failure

Herbicide Resistance: A Growing Issue

Herbicide Resistance Should Only Be Suspected When ……….

- The same herbicide or herbicides with the same mode of action have been used year after year.
- One weed normally controlled is not
- Healthy weeds are mixed with controlled weeds (same species)
- Patches of uncontrolled weeds are spreading.

Causes of herbicide failure are ruled out

Questions

Causes of Herbicide Failures

- weed size**
- moisture
- temperature
- humidity
- rate
- application method
- calibration
- others

All possible reasons for poor performance should be investigated before considering the possibility of resistance!!!

Herbicide Resistance

Managing Herbicide Resistance

- Rotate herbicides from year to year
- Rotate herbicides with different mode-of-action.

Dr. Patrick McCullough
Extension Weed Scientist

Understanding Forage Quality

Dr. Jennifer Tucker, Asst. Professor, Animal and Dairy Scientist

Understanding Forage Quality

UNDERSTANDING FORAGE QUALITY

Jennifer J. Tucker, Ph.D
Assistant Professor
Department of Animal and Dairy Sciences
University of Georgia – Tifton

Forage Quality has High Value Now

Supplementing a Lactating Beef Cow

Crop	Maturity	CP	TDN	Supplement[†]	Cost[‡]
		-- % --	-- % --	lbs/hd/day	$/hd/day
Bermudagrass	4 weeks	10-12	58-62	0	$0
	6 weeks	8-10	51-55	4.8	$0.55
	8 weeks	6-8	45-50	7.5	$0.93
Tall Fescue	Late boot	14-16	66-70	0	$0
	Early head	11-13	60-63	0	$0
	Dough	8-10	50-54	5.3	$0.61

Assuming 50:50 corn gluten:soy hulls supplementation for forage quality on low end of the range.
Approximate prices for Oct. 2013 ($230/ton).

- Overview of forage quality
- Taking a Forage Sample
- Reading a forage quality analysis

Maturity Matters

Forage Quality Parameters for Selected Forage Crops

Crop	Maturity	CP	TDN	NDF	ADF
Bermudagrass					
	4 weeks old	10-12	52-58	33-38	63-68
	8 weeks old	6-8	45-50	40-45	70-75
Alfalfa					
	Bud	22-26	64-67	28-32	38-47
	Early Flower	18-22	64-64	32-36	42-50
	Mid Bloom	14-18	58-61	36-40	46-55
	Full Bloom	9-13	50-57	41-43	56-60
Ryegrass					
	Vegetative – Boot	12-16	63-68	27-33	47-53
	Boot – Head	8-12	59-63	33-39	53-59
Red Clover					
	Early-Flower	14-16	64-67	28-32	38-42
	Late Flower	12-14	59-64	32-38	42-50

Source: Adapted from J.C. Henning and G.D. Lacefield, University of Kentucky

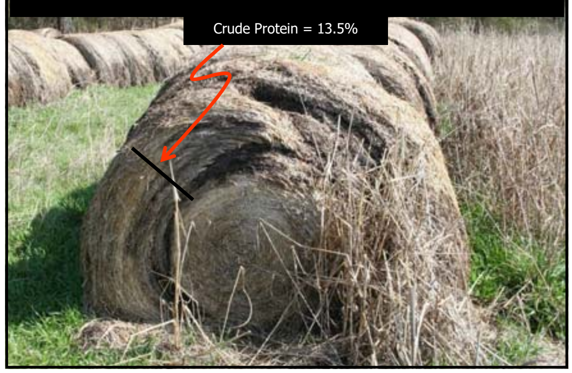
Forage Quality has High Value Now

Supplementing a Lactating Beef Cow

Crop	Maturity
Bermudagrass	4 weeks
	6 weeks
	8 weeks
Tall Fescue	Late boot
	Early head
	Dough

Assuming 50:50 corn gluten:soy hulls supplementation for forage quality on low end of the range.
Approximate prices for Oct. 2013 ($230/ton).

How good is this hay?



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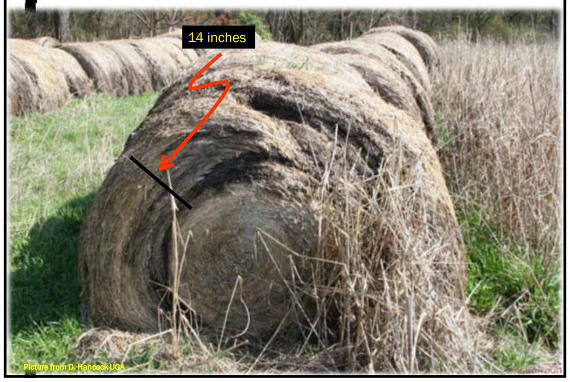
74% of the bale LOST!



How do we get enough energy in the animal?

- The animal eats more forage.
  - *What is the physical limit?*
  - *Can a cow eat enough straw to meet her energy needs?*
- What forage the animal eats must be high in energy.
  - *High digestibility -> High energy*
- Bottomline: Every bite has to count!

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Crude Protein and Hay Quality

- CP is the most overrated measure of quality!
  - *Total N x 6.25 = CP, %*
- Tells you nothing about the form nitrogen is in
  - *Protein (AA), Bound Protein, Nitrates etc.*
- Protein requirements are (typically) easily met
- Somewhat related to maturity

<u>Tells you very little about energy content</u>

- Important- just overemphasized

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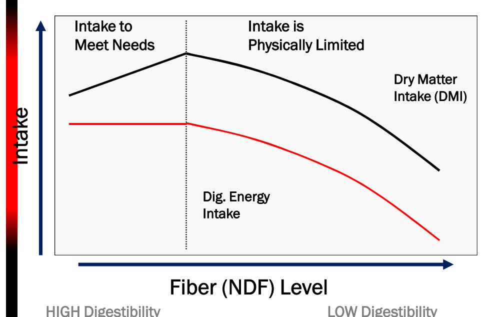
The Relationship between Fiber (NDF) and Dry Matter Intake (DMI)



Source: D Hancock, UGA

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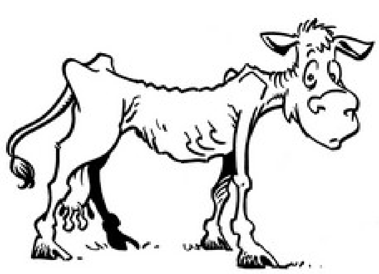
"Low Carb, High Fat" –



do our cattle want that?

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What is "High Quality Forage"?

- Results in high intake
  - *Consumed in large amounts*
  - *High DMI*
- Is digestible
  - *Large amounts of nutrients*
  - *High TDN*
- Contains proper balance of needed nutrients

Relative Forage Quality (RFQ) = TDN * DMI/1.23

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Assistant Professor, Animal Scientist

Understanding Forage Quality

Matching Animal Requirements and Forage Quality

Stage of Production	TDN % Required	CP % Required
Dry Pregnant	48	7
Peak Lactation	60	12
Late Lactation	55	9

?

Source: M.K. Mullenix, ACES

The least used and least understood element of a good forage management plan.

Matching Animal Requirements and Forage Quality

Stage of Production	TDN % Required	CP % Required	Hay % TDN	Hay % CP	Supplement Needed
Dry Pregnant	48	7	48	7	No*
Peak Lactation	60	12	48	7	Yes
Late Lactation	55	9	48	7	Yes

Source: M.K. Mullenix, ACES

FORAGE SAMPLING DO'S AND DON'T'S

Obtaining a Representative Sample

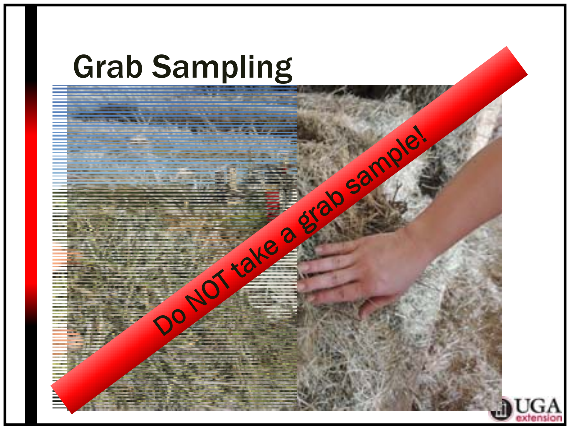
Unless you Test...

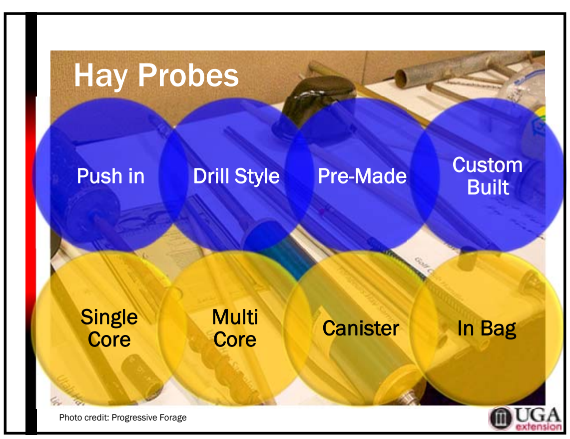
It's Just a Guess!

Grab sampling

Dr. Jennifer Tucker
Assistant Professor, Animal Scientist

Understanding Forage Quality





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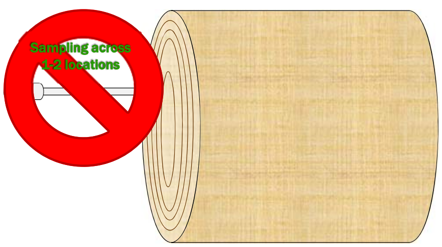
Understanding Forage Quality

Drill Type

Custom built

Cut Across Windrows

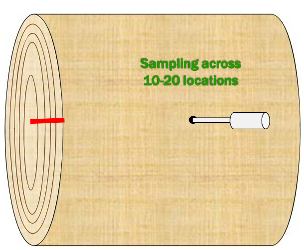
Which way do we cut?



How To Take a Forage Sample

- Sample from each field AND cutting ("Lot" of hay).
- Use bale corer to get a representative sample from 20 bales per lot.
- Insert the sampler fully and cross-ways to the stems.

Which way do we cut?



How To Take a Forage Sample

- Fill a clean quart-size plastic bag with about ½ lb of forage.
- Label each bag with details.
- Send to an accredited lab (National Forage Testing Association), such as the UGA Feed and Environmental Water Lab.
- For details, see the FAQ page on www.georgiaforages.com

Dr. Jennifer Tucker
Assistant Professor, Animal Scientist

Understanding Forage Quality

Do:

- Use the proper tools
- Cut across the windrow
- Sample each "lot" separately
- Randomly select which bales to sample

Don't:

- Grab Sample
- Cut into a windrow
- Combine all samples into one analysis
- Select only the best "looking" bales

Reading a Forage Quality Analysis

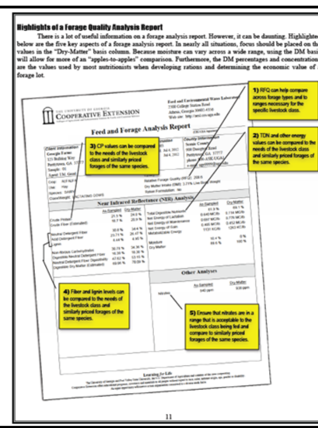
Other Tips and Tricks

- Get a Good Drill with a GOOD battery
- Buy extra tips/adapters

  OR have a way to sharpen/fix them

Nutritive Value

- The potential for supplying nutrients
  - *i.e Nutrient concentration, digestibility, and end-products*
- Nutrient concentration can be determined through lab analysis
  - *Wet Chemistry (Van Soest)*
  - *Near Infrared Reflectance Spectroscopy (NIRS)*
  - *Crude Protein, Acid Detergent Fiber, Neutral Detergent Fiber, and In-vitro Dry Matter Digestibility*



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Assistant Professor, Animal Scientist

Understanding Forage Quality

Table 2. Summary of the primary uses of the forage quality metrics specified on reports from the University of Georgia's Feed and Environmental Water Laboratory.

Metric	Abbrev.	Units	Analytical Method	Important Uses: Ration Balancing	Nutritional Diagnostics	Energy Estimates	Involved in Estimating DM Intake
Standard Procedures							
Relative Forage Quality[1]	RFQ	unitless	NIR				
Crude Protein	CP	%	NIR, WC	x	x		x
Crude Fiber[2]	CF	%	NIR				
Neutral Detergent Fiber	NDF	%	NIR, WC	x	x		x
Acid Detergent Fiber	ADF	%	NIR, WC	x			x
Lignin		%	NIR, WC				
Total Digestible Nutrients	TDN	%	NIR	x	x	x	x
Net Energy of Lactation	NE_l	Mcal/lb	NIR	x	x	x	
Net Energy of Maintenance	NE_m	Mcal/lb	NIR	x	x	x	
Net Energy of Gain	NE_g	Mcal/lb	NIR	x	x	x	
Metabolizable Energy	ME	kcal/lb	NIR	x	x	x	
Moisture		%	Oven				
Dry Matter[3]	DM	%	Oven	x			
Mineral Analyses							
Phosphorus	P	%	ICP	x	x		
Potassium	K	%	ICP	x	x		
Calcium	Ca	%	ICP	x	x		
Magnesium	Mg	%	ICP	x	x		
Manganese	Mn	PPM	ICP	x	x		
Iron	Fe	PPM	ICP	x	x		
Aluminum	Al	PPM	ICP	x	x		
Copper	Cu	PPM	ICP	x	x		
Zinc	Zn	PPM	ICP	x	x		
Sodium	Na	PPM	ICP	x	x		
Other Analyses							
Total Fat		%	WC	x	x		
Nitrates[4]	NO_3-N	PPM	WC	x	x		
Ash		%	Oven				
Sulfur	S	%	ICP		x		
Arsenic	Ar	PPM	ICP		x		
Selenium	Se	PPM	ICP	x	x		
Bound Protein		%	NIR		x		
pH		unitless	WC		x		
Salt		%	WC		x		
Total Alfatoxin[4]		ppb	WC		x		

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RFQ Simplifies Comparisons

- Relative Forage Quality
  - *Predicts energy based on fiber quality and intake*
- Combined into a single value
  - *RFQ of 100 is ~ = to full-bloom alfalfa*
  - *RFQ allows comparisons to be made across forage species*

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Forage Quality of Major Southern Forages: Summary Statistics

Figure 11 provides a graphical summary of the statistics on over 16,000 forage samples that were submitted to the University of Georgia's Feed and Environmental Water Lab between July 2003 – February 2011. To better understand how a particular forage lot compares to others, compare the data on the report to the summary statistics provided here.

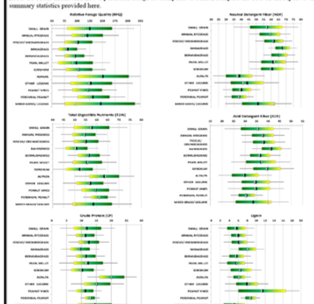

Figure 11. The average (black vertical lines), median (white vertical lines), typical expected[1] range (color bars), and the extent[2] of what is commonly low or high for a species (extent of horizontal gray lines) for RFQ, TDN, CP, NDF, ADF, and lignin in samples of various forage species submitted to the UGA Feed and Environmental Water Laboratory during July 2003 – February 2011.

[1] One standard deviation about the mean.
[2] Two standard deviations about the mean.

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RFQ Simplifies Comparisons

- Relative Forage Quality
  - *Predicts energy based on fiber quality and intake*
- Combined into a single value
  - *RFQ of 100 is ~ = to full-bloom alfalfa*
  - *RFQ allows comparisons to be made across forage species*
  - *Allows hay to be easily assigned to appropriate physiological stages*

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Fiber Factors

Acid Detergent Fiber (ADF)

- Lignin, Cellulose, and Ash (silica)
- Not hemicellulose
- Is a good indicator of digestibility of a forage

Higher ADF = Lower Digestibility

Neutral Detergent Fiber (NDF)

- Includes all cell wall material
- ADF + Hemicellulose
- Is a good indicator or the intake potential of a forage

Higher NDF = Lower Intake Potential

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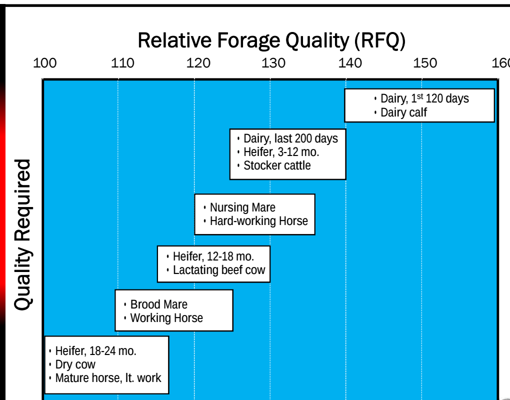

Adapted from Undersander et al., 2011

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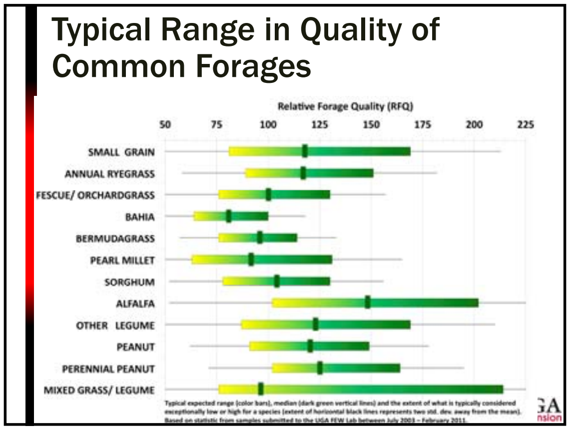
Assistant Professor, Animal Scientist

GRASS www.georgiaforages.com

Understanding Forage Quality



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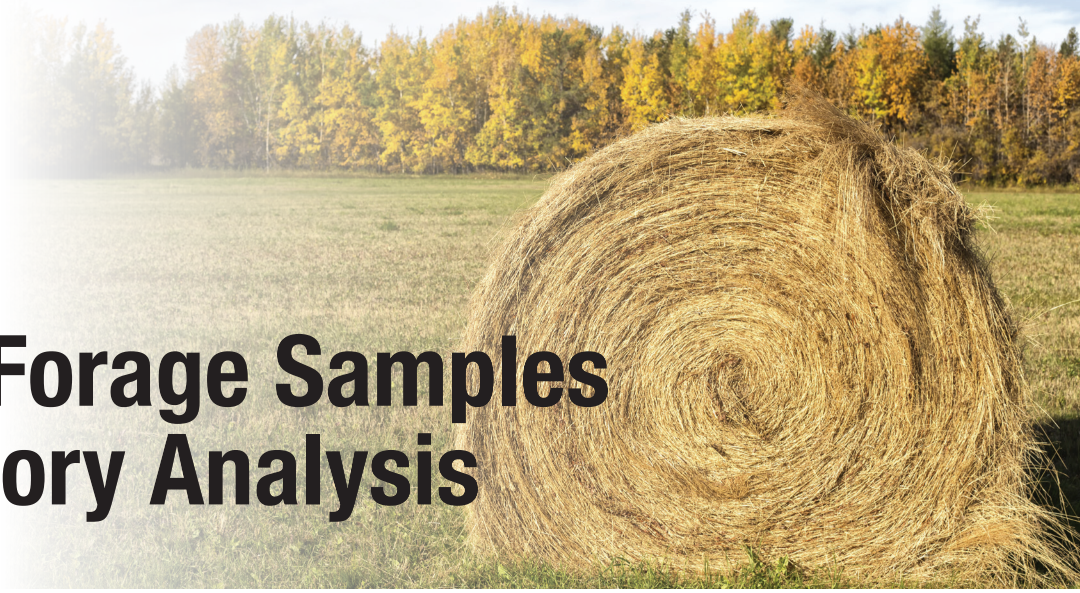

Collecting Forage Samples for Laboratory Analysis

With any type of forage sample, the goal is to collect a representative sample. The following provides some guidelines.

Collecting a Hay Sample

(≤ 20 percent moisture)

1. Test each lot of forage separately. A *lot* is defined as hay that was harvested at the same time out of the same field and under the same conditions.
2. Collect 15 to 20 core samples from each lot. Use a hay coring probe to reduce sampling error. If you don't have a hay probe, contact your county Extension coordinator or regional Extension agent on the Animal Science and Forage team to locate a probe in your area.[1]
3. Insert the hay probe at a 90 degree angle.
    - For a round bale, insert the probe into the curved side of the bale.
    - For a square bale, insert the probe into the center of the end of the bale.
4. Remove the hay probe, and empty the contents into a clean container.
5. After sampling a complete lot (15 to 20 core samples), mix the sample thoroughly and place the sample in a 1-quart plastic bag.
6. Label each sample with an ID (e.g., Back forty, Front lot, Old cotton field).
7. Fill out a Hay and Forage Testing Analysis Form on the Soil Testing Lab website or obtain a form from your county Extension office. Attach the form to the sample and mail it to the Auburn University Soil Testing Laboratory.

Collecting a Haylage[2] Sample

(≥ 40 to 60 percent moisture)

1. Haylage samples may be collected at multiple times: before baling, before wrapping, after wrapping, or before feeding.
    - If collected before baling, collect multiple grab samples from different areas in the field after harvest and just before baling.
    - If collected post-baling/before wrapping, collect core samples (as described above) from various bales in the field or as they are delivered to the wrapper, just before wrapping.
    - If collected after wrapping, collect core samples (as described above) from various locations in the tube or severally individually wrapped bales from the same lot. **Remember to seal the puncture hole in the wrapping with multiple layers of an airtight tape.**
    - If collected just before feeding, collect core samples (as described above) only from the tube or lot of individual bales that you plan to feed next. This eliminates excessive damage from hole punctures over a prolonged period of time.
2. Place each sample into a clean container, mix thoroughly, and empty the sample into a 1-quart plastic bag. **Remove as much air from the bag as possible when sealing.**
3. Label each sample with an ID (e.g., Back forty, Front lot, Old cotton field).

4. Fill out a Hay and Forage Testing Analysis Form on the Soil Testing Lab website or obtain a form from your county Extension office. Attach the form to the sample and mail to the Auburn University Soil Testing Laboratory **immediately** to reduce the chance of spoilage. If possible, mail early in the week so it arrives to the laboratory without spending the weekend in shipment.

Collecting a Silage Sample

(≥ 65% moisture)

Silage can be hand collected from an upright silo or bunk.

1. Collect double handfuls of silage from 20 to 30 different areas in the silo or bunk.
2. Avoid spoiled areas and sites that have been exposed to air for several hours.
3. Place each sample into a clean container and mix thoroughly. Collect a subsample from the container and place into a 1-quart plastic bag. **Remove as much air from bag as possible when sealing.**
4. Label each sample with an ID (e.g., Back forty, Front lot, Old cotton field).
5. Fill out a Hay and Forage Testing Analysis Form on the Soil Testing Laboratory website or obtain a form from your county Extension office. Attach the form to the sample and mail to the Auburn University Soil Testing Laboratory **immediately** to reduce the chance of spoilage. If possible, mail early in the week so it arrives to the laboratory without spending the weekend in shipment.

Collecting a Fresh Forage Sample

(> 80% moisture)

Using hand sheers, collect fresh forage samples from 10 to 20 random areas of a field (not to exceed 40 acres).

1. To best represent the forage that will be consumed, **do not** clip forage to ground level, rather clip samples to the height at which the forage will be harvested or grazed.
2. Place each sample into a clean container, mix thoroughly, and empty the sample into a **paper bag** (avoid plastic bags as these may produce inaccurate results).
3. Label each sample with an ID (e.g., Back forty, Front lot, Old cotton field).
4. Fill out a Hay and Forage Testing Analysis Form on the Soil Testing Laboratory website or obtain a form from your county Extension office. Attach the form to the sample and mail to the Auburn University Soil Testing Laboratory **immediately** to reduce the chance of spoilage. If possible, mail early in the week so it arrives to the laboratory without spending the weekend in shipment.

Sampling for Nitrates

1. Follow sampling procedures as outlined above for a specific forage category.
2. If high-moisture samples are submitted for nitrate testing (such as fresh forage, silage, or haylage), place the samples on ice or freeze them immediately after collection and send to the lab for analysis as soon as possible. For best results, deliver samples to the Auburn University Soil Testing Laboratory on the same day you collected it. This reduces the chance of nitrate reduction during storage and transportation.
3. Nitrates are more stable in hay and **do not degrade** readily over time. Submit a hay sample for nitrate testing according to the outlined procedure above.
4. Label each sample with an ID (e.g., Back forty, Front lot, Old cotton field).

[1] Go to www.aces.edu for a listing of county Extension coordinators and regional Extension agents. Watch the Alabama Cooperative Extension YouTube Channel video *How to Pull a Hay Sample* on how to properly collect a representative forage sample.

[2] Baleage is a form of haylage that has been baled and wrapped.

Kim Mullenix, *Extension Beef Cattle Systems Specialist*; and **Jennifer Johnson**, *Extension Forage Specialist*

For more information, contact your county Extension office. Visit www.aces.edu/directory.

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ANR-2224

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Determining Forage Demand and Animal Intake

This guide illustrates how to determine the acreage needed to meet the forage demand of grazing animals for a defined period of time.

Step 1: Determine animal intake requirements

This is determined by estimating what percent of an animal's body weight it will consume in dry matter in one day. The percentage will vary according to the class of livestock being fed, forage quantity, and nutritive value. The following provides an estimate for different classes of livestock:

Animal Class	Forage consumption, % of body weight
Beef cow (dry)	2.0-2.5%
Beef cow with calf	2.4-2.6%
Heifer, replacement	2.5-3.0%
Stocker	2.5-3.5%

†Adapted from NRC (1996); Alabama NRCS Grazing Stick

Step 2: Determine the efficiency of the grazing system

The efficiency of the grazing system provides an estimate of forage utilization. A range of 40 to 70% pasture utilization is common. Below is an estimate of forage utilization for various grazing methods:

Grazing method†	Efficiency
Continuous stocking	30-40%
Slow rotation (3-4 paddocks)	50-60%
Moderate rotation (6-8 paddocks)	60-70%
Strip grazing	70-80%

†Adapted from Ball et al. (2007)

Step 3: Putting it all together

Calculate the area required per paddock to provide adequate forage intake for a defined number of days.

$$\text{Acres required per paddock} = \frac{\text{Avg. weight of animals to be grazed} \times \text{Dry matter intake, \% of animal body weight} \times \text{Number of animals} \times \text{Days on pasture}}{\text{Available forage mass}^{‡} \times \text{\% Forage utilization}^{†}}$$

*Adapted from IPNI: Forage Crop Pocket Guide (2012)

<u>Where:</u>

‡Available forage mass is the amount of dry matter available in the area to be grazed. (See Using a Grazing Stick for Pasture Evaluation).

†% Forage utilization (See Step 2 above).

<u>Example:</u>

Twenty 1,200 pound (lb) dry, pregnant brood cows
1,200 lb x 2.5% body weight in dry matter intake = 30 lb dry matter needed per day
Days on pasture before rotating = 7 days
Slow rotation, 50% grazing efficiency
Available forage mass = 2,000 lb of dry matter per acre

$$\text{Acres required per paddock} = \frac{\text{1,200 lb} \times 2.5\% \times \text{20 animals} \times \text{7 days}}{\text{2,000 lb dry matter per acre} \times \text{50\% utilization}}$$

$$= \text{4.2 acres required for 7 days}$$

Now determine the total acres needed based on the number of paddocks in your system:

Total Acres Required = Number of Paddocks x Acres Required Per Paddock
= 4 paddocks x 4.2 acres
= 16.8 acres

$$\textbf{Stocking rate} = \frac{\text{Number of animals grazing}}{\text{Total acres grazed}} = \frac{\text{20 animals}}{\text{16.8 acres}} = \text{1.2 animals per acre}$$

Prepared by Kim Mullenix, Ph.D., Extension Beef Cattle Systems Specialist, and Jennifer Johnson, Ph.D., Extension Forage Specialist, Auburn University, Auburn, AL. MKM-15-4. May 2015.

Recommended Principles for Proper Hay Sampling

Dan Putnam, University of California, Davis

INTRODUCTION

Proper sampling of hay and forage is of tremendous importance to assure an accurate forage test. Remember, a lab test is only as good as the sample provided to the lab. Here's the dilemma: Hundreds of thousands of pounds of highly variable plant material must be represented in a single, tiny, thumbnail-sized sample!! Often, the sample actually analyzed by the lab is often only ½ gram! This sample must not only represent the proper leaf-stem ratio and the legume/grass mix, but also reflect the spotty presence of weeds. Sampling variation is a significant problem in hay testing, and causes millions of dollars in lost revenue each year by either buyer, seller, or in animal performance. In practice, hay sampling produces more variation in results than does lab error. However, if sampling protocol is carefully followed, sampling variation can be reduced to an acceptable level, and the potential forage quality successfully predicted. The following steps have been compiled from various recommendations that have been in place for years and are widely considered to be the key elements of a standardized sampling protocol:

STANDARDIZED PROTOCOL TO ASSURE A REPRESENTATIVE SAMPLE OF HAY

1. **Identify a single 'lot' of hay.**
   This is a key first step to proper hay sampling, and one frequently ignored. A hay lot should be identified which is a single cutting, a single field and variety, and generally be less than 200 tons. Combinations of different lots of hay cannot be represented adequately by a forage sampling method; different lots should be sampled separately. Don't mix cuttings, fields, or hay types.

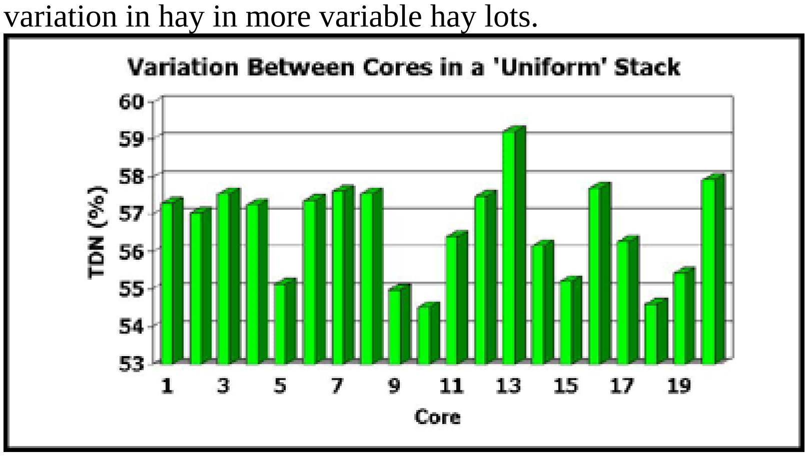
2. **When to Sample?**
   It is important to sample the hay either as close to feeding, or as close to point of sale as possible. Dry matter measurements are especially subject to changes after harvest and during storage, but other measurements may also change. Hay immediately after harvest normally goes through a process of further moisture lost known as a 'sweat'. During this period, hay may heat up due to the activities of microorganisms, driving residual moisture from the hay. Thus, moisture content is likely to be reduced in the days and weeks after harvest. If the hay has been baled at excess moisture, further biological activity may result in molding, or even (under very high moisture conditions) spontaneous combustion of hay. However, after hay has equilibrated to the range of 90% DM (10% moisture, depending upon humidity), it is typically quite stable. 'As received' dry matter measurements should be used to adjust quantity (tonnage, yield), not quality parameters, which should be compared on 100% DM basis.

3. **Choose a sharp, well-designed coring device.**
   Use a sharp coring device 3/8-3/4" diameter. <u>Never</u> send in flakes or grab samples, it is nearly impossible for these samples to represent a hay lot. "Hand-grab' samples have been shown to be significantly lower in quality than correctly sampled forage. The corer should have a tip 90o to shaft, not angled—studies have shown that angled shafts push aside some components of hay, providing a non-representative sample of the entire mix. Very small diameter tips (<3/8") do not adequately represent the leaf-stem ratio of the hay. Too-large diameter or too-long probes (e.g. > 24") provide good samples, but give too much forage in a 20 probe composite sample—thus the

sampler may stop before 20 cores are completed or the lab may not grind the whole sample (see below). The length of probe should allow probing to a depth of 12”-24”. Studies have shown this depth to successfully characterize the variation in hay, even in large (1 ton) bales, and no significant differences were seen between a 32” and 12” probe. A range of probe tip designs have been used successfully, from serrated to non-serrated tips—it is probably most important that the tip be sharp (and maintained sharp), and not create ‘fines’ during the cutting action, but cleanly cut across a cross-section of hay. Some probes are power, hand-brace, or auger driven, whereas others are push-type, both of which may work well. Many (not all) probes can be used to successfully represent a hay lot as long as they follow these principles: they easily penetrate the bale, fairly represent the leaf-stem ratio, can be easily sharpened, and produce approximately ½ lb (200 g) of sample in about 20 cores to a depth of 12”-24”. See a listing of probes at NFTA website.

4. **Sample at random.**
The sampler should walk around the stack as much as possible, and sample bales at random. Both ends of bales should be sampled by walking around the stack. This is sometimes difficult since all of the bales are not available to the sampler (they may be against walls of a barn or up too high for practical sampling). However, the sampler should make every attempt to sample in a random fashion—this means not to bias either for or against any bales in the stack. For example, the sampler may walk 15 steps, sample, walk 20 steps, sample, walk 5 steps, sample, while walking around stack—trying to represent all areas of the stack. Don’t avoid or choose bales because they look especially bad or good--If 20 cores are taken, they won’t make much difference anyway. Avoiding or choosing bales introduces bias.

5. **Take enough cores.**
We recommend a minimum of <u>20 cores</u> for a composite sample to represent a hay lot. This is the same for large (e.g. 1 ton bales), or small 2-tie or 3-tie bales. This is because core-core (and bale-bale) variation in forage quality is tremendous (e.g. 5-7 % points ADF or CP). Sampling a large number of locations and bales throughout the stack to create a composite sample is a key aspect of representing the full variation contained in a hay lot. It is recommended to take <u>more</u> than 20 cores (e.g. up to 35) with very large lots (100-200 tons), or with highly variable lots (e.g. lots that may have non-attached leaves or are from very weedy fields). With small bales, sample 1 core per bale, >20 bales; with larger (e.g. 1 ton) bales, take 2-3 cores per bale in the center of the ends, sampling >10-12 bales. A larger number of core samples is generally better at characterizing variation in hay in more variable hay lots.



6. **Use proper technique.**
   Sample butt ends of hay bale, between strings or wires, not near the edge. Probe should be inserted at 90º angle, 12”-18” deep. Do not sample in the same exact spot twice. Do not use any technique which is likely to misrepresent the leaf-stem ratio. The sides or the top of the bale should not be sampled, since these cores will only represent one flake from a single area of the field, and additionally misrepresent the leaf-stem ratio. With round bales, sample towards middle of bale on an angle directly towards the center of the bale.

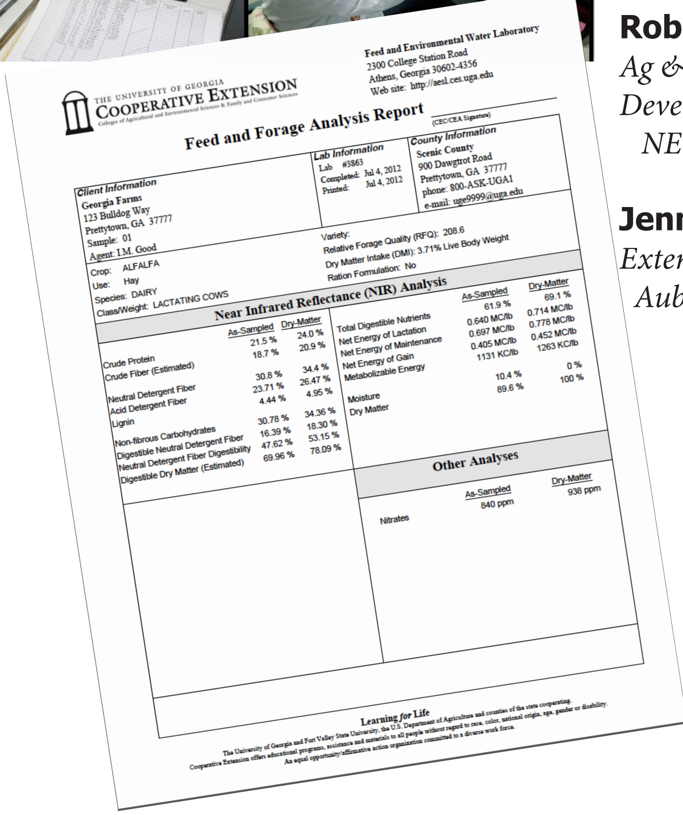
7. **Sample amount: “not too big, not too small”.**
   Sampling should be done so that about ½ lb of sample is produced. Too-small samples don’t fairly represent the full range of variation in the hay lot. Very big samples (common with large length or diameter probes) are excellent at representing the hay but have practical disadvantages. Large samples cannot be easily ground by the labs—many labs will simply sub-sample such large samples before grinding, defeating the entire purpose of good sampling technique! The sampler should ensure that the entire sample is ground by the lab—this is important to check. If your lab is not grinding the whole sample, ask why—it could be that your sample is too large. Only work with labs that are willing to grind the entire sample (after a DM sample for field DM is taken). But you should also assure that you are providing a reasonable ½ lb sample, so that it can be practically handled by the lab. If a probe is too big or small to produce about ½ pound in 20 cores—get a different one! (see list of probes on NFTA website)

8. **Handle samples correctly.**
   Seal Composite 20-core sample in a well-sealed plastic bag and protect from heat. Double bagging is beneficial, especially for DM measurements. Deliver to lab as soon as possible. Do not allow samples to be exposed to excess sun (e.g. in the cab of a pickup truck). Refrigeration of hay samples is helpful, however, dry hay samples (about 90% DM) are considered fairly stable.

9. **Never split samples without grinding.**
   It is important to occasionally double check the performance of your lab by comparing with another (or several other) labs. However, never split un-ground samples and send them to two different labs—the samples are likely to be genuinely different! To test two labs, either grind and carefully split the sample, or better yet, ask for your ground sample back to send to another lab. Use several samples to test average potential bias between labs. Don’t work with labs that are unwilling to do this—good labs should be wiling to test their performance and answer questions with regards to consistency of lab results. Ask for their NFTA results!

10. **Choose an NFTA-Certified Lab.**
    The first step in choosing a high-quality hay testing lab is to determine whether they participate in the NFTA proficiency certification program. The National Forage Testing Association, a volunteer group set up by hay growers, sends blind samples to labs, and they must match the true mean within an acceptable range of variation. NFTA labs have demonstrated their commitment to good results, are more likely to be interested in accuracy. Additionally, programs such as California’s ‘California Recognized’, the Midwest NIRS consortium, or other voluntary proficiency programs provide an additional opportunity for labs to prove their proficiency. However, these programs only work if the clientele (you) pays attention to them. Choose a lab that chooses EXCELLENCE! Choose an NFTA lab (see www.foragetesting.org for a listing of NFTA-certified labs)!

Understanding and Improving Forage Quality



THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Feed and Environmental Water Laboratory
2300 College Station Road
Athens, Georgia 30602-4356
Web site: http://aesl.ces.uga.edu

(CEC/CEA Signature)

Feed and Forage Analysis Report

Client Information
Georgia Farms
123 Bulldog Way
Prettytown, GA 37777
Sample: 01
Agent: I.M. Good

Lab Information
Lab #3863
Completed: Jul 4, 2012
Printed: Jul 4, 2012

County Information
Scenic County
900 Dawgtrot Road
Prettytown, GA 37777
phone: 800-ASK-UGA1
e-mail: uge9999@uga.edu

Crop: ALFALFA
Use: Hay
Species: DAIRY
Class/Weight: LACTATING COWS

Variety:
Relative Forage Quality (RFQ): 208.6
Dry Matter Intake (DMI): 3.71% Live Body Weight
Ration Formulation: No

Near Infrared Reflectance (NIR) Analysis

	As-Sampled	Dry-Matter
Crude Protein	21.5 %	24.0 %
Crude Fiber (Estimated)	18.7 %	20.9 %
Neutral Detergent Fiber	30.8 %	34.4 %
Acid Detergent Fiber	23.71 %	26.47 %
Lignin	4.44 %	4.95 %
Non-fibrous Carbohydrates	30.78 %	34.36 %
Digestible Neutral Detergent Fiber	16.39 %	18.30 %
Neutral Detergent Fiber Digestibility	47.62 %	53.15 %
Digestible Dry Matter (Estimated)	69.96 %	78.09 %

	As-Sampled	Dry-Matter
Total Digestible Nutrients	61.9 %	69.1 %
Net Energy of Lactation	0.640 MC/lb	0.714 MC/lb
Net Energy of Maintenance	0.697 MC/lb	0.778 MC/lb
Net Energy of Gain	0.405 MC/lb	0.452 MC/lb
Metabolizable Energy	1131 KC/lb	1263 KC/lb
Moisture	10.4 %	0 %
Dry Matter	89.6 %	100 %

Other Analyses

	As-Sampled	Dry-Matter
Nitrates	840 ppm	938 ppm

Learning *for* Life
The University of Georgia and Fort Valley State University, the U.S. Department of Agriculture and counties of the state cooperating.
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CONTENTS

Understanding and Improving Forage Quality

The nutritive value of a specific lot of forage is defined by the amount of nutrition that can be derived from it and the presence/concentration of any toxic compounds that could reduce animal performance or threaten animal health. In combining the nutritive value of the forage with assumptions/predictions of how much of the forage an animal could eat, one can determine if the forage's quality is sufficient. It is important to understand the quality of the forage being used so as to develop a least-cost ration for the animals being fed. Estimates of protein, mineral, and vitamin content can be made relatively easily. However, the majority of the available energy in a forage crop is in a fibrous form. Several analytical procedures have been developed to provide estimates of fiber content and digestibility. These estimates have also been calibrated to predict animal nutrition and performance.

The goal of this publication is to guide the user to a better understanding of basic forage quality terms and to recommend management changes that will improve forage quality. To that end, our objectives are to explain how forage quality is measured, describe how to interpret a forage analysis, present the effects of management on forage quality, and list the key management strategies that can increase the nutritive value of forage crops. This publication is written with the understanding that the reader either knows or can quickly find the definition of key forage quality terms. The reader is encouraged to refer to the glossary of UGA Extension Bulletin 1367, "Common Terms Used in Animal Feeding and Nutrition," for unfamiliar terms used in this publication.

Forage Quality Has Value

Commodity and by-product feeds are relatively expensive. Certainly, providing high-quality forage (either as pasture, hay, baleage/haylage, or silage) is not inexpensive, either. With recent feed prices, however, high-quality forage is cheaper than most supplements that are typically fed. Forage that is lower in digestibility will not meet the nutrient requirements of the animal requiring supplementation, which increases the cost of production. As a result, more and more supplement is needed to meet the requirements of the animal (Table 1).

Table 1. The effect of bermudagrass and tall fescue maturity on hay quality, supplementation rate, and cost of supplementing a lactating beef cow.[1]

Crop	Maturity	Crude Protein (CP)	Total Digestible Nutrients (TDN)	Supplement Req. for a Lact. Beef Cow	Cost to Supplement
		---- % ----	---- % ----	lbs/hd/day	$/hd/day
Bermudagrass	4 weeks	10-12	58-62	0	$0
	6 weeks	8-10	51-55	2.3 – 4.8	$0.23 – 0.48
	8 weeks	6-8	45-50	5.3 – 7.5	$0.53 – 0.75
Tall Fescue	Late boot	14-16	66-70	0	$0
	Early head	11-13	60-63	0	$0
	Dough (seed)	8-10	50-54	3.0 - 5.3	$0.30 – 0.53

The Need for Forage Testing

There is no technique for assessing the nutritional value of the forage in a pasture or lot of hay or silage strictly on the basis of feel, texture, smell, or appearance. In fact, attempting to do so has frequently caused producers to buy or use forage that has lower nutritional value and is often uneconomical or counterproductive (Figure 1). The nutritional value of the forage can only be evaluated by obtaining a representative sample of the forage and subjecting that sample to analysis in a qualified laboratory.

[1] Assumptions: 1,200 lb beef cow, average to above-average milking ability, first three months postpartum, 6.0 lbs of TDN required daily, and supplement that provides 85% TDN and costs $200/ton ($0.10/lb).

Figure 1. Though different in appearance, lots 1 and 2 are essentially the same quality.

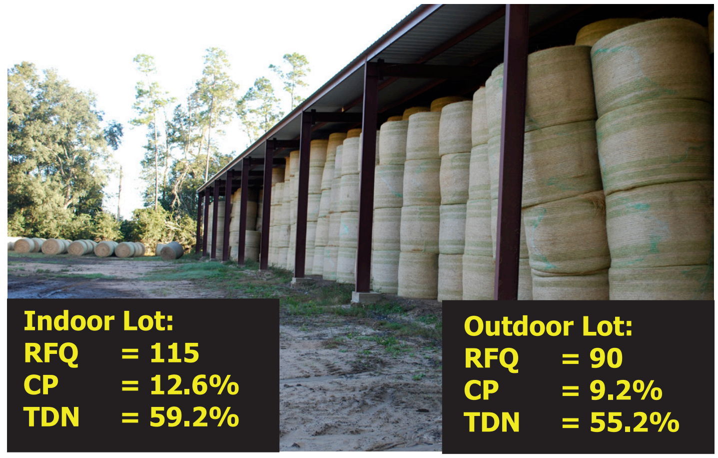


Figure 2. Sampling for forage quality can aid decisions, such as storage priority.

The results of a forage test can be used for a number of purposes. One of the most important uses is to formulate cost-effective rations. Forage testing is also used to establish the nutritive and, therefore, market value of the lot. Though hay, silage, and other conserved forages have not typically been marketed in the Southeast on the basis of nutritive quality, savvy producers are increasingly insisting upon having a forage quality analysis for any lots that they may be purchasing. Another purpose for sampling forage is to prioritize the lots that one may have in inventory for timely use (Figure 2). For example, a beef cow-calf producer with limited hay storage space may want to store their low-quality forage outside while storing the higher quality lots under cover so as to better protect the more valuable forage.

Obtaining a Representative Forage Sample

Obtaining a representative forage sample is critical. The first step is to identify a single lot (forage taken from the same farm, field, and cut under uniform conditions within a 48-hour time period). Once a lot is defined, sub-samples should be obtained from at least 20 different bales (hay, baleage) or areas (silage) that are selected at random. Detailed procedures for sampling forage are provided by the National Forage Testing Association (http://www.foragetesting.org/). Avoid taking grab samples from the bale or stack, as this may cause leaf loss and result in a sample that is not a fair representation of the lot. It is best to use a clean, sharp, forage probe (Figure 3). For information on selecting and purchasing forage probes, see the frequently asked question page titled "What hay probe do you recommend and where can I get one?" (http://www.caes.uga.edu/commodities/fieldcrops/forages/questions/hayprobes.html) on the University of Georgia's Forage Extension website (www.georgiaforages.com).

Figure 3. Sampling a lot of hay bales using a Colorado hay probe.

Measures of Forage Quality

Certainly, the ultimate evaluation of forage quality is animal performance. But, it is obviously not practical to do feeding trials to estimate the quality of each lot of forage crop. Thus, predictions of forage digestibility and rate of intake have been developed that allow one to better estimate the forage crop's nutritive value.

Predictions of forage digestibility and intake rate are based on the fibrous part of the forage. Since a forage crop is essentially a collection of many plant cells, a simplified example of a single plant cell can help to illustrate the various fractions and components (Figure 4).

A plant cell is made up of a cell wall and cell contents (i.e., material inside the cell). Essentially, all of the cell contents are easily digestible. However, the cell wall is fibrous and less digestible. This fibrous fraction can be measured and divided into components using a stepwise laboratory procedure. This procedure involves the extraction of the cell components in a progressive manner, starting with the most easily removed components (cell contents and pectins). The soluble cell contents and the pectin within the cell wall are removed by boiling the sample in a neutral detergent. The whole fibrous fraction that remains is known by the first step in the chemical analysis, neutral detergent fiber (NDF) analysis. This NDF fraction consists of hemicellulose, cellulose, lignin, and silica/minerals. The next step involves boiling the NDF fraction in an acid detergent, which dissolves and washes away the hemicellulose component. This leaves the acid detergent fiber (ADF) fraction, which consists of cellulose, lignin, and silica/minerals. Next, the ADF fraction is further treated with a stronger acid to dissolve the cellulose to leave just the lignin and silica/mineral components. Finally, the remaining fraction is burned in a 500° C furnace, leaving just the silica/mineral components in the ash.

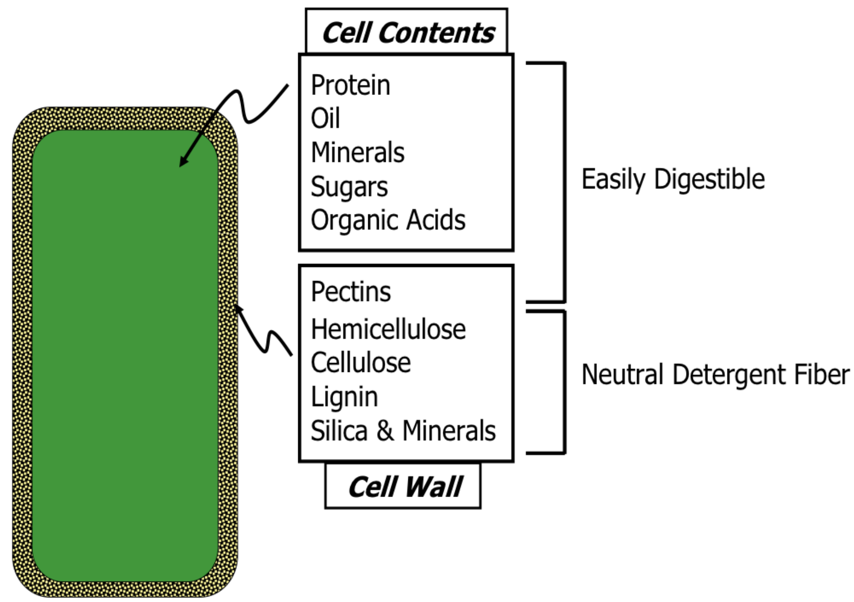


Figure 4. The easily digestible components of a cell and the fibrous components (NDF) of the cell wall.

The concentration of NDF and the ratios of the subcomponents of NDF in relation to one another have direct effects on the digestibility of the forage. Cellulose (a long chain of glucose molecules linked end to end) and hemicellulose (a branched polymer of glucose, xylose, galactose, and other carbohydrates) can be broken down by enzymatic action of bacteria and other microbes in the animal's digestive tract, though their digestion is markedly slower than the digestion of sugars, starches, and other freely available non-structural carbohydrates. In contrast, lignin is not carbohydrate-based but is a phenolic compound. As such, lignin is not digestible. Moreover, the very presence of lignin acts as a physical barrier to the microbial enzymes that break down cellulose and hemicellulose. As a result, the amount of NDF and proportion of the NDF that is hemicellulose, cellulose, lignin, and silica/mineral are known to influence and can be used to estimate other aspects of forage quality. It is those components that are used to calculate metrics like total digestible nutrients (TDN), metabolizable energy (ME), and net energy for maintenance (NE_m), gain (NE_g), and lactation (NE_l)[1]. These variables, along with a measure of crude protein (CP) and mineral content, can then be used to develop a balanced ration that meets the nutritional needs of the animal type/class.

In addition to ration balancing, the results of a forage analysis can be helpful to identify nutritional problems or toxin-related disorders. Frequently, a ration may be balanced for CP but not supply enough energy or mineral content. Furthermore, some measures of forage quality can be used to estimate dry matter (DM) intake by the livestock class being fed. An overview of the important uses of the forage quality metrics specified on reports from the University of Georgia's Feed and Environmental Water Laboratory are presented in Table 2.

[1] It is important to note that the estimates of TDN, ME, NEm, NEg, and NEl are made using predictions specific to the animal species and class that is being fed.

Table 2. Summary of the primary uses of the forage quality metrics specified on reports from the University of Georgia's Feed and Environmental Water Laboratory.

				Important Uses			
Metric	**Abbrev.**	**Units**	**Analytical Method**	**Ration Balancing**	**Nutritional Diagnostics**	**Energy Estimates**	**Involved in Estimating DM Intake**
Standard Procedures							
Relative Forage Quality[2]	RFQ	--	NIR				
Crude Protein	CP	%	NIR, WC	x	x		x
Crude Fiber[3]	CF	%	NIR				
Neutral Detergent Fiber	NDF	%	NIR, WC	x	x	x	x
Acid Detergent Fiber	ADF	%	NIR, WC	x		x	x
Lignin		%	NIR, WC			x	
Total Digestible Nutrients	TDN	%	NIR	x	x	x	x
Net Energy of Lactation	NE_l	Mcal/lb	NIR	x	x	x	
Net Energy of Maintenance	NE_m	Mcal/lb	NIR	x	x	x	
Net Energy of Gain	NE_g	Mcal/lb	NIR	x	x	x	
Metabolizable Energy	ME	kcal/lb	NIR	x	x	x	
Moisture		%	Oven				
Dry Matter[4]	DM	%	Oven	x			
Mineral Analyses							
Phosphorus	P	%	WC, ICP	x	x		
Potassium	K	%	WC, ICP	x	x		
Calcium	Ca	%	WC, ICP	x	x		
Magnesium	Mg	%	WC, ICP	x	x		
Manganese	Mn	PPM	WC, ICP	x	x		
Iron	Fe	PPM	WC, ICP	x	x		
Aluminum	Al	PPM	WC, ICP	x	x		
Copper	Cu	PPM	WC, ICP	x	x		
Zinc	Zn	PPM	WC, ICP	x	x		
Sodium	Na	PPM	WC, ICP	x	x		
Other Analyses							
Total Fat		%	WC	x	x		
Nitrates[5]	NO_3-N	PPM	WC	x	x		
Ash		%	Oven	x			
Sulfur	S	%	WC, ICP	x	x		
Arsenic	As	PPM	WC, ICP		x		
Selenium	Se	PPM	WC, ICP	x	x		
Bound Protein		%	NIR		x		
pH		unitless	WC		x		
Salt		%	WC		x		
Total Aflatoxin[4]		ppb	WC	x	x		

[2] An index (unitless) most commonly used for forage categorization and marketing.
[3] A term that is now obsolete, with the exception that many states still mandate its listing on the label of commercial feedstuffs.
[4] When comparing forage lots, feed tags, and/or labels, balancing rations, or conducting cost assessments of forages and all feedstuffs, it is important to use values corrected for moisture (i.e., on a DM basis).
[5] Anti-quality factor assessed when conditions for toxic concentrations of the compound are suspected.

Evaluate Forage on More than Just Crude Protein

Most of the classes of livestock that are being fed in the Southeast have relatively low requirements for CP. For example, the CP requirement for beef cows peaks during early lactation at 12% CP and declines to about 7% CP for dry cows. Most of the forages produced in the Southeast can meet these requirements (see inset, "Forage Quality of Major Southern Forages: Summary Statistics").

Unfortunately, there is a false perception that protein is the most limiting nutrient in the animal's diet. The reality is that the energy value of the forage is usually the most limiting factor in meeting a livestock class's requirements. As a result, many mistakenly believe that CP is the ultimate measure of a forage crop's quality.

Using CP as the sole measure of forage quality can be deceiving. Crude protein, as the name implies, is a crude method for measuring protein. In fact, CP is merely an estimate of nitrogen content (N, % x 6.25 = CP, %) and must be considered in context of plant maturity, species, fertilization rate, and many other characteristics. For example, a high nitrate concentration in the forage would be measured in the total N fraction, but nitrates are non-protein N.

Certainly, CP is an important indicator of the protein content of a forage crop. However, focusing on CP may cause one to fail to place enough emphasis on meeting energy requirements. Instead of focusing on CP, one should focus first on the amount of digestible energy in the forage.

Near Infrared Spectroscopy

The multiple steps and chemicals involved in the stepwise, "wet chemistry" extraction procedures are dangerous to laboratory workers, time consuming, and expensive. Consequently, forage researchers and nutritionists have developed alternative analysis techniques to mitigate these issues. In the early 1980s, scientists began measuring near infrared reflectance of known forage samples and found good relationships between the reflectance data and many of the forage quality metrics. Near infrared light in the 1100 to 2500 nm wavelength bands reflects in a known and repeatable way when it contacts compounds that contain hydrogen bonds to carbon, nitrogen, and oxygen. Consequently, complex carbon- and nitrogen-containing compounds (e.g., NDF, ADF, lignin, CP, etc.) can be accurately and precisely estimated by measuring the near infrared reflectance spectra. Using these relationships, researchers and engineers developed near infrared reflectance spectroscopy (NIRS) equipment and software that provide a safe, time-efficient, and cost-effective alternative to wet chemistry extraction methods (Figure 5).

Figure 5. Analyses that once took numerous hours in the laboratory can now be performed in seconds using near infrared (NIR) spectroscopy. Though wet chemistry methods are still performed to check the calibration of the NIR system, the main forage quality measurements can now be accurately made at relatively low cost.

Additionally, the NIRS technology does not cause a sample to be destroyed. This enables researchers at multiple laboratories to analyze the exact same sample. Consequently, researchers can develop, refine, and verify calibration equations for new forage species or new metrics of nutritive value. For example, the NIRS system enables laboratory technicians to identify outliers (samples that do not fit the calibration well), which can be analyzed with wet chemistry and included in the calibration equation to make the equation more robust. In this same way, the NIRS Forage and Feed Testing Consortium continually refines a number of standardized equations and provides them to forage and feed testing laboratories. The non-destructive nature of NIRS also allows laboratories to use standard samples to conduct quality assurance procedures, which ensures accuracy and precision in their results. The National Forage Testing Association (NFTA) coordinates a certification process that conducts random tests of their member laboratories. They send a known sample to the participating lab and grade the lab's results. In this way, the advent of NIRS has substantially improved the quality and consistency of forage analysis results.

Simplifying Forage Quality Assessments

Animal performance (whether defined as the production of meat, milk, fiber, or work, or merely the maintenance of body weight and condition) is driven by the number of calories the animal consumes. Though protein, minerals, vitamins, and water must also meet or exceed the requirements for the desired level of performance, the most limiting factor is the amount of digestible energy that the animal consumes.

As a result, a high-quality forage can be defined as one that contains large concentrations of digestible energy and is capable of being consumed in large amounts. Scientists have developed several different measures of forage quality. However, the majority of those forage quality metrics do not easily allow for a comparison of different forage types or species.

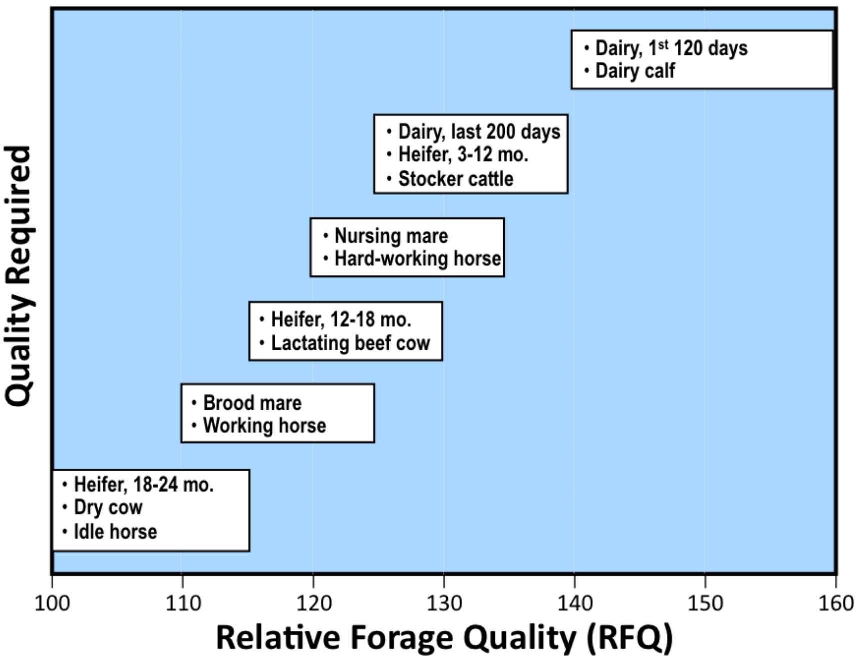
To simplify assessments of forage quality, Drs. John E. Moore (University of Florida) and Dan Undersander (University of Wisconsin) developed the **Relative Forage Quality (RFQ)** calculation. There are two factors used in the RFQ measurement (Equation 1). These include: 1) Total Digestible Nutrients (TDN), which is a measure of digestible energy and 2) a calculated prediction of dry matter intake (DMI).

$$\text{Equation 1:} \quad \mathbf{RFQ = \frac{TDN \times DMI}{1.23}}$$

Nutritionists know that TDN and digestible energy (DE) can be thought of as synonyms and used interchangeably, since TDN multiplied by 4.409 equals the DE in Mcal/kg. Additionally, animal scientists have conducted numerous feeding studies and continue to refine prediction equations of DMI for many forage species. Individually, the factors of TDN and DMI can fairly represent elements of forage quality for a particular forage species and type. However, when combined, these two factors provide a robust measure of forage quality. For a more in-depth definition of RFQ and the determination of TDN and DMI, see UGA Extension Bulletin 1367, "Common Terms Used in Animal Feeding and Nutrition."

As a result of the robustness of the RFQ measure, scientists have been able to link ranges of RFQ that are most likely to meet the needs of different animal classes. These ranges can be found in Figure 6 and would allow the livestock manager who has RFQ data on a particular lot of forage to quickly determine if it is appropriate to the needs of the animal class being managed.

These ranges illustrate the RFQ values that are most likely to minimize supplementation. Just because a forage lot falls within these recommended ranges DOES NOT mean that it will automatically provide all the nutrients needed for the livestock being fed. One does not use RFQ to develop a ration. However, RFQ provides a reasonable first approximation as to whether or not a forage will provide a cost-effective base to the diet being fed to the selected animal class.



Adapted from Undersander et al., 2011.

Figure 6. The Relative Forage Quality (RFQ) ranges that are suitable to various livestock classes. Adapted from Undersander et al., 2011.

Figure 7. A 25-lb pile of alfalfa (L) and bermuda-grass (R) that had been freshly cut with a flail plot harvester. The loose pile (no compression) illustrates the difference in volume each required.

An RFQ value that is lower than the identified range could still work for the animal class that is being fed. However, additional supplementation will likely be required. This additional supplementation may make the ration (forage + supplement) less economical.

RFQ is a Better Equalizer

Consider the following, real-world example. Pictured in Figure 7 are 25-lb piles of choice alfalfa and standard bermudagrass that were freshly cut from plots at the UGA Plant Science Farm in Athens, Ga. Selected measures of forage quality for these two piles of fresh forage are listed in Table 3, along with measurements of the size and volume of each pile.

Note that despite having the exact same weight, the loose pile of alfalfa is shorter and narrower than that of the bermudagrass. Consequently, it has a smaller volume. The forage quality analysis indicates similar levels of TDN. However, the RFQ of the alfalfa is substantially higher. This is because the DMI predicted for these forage lots differs substantially. If one were to feed forage from these two lots *ad libitum* (free choice) with no additional supplementation to dairy cows, for example, it is estimated that the cows fed the choice alfalfa would consume 70 lbs more forage per 1000 lbs of b.w. relative to the cows fed the standard bermudagrass. Consequently, those dairy cows on the alfalfa would have consumed ~24% more TDN than those fed the bermudagrass.

Table 3. An illustration of the combination of energy concentration and the importance of supporting high DM intake (DMI). Note that despite similar TDN values, the higher DMI of the alfalfa predicts much higher TDN intake.

Item	Units	Alfalfa	Bermuda
Weight	lbs	25.0	25.0
Loose Pile Height	in.	22.5	25.5
Loose Pile Diam.	in.	44.3	60.0
Approx. Volume	$in.^3$	12,000	24,000
RFQ		144.7	110.4
TDN	%	60.2	59.6
DMI	% of b.w.	3.0	2.3
TDN Intake	lbs per 1000 lbs b.w.	17.8	13.6

This example illustrates that RFQ is a more robust and superior measure of forage quality than other single measurements. By combining TDN and DMI, the RFQ index provides a better indication of overall forage quality.

Reading a Forage Quality Analysis

The results of a forage quality analysis performed at the University of Georgia's Feed and Environmental Water Laboratory are presented in a report (see inset, "Highlights of a Forage Quality Analysis Report"). The results of a forage quality analysis are reported on an "As-Sampled" and on a "Dry-Matter" basis. Other laboratories may report "As-Sampled" basis values as "As Fed," "As Received," or similar. In each case, their meaning is that the percentages and concentrations are not on a dry-matter basis. In nearly all situations, however, the values in the "Dry-Matter" basis column are the most useful for comparisons among forage lots, ration balancing, and assessments of economic value.

In addition to the items highlighted in the inset, care should be taken in interpreting the values in the context of the forage crop species and livestock species/class being fed. A common example is that TDN values from a forage lot that is analyzed in the context of beef or dairy cattle feed will be approximately 20 percentage points higher than the same lot analyzed as a feedstock for horses. The reason for this is the inherent differences in gastrointestinal physiology of these herbivorous species (pre-gastric vs. hind-gut fermenter) and not because of differences in the forage quality.

Management Factors Affect Forage Quality

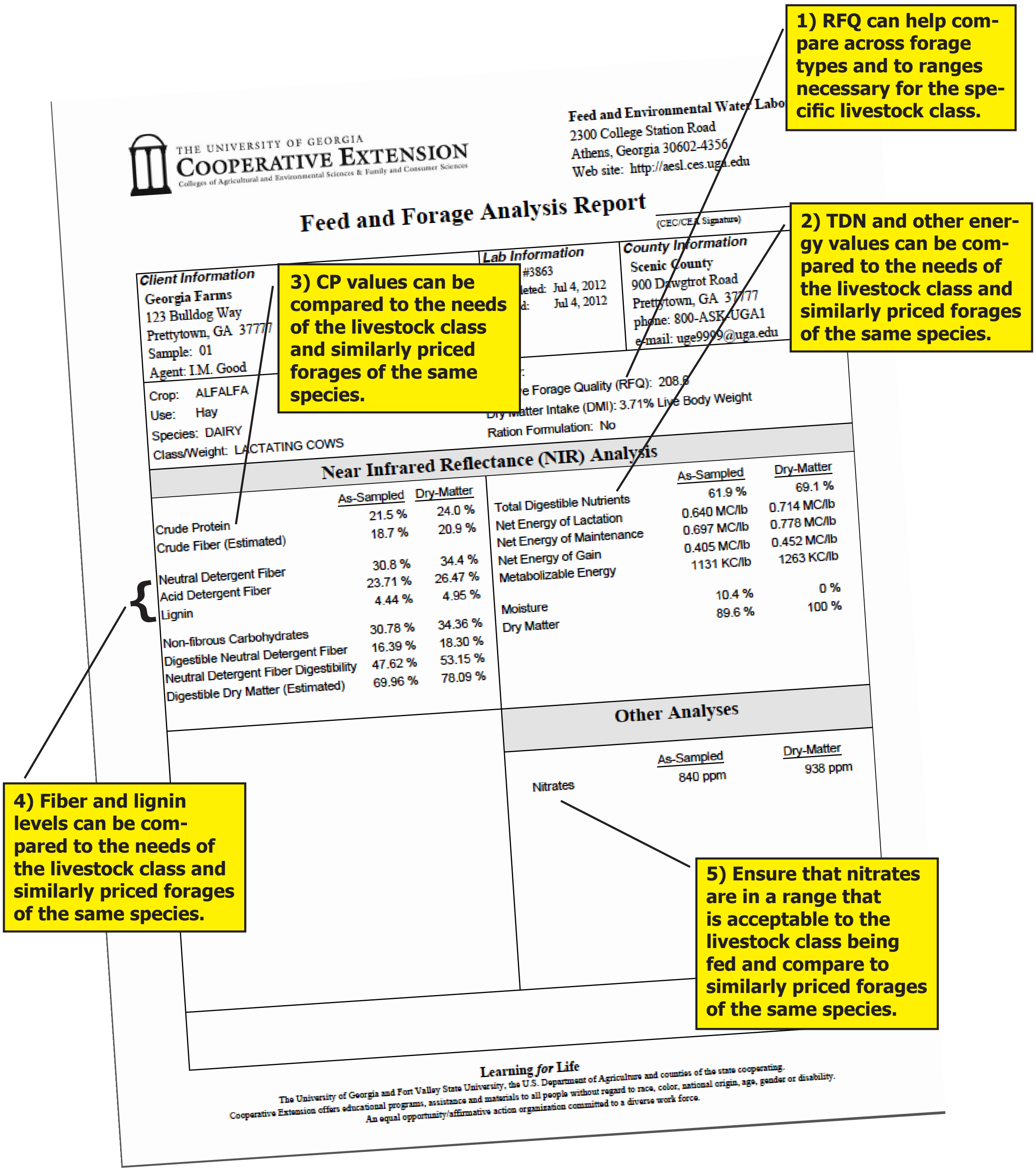
As implied in the previous sections, implementing proper management is critical to producing and harvesting high-quality forage. The most critical management factors and their relative importance with regard to forage quality are listed in Table 4. Certainly, there are many additional factors that affect forage quality. However, following the recommendations for each of these factors will enable one to produce and utilize forage that optimizes quality and nutrient yield.

Table 4. The relative importance of the primary factors that affect the nutritive quality of forage and general recommendations on best management practices that optimize quality.

Importance	Factor	Recommendations
High	Forage Maturity	Cut the forage in the late vegetative or early reproductive stages of growth. See the harvest recommendations in Table 5 for detailed information on individual species.
High	Forage Species	Use a high-quality forage species that persists and can be produced economically in your environment. Species resistant to drought and temperature extremes should be used.
Moderate	Forage Utilization	Grazed forage is generally higher quality than conserved forage (i.e., hay, silage, etc.) because of animal selectivity and because fresh forage is generally higher in digestible nutrients. However, selectivity may reduce overall forage utilization compared to mechanically harvested systems.
Moderate	Variety	Use varieties that have proven to provide a good balance of high quality and high yields. Select disease- and insect-resistant varieties.
Moderate	Storage	Protect hay bales from rainfall and weathering during storage (e.g., barn, tarp, etc.). Properly pack and exclude oxygen from forage that is being ensiled.
Moderate	Rain Damage	Avoid cutting if significant rainfall (> 0.50 inches) is predicted during curing, but take care to avoid allowing forage to become overly mature.
Moderate	Heat Damage	Dry forage to the appropriate moisture for making hay (Round: 15%; Square: 18%) and store in a manner that allows adequate ventilation. Maintain integrity of oxygen barrier in silage storage.
Low	Fertilization	Fertilize based on soil test recommendations and at recommended times to sustain CP/mineral concentrations in the forage and to maximize vegetative mass in the standing forage.

Highlights of a Forage Quality Analysis Report

There is a lot of useful information on a forage analysis report. However, it can be overwhelming. Highlighted below are the five key aspects of a forage analysis report. In nearly all situations, focus should be placed on the values in the "Dry-Matter" basis column. Because moisture can vary across a wide range, using the DM basis will allow for more of an "apples-to-apples" comparison. Furthermore, the DM percentages and concentrations are the values used by most nutritionists when developing rations and determining the economic value of a forage lot.



	As-Sampled	Dry-Matter
Crude Protein	21.5 %	24.0 %
Crude Fiber (Estimated)	18.7 %	20.9 %
Neutral Detergent Fiber	30.8 %	34.4 %
Acid Detergent Fiber	23.71 %	26.47 %
Lignin	4.44 %	4.95 %
Non-fibrous Carbohydrates	30.78 %	34.36 %
Digestible Neutral Detergent Fiber	16.39 %	18.30 %
Neutral Detergent Fiber Digestibility	47.62 %	53.15 %
Digestible Dry Matter (Estimated)	69.96 %	78.09 %

	As-Sampled	Dry-Matter
Total Digestible Nutrients	61.9 %	69.1 %
Net Energy of Lactation	0.640 MC/lb	0.714 MC/lb
Net Energy of Maintenance	0.697 MC/lb	0.778 MC/lb
Net Energy of Gain	0.405 MC/lb	0.452 MC/lb
Metabolizable Energy	1131 KC/lb	1263 KC/lb
Moisture	10.4 %	0 %
Dry Matter	89.6 %	100 %

Other Analyses

	As-Sampled	Dry-Matter
Nitrates	840 ppm	938 ppm

Learning *for* Life

The University of Georgia and Fort Valley State University, the U.S. Department of Agriculture and counties of the state cooperating. Cooperative Extension offers educational programs, assistance and materials to all people without regard to race, color, national origin, age, gender or disability. An equal opportunity/affirmative action organization committed to a diverse work force.

Forage Maturity

Maturity is the most important factor affecting forage quality. Young, leafy vegetative growth has a higher level of digestible nutrients and protein, which declines as the plants progress toward maturity (Figure 8). Older forage has fewer leaves, more stems, and a higher fiber (NDF) content. As plants mature, more lignin is deposited. Lignin gives the plant strength and rigidity. Lignin also is a natural chemical barrier that plants use to protect themselves from attacks from bacteria, fungi, and insects. The mechanism that the plant uses to provide this protection also means the forage is protected against digestion. Therefore, lignin causes the forage to be much less digestible and less capable of providing the energy needs of the animal. Even though more total DM yield accumulates with advancing forage maturity from vegetative to reproductive stage of growth, there is a point where the amount of digestible dry matter harvested per acre (digestible yield) no longer increases. Figure 9 highlights this phenomenon in bermudagrass, but all forage crops exhibit this same relationship.

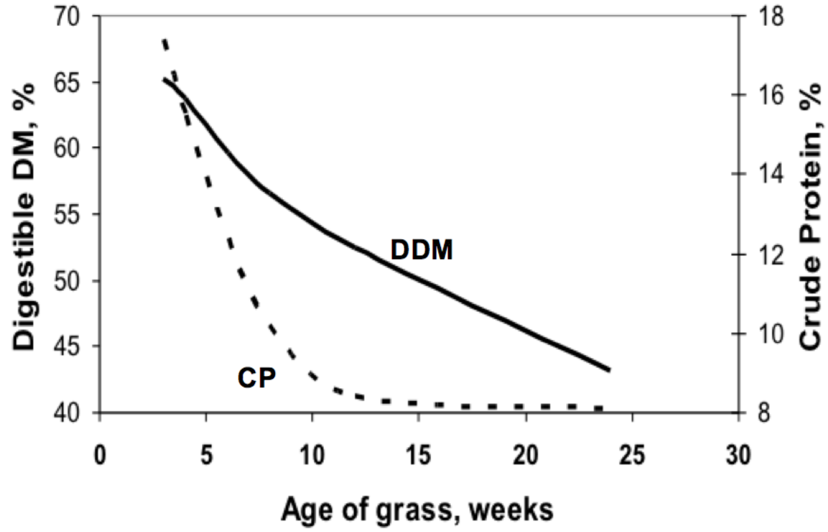


Figure 8. The digestible dry matter (DDM) and crude protein (CP) of 'Coastal' bermudagrass as affected by plant maturity in south Georgia. **Source:** Burton et al., 1963. Agron. J. Coastal Plain Experiment Station, Tifton, Ga.

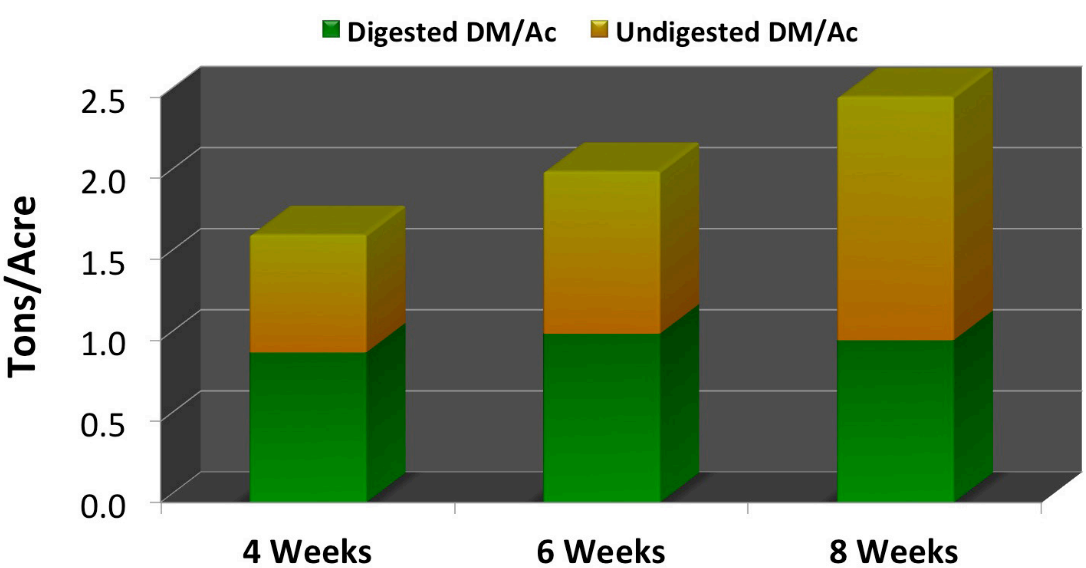


Figure 9. As an illustration of a typical situation, the total yield of bermudagrass increases with maturity, but the amount of digestible dry matter (DM)/acre does not generally increase beyond four-week-old growth. Because of increasing fiber and lignin concentrations, more undigestible DM is produced and lowers the quality.

Because of the effects of advancing maturity on quality, it is critical to harvest the crop whenever the forage reaches the recommended stage for harvest. Table 5 lists the maturity stages that should be targeted for some of the major forage crops. Delaying a harvest beyond the recommended maturity stage will result in forage that is less digestible and much less capable of being consumed at a high rate of intake. Harvesting slightly earlier than the recommended maturity is an option and may be advisable to avoid weather-related risk.

Table 5. Harvest recommendations for some of the major hay crops.

	Harvest Recommendations		
Hay Crop	**First Harvest**	**Subsequent Cutting**	**Special Considerations**
Alfalfa*	Late bud stage	Early bloom (usually after every 28-32 days).	In the spring after establishment, allow the first cutting to reach mid-bloom.
Annual Ryegrass	Boot stage	When regrowth reaches 10-12 in. (if applicable)	Harvest if forage growth ceases because of hot or dry weather.
Bermudagrass	12 - 16 inches	3.5 - 5 week intervals	If the variety rarely gets taller than 14 - 15 inches, take the first harvest at 12 inches.
Orchardgrass	Boot - early head	4 - 6 week intervals	Harvest if forage growth ceases because of hot or dry weather.
Red or Ladino Clover	Early Bloom	Early Bloom	When grown with a grass, cut at the correct stage for the grass.
Small Grains	Boot - early head	N/A	If the boot-early head stage is missed, take the first harvest at the dough stage.
Tall Fescue	Boot - early head	4 - 6 week intervals	Harvest if forage growth ceases because of hot or dry weather.
Winter Annual Legume	Early Bloom	N/A	When grown with a grass, cut at the correct stage for the grass.

* These recommendations aid the longevity of the alfalfa stand in the South and may not be appropriate for other areas in the U.S., especially when extremely high quality is desired.

Forage Species Differ in Quality

Comparing the forage quality of one lot to another lot from the same crop species can be done simply by simultaneously comparing the TDN, CP, ME, and other measures previously discussed. However, comparing forage from one species to another is more difficult.

It is well known that different forage types exhibit differences in digestibility and nutritive value (Figure 10). In general, grasses have much higher NDF than legumes. As a result, legumes are generally more digestible than grasses. Similarly, cool season grasses are typically lower in NDF and more digestible the warm season grasses. However, the digestibility of NDF differs between these forage types. For example, a cool season grass with 60% NDF may actually be less digestible than a warm season grass with 60% NDF. This is because of differences in the type of fiber and lignin created by these forage types and species. Even within a forage species, differences are sometimes found. For example, there are substantial differences in digestibility among some bermudagrass varieties (see inset, "Digestibility Sometimes Differs Between Varieties").

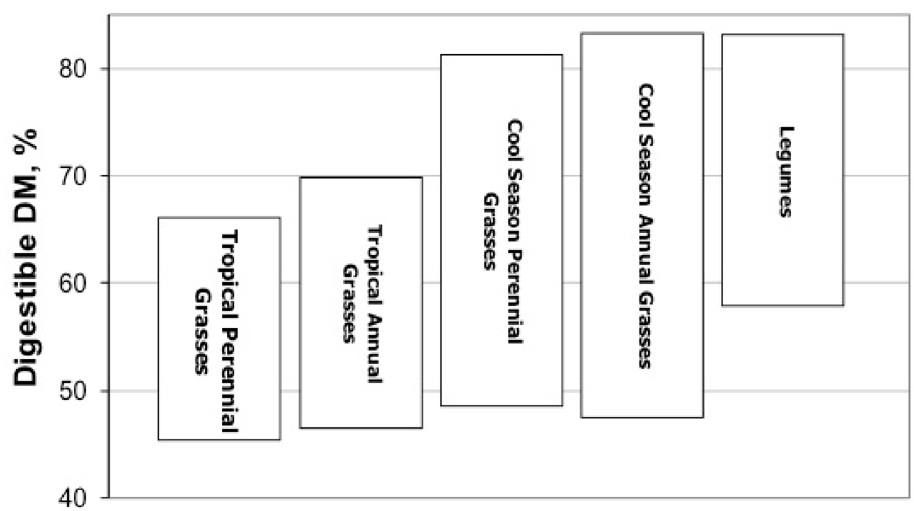


Figure 10. Digestibility ranges of major forage types. Note that the ranges overlap, but some forage types are more likely to be lower in quality than others.

Forage Quality of Major Southern Forages: Summary Statistics

Figure 11 provides a graphical summary of the statistics on more than 16,000 forage samples that were submitted to the University of Georgia's Feed and Environmental Water Lab between July 2003 and February 2011. To better understand how a particular forage lot compares to others, compare the data on the report to the summary statistics provided here.

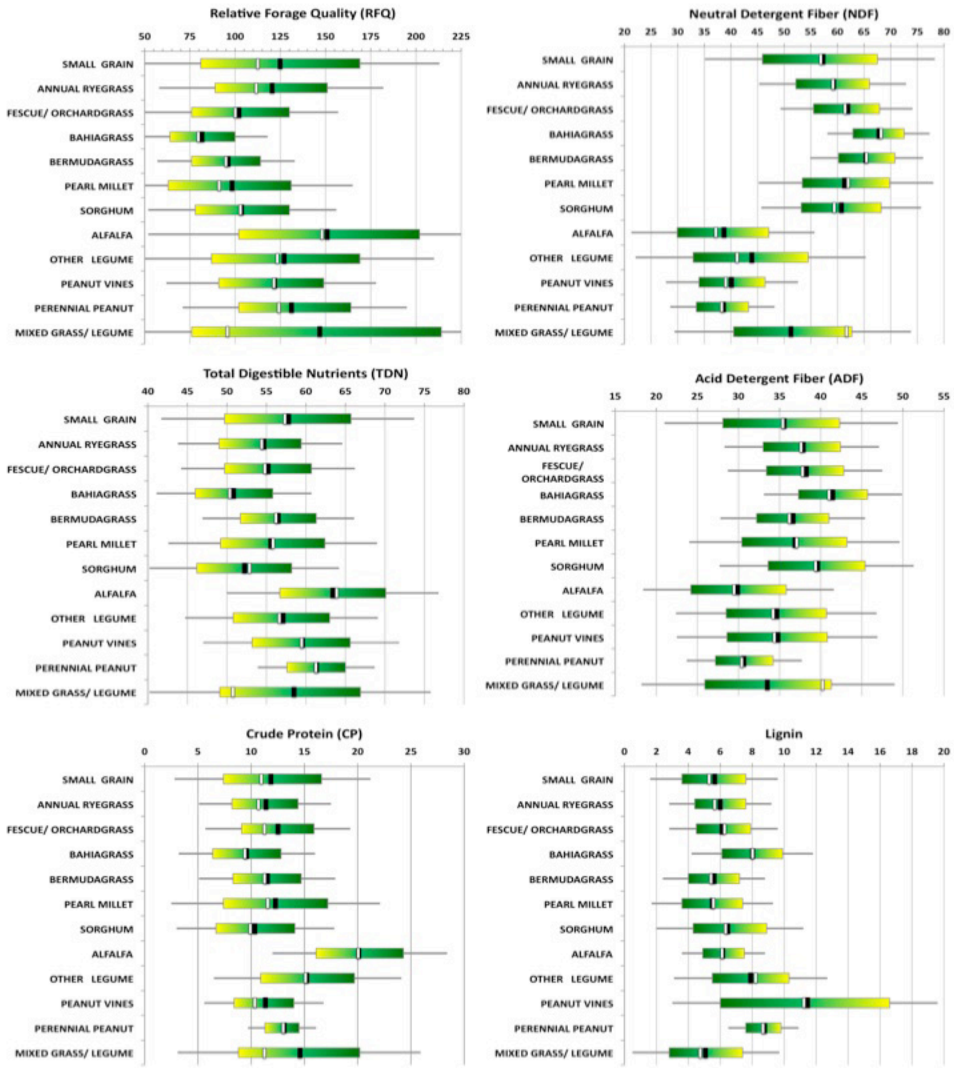


Figure 11. The average (black vertical lines), median (white vertical lines), typical expected[6] range (color bars), and the extent[7] of what is commonly low or high for a species (extent of horizontal gray lines) for RFQ, TDN, CP, NDF, ADF, and lignin in samples of various forage species submitted to the UGA Feed and Environmental Water Laboratory from July 2003 – February 2011.

[6] One standard deviation about the mean.

[7] Two standard deviations about the mean.

Digestibility Sometimes Differs Between Varieties

In general, digestibility decreases as the fiber content (NDF) increases. However, **NOT ALL FIBER IS CREATED EQUAL**. Differences in NDF values alone do not always correspond to similar differences in digestibility within a species. This is best illustrated by examining the differences between 'Coastal' bermudagrass and 'Tifton 85' bermudagrass. Studies performed at the Coastal Plain Experiment Station in Tifton, Ga., found that despite a higher NDF concentration, 'Tifton 85' bermudagrass provided more animal gains. An examination of DM digestibility showed that the 'Tifton 85' was more digestible than 'Coastal,' despite having higher NDF (Table 6). When the digestibility of the NDF was examined, it confirmed that the NDF produced by the 'Tifton 85' was more easily digested. Further examination showed that this was because the type of lignin in 'Tifton 85' is degraded more easily than the lignin in 'Coastal.'

Table 6. Differences in neutral detergent fiber (NDF) concentration, actual digestibility, and NDF digestibility of 'Coastal' and 'Tifton 85' bermudagrass at two different maturities. Adapted from: Mandebvu et al., 1999. *J. Ani. Sci.* 77:1572-1586.

Variety	Maturity	NDF	DM Digestibility$_{48h}$[1]	NDF Digestibility$_{48h}$[2]
			-------------- % of dry matter --------------	
Coastal	3-wk	66.9	51.4	42.6
	6-wk	68.9	50.8	41.0
Tifton 85	3-wk	68.6	61.7	60.6
	6-wk	72.3	56.9	55.6

[1] *In vito* dry matter digestibility (IVDMD) during a 48 h period.
[2] NDF digestibility during a 48 h period.

Summary

Many forage buyers and sellers judge and appraise the value of a hay crop based on feel, texture, smell, or appearance. Attempting to assess forage quality in this way will likely lead to erroneous and uneconomical purchasing and feeding decisions. Evaluating forages for nutritive value allows the producer/manager to more accurately appraise and market available forage lots, develop a balanced ration, and use forages more cost-effectively in feeding programs.

Modern forage quality determinations can be done quickly and cost-effectively. In addition, nutritionists have developed the Relative Forage Quality (RFQ) index to be an easy-to-use tool for comparing forage lots. With the development of RFQ, producers/managers can make comparisons among forage lots from widely different species and determine if the lots are appropriate to the livestock class being fed. Once this is determined, the usefulness and economic value of the forage lot can be refined through ration development using other aspects of forage quality, such as TDN, metabolizable and net energy, CP, etc.

Managers should also be aware of the influence of management on forage quality. Key factors, such as maturity of the crop at harvest and the forage species, should be focal points.

Using tabular data out of a nutritional guide can cause one to over- or underestimate the nutritive value of a forage lot. Long-term averages, such as those provided in Figure 11, provide a benchmark by which to judge a given lot of forage. As illustrated in Figure 11, however, the actual results will vary, in some cases considerably.

The only way to know what the nutritive value and quality of the lot of forage one is dealing with is to conduct a forage test. By measuring, monitoring, and managing forage quality and adjusting the ration accordingly, producers can keep animal production costs low and increase profitability.

Related Publications and Resources

UGA Extension Bulletin 1373, “Cutting Costs, Not Corners: Managing Cattle in Tough Times.”

UGA Extension Bulletin 1367, “Common Terms Used in Animal Feeding and Nutrition.”

UGA Extension Special Bulletin 58, “Measuring the Dry Matter Content of Feeds.”

UGA Extension Bulletin 895, “Mineral Supplements for Beef Cattle.”

UGA Extension Bulletin 1371, “UGA Basic Balancer Spreadsheet.”

UGA Extension Bulletin 1377, “UGA Feed Cost Analyzer.”

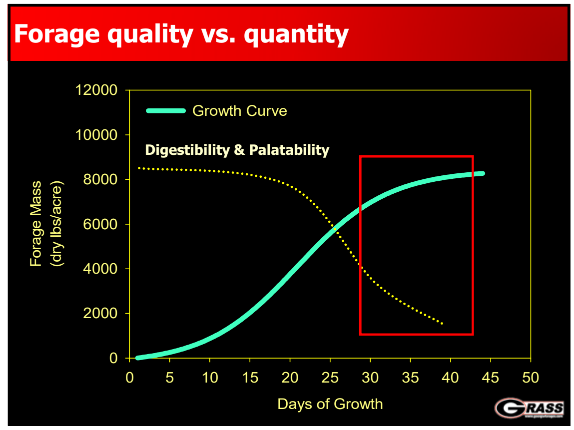
UGA Crop and Soil Sciences CSS-F048, “Using Relative Forage Quality to Categorize Hay.” http://www.caes.uga.edu/commodities/fieldcrops/forages/pubs/RFQcategorization.pdf.

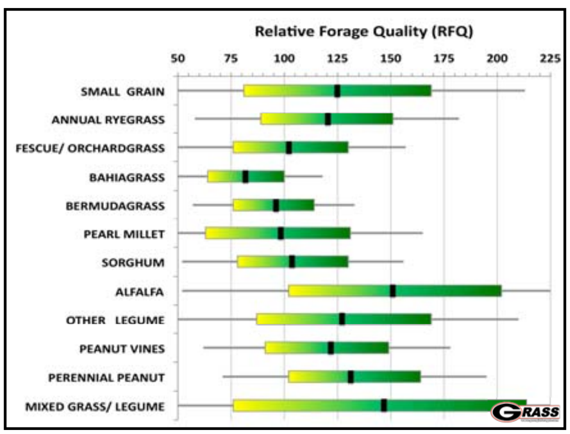
Bulletin 1425 **January 2014**

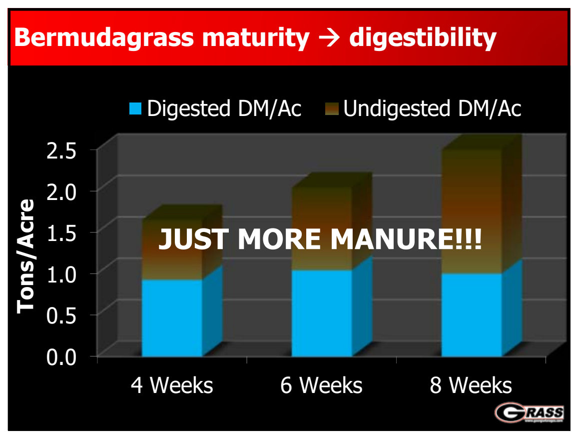
Improving Forage Quality

Dr. Lisa Baxter, Post-Doctoral Associate and Forage Agronomist

Improving Forage Quality







Primary factors affecting forage quality

Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.

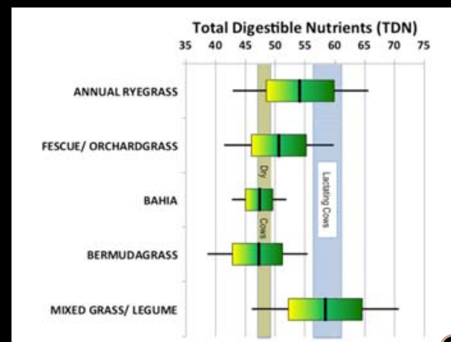
Harvest timing recommendations

- **Hybrid Bermudagrass**
  - 1st cut at 12-16 inches
  - Subsequent cuttings at 3.5-5 week intervals
- **Tall fescue, ryegrass, orchardgrass, etc.**
  - Spring cut at early flower stage or mid to late boot stage for higher quality
  - Subsequent cuttings at 10-12 inches (better quality)
- **Alfalfa**
  - Spring cut at when 10-20% of plants are blooming
  - Cut at late bud, ~ 10% bloom stage

Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

Improving Forage Quality

Quality differences in major forage species



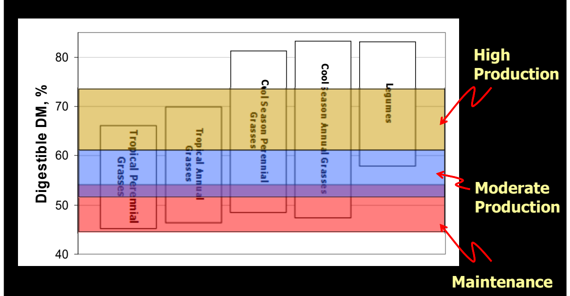
Primary factors affecting forage quality

Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.
Forage Species	Use the highest-quality species that will persist in your environment.

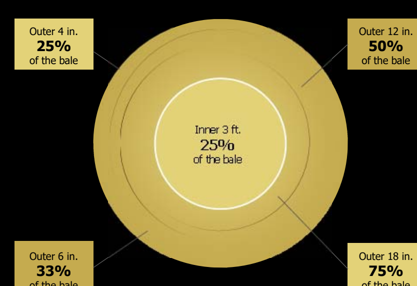
Primary factors affecting forage quality

Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.
Forage Species	Use the highest-quality species that will persist in your environment.
Bale Storage	Protect bales from rainfall and weathering during storage (i.e., barn, tarp, etc.).

Quality differences in forage types



Approximate proportions of hay within the structure of a 6 ft. diameter bale

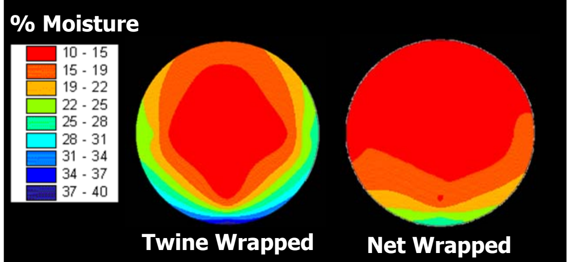


Source: Haag, E. Baling Strategy Cuts Losses. Angus Journal October 2007, pg. 282-285.

Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

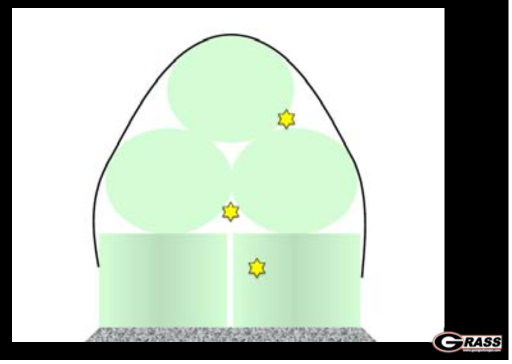
Improving Forage Quality

Moisture distribution of mixed grass-legume round bales stored on the ground

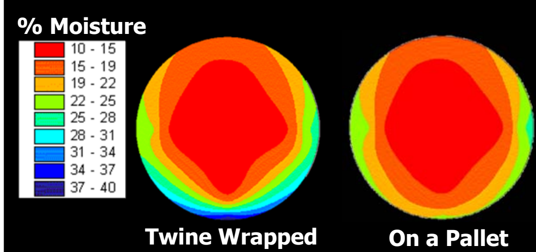


Shinners, University of Wisconsin

Consider air flow in stacked hay



Moisture distribution of mixed grass-legume round bales stored on the ground vs. elevated



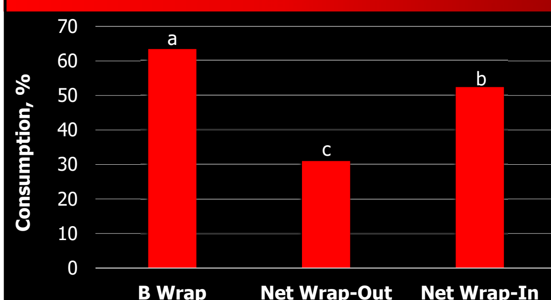
Shinners, University of Wisconsin

Breathable Net Wrap (“B-Wrap”)

- Sheds rain, snow, and ice
- Permeable to water vapor
- On Deere’s 6’ balers in the 7, 8, 9, and 0 series
  - Requires application kit
- More expensive than barn storage
  - ~$7-8/roll

Consider air flow in stacked hay

Consumption of hay made on offer – Avg. over 5 trials



Shinners et al. 2013. Prof. Ani. Scientist. 665-670.

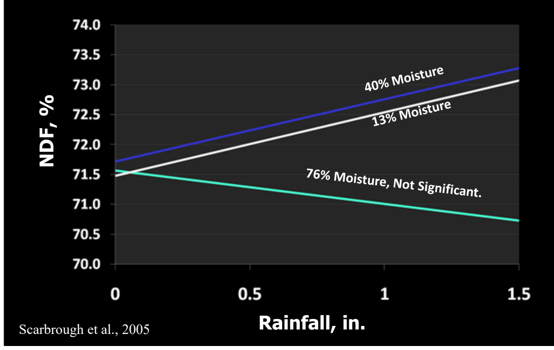
Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

Improving Forage Quality

Primary factors affecting forage quality

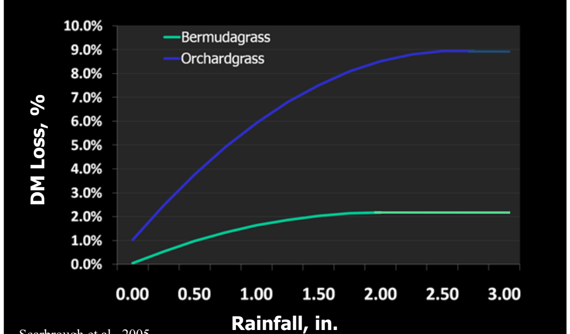
Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.
Forage Species	Use the highest-quality species that will persist in your environment.
Bale Storage	Protect bales from rainfall and weathering during storage (i.e., barn, tarp, etc.).
Rain during curing	Avoid cutting if significant rainfall (> 0.50 inches) is predicted during curing.

Crop moisture lessens rain damage on bermudagrass



Scarbrough et al., 2005

The effect of rainfall on DM loss



Scarbrough et al., 2005

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Bale Storage	Protect bales from rainfall and weathering during storage (i.e., barn, tarp, etc.).
Rain during curing	Avoid cutting if significant rainfall (> 0.50 inches) is predicted during curing.
Moisture at baling	Allow forage to dry to the appropriate moisture (Round: 15%; Square: 18%)

The effect of rainfall on tall fescue hay

	No Rain	Rain Damage
➔ Intake, % of b.w.	2.10	1.92
NDF, %	68.1	76.0
➔ Digestibility, %	63.2	59.7

Turner et al., 2003

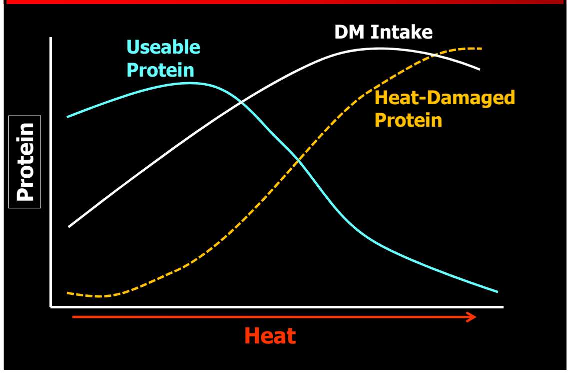
Spontaneous combustion of hay

Picture Credit: G.J. Charlet III, Clinton, LA Vol. Fire Dept. via flickr.com

Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

Improving Forage Quality

Heat damage to crude protein



Primary factors affecting forage quality

Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.
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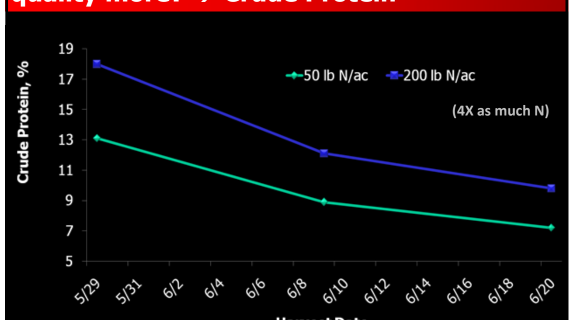
Bale Storage	Protect bales from rainfall and weathering during storage (i.e., barn, tarp, etc.).
Rain during curing	Avoid cutting if significant rainfall (> 0.50 inches) is predicted during curing.
Moisture at baling	Allow forage to dry to the appropriate moisture (Round: 15%; Square: 18%)
Variety	Use varieties that have proven to be higher in quality.
Fertilization	Provide fertilizer based on soil test recommendations.

Primary factors affecting forage quality

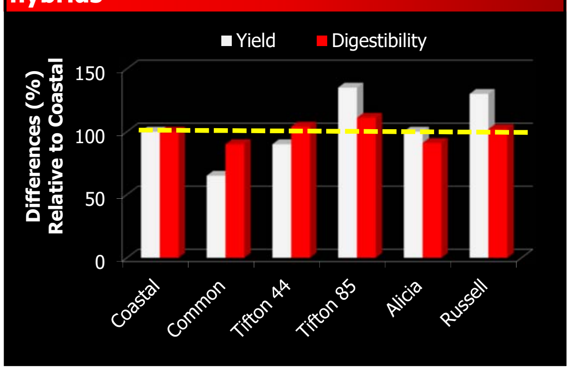
Factor	Recommendation
Plant Maturity	Cut bermudagrass every 4-5 wks; cut tall fescue in the boot or early head stage.
Forage Species	Use the highest-quality species that will persist in your environment.
Bale Storage	Protect bales from rainfall and weathering during storage (i.e., barn, tarp, etc.).
Rain during curing	Avoid cutting if significant rainfall (> 0.50 inches) is predicted during curing.
Moisture at baling	Allow forage to dry to the appropriate moisture (Round: 15%; Square: 18%)
Variety	Use varieties that have proven to be higher in quality.

Does fertility or harvest timing affect quality more? → Crude Protein

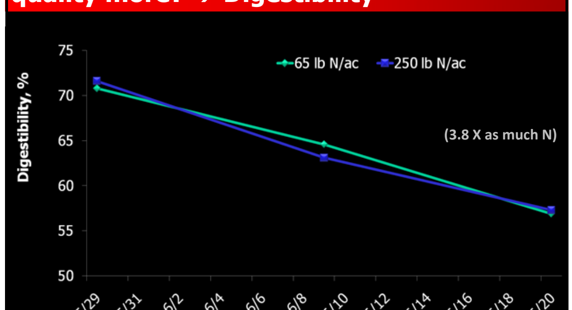


Bromegrass
Colovos et al. 1961

Yield and digestibility of bermudagrass hybrids



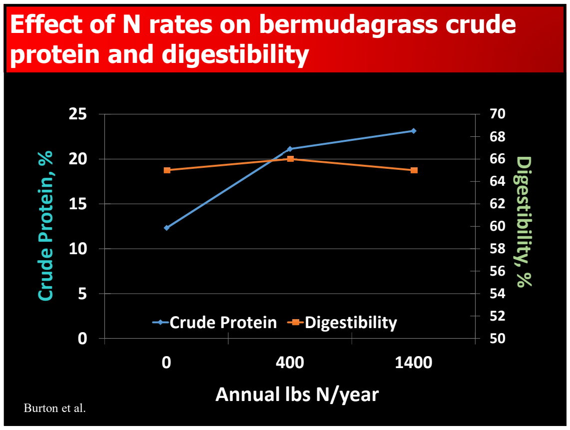
Does fertility or harvest timing affect quality more? → Digestibility



Bromegrass
Colovos et al. 1961

Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

Improving Forage Quality



Dr. Lisa Baxter
Post-Doc Associate & Forage Agronomist

Balancing a Ration Utilizing Hay Samples (Interactive)

Dr. Lawton Stewart, Extension Beef Cattle Nutritionist

Balancing a Ration Using Hay Samples

Balancing Rations Utilizing Hay Samples

Lawton Stewart
The University of Georgia
March 8, 2018

UNIVERSITY OF GEORGIA EXTENSION

G BEEF
UGABEEF.COM

Developing a Nutritional Strategy

1. Understand your production system
   - Fall Calving
   - Spring Calving
   - Continuous
2. Understand your forage system
   - Pasture
   - Conserved forage
3. Develop an economical supplement

What we want

Reproductive Efficiency

- The most important factor affecting profitability
- Highly dependent on proper nutrition

What we DO NOT want

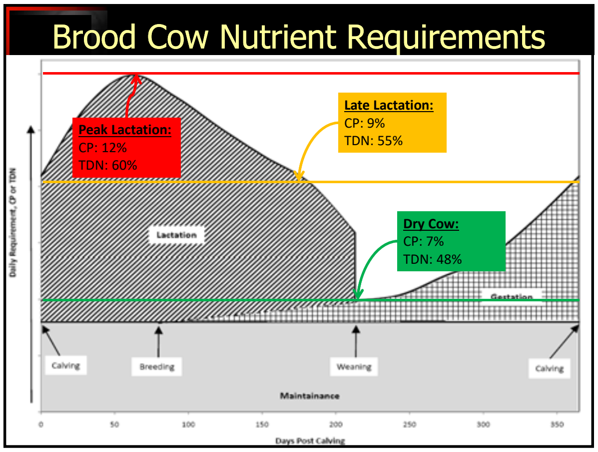
Nutrient Priorities

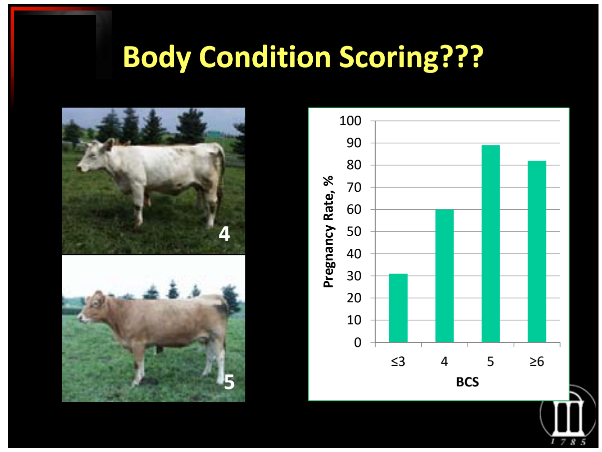
1. Maintenance
2. Growth (Heifers)
3. Lactation
4. Reproduction

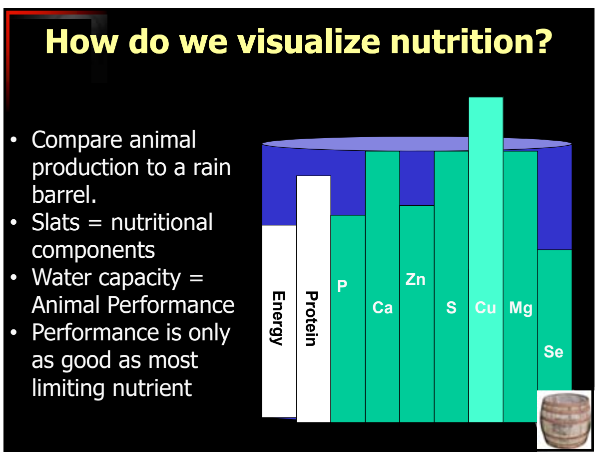
Dr. Lawton Stewart
Extension Animal Scientist

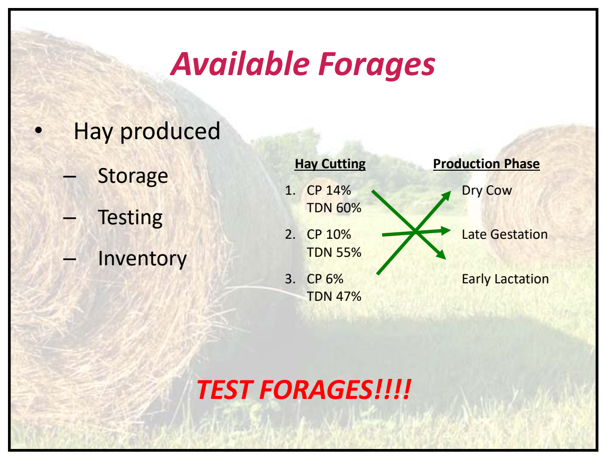
UGA extension

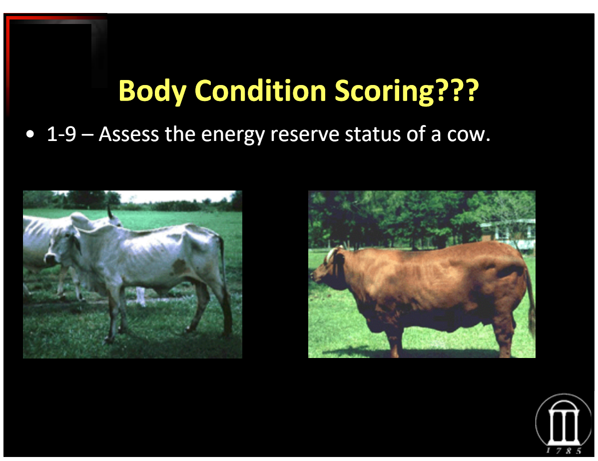
Balancing a Ration Using Hay Samples

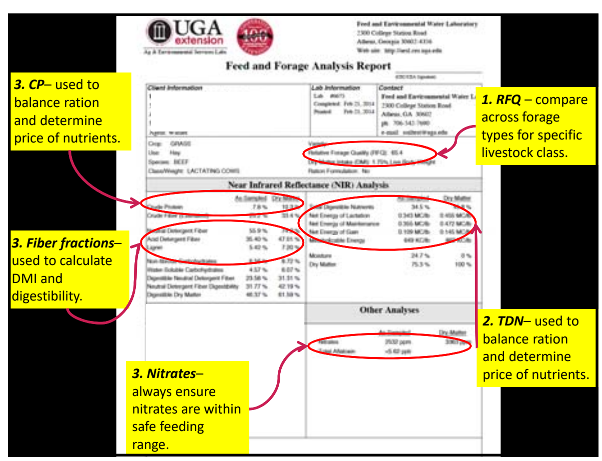






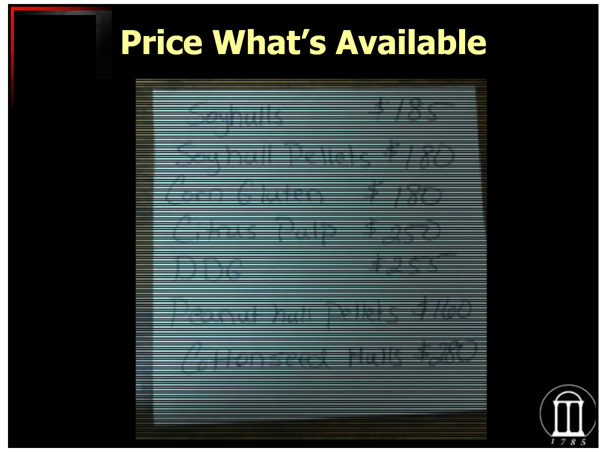


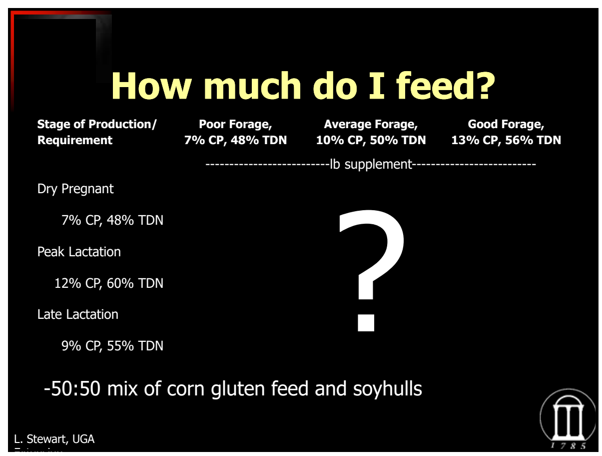


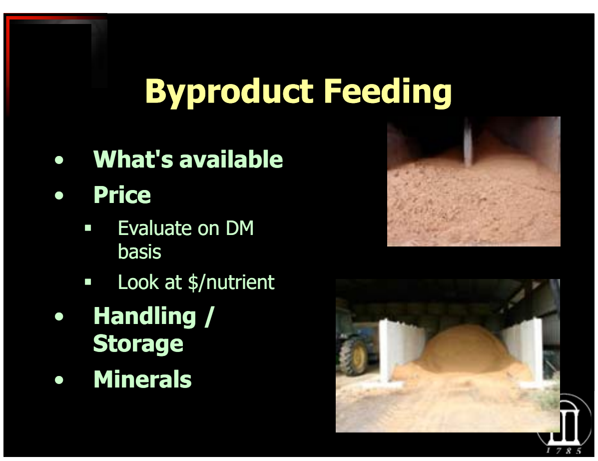


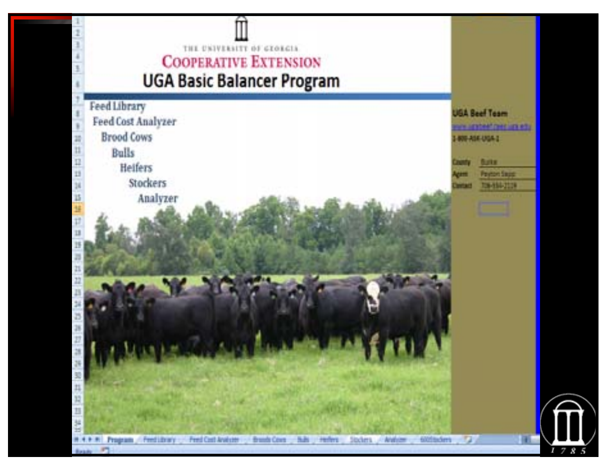
Dr. Lawton Stewart
Extension Animal Scientist

Balancing a Ration Using Hay Samples









Dr. Lawton Stewart
Extension Animal Scientist

UGA extension

Balancing a Ration Using Hay Samples

How much do I feed?

Stage of Production/ Requirement	Poor Forage, 7% CP, 48% TDN	Average Forage, 10% CP, 50% TDN	Good Forage, 13% CP, 56% TDN
		------------------------lb supplement------------------------	
Dry Pregnant			
7% CP, 48% TDN			
Peak Lactation			
12% CP, 60% TDN			
Late Lactation			
9% CP, 55% TDN			

Is buying hay the economic choice?

Hay replacement rations (1200 lb dry cow)

Ingredient	$/ton	Hay	Hay Replacement
Fair Hay (48% TDN, 7% CP)	$100	100%	--
Peanut Hulls	$60		60
Citrus Pulp	$225	--	20
Corn Gluten Feed	$215	--	20
Daily Intake, lbs		25	25
Cost/hd		**$1.25**	**$1.55**

Potential Supplement Strategies[1]

Forage	CP (%)	TDN (%)	Early Lactation	Late Lactation	Dry Cow	4-5 cwt Calves[2]
			----------------lb/head/day----------------			
Poor Forage	<5	<44	19.5	13	7	10
Fair Forage	6	48	17	8.5	-	8
Average Forage	10	54	8.5	2	-	6.5
Good Forage	12	60	-	-	-	5
Excellent	>12	>60	-	-	-	3-4

[1] Can be a 50:50 of an energy and protein supplement

Energy supplements: Soybean hulls, citrus pulp, grain, hominy

Protein supplements: Dried distillers grains, corn gluten feed, cottonseed meal, soybean meal, canola meal, sunflower meal

[2] To maintain 2 lb per day weight gain

Developing a Nutritional Strategy

1. Understand your production system
   - Fall Calving
   - Spring Calving
   - Continuous
2. Understand your forage system
   - Pasture
   - Conserved forage
3. Develop an economical supplement

What if hay is not available?

Hay replacement rations

- Consider weaning calves
- Utilize a roughage source such as peanut hulls, cottonseed hulls, cotton residue, corn residue, gin trash

Ingredient	Dry Cow	Early Lact.	Late Lact.
	-----------% of ration-----------		
Roughage	60	30	45
Energy and/or byproduct feed	40	45	45
Protein Source	--	25	10

Georgia Beef Commission

BEEF

Dr. Lawton Stewart
Extension Animal Scientist

UGA extension

Nutrient Requirements

Brood Cows - Average Milking

Prepared by:
Lawton Stewart - Extension Animal Scientist
Jacob Segers - Extension Animal Scientist

UGA extension

Legend

DMI = Dry Matter Intake
CP = Crude Protein
TDN = Total Digestible Nutrients
Ca = Calcium
P = Phosphorus

	Requirements				
	DMI	**CP**	**TDN**	**Ca**	**P**
	% of BW	------------------------%------------------------			
Dry Cow (Post Weaning)					
1,000 lb	1.81%	7.0	48	0.20	0.20
1,200 lb	1.86%	7.0	48	0.20	0.20
1,400 lb	1.78%	7.0	48	0.20	0.20
Late Gestation (3 mo pre-calving)					
1,000 lb	1.96%	8.0	53	0.26	0.21
1,200 lb	1.86%	8.0	53	0.26	0.21
1,400 lb	1.78%	8.0	53	0.26	0.21
Peak Lactation (First 3 mo post-calving)					
1,000 lb	2.10%	11.0	60	0.28	0.19
1,200 lb	2.00%	10.5	60	0.28	0.19
1,400 lb	1.91%	10.0	60	0.28	0.18
Late Lactation (Last 3 mo pre-weaning)					
1,000 lb	2.20%	9.0	55	0.24	0.17
1,200 lb	2.13%	9.0	54.5	0.24	0.17
1,400 lb	2.07%	9.0	54	0.24	0.17

Source: NRC, 2000. Adapted from NRC Nutrient Requirement of Beef Cattle

Nutrient Requirements

Heifers

Legend

DMI = Dry Matter Intake
CP = Crude Protein
TDN = Total Digestible Nutrients
Ca = Calcium
P = Phosphorus

Prepared by:
Lawton Stewart - Extension Animal Scientist
Jacob Segers - Extension Animal Scientist

	Requirements				
	DMI	CP	TDN	Ca	P
GROWING HEIFERS	% of BW	-----------------------	%	-----------------------	
BW 400 lb					
ADG - 1.0 lb/d	2.48%	10.2	62	0.36	0.20
1.5 lb/d	2.55%	11.4	68.5	0.45	0.24
2.0 lb/d	2.50%	12.9	77	0.57	0.29
BW 500 lb					
ADG - 1.0 lb/d	2.36%	9.4	62	0.30	0.21
1.5 lb/d	2.42%	10.3	68.5	0.38	0.22
2.0 lb/d	2.36%	11.4	77	0.45	0.24
BW 600 lb					
ADG - 1.0 lb/d	2.25%	8.8	62	0.28	0.20
1.5 lb/d	2.30%	9.5	68.5	0.32	21.00
2.0 lb/d	2.25%	10.4	77	0.38	0.23
BW 700 lb					
ADG - 1.0 lb/d	2.16%	8.4	62	0.25	0.19
1.5 lb/d	2.21%	9.0	68.5	0.28	0.20
2.0 lb/d	2.17%	9.6	77	0.32	0.22
BW 800 lb					
ADG - 1.0 lb/d	2.09%	8.1	62	0.22	0.18
1.5 lb/d	2.15%	8.5	68.5	0.24	0.19
2.0 lb/d	2.10%	9.0	77	0.28	0.19
PREGNANT HEIFERS					
ADG - 1.0 lb/d	2.02%	8.5	55.1	0.26	0.20
1.5 lb/d	2.11%	9.0	60	0.30	0.21
2.0 lb/d	2.14%	9.5	66	0.34	0.22
LACTATING HEIFERS					
	2.12%	11	63	0.34	0.24

Source: NRC, 2000. Adapted from NRC Nutrient Requirement of Beef Cattle

Nutrient Requirements

Growing Bulls

Prepared by:
Lawton Stewart - Extension Animal Scientist
Jacob Segers - Extension Animal Scientist

Legend

DMI = Dry Matter Intake
CP = Crude Protein
TDN = Total Digestible Nutrients
Ca = Calcium
P = Phosphorus

	Requirements				
	DMI	CP	TDN	Ca	P
	% of BW	----------------	%	----------------	
BW 400 lb					
ADG - 1.0 lb/d	2.58%	11.6	57.5	0.39	0.21
1.5 lb/d	2.68%	13.4	61.5	0.49	0.25
2.0 lb/d	2.75%	15.2	65.5	0.60	0.28
2.5 lb/d	2.78%	17.0	70	0.70	0.32
3.0 lb/d	2.70%	19.3	76.5	0.84	0.37
BW 600 lb					
ADG - 1.0 lb/d	2.32%	9.2	57.5	0.30	0.79
1.5 lb/d	2.42%	10.0	61.5	0.36	0.21
2.0 lb/d	2.48%	10.8	65.5	0.43	0.24
2.5 lb/d	2.50%	11.6	70	0.50	0.25
3.0 lb/d	2.45%	12.7	76.5	0.57	0.29
BW 800 lb					
ADG - 1.0 lb/d	2.16%	8.4	57.5	0.25	0.19
1.5 lb/d	2.25%	9.0	61.5	0.29	0.20
2.0 lb/d	2.31%	9.5	65.5	0.33	0.21
2.5 lb/d	2.33%	10.1	70	0.38	0.23
3.0 lb/d	2.28%	10.8	76.5	0.44	0.24
BW 1,000 lb					
ADG - 1.0 lb/d	2.04%	8.0	57.5	0.24	0.19
1.5 lb/d	2.13%	8.4	61.5	0.26	0.19
2.0 lb/d	2.18%	8.7	65.5	0.28	0.19
2.5 lb/d	2.20%	9.1	70	0.31	0.20
3.0 lb/d	2.15%	9.6	76.5	35.00	0.21
BW 1,500 lb					
ADG - 2.0 lb/d	1.70%	6.1	65	0.22	0.19
BW 2,000 lb					
ADG - 0.0 lb/d	2.10%	6.8	48.5	0.22	0.19

Source: NRC, 2000. Adapted from NRC Nutrient Requirement of Beef Cattle

Nutrient Requirements

Medium-Frame Steer Calves

Prepared by:
Lawton Stewart - Extension Animal Scientist
Jacob Segers - Extension Animal Scientist

Legend

DMI = Dry Matter Intake
CP = Crude Protein
TDN = Total Digestible Nutrients
Ca = Calcium
P = Phosphorus

	Requirements				
	DMI	CP	TDN	Ca	P
	% of BW	-----------------	%	-----------------	
BW 400 lb					
ADG - 1.0 lb/d	2.60%	10.3	58.5	0.38	0.21
1.5 lb/d	2.70%	11.5	63	0.47	0.25
2.0 lb/d	2.75%	12.7	67.5	0.56	0.26
2.5 lb/d	2.75%	14.2	73.5	0.68	0.30
3.0 lb/d	2.50%	16.6	85	0.86	0.37
BW 500 lb					
ADG - 1.0 lb/d	2.46%	9.5	58.5	0.32	0.20
1.5 lb/d	2.56%	10.5	63	0.40	0.22
2.0 lb/d	2.62%	11.4	67.5	0.47	0.24
2.5 lb/d	2.60%	12.5	73.5	0.56	0.27
3.0 lb/d	2.36%	14.4	85	0.69	0.32
BW 600 lb					
ADG - 1.0 lb/d	2.35%	9.0	58.5	0.28	0.19
1.5 lb/d	2.45%	9.8	63	0.35	0.21
2.0 lb/d	2.50%	10.5	67.5	0.40	0.22
2.5 lb/d	2.48%	11.4	73.5	0.46	0.24
3.0 lb/d	2.25%	12.9	85	0.57	0.29
BW 700 lb					
ADG - 1.0 lb/d	2.26%	8.6	58.5	0.27	0.18
1.5 lb/d	2.36%	9.2	63	0.31	0.20
2.0 lb/d	2.40%	9.8	67.5	0.34	0.21
2.5 lb/d	2.39%	10.5	73.5	0.40	0.22
3.0 lb/d	2.17%	11.7	85	0.49	0.26
BW 800+ lb					
ADG - 1.0 lb/d	2.19%	8.0	58.5	0.23	0.18
1.5 lb/d	2.28%	8.4	63	0.25	0.19
2.0 lb/d	2.33%	8.8	67.5	0.28	0.20
2.5 lb/d	2.31%	9.3	73.5	0.31	0.20
3.0 lb/d	2.10%	10.1	85	0.37	0.23

Source: NRC, 2000. Adapted from NRC Nutrient Requirement of Beef Cattle

UGA Basic Balancer Instructions

Prepared by Lawton Stewart, Extension animal scientist; Dennis Hancock, Extension forage specialist; and Jacob Segers, Extension animal scientist

Introduction

The UGA Basic Balancer is a spreadsheet based decision aid to formulate basic rations for beef cattle operations. The nutrient requirements used in this program are adapted from guidelines presented in the 2000 National Research Council publication "Nutrient Requirement of Beef Cattle: Seventh Revised Edition: Update 2000." This program consists of a feed library, least cost feedstuff analyzer, a ration analyzer, and sections to balance rations for brood cows, bulls, heifers, and stockers. This document gives step-by-step instructions on how to use this program. The program is available for download on the UGA Beef Team Website (www.ugabeef.com/tools.html) or at http://extension.uga.edu/publications/detail.cfm?number=B1371.

Disclaimer

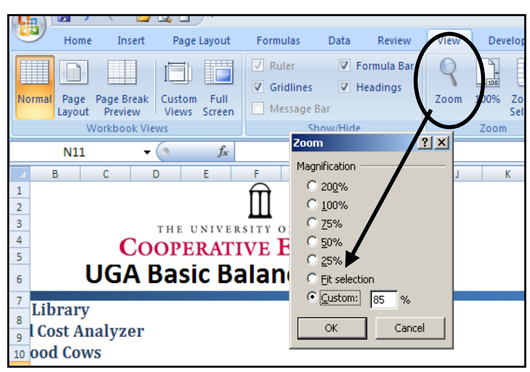
The UGA Basic Balancer is intended to be a simple ration balancer that addresses energy (TDN) and crude protein (CP) requirements of cattle. This program does not take into consideration other requirements or limitations (e.g. micro minerals, fat level, effective fiber, nonstructural carbohydrates, etc.). Before feeding any rations developed in this program, contact your local Extension office to address any potential problem.

System Requirements

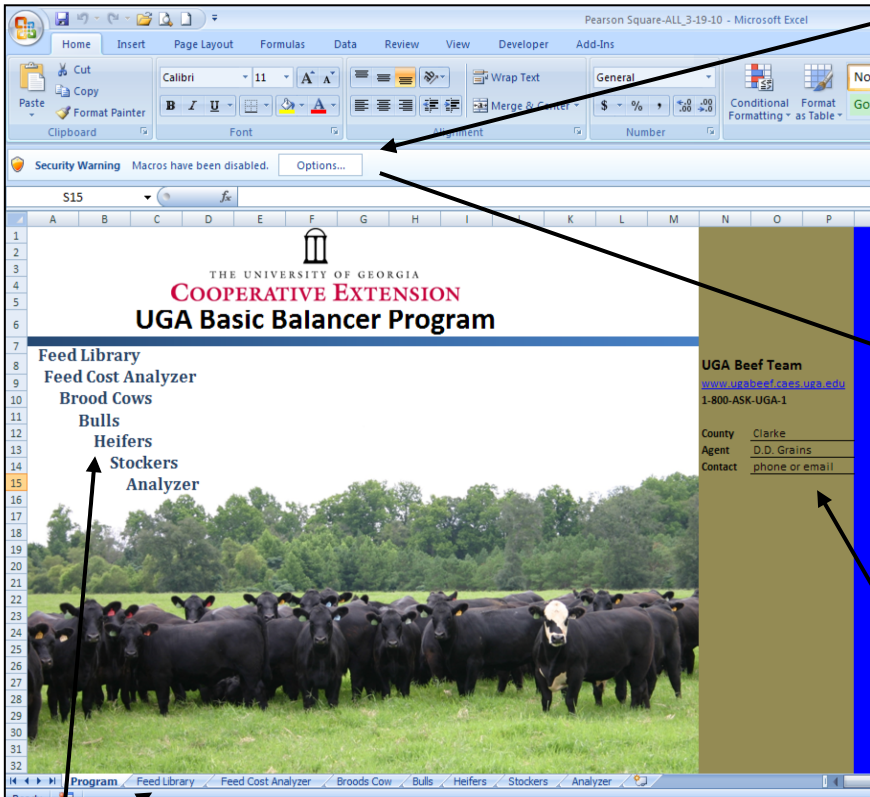
This program was developed to run on Microsoft Excel 2007 or later. Using an earlier version of Excel, or another spreadsheet software, may result in some loss of functionality. Check for free software patches that are available from Microsoft's website (http://support.microsoft.com) for your version of Windows and Excel. If you are already using Excel 2007, be sure to check for and download the latest patches to prevent graphics from becoming distorted when viewing the screens.

Viewing the Program

This program was developed for use on a widescreen monitor. If all components of a given spreadsheet are not visible on your screen, adjust the view by selecting the "View" tab, "Zoom," and adjusting the screen size.

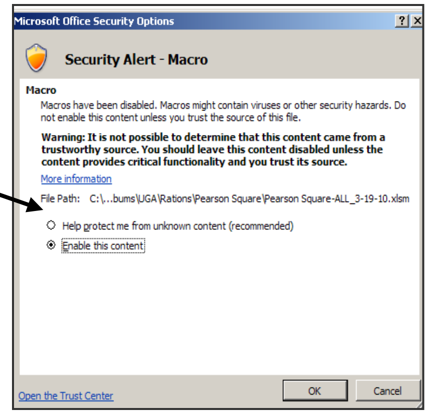


Program Page



Macros

Macros must be enabled to maintain full function of the spreadsheet.

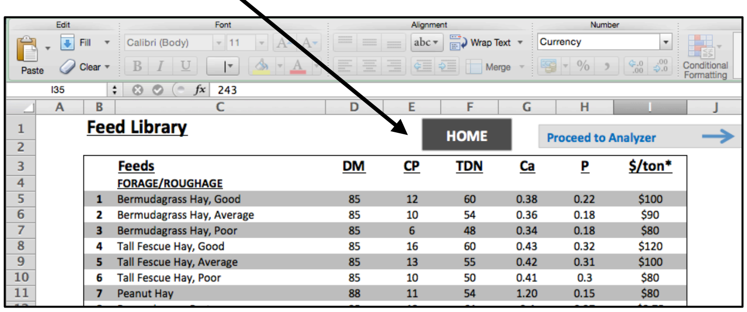


Contact Information

County Extension agents should enter their info so that it is incorporated into the report sheets.

Tabs and Links

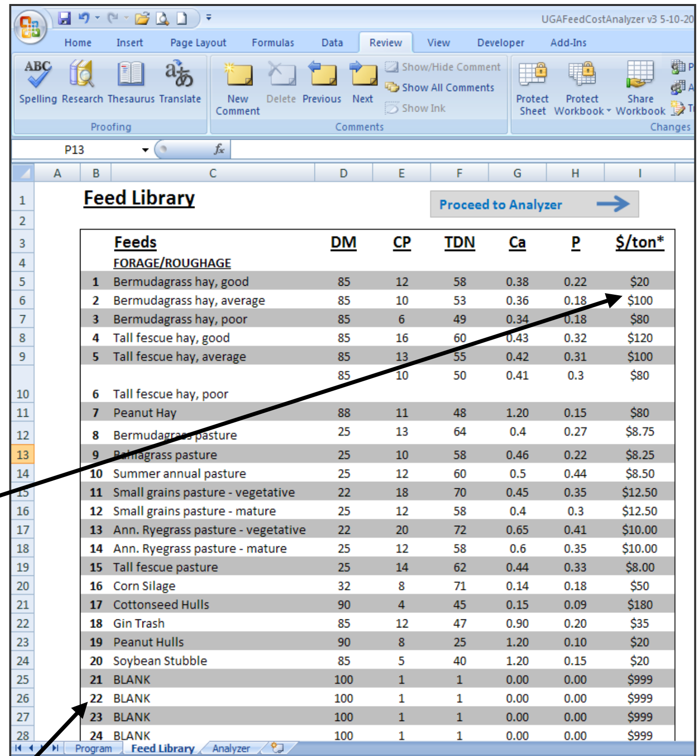
Each section of the workbook can be accessed through links on the main program page or the tabs across the bottom of the workbook. Also, the homepage is accessible on subsequent pages by following the "**HOME**" link located at the top of each section.



	Feeds	DM	CP	TDN	Ca	P	$/ton*
	FORAGE/ROUGHAGE						
1	Bermudagrass Hay, Good	85	12	60	0.38	0.22	$100
2	Bermudagrass Hay, Average	85	10	54	0.36	0.18	$90
3	Bermudagrass Hay, Poor	85	6	48	0.34	0.18	$80
4	Tall Fescue Hay, Good	85	16	60	0.43	0.32	$120
5	Tall Fescue Hay, Average	85	13	55	0.42	0.31	$100
6	Tall Fescue Hay, Poor	85	10	50	0.41	0.3	$80
7	Peanut Hay	88	11	54	1.20	0.15	$80

Feed Library

- The feed library comes pre-populated with several common feedstuffs.
- The ingredients are categorized by feed type (forage/roughage, protein, energy, and mineral).
- The nutritive value of these feeds are listed based on the 2000 NRC. If an individual analysis of feed has been performed, values can be updated for a given feedstuff (**highly recommended**, especially for forages).
- Prices should be updated regularly to ensure proper calculations of feed costs. Prices are obtained by contacting your local feed supplier. A list of commodity feed sources can be found on the UGA Beef Team website: www.ugabeef.com/tools.
- Blanks are provided for additional feeds to be added to the library.

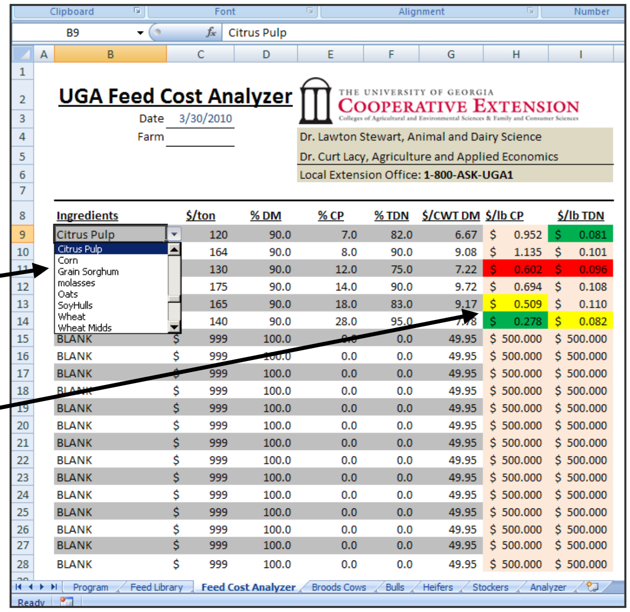


Feed Library — Proceed to Analyzer

	Feeds	DM	CP	TDN	Ca	P	$/ton*
	FORAGE/ROUGHAGE						
1	Bermudagrass hay, good	85	12	58	0.38	0.22	$20
2	Bermudagrass hay, average	85	10	53	0.36	0.18	$100
3	Bermudagrass hay, poor	85	6	49	0.34	0.18	$80
4	Tall fescue hay, good	85	16	60	0.43	0.32	$120
5	Tall fescue hay, average	85	13	55	0.42	0.31	$100
6	Tall fescue hay, poor	85	10	50	0.41	0.3	$80
7	Peanut Hay	88	11	48	1.20	0.15	$80
8	Bermudagrass pasture	25	13	64	0.4	0.27	$8.75
9	Bahiagrass pasture	25	10	58	0.46	0.22	$8.25
10	Summer annual pasture	25	12	60	0.5	0.44	$8.50
11	Small grains pasture - vegetative	22	18	70	0.45	0.35	$12.50
12	Small grains pasture - mature	25	12	58	0.4	0.3	$12.50
13	Ann. Ryegrass pasture - vegetative	22	20	72	0.65	0.41	$10.00
14	Ann. Ryegrass pasture - mature	25	12	58	0.6	0.35	$10.00
15	Tall fescue pasture	25	14	62	0.44	0.33	$8.00
16	Corn Silage	32	8	71	0.14	0.18	$50
17	Cottonseed Hulls	90	4	45	0.15	0.09	$180
18	Gin Trash	85	12	47	0.90	0.20	$35
19	Peanut Hulls	90	8	25	1.20	0.10	$20
20	Soybean Stubble	85	5	40	1.20	0.15	$20
21	BLANK	100	1	1	0.00	0.00	$999
22	BLANK	100	1	1	0.00	0.00	$999
23	BLANK	100	1	1	0.00	0.00	$999
24	BLANK	100	1	1	0.00	0.00	$999

Feed Cost Analyzer

The UGA Feed Cost Analyzer is also available as an individual spreadsheet. This spreadsheet allows side-by-side comparison of feeds to identify the least cost options for crude protein (CP) and energy (TDN) feeds.



Ingredients	$/ton	% DM	% CP	% TDN	$/CWT DM	$/lb CP	$/lb TDN
Citrus Pulp	120	90.0	7.0	82.0	6.67	$ 0.952	$ 0.081
	164	90.0	8.0	90.0	9.08	$ 1.135	$ 0.101
	130	90.0	12.0	75.0	7.22	$ 0.602	$ 0.096
	175	90.0	14.0	90.0	9.72	$ 0.694	$ 0.108
	165	90.0	18.0	83.0	9.17	$ 0.509	$ 0.110
	140	90.0	28.0	95.0	7.78	$ 0.278	$ 0.082
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
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BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
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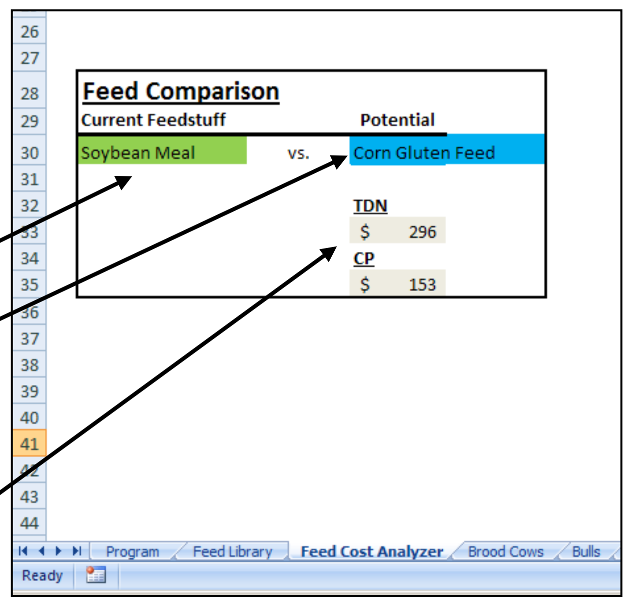
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000
BLANK	$ 999	100.0	0.0	0.0	49.95	$ 500.000	$ 500.000

- Feed ingredients to be compared can be selected from a drop down menu (populated from the Feed Library).
- The least cost feed analyzed as $/pound of CP will be highlighted green, second will be yellow, and third will be red.
- The same least cost analysis will be performed for $/pound of TDN.
- The spreadsheet will allow for up to 20 feeds to be compared simultaneously.
- To include a feedstuff that is not in the Feed Library, edit a "BLANK" entry on the Feed Library sheet and then select it from the drop-down menu.
- To remove a feed from the analyzer, select "BLANK" from the drop-down menu in the ingredients column.

Feed Comparison

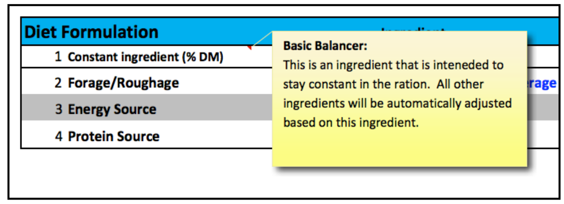
The Feed Comparison tool on the Feed Cost Analyzer page calculates the price a potential feed needs to be equal to or lower than in order to replace a current feed as a CP or TDN supplement.



- In this example, soybean meal is the current source of CP, and corn gluten feed is considered as a replacement.
- Feeds to be compared can be selected from a drop-down menu (populated from the **Feed Library**).
- The price at which the potential feed (corn gluten) must be, or lower, to replace the current feed (SBM) will be listed for both TDN and CP.
- In this example, corn gluten feed must be less than $153/ton to replace soybean meal as a CP supplement at <u>its current price</u>. *PLEASE NOTE:* these prices only indicate the value of replacing a feedstuff as source of TDN or CP. It DOES NOT take into consideration the value, or lack of, other nutrients.

Balancer Worksheets

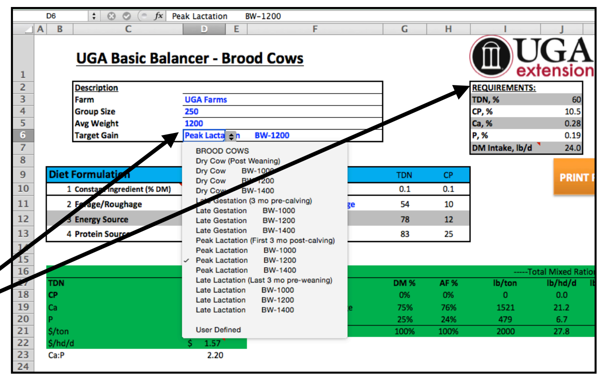
A spreadsheet is available for each class of cattle (brood cows, bulls, heifers, and stockers). Each spreadsheet has the same basic design, but the specifics differ based on the nutrient requirements of that animal class. Throughout the sections, **only change the cells with blue font**. Changing other cells will cause a loss of function and incorrect diet formulation. Notes are available to explain the content of cells with a small red triangle in the upper, right corner. Scrolling over the cell will make the note appear. When trying to formulate a least cost ration, it is advised to start by determining the least cost feed ingredients for forage, CP, and energy from the Feed Cost Analyzer**.** Please note that this program does not take into consideration safe feeding levels of any feeds (e.g., corn gluten feed, distillers grains, etc.) or the value of other nutrients. Consult with your county Extension agent to determine if feeding certain levels of a given feed is safe.

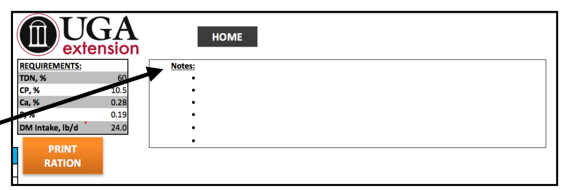


Example of Displaying an Informational Note

Getting Started

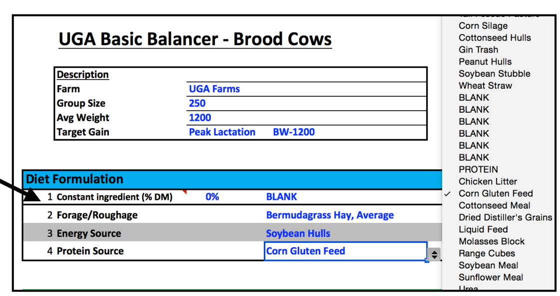
- Start by describing the group of cattle of interest. This includes the farm name, number of head, average weight of the group, and the target gain (stage of production). Note the target gain/stage of production will be from a drop down menu.
- The requirements will be based on the target gain/stage of production and will be listed.
- If any notes need to be recorded for the ration session, they can be made in the notes box and will be incorporated into the printed report.





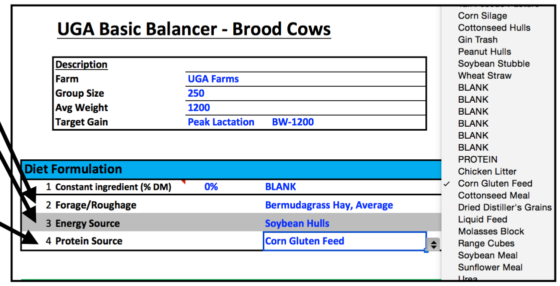
Diet Formulation

The spreadsheet is designed to handle up to four ingredients.



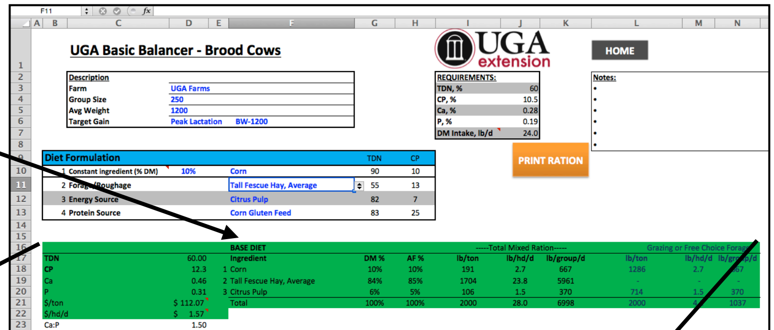
1. **Constant Ingredient.** Any ingredient that is intended to be held constant in the diet (e.g., a producer has corn on hand and wants to use it up, even though there are additional ingredients available and more economical). Choose from the drop-down menu populated from the Feed Library. Next determine the percentage of inclusion in the diet (dry matter basis). If a constant ingredient is not to be used, select BLANK from the drop-down menu and 0% for the inclusion rate.

2. **Forage/Roughage.** Choose the forage base in the diet. Select from the drop-down menu populated from the Feed Library.
3. **Energy Source.** Choose an ingredient to serve as an energy (TDN) supplement.
4. **Protein Source.** Choose an ingredient to serve as a protein (CP) supplement.



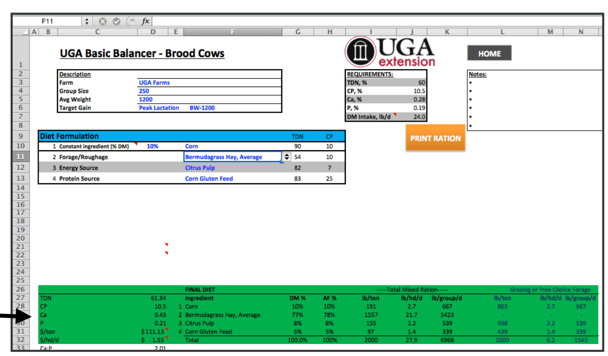
Interpreting the Diet

Based on the "Constant Ingredient" and the first two ingredients, a base diet ration is formulated. Note that the fourth ingredient is used only if ingredients 1, 2, and 3 do not meet the CP requirement.



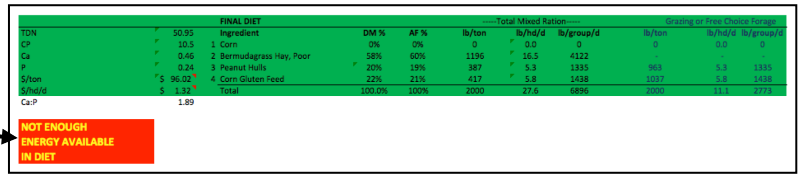
		BASE DIET	-----Total Mixed Ration-----					Grazing or Free Choice Forage		
TDN	60.00	Ingredient	DM %	AF %	lb/ton	lb/hd/d	lb/group/d	lb/ton	lb/hd/d	lb/group/d
CP	12.3	1 Corn	10%	10%	191	2.7	667	1286	2.7	667
Ca	0.46	2 Tall Fescue Hay, Average	84%	85%	1704	23.8	5961	-	-	-
P	0.31	3 Citrus Pulp	6%	5%	106	1.5	370	714	1.5	370
$/ton	$ 112.07	Total	100%	100%	2000	28.0	6998	2000	4.1	1037
$/hd/d	$ 1.57									
Ca:P	1.50									

- The diet will be characterized on the left-hand side of the "Base Diet" box. Note that $/ton and $/head/day **include forage costs.** If the cost of a supplement without the cost of forage is wanted, enter $0 for the cost of the particular forage in the Feed Library.
- The ingredient amounts will be given on a pound per ton, pound per head per day, and pound per group per day basis (AF) as a "**Total Mixed Ration"** and "**Grazing or Free Choice Forage."** Total Mixed Ration is reported for producers that will mix all feeds together (i.e., corn silage based diets, ground hay, etc.). Grazing or free choice is reported for producers that will provide forage as grazing or free choice hay and only need to mix the supplemental components
- If the TDN and CP requirements are met without using the ingredient selected as the "Protein Source," then this ingredient will not be include in the **BASE DIET**. However, if CP is deficient, the program will automatically incorporate the "Protein Source" ingredient and provide a **FINAL DIET**.

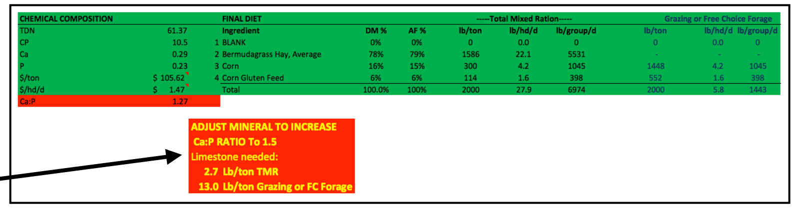


Errors

Two errors may occur during formulation:



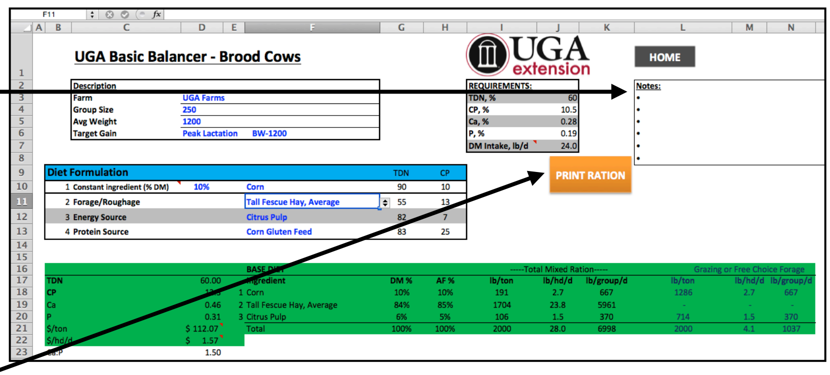
1. **Not enough energy.** The ration developed does not contain enough TDN. This occurs when the diet is balanced for CP first or when too many low-energy feeds are used.



2. **Adjust mineral.** The ration developed needs additional calcium to maintain a Ca:P ration above 1.5:1. This is common when using feeds such as corn gluten feed and distiller's grains that are high in P. This can be corrected by using a limestone or a low-P mineral. The program will calculate the amount of limestone needed to mix into a ton of feed to be delivered in a TMR or in a supplement to grazing or free choice forage. Note that this program does not account for other macro/micro minerals or vitamins.

Notes

While working on a specific diet, notes can be recorded specific to the ration, producer, feeding situation, etc. These will be incorporated into the final report.

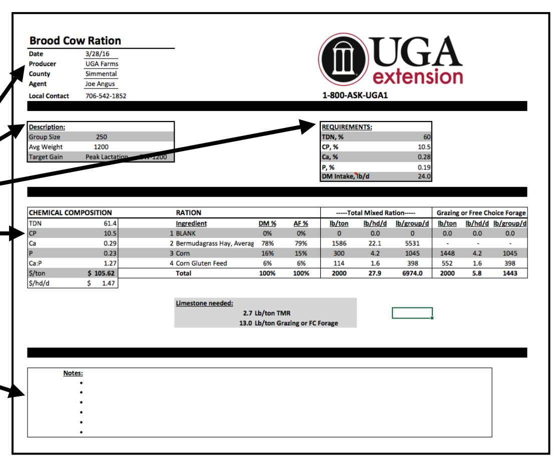


Printing a Report

Once the diet is formulated, a report can be printed with the final diet. Select the orange "Print Ration" button (macros must be enabled to allow this function to work). *NOTE:* This macro will not work on Mac computers. Mac users should follow the print command under "File" or press the "Command" key and "P" key simultaneously.

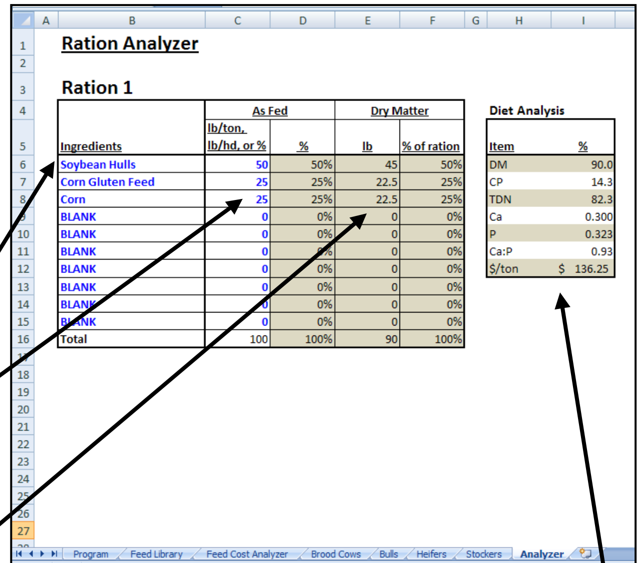
A print preview screen will appear for the formulated ration. This ration summary sheet will include:

- The producer and county agent information previously entered.
- The description of the cattle and requirements.
- The diet ration formulated.
- Any notes about the ration.



Ration Analyzer

The ration analyzer allows custom mixes to be analyzed for nutritional value and price. This will aid in evaluating premixed feeds and custom rations of known ingredient amounts. These results can be incorporated into the Feed Library by replacing a BLANK. Only change cells with blue text.



Ration Analyzer

Ration 1

Ingredients	As Fed: lb/ton, lb/hd, or %	As Fed: %	Dry Matter: lb	Dry Matter: % of ration
Soybean Hulls	50	50%	45	50%
Corn Gluten Feed	25	25%	22.5	25%
Corn	25	25%	22.5	25%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
BLANK	0	0%	0	0%
Total	100	100%	90	100%

Diet Analysis

Item	%
DM	90.0
CP	14.3
TDN	82.3
Ca	0.300
P	0.323
Ca:P	0.93
$/ton	$ 136.25

- Ingredients can be selected from the drop-down menu, which is populated from the Feed Library.
- Enter amounts as pounds/ton, pounds/head or percent of ration.
- Percent of ration as fed, pounds of dry matter, and percent of ration (dry matter) will be calculated automatically.
- The diet analysis will be calculated based on nutritional values entered in the Feed Library. (Remember: these are based on NRC listed values unless otherwise entered by the user.)

A second ration analyzer is available to the right of “Ration 1” (not shown) to allow side-by-side comparison of custom rations.

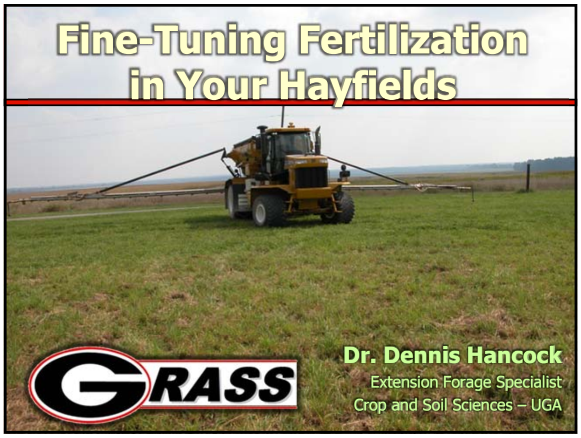
For questions or support for the program,
please contact your local extension office (1-800-ASK-UGA-1).

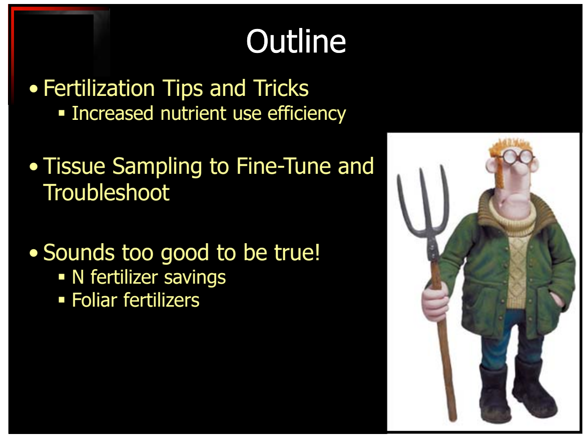
Bulletin 1371 / Revised May 2016

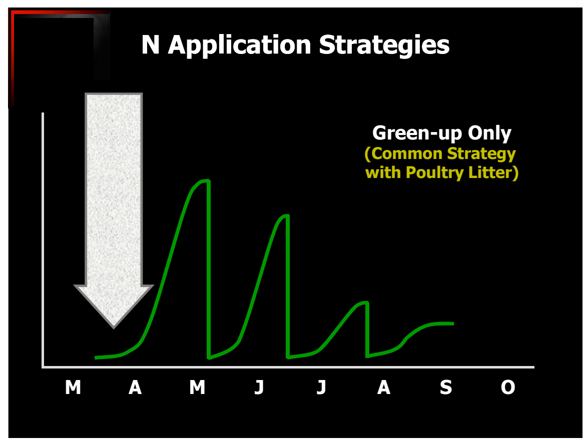
Fine-Tuning Forage Fertilization

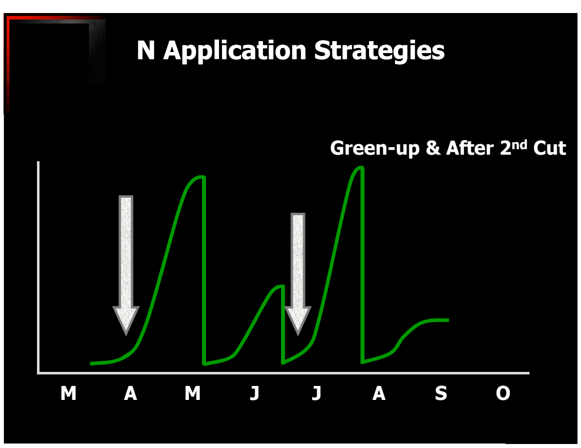
Dr. Dennis Hancock, Extension Forage Agronomist

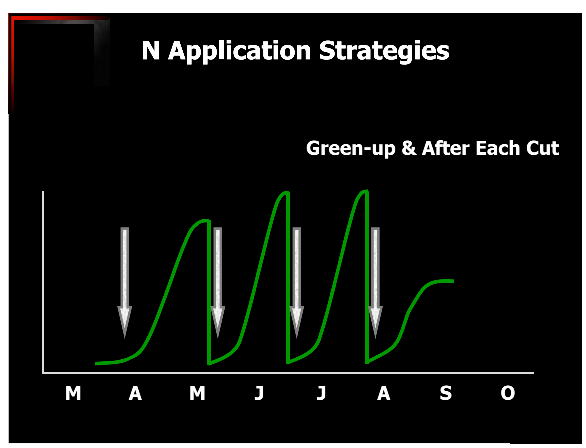
Fine-tuning Fertilization in Your Hayfields





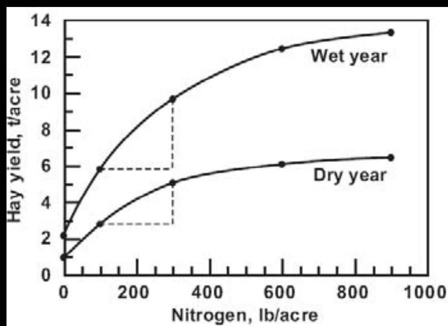






Fine-tuning Fertilization in Your Hayfields

Hybrid Bermudagrass Yield Response to N Rate



Nitrogen Response: Rules of Thumb

Forage Type	N Response Above Critical Level* Early Season	Mid-Season	Late-Season
	------- lb of DM/lb of N added -------		
Coastal bermuda	30-45	35-45	20-35
Tifton 85 bermuda	30-40	45-55	30-40
Annual ryegrass	5-12	10-20	15-30

* N fertilization above an annual ~40, 50, or 25 lbs of N/acre for Coastal, Tifton 85, and ryegrass, respectively.

Cost Implications of Different Nitrogen Response Rates

	Cost of N, $/lb of N $0.50	$0.60	$0.75	$1.00
Nitrogen Response	N Cost of Additional Production			
lbs of DM/lb of N	------------------------- $/lb of DM -------------------------			
5	$0.100	$0.120	$0.150	$0.200
10	$0.050	$0.060	$0.075	$0.100
15	$0.033	$0.040	$0.050	$0.067
20	$0.025	$0.030	$0.038	$0.050
25	$0.020	$0.024	$0.030	$0.040
30	$0.017	$0.020	$0.025	$0.033
35	$0.014	$0.017	$0.021	$0.029
40	$0.013	$0.015	$0.019	$0.025
45	$0.011	$0.013	$0.017	$0.022
50	$0.010	$0.012	$0.015	$0.020
55	$0.009	$0.011	$0.014	$0.018

Fertilization Trick

Account for N Loss from Urea-based Products

The Effectiveness of Some Alternative N Sources at Low, Medium, and High Fertilization Rates on Hybrid Bermudagrasses (Relative to Ammonium Nitrate).

Nitrogen Source	Fertilization Rates < 200 lbs*	250-350 lbs	> 400 lbs
Ammonium Nitrate	100%	100%	100%
Amm. Sulfate	95-97%	95-105%	60-70%
Anhyd. Ammonia	92-94%	93-95%	94-95%
UAN Solution	80-85%	85-92%	92-95%
Urea	79-82%	82-92%	88-93%

* Actual lbs of N per acre per year.
Source: Burton and Jackson, 1962; Silveria et al., 2007.

Use of Urea-Based Products

- Without AN, users of N face risky alternatives.
  - NH_3 volatilization loss
- Urease is abundant in thatch & organic layers
  - High N use in hay.
- Enhanced Efficiency N Fertilizer Products may reduce volatilization loss
  - Urease inhibition
  - Encapsulate & release


Ammonium Nitrate


Urea

AGROTAIN — NBPT

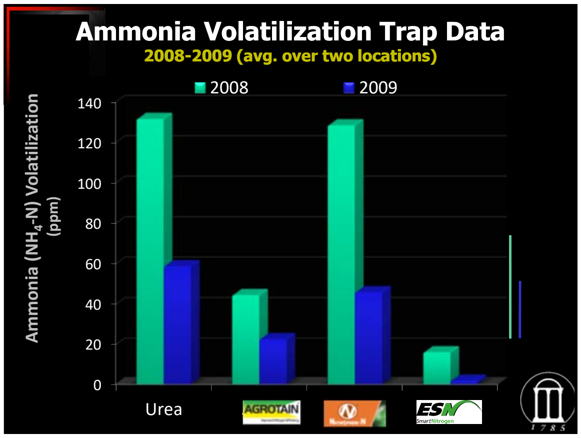
ESN SmartNitrogen — Polymer Coating

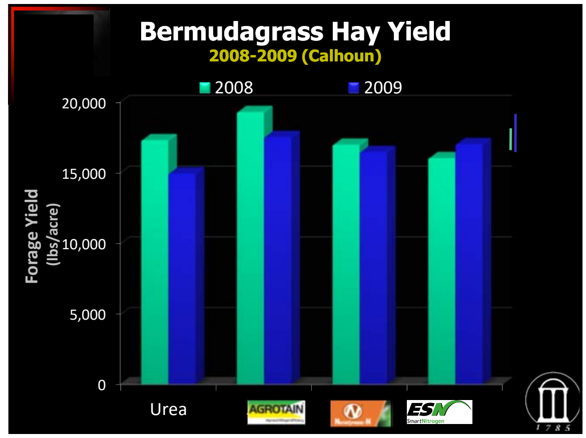
NutriSphere-N — maleic-itaconic co-polymer

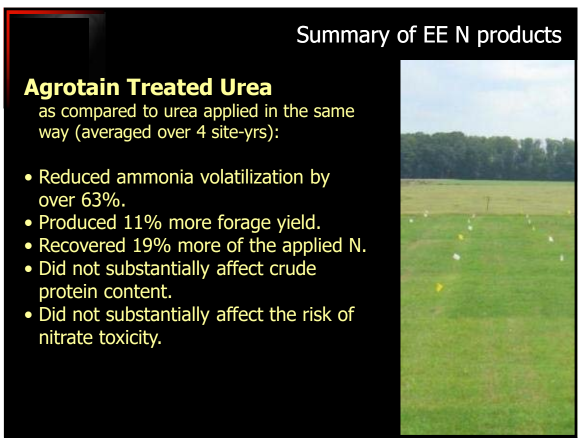
Dr. Dennis Hancock
Extension Forage Agronomist

GRASS

Fine-tuning Fertilization in Your Hayfields







Dr. Dennis Hancock
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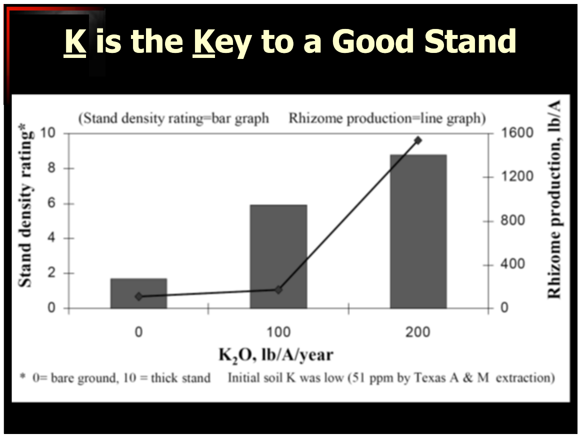
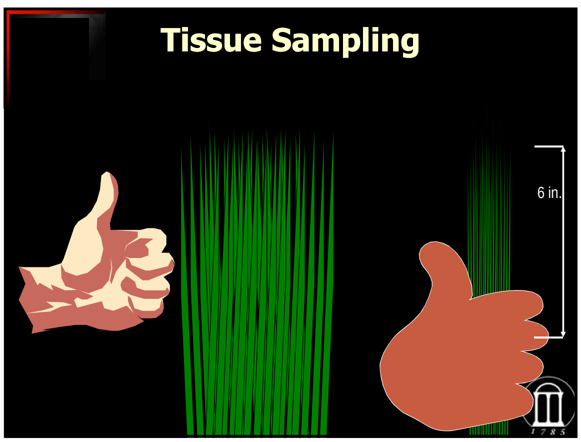
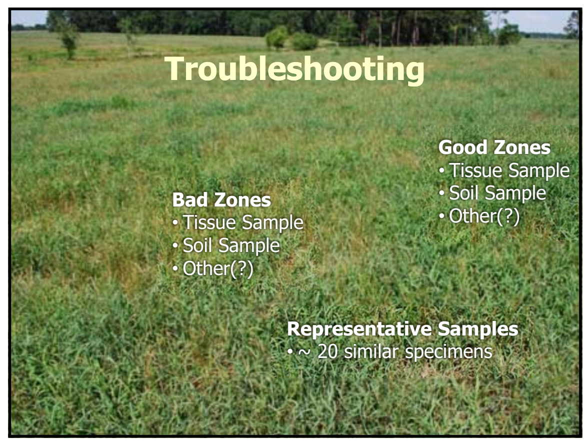
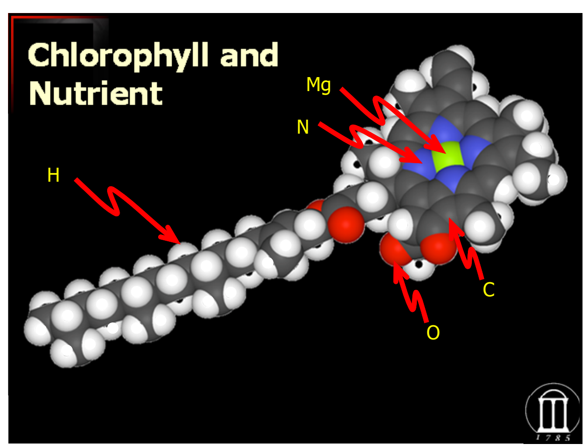
Fine-tuning Fertilization in Your Hayfields







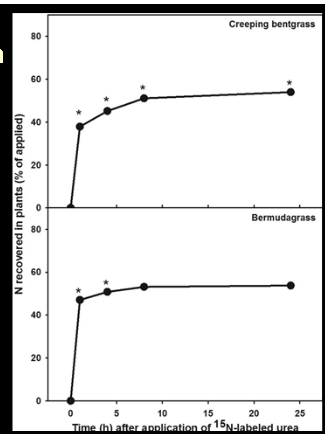


Dr. Dennis Hancock
Extension Forage Agronomist

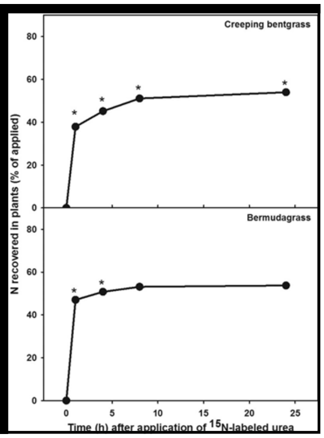
Fine-tuning Fertilization in Your Hayfields

Foliar Fertilization for Forage Crops?

- Over 50% of applied N is absorbed in < 5 hrs.
- But, this is at relatively low rates
  - Avg. over 4.5 and 11 lbs of N/acre in this study.
  - Stiegler et al., 2010. Crop Sci. 51:1253-1260.



- Even if 60% absorption, at rate of 11 lbs/acre, that's only 6.7 lbs of N absorbed foliar.
  - Highest rate of absorption I could find in literature.
- At higher rates, foliar fertilizers often burn (salt or chemical injury) the plant tissue
- In a separate study (Totten et al., 2008. J. Plant Nutr. 31:972-982), no consistent difference in clipping yield of turf.



Calculations Using 42-0-0

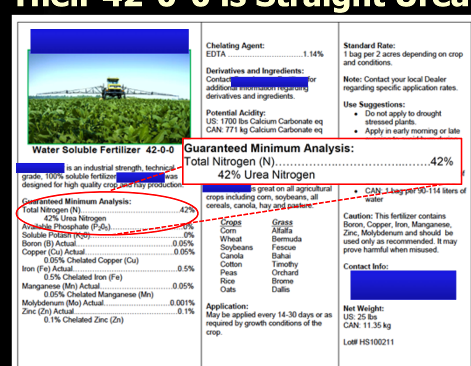
- Five 25-lb bags/100 gallons of spray = 10 A
  - 125 lbs of product/10 A or 12.5 lbs of product/A
  - 12.5 lbs x 42% N = 5.25 lbs of N/A
- 42% N x 25 lbs = 10.5 lbs of N
- \$47/bag / 10.5 lbs of N = \$4.48 per lb of N
- Ammon. Nitrate is currently ~\$0.70 per lb of N

Calculations Using 42-0-0

- Let's assume 4 applications of 75 lbs of N/acre
  - Conventional: 4 x 75 lbs x \$0.70/lb= \$210
    - Plus: spreading costs
  - Liquid product (their rate): 4 x 5.25 lbs x \$4.48/lb = \$94
  - " (rec. N rate): 4 x 75 lbs x \$4.48/lb = \$1344
    - Plus: water and spreading costs
- 1-ton of bermudagrass, @ 1.6% N = 32 lbs of N

Bottomline: their math doesn't add up (5.25 < 32).

Their 42-0-0 is Straight Urea!



Dr. Dennis Hancock
Extension Forage Agronomist

Fine-tuning Fertilization in Your Hayfields

Foliar Fertilizer Applications

- Even if the product is 100% efficient (likely isn't)
- The most a plant can take up across via the leaves is the equivalent of 10-12 lbs/acre of the nutrient
  - Works for many micro-nutrients (small quantities needed)
  - Not feasible for macro-nutrients without multiple applications. (large quantities needed)

Soil and Fertilizer Management Considerations for Forage Systems in Georgia

Dennis W. Hancock, Extension Agronomist - Forage Crops, Crop & Soil Sciences Dept.
Glen H. Harris, Extension Agronomist - Soils and Fertilizer, Crop & Soil Sciences Dept.
Randy W. Franks, County Extension Coordinator, Wayne County
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Exploring a Soil's Characteristics

When designing a forage management system, it is important to understand the soil environment of the site. There are four levels or scales that must be considered when developing a management plan for a specific site: the geographic region, soil province, soil types, and site-specific conditions (Figure 1).

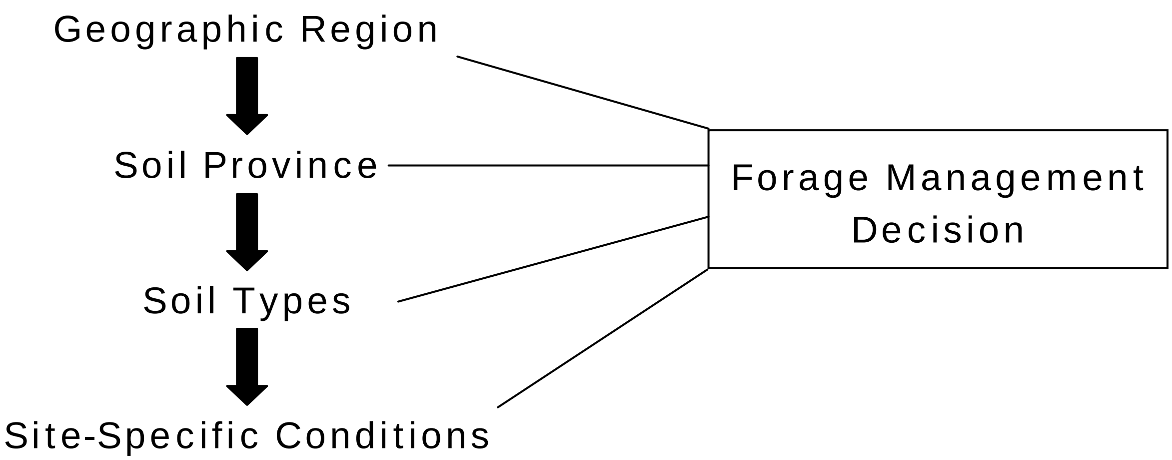

Figure 1. Forage management decisions are affected by soil characteristics on four basic scales.

Geographic Regions in Georgia

Essentially, Georgia can be thought of as having three main geographic regions: 1) the Limestone Valley/Mountains Region, 2) the Piedmont Region and 3) the Coastal Plain Region (Figure 2). Some forage management recommendations are based on these regional breakdowns. The two most notable examples of recommendations based on region are planting dates[1] and variety[2] recommendations. These region-specific recommendations are primarily the result of climatic differences from one region to another rather than differences in soil characteristics.

Soil Provinces in Georgia

It is often helpful to understand soil differences within the geographic regions when refining forage management recommendations. Crop and soil scientists at the University of Georgia recognize six soil provinces in Georgia: 1) Limestone Valley, 2) Blue Ridge, 3) Southern Piedmont, 4) Sand Hills, 5) Southern Coastal Plain and 6) Atlantic Coast Flatwoods (Figure 3). These soil provinces differ from each other in many ways (e.g., texture, drainage, parent material, organic matter content, etc.). As a result, the forage system must accommodate these differences.

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[1] See Cooperative Extension Circular C-814: Planting Guide to Grasses and Legumes for Forage and Wildlife in Georgia.

[2] See the website titled: "Forage Species and Varieties Recommended for Use in Georgia" (http://www.caes.uga.edu/commodities/fieldcrops/forages/species.html).

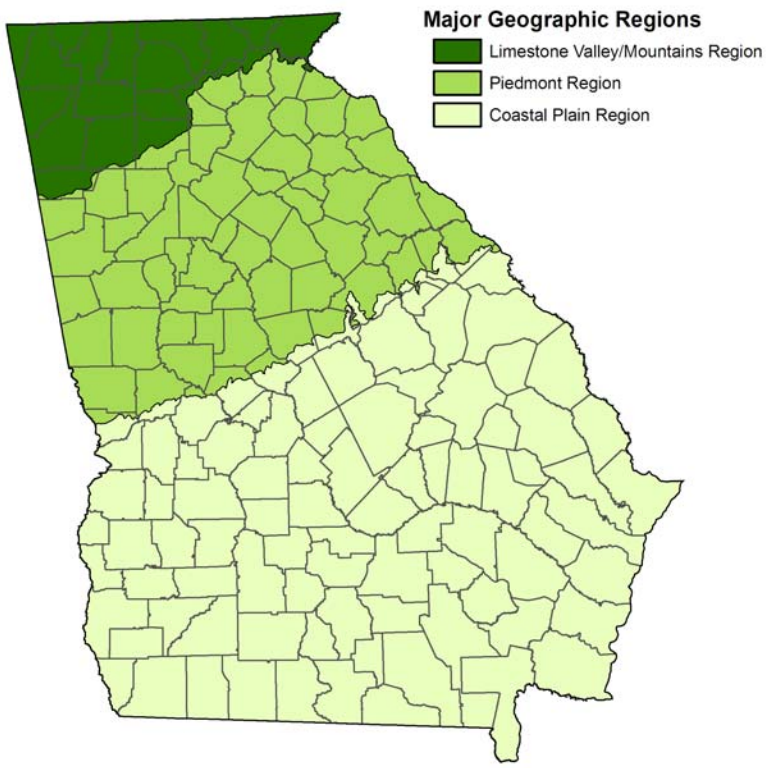


Figure 2. The three major geographic regions of Georgia.

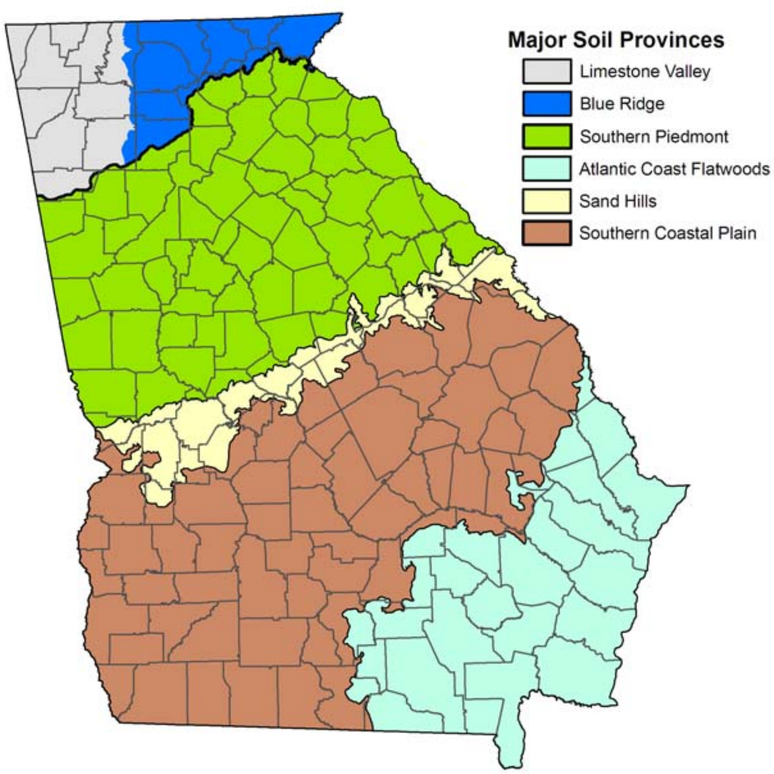


Figure 3. The six soil provinces in Georgia.

Limestone Valley – This province contains fertile upland soils and zones along streams that make excellent pastures. Good pastures can be produced on almost any land in the valleys. Steep and undulating terrain is mostly woodlands, but some areas can support pasture growth if care is taken to establish sod-forming permanent pastures. Soil erosion potential is high in the Limestone Valley and Blue Ridge soil provinces. When establishing or renovating pastures, establishment practices that minimize the risk of soil erosion (i.e., no-till or minimum till) should be employed. Cool-season perennials make excellent pasture in this province, but cold-hardy bermudagrasses are well-suited to hay lands and pastures in well-drained, sunny sites.

Though this area averages more than 52 inches of rainfall per year, dry weather frequently occurs in the spring, summer, and fall. Some use of drought-tolerant plants is recommended. (For more information about soils in the Limestone Valley, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from Pastures and Hayfields Originating from the Limestone Valley Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/commodities/fieldcrops/forages/soils/LV.html.)

Blue Ridge – The rich cove lands of this province are well-adapted to cool-season perennial pasture and hay production. Cold-hardy bermudagrasses can be used successfully for hay lands and summer grazing in this area, but are rare because of terrain and drainage issues. Winter annual pastures can be planted on any of the cultivated soils of this province. However, the upland soils have better drainage and are better suited to winter annual pasture. This area receives abundant rainfall (more than 65 inches per year in most areas). (For more information about soils in the Blue Ridge soil province, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from Pastures and Hayfields Originating from the Blue Ridge Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/commodities/fieldcrops/forages/soils/BR.html.)

Southern Piedmont – The Piedmont region of Georgia contains one large soil province, the Southern Piedmont. This is not to say, however, that areas within the Southern Piedmont are the same. Quite the contrary is true. In fact, the Southern Piedmont is difficult to characterize, as its soils are quite variable.

The Southern Piedmont contains more of the state's forage-based livestock enterprises than any other soil province. Pastures in this region contain mixtures of cool-season and warm-season perennials, while hay lands are predominantly bermudagrass. Though there are exceptions, the lower Piedmont is generally considered the southern edge of adaptation for tall fescue and the northern edge of adaptation for bahiagrass. As a result, pastures in the lower Piedmont often contain significant amounts of bahiagrass, bermudagrass and tall fescue.

The best land for pastures is along the streams and river bottoms of this area. These low, moist zones are excellent for summer pastures, if adequately drained. Many parts of the Piedmont were extensively row cropped in the 19th and early 20th centuries. Severe soil erosion during this era resulted in the loss of much of the topsoil throughout this area. Though the upland soils still provide good spring and fall grazing, periodic droughts during the spring, summer and/or fall severely limit forage production in this area. Drought-tolerant plants should be used on the uplands for summer grazing. (For more information about soils in the Southern Piedmont, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from

Pastures and Hayfields Originating from the Southern Piedmont Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/commodities/fieldcrops/forages/soils/SP.html.)

Sand Hills – Soil in the Sand Hills province is quite variable, and, as the name suggests, is characterized by sandy soils and undulating terrain. The Sand Hills province is located around the Fall Line (where the Piedmont transitions to the Coastal Plain).

Land that produces row crops in this area will provide acceptable forage yields. Some of the better areas will produce winter and summer annual pastures. However, because many of these soils are quite prone to drought, hybrid bermudagrasses that develop deep-root systems should be used for hay and grazing in this area. (For more information about soils in the Sand Hills, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from Pastures and Hayfields Originating from the Sand Hills Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/commodities/fieldcrops/forages/ soils/SH.html.)

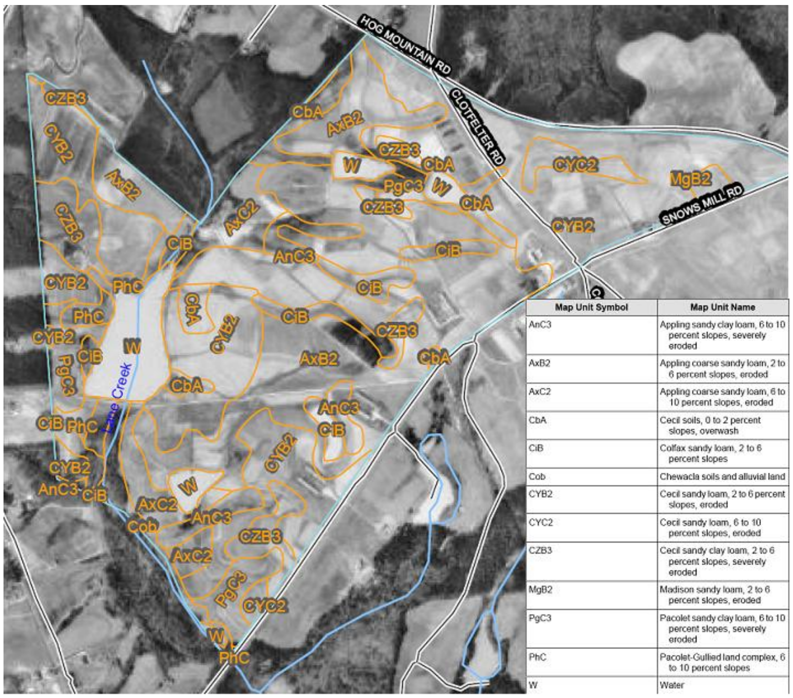
Southern Coastal Plain – Just south of the Sand Hills, the terrain in the upper sections of the Southern Coastal Plain becomes less rolling. Soils in this soil province are typically heavier and more fertile than the soils in the Sand Hills and Atlantic Coast Flatwoods. The best soils are in moist zones along streams. However, productive pastures can occur on better upland sites. Winter annual pastures often do best on upland soils in this area.

The Southern Coastal Plain is the second-largest soil province in Georgia and is home to the state's official soil, the Tifton soil series. The Tifton soil series is the predominant soil series in the Southern Coastal Plain, occupying more than 75 percent of the lower and eastern part of this soil province. (For more information about soils in the Southern Coastal Plain, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from Pastures and Hayfields Originating from the Southern Coastal Plain Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/commodities/ fieldcrops/forages/soils/SCP.html.)

Atlantic Coast Flatwoods – Flatwoods soils in Georgia are often poorly drained, with the water table periodically (usually in the winter) reaching within a few inches of the soil surface. Soils in this area also commonly contain organic hardpans. As a result, the best pasture soils are on good uplands and well-drained lowlands. Most of the uplands can produce winter annual pasture and perennial summer pasture. Closer to the Atlantic Coast, the soils are predominately poorly-drained and may not be suitable for pasture use. In the Flatwoods soils, bahiagrass swards generally will persist better than bermudagrass, unless the site is well-drained. (For more information about soils in the Atlantic Coast Flatwoods, see the Crop and Soil Sciences Department Factsheet titled "Summary of Soil Test Results from Pastures and Hayfields Originating from the Atlantic Coast Flatwoods Soil Province in Georgia between 1996 and 2007" at http://www.caes.uga.edu/ commodities/fieldcrops/forages/soils/ACF.html.)

Soil Types in Georgia

There are literally hundreds of soil types in Georgia. It is not uncommon for a single pasture or hay field to contain several different soil types. Each soil type has its own characteristics. The easiest way to determine what soil types are on a given farm is to examine the soil survey (Figure 4).



Map Unit Symbol	Map Unit Name
AnC3	Appling sandy clay loam, 6 to 10 percent slopes, severely eroded
AxB2	Appling coarse sandy loam, 2 to 6 percent slopes, eroded
AxC2	Appling coarse sandy loam, 6 to 10 percent slopes, eroded
CbA	Cecil soils, 0 to 2 percent slopes, overwash
CiB	Colfax sandy loam, 2 to 6 percent slopes
Cob	Chewacla soils and alluvial land
CYB2	Cecil sandy loam, 2 to 6 percent slopes, eroded
CYC2	Cecil sandy loam, 6 to 10 percent slopes, eroded
CZB3	Cecil sandy clay loam, 2 to 6 percent slopes, severely eroded
MgB2	Madison sandy loam, 2 to 6 percent slopes, eroded
PgC3	Pacolet sandy clay loam, 6 to 10 percent slopes, severely eroded
PhC	Pacolet-Gullied land complex, 6 to 10 percent slopes
W	Water

Figure 4. Example of a soil survey map available from the USDA NRCS's Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/).

Most areas of Georgia have been surveyed by soil scientists from the USDA Natural Resources Conservation Service (NRCS). These soil surveys are published by the USDA NRCS either as surveys of single counties or combinations of two or three counties. Though not all counties have a modern soil survey available, NRCS soil scientists are working hard to provide statewide coverage. The status of soil survey work in Georgia can be found at http://www.ga.nrcs.usda.gov/technical/soils/publications.html.

Soil survey information is a powerful tool. In addition to outlining generalized physical and chemical properties of the soil types of interest, it can give relative estimates of crop performance. The soil survey even provides estimates of hay yields on a soil type and the number of animal units a particular soil type can carry.

Hard copies of the soil survey (assuming the survey for the area is complete) can be obtained from the local NRCS office, Conservation District, or library. Fortunately, the soil surveys of most counties in Georgia have been digitized and are available online via the USDA NRCS's Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/). Tutorials and guides on how to use the Web Soil Survey are also available on their website.

Site-Specific Conditions

On every farm, there will be variation that cannot merely be explained by differences in soil type. These differences will often be substantial between fields, and conditions are often highly variable within a field. The variability may be the result of natural differences in soil formation, water-holding capacity, soil organic matter, slope or other factors. However, the most common contributor to differences between fields or areas within a field is historical management (e.g., pastures vs. hayfields, historical applications of nutrients, areas in a pasture where animals congregate versus areas where animals spend little time, etc.).

Soil conditions may be variable enough within a field that it warrants the identification of specific areas that are managed separately from other areas. Such “site-specific management” has been enabled by “precision ag” tools such as GPS, GIS, variable-rate applicators, etc.[3] These techniques are often more expensive than traditional, uniform management systems. As a result, site-specific management is usually not cost-effective, except for the most intensively-managed forage systems.

Most soil conditions are difficult or cost-prohibitive to change (e.g., soil water-holding capacity, organic matter, slope, etc.). However, the fertility of the soil is easier to improve. The first step in improving soil fertility is to take a soil test (see “Sampling the Soil in Pasture and Hayfields” below). Soil samples submitted through your county extension agent will be analyzed at the University of Georgia Agricultural and Environmental Services Laboratories’ Soil Lab. Lime and fertilizer recommendations will be made based on those soil test results.

Sampling the Soil in Pasture and Hayfields

A soil test is the best tool for assessing soil fertility. Soil testing is a chemical analysis that reveals any soil fertility issues that may be limiting production.[4] The soil sample analysis provides a guideline for the amount of lime or fertilizer needed to correct deficiencies or imbalances in soil pH or available nutrients. These amounts are determined by the specific needs of the crop being grown. Furthermore, soil test recommendations from the Cooperative Extension office are based on decades of scientific studies. Thus, by regularly testing soil and following the recommendations, soil fertility can be maintained at levels that result in optimum productivity of the pasture or hayfield.

The key to soil testing is to ensure that the sample is representative of the area of interest. At the very least, each field should be sampled separately. Soil pH and some nutrients will often vary with soil type. Fields with substantially different soil types should be sampled separately within major soil types.

[3] Global Positioning Satellites (GPS) allow the precise positioning of points, lines or shapes (polygons) within a field or location. Geographic Information Systems (GIS) are record-keeping and management software programs that allow for the collection and management of data on these points, lines and shapes. Collectively, GPS and GIS have enabled the management of specific sites within a field.

[4] Some essential nutrients (e.g., nitrogen, sulfur and boron) are not consistently held in the soil and are not analyzed in routine soil tests. Recommendations for these nutrients are made based on the results from many research trials.

When sampling pastures, be sure to avoid areas around water sources, shade, mineral feeders, where hay has been fed, or any other area where animals may have congregated and created a nutrient buildup. It is also important to avoid sampling in areas immediately surrounding urine or dung patches (Figure 5). In general, soil samples should be obtained from pastures every three years and from hayfields each year. More information on how to take a representative soil sample can be found in the Cooperative Extension Leaflet titled "Soil Testing" (http://pubs.caes.uga.edu/caespubs/pubcd/L99.htm).

Figure 5. Urine and dung patches should be avoided when sampling soils. The prevalence of these hummocks is a common indicator of nutrient deficiencies in other areas of the pasture.

The Importance and Role of Specific Nutrients and Soil Amendments

As with all crops, forages must be provided an ample supply of available nutrients. Maintaining optimum soil fertility is critically important for ensuring good establishment, persistence, winter hardiness, pest resistance, drought tolerance, sufficient forage quality, adequate yields, and economic returns. If any nutrient is deficient, problems in one or all of these areas can occur. Thus, it is critical that a good soil fertility program be the basis of any forage management system. This section presents factors that affect the availability of the nutrients in soil, briefly conveys the importance of several essential elements and identifies the most common sources of individual nutrients.

Soil pH

Soil pH measures soil acidity. Most forage crops grow best when the soil pH is 6.0 – 6.5. However, some legume species require a slightly higher soil pH (e.g., alfalfa requires a pH of 6.5 – 7.0). When soils are too acid (pH is too low), crop growth will be reduced. On the other hand, soils can become too basic (pH is too high) when too much lime is applied. Though this can also have a detrimental effect on plant growth, high soil pH values (> 7.0) are rare in Georgia.

When soil pH is kept at the level appropriate for the forage crop(s) being grown, the nutrients stored in the soil will be most freely available to the plant. This increases the plant's ability to efficiently use fertilizer and nutrients already in the soil. Proper soil pH also prevents high concentrations of toxic elements (e.g., aluminum) that can injure root tips and prevent proper rooting. Maintaining the appropriate soil pH also promotes desirable bacterial activity in the soil.

Most Georgia soils are acidic or will naturally become more acidic over time. The addition of ammoniacal forms of nitrogen fertilizer (e.g., ammonium sulfate, urea, UAN solutions, ammonium nitrate, etc.) can accelerate soil acidification. To correct low soil pH, the soil acidity must be neutralized. Lime supplies carbonate ions that neutralize soil acidity (increase soil pH). Agricultural lime is the most common product used to raise soil pH values, though other products (e.g., wood ash, marl, basic slag, egg shells, etc.) can also be used.

Liming agents differ in the amount of calcium and magnesium they contain. Both calcitic and dolomitic limestone contain calcium. However, dolomitic limestone also contains magnesium and should be used (if possible) to maintain sufficient soil magnesium levels. If magnesium is present in adequate levels, then calcitic limestone can be used.

One reason for maintaining a rather neutral soil pH is that it prevents aluminum (Al) from becoming soluble in the soil. When the pH drops, Al becomes dissolved in the soil moisture. Soluble Al is toxic to plants and drastically inhibits root growth. The addition of lime raises the soil pH, and the Al returns to a solid form.

Unfortunately, it is difficult for lime to quickly infiltrate deep into the soil profile. As a result, the soil surface may be neutral while the subsoil is very acidic. In this situation, the addition of gypsum ($CaSO_4$) may be helpful for some crops. Although gypsum does not alter the soil pH, it can infiltrate the soil profile and reduce the toxicity of soluble Al. For example, research with alfalfa has shown significant yield increases in response to gypsum application on some soils with acidic subsoils. A subsoil sample (soil from deeper than 15 inches) must be tested to determine whether gypsum is needed.

Soil Organic Matter

Soil organic matter (OM) plays a critically important role in the biological, chemical, and physical characteristics of the soil. Soil OM supports soil microbes that are critical to making some essential nutrients available to the plant. Soil OM is also important in supporting populations of nitrogen-fixing bacteria that infect nodules on legume roots. The acidifying effects of ammonium fertilizers can be slowed by sufficient levels of soil OM. Soil OM also increases the ability of a soil to be well-drained while at the same time hold sufficient water to promote plant growth. In many of Georgia’s heavy clay soils, high levels of soil OM helps to prevent soil compaction.

Decaying roots, crop residue and animal dung provide the primary source of OM in the soils of pasture and haylands. To retain this OM, tillage operations should be kept to a minimum. Excessive tillage during seedbed preparations, use of aeration equipment, treading damage and other soil disturbances may decrease soil OM levels.

Essential Nutrients

Sixteen chemical elements are essential for normal plant growth and reproduction (Table 1).[5] Some of these are non-mineral nutrients (e.g., hydrogen, carbon, oxygen, etc.) that are freely available to all plants, with very rare exceptions. However, several mineral nutrients may need to be supplemented.

Essential nutrients are generally grouped into two categories, macronutrients and micronutrients, based on the concentration of the nutrients found in the plant. The nutrients required in the largest quantities are called macronutrients and are further grouped into primary and secondary nutrients. Primary nutrients are mineral elements that are needed in the highest concentration and that most frequently need to be supplemented. Primary nutrients include nitrogen (N), phosphorus (P) and potassium (K). Secondary nutrients (calcium (Ca), magnesium (Mg), and sulfur (S)) are also needed in high concentrations, but are not as frequently deficient in most soils. Other nutrients are also essential, but are required in much smaller quantities. These micronutrients include boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn).

Georgia soils often do not contain sufficient concentrations of primary macronutrients. Occasionally, secondary macronutrients and micronutrients are not available in the appropriate concentrations for proper plant growth and the addition of fertilizer (inorganic or organic) may be necessary to correct the imbalance. Sometimes, however, this lack of nutrient availability (e.g., micronutrient deficiencies) may be because the soil pH has become too low or too high. Even when a deficiency does exist, there are many cases where the addition of the fertilizer may cost more than the value of the increased plant performance and/or come with some environmental consequence. Thus, the use of soil test-based recommendations from the University of Georgia is critical to the appropriate use of fertilizer.

Table 1. The 16 nutrients that are essential for normal plant growth and reproduction.

Groups	Essential Nutrients
Non-Mineral	1. Carbon (C),
	2. Hydrogen (H),
	3. Oxygen (O)
Macronutrients	
Primary	4. Nitrogen (N)
	5. Phosphorus (P)
	6. Potassium (K)
Secondary	7. Calcium (Ca)
	8. Magnesium (Mg)
	9. Sulfur (S)
Micronutrients	10. Boron (B)
	11. Chlorine (Cl)
	12. Copper (Cu)
	13. Iron (Fe)
	14. Manganese (Mn)
	15. Molybdenum (Mo)
	16. Zinc (Zn).

Nitrogen (N)

Nitrogen is necessary for rapid growth and high yields, and is an essential component of plant proteins. The amount of N fertilizer needed and the correct timing of applications varies with crops and how they are used (for grazing or hay). Application rates for N fertilizer will typically be higher for hay crops than in pastures that are grazed, because N is recycled

[5] Nutrients that are essential for plant growth share some similarity to nutrients essential for animal growth; however, there are some substantial differences. Some micronutrients, including selenium, chromium, cobalt, sodium and iodine are not required by plants but must occur at critical levels in the animal's diet. Deficiencies of these nutrients in the animal are often solved most economically by providing the animal with mineral supplements.

via the urine and feces of grazing animals. Since the amount of N available from the soil is typically much less than the forage could utilize, N can be effectively used as a tool to increase or decrease forage productivity in pastures, as needed.

Nitrogen-deficient plants will be light green or slightly yellow, especially in the lower (older) leaves, and will be much less vigorous. In pastures, N deficiency is often exhibited by a great difference in growth and color between spots where animals have urinated and the surrounding areas.

Phosphorus (P)

Phosphorus is an essential plant element that plays a key role in many vital plant processes such as root development, reproduction, and energy transfer. Low soil levels of P can cause difficulties in establishing new pastures. This element does not readily leach from most soils, and one application per year is sufficient.

Phosphorus levels in most of Georgia's soils are naturally low. For forage crops, however, P deficiencies are less frequent than deficiencies in other nutrients. Applications of animal manures have occurred routinely on many areas where forage is produced. As a result, these soils are usually high in P. However, P deficiencies are quite problematic when they occur. Stands that are deficient in P will be stunted, but may be relatively dark green. In grasses, the base of the tiller is often dark purple. In legumes, the leaves will be much smaller than normal and older leaves may be dark green or purple.

Potassium (K)

Potassium is second only to nitrogen in the concentration found in plants, and is essential for producing economical yields (especially when stress conditions occur). It is also critical to maintaining thick, persistent stands (see insert, "Potassium Fertility for Bermudagrass"). It affects plant vigor, disease resistance, forage quality, and winter survival. It is important to split K applications across two or more application times to prevent excess K uptake (described in detail in the "Timing and Method of Nutrient Applications" section of this publication). This is particularly important with alfalfa and bermudagrass stands that are harvested for hay.

Sulfur (S)

Sulfur is critical to protein formation, N-fixation in legumes, and maintaining root growth. Sulfur may become a limiting nutrient in plants that accumulate high levels of nitrogen in their tissues. In Georgia, the need for S varies considerably. Like N, the S in the soil is held and released from soil OM and it will leach out of the soil. Much of the S available to the plant results from atmospheric deposition of S that was released during the burning of fossil fuels (coal, gas, diesel, etc.). Another substantial source of S is animal waste (especially poultry litter). As the OM in the animal waste breaks down, an abundance of S is supplied to the plants.

Potassium Fertility for Bermudagrass

Each ton of bermudagrass hay will often contain the equivalent of more than 40 lbs. of K fertilizer (K_2O). High-producing bermudagrass hayfields may yield well over 10 tons per acre. As a result of this high rate of nutrient removal, K deficiencies occur frequently in bermudagrass hayfields. Stands that are K deficient become less vigorous, less dense, more disease prone, and more apt to winterkill.

In most cases, K deficiency comes about slowly. Deficiency symptoms occur initially in the margins of lower leaves in the form of chlorosis (yellowing) followed by necrosis (death). In fact, a bermudagrass stand may be very old before it begins to exhibit severe stand thinning as a result of K deficiency. However, some varieties are more prone to K deficiency problems than others. For example, "Alicia" is very susceptible to leafspot diseases when K deficiency occurs.

Research has shown that stands can recover if given adequate K supplementation. One major reason for this is that K fertility is critical for healthy rhizomes, the underground stems that aid the spread of bermudagrass. Rhizome production is nearly 800 percent greater when K fertilization is adequate than when K is deficient.

Deficiencies do occasionally occur, especially on soils in the Coastal Plain Region that are deep sands and have lower OM. Drought or low pH can cause slow OM decomposition and can also be a factor in S deficiency, which is often confused with N deficiency since the two share symptoms of yellowing and stunted appearance. However, they can be differentiated based on where the symptoms occur on the plant. Sulfur is less mobile than N and deficiency symptoms tend to first appear in younger leaves, in contrast to N deficiency, which tends to appear first in older leaves.

Calcium (Ca)

Calcium is critical for several basic plant functions (cell growth, stress detection, signaling, cell division, etc.). Fortunately, Ca deficiencies are rare in Georgia, especially if the soil has been limed. Legumes accumulate higher levels of calcium than grasses.

Magnesium (Mg)

Magnesium is a critical element of chlorophyll, the green pigment in plants that enables photosynthesis. It is fairly common for Mg to be deficient in Georgia, especially on acid, sandy soils in the Coastal Plain region. Magnesium deficiency causes yellowing between the veins of the leaf and will be found first in the lower or older leaves of the plant. Dolomitic limestone can be used to increase soil Mg and reduce deficiencies.

Magnesium deficiency is often more problematic when the forage is growing quickly. The uptake of Mg by plant roots is sometimes slow, especially if K is high. In addition to the detrimental effects that Mg deficiency has on the plants, animals grazing forage that is low in Mg may develop low Mg levels in the blood. This causes hypomagnesemia (grass tetany), and these animals may stagger, collapse, convulse, and, if not given timely treatment (calcium-magnesium gluconate), can die.

Micronutrients

In general, forages in Georgia rarely need to be supplemented with micronutrients. Occasionally, studies have shown a yield increase as a result of fertilizing with micronutrients (usually a foliar spray). However, these applications are expensive and rarely cost-effective. Usually, micronutrient deficiencies are a symptom of a soil that is too acidic or basic.

There are two notable exceptions to this generalization: B and Mo. These nutrients are needed in small quantities by plants, but supplementing with B and Mo may occasionally be necessary for proper legume growth, as they play significant roles in nodule formation and N-fixation. For alfalfa, an annual application of B (three pounds B per acre) is recommended, and an application of Mo (eight ounces of sodium molybdate in 25 gallons of water per acre) should be made every other year. The need for B supplementation in grasses is rare.

Nutrient Sources

There are many materials (both organic and inorganic) that can be added to the soil that provide nutrients. Commercial fertilizers provide these nutrients in relatively concentrated forms. Animal wastes and other organic sources of nutrients will typically provide fewer nutrients per pound of product and be highly variable. Regardless of nutrient source, it is important to understand what and how many nutrients are being provided by the product (Table 2). Commercial fertilizers will have guaranteed analysis. However, animal wastes and other such materials need to be tested for nutrient content because of their variability from source to source. Additionally, the effect a nutrient source may have on soil pH should be considered.

Table 2. Selected sources of nutrients that are commonly used in forage production.

Nutrient Source	N	P_2O_5	K_2O	S	Ca	Mg	Effect on Soil pH†	Comments
	---------------------------- % ----------------------------							
Ammonium Nitrate	34	-	-	-	-	-	↓↓	Not as widely used as in the past. Usually not available in smaller markets.
Ammonium Sulfate	21	-	-	24	-	-	↓↓↓↓	Very acidifying effect on soil.
UAN Solution	28-32	-	-	-	-	-	↓↓	Liquid nitrogen solution containing urea and ammonium nitrate.
Urea	46	-	-	-	-	-	↓↓	Prone to substantial volatilization losses.
Urea (Sulfur-coated)	38	-	-	16	-	-	↓↓↓	Sulfur reduces volatility, but increases the negative effect on soil pH.
Diammonium Phosphate	18	46	-	-	-	-	↓↓↓	Commonly called DAP. Used to provide P and part of N needs.
Monoammon. Phosphate	11	48	-	-	1	-	↓↓↓↓	Commonly called MAP. Also used to provide P and part of N needs.
Triple Superphosphate	-	46	-	2	14	-	None	Usually used in blends with other fertilizers or when fertilizing legumes.
Muriate of Potash	-	-	60	-	-	-	None	One of the most widely-used fertilizers in the world. Commonly used in blends.
Poultry Litter (Broiler)	3	3	2	1	2	-	↑	Highly variable. Only 50% of N is available.
Cattle Manure	1.5	1.5	1.2	-	1.1	0.3	↓	Data represent feedlot manure. Barn manure will be much lower in N.
Horse Manure	1.0	0.7	1.8					Highly variable. Very little N will be available immediately.
Sulfate of Potash Magnesia	-	-	21	23	-	11	None	Second most common form of K fertilizer.
Calcitic limestone	-	-	-	-	36	-	↑↑↑↑↑	A common, high-calcium type of ag lime in Georgia.
Dolomitic limestone	-	-	-	-	24-30	6-12	↑↑↑↑↑	A common, magnesium-containing ag lime in Georgia
Gypsum	-	-	-	18	22	-	None	Naturally mined or a by-product of coal-burning power plants or the phosphate industry. Can improve soil structure and reduce soluble Al in acidic soils.

† Number and direction of the arrows indicate the relative effect that the nutrient source will have on soil pH (e.g., ↓ indicates slight decrease in soil pH, ↑↑↑↑↑ indicates substantial increase in soil pH). In the case of N-containing fertilizers, these relative indicators are corrected on the basis of their N content (i.e., lbs. of $CaCO_3$ required to neutralize 1 lb. of N).

Timing and Method of Nutrient Applications

Fertilizers and other nutrient sources are quite valuable and potent. As a result, they pose economic and environmental risks. Nutrients that end up in runoff, groundwater, or the air reduce economic efficiency and impair water and air quality. Consequently, it is important to apply these nutrients at a rate, at a time and in a way that maximizes the efficiency of their use and minimizes their environmental impact.

Forages differ in the amount of nutrients required and the time of year in which the nutrients are needed. These crop-specific recommendations are provided for each forage crop in the Soil Test Handbook for Georgia (http://aesl.ces.uga.edu/). The crop-specific recommendations are also printed on every soil test report, along with any additional comments or recommendations by the county extension agent. More information and up-to-date soil fertility recommendations for forages can be found in the Soil Test Handbook or on the "Fertilization Guidelines" page of the Georgia Forages Web site (http://www.caes.uga.edu/commodities/fieldcrops/forages/fertilization.html).

In this section, recommended application timing and methods will be presented for lime and the three most commonly applied nutrients: N, P, and K. This is presented from the perspective of common forage production constraints (i.e., predominantly permanent sod/no-tillage systems, erodible soils, etc.) and may not be applicable to other production systems.

Applying Lime

In general, lime applications can be made anytime during the year. However, consideration must be given to the fact that lime may take several months (sometimes more than a year) to be fully effective. If changes or new plantings are planned and the soil test indicates lime is needed, lime applications should be made at least eight months prior to new plantings or other such renovations. High-quality liming materials are available that act faster than traditional "ag lime," but they are generally less cost-effective for forage production scenarios. If the soil is to be plowed and/or prepared with conventional tillage, the lime application should be split so that half is applied prior to plowing and the other half applied during final seedbed preparation stages.

Research has shown that the infiltration of lime into the top two feet of the soil profile is generally better in no-till and permanent sods than in soils that are routinely turned (plowed and prepared with conventional tillage). One of the major reasons for this is that larger pores exist in undisturbed soil than in tilled soil as the result of natural soil particle aggregations, channels that form around decaying roots, and activity by earthworms and other soil biota. Proper soil pH is critical to maintaining these large pores. Thus, it is important that lime applications are made whenever regular soil tests indicate a need.

When lime is needed on pastures or hayfields, ensure that the soil is dry enough to support heavy equipment traffic. Ruts or compaction made in permanent sods during lime application will be especially difficult to manage around, expensive to remediate, and make harvesting or mowing more difficult.

Applying Nitrogen

Nitrogen fertilizers generally contain some percentage of ammoniacal (NH_2, NH_3 or NH_4) or nitrate (NO_3) forms of N or both. Organic N, such as in animal manures, generally contains N in the form of urea, ammonium (NH_4), uric acid, amino acids, and additional N forms that become available to the plant over time. For example, Table 3 shows the differences in N content and form that exists between the manure from selected livestock species.

Table 3. Approximate amount of N and N forms in the manure of selected livestock species.†

Animal Species	Total N	Amino Acid	Urea	NH_4	Uric Acid	Other
	(%)	-------------------------------	-----------	(% of Total N)	-----------	-------------------------------
Poultry	3.0	27	4	8	61	1
Beef	1.5	20	35	<0.5	-	44
Dairy	1.0	23	28	<0.5	-	49
Horse	1.0	24	25	<1.0	-	49
Swine	1.0	27	51	<0.5	-	22
Sheep	2.0	21	34	<1.5	-	43

† Adapted from Havlin et al., 1999. "Soil Fertility and Fertilizers: An Introduction to Nutrient Management" pg. 137 6th ed. Prentice Hall, Inc.

Plants can take up and use N either as ammonium or nitrate. Unfortunately, not all the N that is applied to the soil will make it into the soil, be made available to the plant, be taken up by the plant or be held by the soil. This lost N can pose significant economic and/or environmental risks. This section describes the mechanisms of N loss, presents conditions that make the losses worse and lists practices that can reduce the risk of loss (Table 4).

Volatilization

When urea (either as a fertilizer or in animal manures), uric acid (found in poultry litter), or other organic N sources are applied, these N forms may be enzymatically converted to ammonia (NH_3). Ammonia is typically then converted to ammonium (NH_4). Ammonium that is not taken up by the plant can be absorbed and held by the soil or tied up in less available forms (immobilization or ammonium fixation) or converted to nitrate by soil bacteria (mineralization and nitrification). However, ammonia is a volatile gas that can escape to the atmosphere before the N source makes it into the soil and is converted to ammonium.

Fertilizers such as ammonium sulfate, ammonium nitrate and other nitrate-based sources of N do not have ammonia as a direct intermediary step. Therefore, these fertilizers do not result in ammonia loss. Urea-ammonium nitrate (UAN) solutions may have some volatilization loss, but since half its N is in the form of ammonium nitrate, its volatilization losses will typically be half that of urea alone. Still, applications of UAN or other urea or organic N sources should be made in a way that minimizes the risk of volatilization (Table 4).

Volatilization loss is made worse by hot, humid and windy conditions. Furthermore, forage crop residue and thatch contain more urease and ureolytic microbes than the underlying soil. As a result, 10 to 25 percent of the total N applied is usually lost to volatilization (ammonia gas) when urea or animal wastes are applied to forage lands. Under the most severe conditions, volatilization losses of more than 45 percent of the total N applied (as urea) have been observed in Georgia.

Table 4. Factors affecting the four key mechanisms of N loss and the practices that can decrease the risk.

Volatilization

Factors that Increase the Risk of N Loss	Practices that Decrease the Risk of N Loss
• Hot, humid conditions • High wind speeds • Soils that are sandy and/or low in buffering capacity • Use of N sources that contain urea (fertilizers and animal manures) or uric acid (primarily poultry litter) • Small droplet size when using liquid N (UAN soln.)	• Use ammonium nitrate or other nitrate sources as the N fertilizer to eliminate the risk.† • Time the N application to occur before a rainfall event ($\geq$ 0.50 in.) or irrigation. • Avoid using broadcast spray nozzles when applying liquid N products. Use dribble or flood nozzles to obtain larger droplet sizes. • Split N applications between harvests (grazings or hayings), applying N prior to each growth period. • Avoid applying urea-based products when it is excessively hot and humid. • If urea-based fertilizers are used, volatility may be reduced by using a product treated with either the urease-inhibitor NBPT (N-(n-butyl) thiophosphoric triamide, trade name Agrotain™) or a controlled-release polymer (ESN®) technology.‡

Leaching

Factors that Increase the Risk of N Loss	Practices that Decrease the Risk of N Loss
• High N fertilization rates at one time • Slow rate of N uptake by the plant • Overgrazed pastures • Well-drained soils that regularly receive soaking rains or are over-irrigated	• Split N applications between harvests (grazings or hayings), applying N prior to each growth period. • Use slow-release N fertilizer or organic N products. • Promote good root development by rotational grazing and preventing overgrazing.

Runoff

Factors that Increase the Risk of N Loss	Practices that Decrease the Risk of N Loss
• Overgrazed pastures or very short forage canopy • Sloped areas within a field • Poorly drained or water-logged soils	• Avoid overgrazing pastures. • Minimize the N rate applied to sloping areas within a field. • Split N applications between harvests (grazings or hayings), applying N prior to each growth period. • Use a highly-soluble N fertilizer that enables the N to quickly dissolve and infiltrate into the soil before high rainfall intensities result in runoff or erosion (Table 5). • Avoid applying N to saturated soils.

Denitrification

Factors that Increase the Risk of N Loss	Practices that Decrease the Risk of N Loss
• Poorly drained or water-logged soils • High N fertilization rates • High OM content in soils	• Split N applications between harvests (grazings or hayings), applying N prior to each growth period. • Minimize the N rate applied to poorly drained or saturated soils. • Use slow-release N fertilizer or organic N products.

† This practice eliminates volatilization loss. However, availability of ammonium nitrate and other nitrate sources may be low in many areas or cost prohibitive.

‡ Research results in row crops and (to a lesser degree) in forage crops indicate that both the urease-inhibitor NBPT (N-(n-butyl) thiophosphoric triamide, trade name Agrotain™) and a controlled-release polymer (ESN®) have the potential to reduce the loss of N to volatilization. Other such products have failed to demonstrably reduce N volatility or have not been adequately evaluated. Even when effective at reducing N lost to volatilization, it is still not clear that these fertilizer treatments will be of economic benefit to forage producers.

Volatilization losses are minimized when N applications are quickly followed by rainfall events ($\geq$ 0.50 inches). Unfortunately, rainfall events are quite random during the growing season, especially during the summer months. Often, little or no rain will occur when one would prefer to apply fertilizer.

Runoff

In contrast, heavy rains may occur and cause significant runoff. This can result in environmentally significant losses of N if heavy rains occur before the N has percolated into the soil. For producers who use poultry litter as the primary source of N, runoff poses a significant risk of contaminating surface waters. Though N runoff can occur with commercial fertilizers, University of Georgia researchers have shown that N in runoff was substantially greater from pasture areas treated with poultry litter than from pasture areas treated with an inorganic (highly soluble) commercial fertilizer (Table 5). Management practices that minimize runoff are presented in Table 4.

Table 5. Nutrients in runoff from both an area fertilized with broiler litter and a commercial fertilizer containing nutrients equivalent to the broiler litter.[†]

Nutrient Source	Ammonium N	Dissolved Reactive P	Total P
	(lbs. NH_4-N/acre)	----- (lbs. P/acre) -----	
Broiler Litter	0.70	0.52	0.66
Equivalent Commercial Fertilizer	0.28	1.62	1.96

† Average of two runs (late April and late May 2002) of a rainfall simulation on a mixed tall fescue-bermudagrass pasture at the Central Georgia Research and Education Center in Eatonton. These simulations were designed to examine the effect of a fairly heavy rainfall event (one inch of rain over 30 minutes).

Leaching

Another potential mechanism of N loss is nitrate leaching. When high N rates are applied and/or high rainfall rates occur, the plants may not be able to take up nitrate fast enough. As moisture percolates down through the soil profile, some nitrate may be leached away in it. Ultimately, the nitrate may be taken below the rooting depth and may end up in the groundwater. Although high nitrate content in water systems poses a substantial risk to water quality, nitrate leaching from properly managed pastures and hayfields is generally expected to be fairly low. Management practices that minimize the risk of leaching losses are presented in Table 4.

Denitrification

One final mechanism of N loss is denitrification. Denitrification is the process by which nitrate is transformed by soil bacteria into nitrogen oxides (NO and N_2O) and nitrogen gas (N_2). This process occurs when soils become waterlogged and low in oxygen. Thus, N applications to poorly drained or saturated soils should be minimized or avoided. Denitrification losses are also generally expected to be quite low. However, the use of recommended management practices presented in Table 4 will ensure that denitrification losses are insignificant.

Splitting Applications

Applying large rates of N at one time results in inefficient N use because of these losses. By dividing the total recommended N rate by the number of anticipated harvests (grazings or hay cuttings) and applying these smaller amounts prior to each growth period, the economic and environmental risk of N loss will be greatly reduced (Table 4). For example, long-term hay production studies in Tifton have shown that N is used much more efficiently by bermudagrass (25 to 30 percent increase in the lbs of forage produced per lb of N added) when N applications are split between the expected harvests and adjustments are made for poor growing conditions (especially drought) rather than provided all at green-up. Further, this long-term study also demonstrated that splitting N applications can increase hybrid bermudagrass yields by 10 to 20 percent.

Applying Phosphorus

When P is applied to the soil, the fertilizer dissolves into rainwater and/or soil moisture. It reacts very rapidly with soil particles, soil OM and Fe/Al oxides in the soil. Once this occurs, the P is tightly held in the soil and becomes much less soluble than the form in which the fertilizer was added. Consequently, P is not very mobile in the soil, and leaching losses are generally insignificant. Phosphorus is also not subject to gaseous losses.

Since P applied to the soil is relatively stable and generally available to the plant as it is needed, P fertilizer can be applied virtually any time during the year on forage crops. This flexibility in application timing allows the producer to purchase P fertilizer in "off-peak" times of the year (i.e., summer and fall) when demand for the product and spreading services is lower. One exception to this flexibility is that the recommended P rate should always be applied before planting annual crops or plantings of new perennial forages.

Producers should avoid spreading P fertilizer when the risk of runoff is high (November through March in Georgia). The loss of P in runoff is the primary way in which P is lost from soils. Phosphorus loss occurs when P-containing soil or organic matter particles are eroded away in runoff water and when runoff water dissolves P from surface-applied fertilizers and manures. Runoff that contains high P levels can end up in surface waters and lead to eutrophication, excessive algal growth and hypoxia. Thus, the presence of elevated P concentrations in the runoff from pastures, hayfields and associated livestock facilities are of concern. This runoff can occur regardless of the source of P being used, but when used at similar P rates, losses from commercial fertilizers can be much larger than losses from poultry litter (Table 5).

Therefore, producers should take precautions to ensure that P applications are made in ways that minimize the risk of runoff, especially when dealing with inorganic P sources (i.e., commercial fertilizer). Table 6 presents the factors that increase the risk of P loss in runoff and management practices that can reduce this risk.

Table 6. Factors affecting P loss via runoff and practices that can decrease the risk of P loss.

Runoff	
Factors that Increase the Risk of P Loss	**Practices that Decrease the Risk of P Loss**
• Overgrazed pastures or very short forage canopy • Sloped areas within a field • Poorly drained or water-logged soils • Use of inorganic P sources • Applying animal waste at a rate meant to meet the N needs of the crop (i.e., an excessive P rate)	• Avoid overgrazing pastures. • Minimize the P rate applied to sloping areas within a field or to poorly-drained soils. • Apply P during times of the year when heavy rains are less likely. • Avoid applying P to saturated soils.

Applying Potassium (K)

In contrast to N and P, the environmental risk posed by K is very low. However, K is quite expensive and necessary for optimum forage production. As a result, K applications should be made in a way that maximizes the availability of K over the entire growing season.

Muriate of potash (KCl) is by far the most common K fertilizer, though other K fertilizers are occasionally used. Substantial amounts of K may also be found in animal wastes. However, if these products are applied at rates designed to supply recommended N and P levels, additional K may be needed on K-deficient soils.

When K comes in contact with water, it quickly dissolves and enters the soil. Potassium is a cation (has a positive charge) and is attracted to the soil (which carries a negative charge). As a result, the risk of K runoff is quite low. Furthermore, very little K remains dissolved in the soil water. Thus, losses of K to leaching are lower than losses of nitrate.

However, some soils in Georgia have a very low cation exchange capacity (CEC), which means they do not have much capacity for attracting cations (K, Ca, Mg, etc.) or making them available to the plant. Consequently, significant amounts of K can be lost to leaching in those soils. This problem is more common in the sandy soils in the Coastal Plain region and can be exacerbated by low soil pH.

Nonetheless, the biggest potential for inefficient use of K is a phenomenon called “luxury consumption.” Most plants (especially forage crops) will take up more K than is required for optimum growth. Thus, if relatively large rates of K are applied early in the growing season, forage crops will absorb excess K and reduce the amount available for later growth cycles.

Because of this potential for luxury consumption and (in some cases) K loss to leaching, it is recommended that K applications be split across two or more application times. This will lower the risk of luxury consumption and leaching, allowing K to be used more efficiently and be available throughout the growing season. This is particularly important for forage crops that are harvested for hay or silage.

Further Information

- Soil Testing (http://pubs.caes.uga.edu/caespubs/pubcd/L99.htm).
- Soil Test Handbook for Georgia (http://aesl.ces.uga.edu/).
- Poultry Litter Application on Pastures and Hayfields (http://pubs.caes.uga.edu/caespubs/pubcd/B1330/B1330.htm).
- Best Management Practices for Storing and Applying Poultry Litter (http://pubs.caes.uga.edu/caespubs/pubcd/B1230.htm).
- Maximizing Poultry Manure Use Through Nutrient Management Planning (http://pubs.caes.uga.edu/caespubs/pubcd/B1245.htm).
- NRCS's Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/).

Summary

Georgia possesses diverse soil conditions and many forage production factors are influenced by this diversity. As a result, the soil environment of a given site must be considered when selecting forage species, determining fertilization strategies and planning forage utilization systems. This article guides forage producers through the process of exploring their soil's characteristics and sampling the soil in pastures and hayfields for testing, and provides information about specific nutrients and soil amendments relative to forage production practices. Recommendations are also made on how to minimize the economic and environmental risks associated with the addition of nutrients to pasture and hayfields.

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Alfalfa Production in the South

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THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Alfalfa

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AT-A-GLANCE

Adaptation:	Entire state. Very drought tolerant. Requires well drained soil and does not tolerate low soil fertility or acidity.
Establishment:	Seed 18 to 25 lb/A drilled with a cultipacker seeder, 22-25lb/A broadcast on a prepared seedbed in September.
Varieties:	North GA – Bulldog 505. South GA – Bulldog 805.

Alfalfa is often referred to as the "Queen of Forages" because it produces high yields that are highly digestible and high in protein. Alfalfa can be effectively utilized in managed grazing, hay, or silage systems. It is often used in rations when nutritional needs are very high. This factsheet provides a brief overview of alfalfa management. A more detailed description is available in Extension Bulletin B1350: "Alfalfa Management in Georgia" (available at: http://pubs.caes.uga.edu/caespubs/ pubcd/B1350/B1350.htm).

Alfalfa (*Medicago sativa*)

Alfalfa requires a combination of proper soil characteristics (well-drained, fertile, low acidity, etc.) with outstanding management (appropriate variety selection, timely harvests, pest control, etc.) to maintain long-lived, productive stands. Alfalfa requires deep, well-drained soils. It develops a deep root system if root growth is not restricted by hardpans, high water tables, or acid subsoil.

Alfalfa can be grown throughout the state where suitable soils occur. In general, well-drained bottomlands in the Limestone Valley/Mountains and Piedmont regions will provide the best results. Within the Coastal Plain region, the sandy loam soils provide good sites, especially if irrigation is available. Most sites in the Atlantic Coast Flatwoods and Tidewater areas will not be sufficiently well-drained to successfully produce alfalfa.

Alfalfa requires a relatively neutral soil pH (6.5-6.8) and non-limiting levels of essential nutrients. Alfalfa is especially sensitive to potassium (K), phosphorus (P), boron (B), and molybdenum (Mo) deficiencies. Close adherence to soil test recommendations during and after establishment are critical.

Alfalfa stands eventually thin to a point where the land must be rotated out of alfalfa. However, the lack of sufficient soil fertility is the most common contributor to accelerated stand declines. Disease pressure, insect damage, poor weed control, overgrazing, and improper cutting management also contribute to poor persistence. Stands in the Coastal Plain region generally have a shorter life (two – five years) than stands on the heavier soils in north Georgia. It is not uncommon for stands to persist for four – seven years (or longer) in the Piedmont and Limestone Valley/Mountains regions.

Establishing Alfalfa

For monoculture stands, it is best to seed alfalfa on a well-prepared, firm seedbed. On prepared land, plowing and disking operations should be done as needed to incorporate pre-plant applications of lime and fertilizer and to ensure a good firm seedbed. A preemergence application of a labeled herbicide, such as EPTC (Eptam) or benefin (Balan), is desirable (for currently labeled herbicides, see the Georgia Pest Management Handbook at http://www.ent.uga.edu/pmh/). Alfalfa may be seeded with a cultipacker-seeder (best) or a grain drill with a small seed attachment. Cultipacking or rolling before and after seeding will give a firm seedbed and improve stands.

When seeding alfalfa with a grass such as tall fescue or orchardgrass, drill the grass in rows and immediately overseed the alfalfa with a cultipacker-seeder. For seeding into existing cool season grass sods (e.g., tall fescue, orchardgrass), suppress the grass by closely mowing or grazing, follow with a contact herbicide, and then plant with a no-till drill.

When planting alfalfa into a bermudagrass sod, ensure that the grass is dormant and closely mowed or grazed. If the stand is to be primarily an alfalfa stand, use a row-spacing of 15 in. or less. If the stand is to be managed as a mixture of bermudagrass and alfalfa, use a row-spacing of 21 in. or more.

Alfalfa should be seeded at a rate of 18 – 25 lbs per acre (Table 1). Rates at the high end of this range should be used when planting with a no-till drill. Regardless of the system used to plant the alfalfa, the seed should not be placed too deep (1/8 – 1/4 in. in loamy or clay loam soils; 1/4 – 1/2 in. in sandy loam or sandy soils). Soil should be firm around the seed to provide proper seed-soil contact. An insecticide application after initial germination may be needed to control insects such as field crickets.

In the Limestone Valley/Mountains region and the upper half of the Piedmont, a fall seeding in mid-September – late October is recommended. In the lower two-thirds of the state (Lower Piedmont and Coastal Plain), a mid-October – late November seeding is recommended. Plantings made in early March – mid-April are much less desirable, but may be successful in north Georgia if there is a very aggressive defense against weeds and irrigation is available. When planting into cool or warm season perennial grass sods, do not plant in the spring.

Table 1. Seeding rate of alfalfa when broadcast, drilled, or planted with a cultipacker-seeder (CPS).

Method†	Seeding Rate (lbs of pure live seed per acre)
Broadcast	22 - 25
Drilled or CPS	18 - 25

† CPS: cultipacker-seeder.

Additional information about the management and use of alfalfa can be found in "Alfalfa Management in Georgia." Specific information about alfalfa varieties that are currently recommended may be found on the web page entitled "Forage Species and Varieties Recommended for Use in Georgia" (http://www.caes.uga.edu/commodities/fieldcrops/forages/ species.html).

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Alfalfa Management in Georgia

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Alfalfa growing on a farm in Walker County, GA

Alfalfa is a high-yielding, perennial legume that is well-suited to hay, silage, or pasture production. Alfalfa is known as the "Queen of Forages" because it produces an excellent quality, high-protein forage. These properties make alfalfa one of the most widely-grown crops in the world.

Acreage in Georgia devoted to the production of alfalfa hay peaked in the late 1950s at around 24,000 acres. Most of this production was concentrated on the Piedmont and Limestone Valley/Mountain regions and provided high-quality forage for the dairy and beef cattle industry in north Georgia. The heavier soils in these areas tend to be more fertile and less acidic, which allows well-managed alfalfa to persist for at least four to seven years.

Although acreage declined in the 1960s because of more cost-effective forages, alfalfa production in Georgia recently has been steadily increasing. Breeding efforts at the University of Georgia and elsewhere have greatly improved stand-life in the Southeast. These new varieties are better adapted to specific soil and climatic regions in Georgia, especially the Coastal Plain region. In these areas, adapted varieties generally produce four to six tons of dry matter (DM) per acre under normal growing conditions. Well-managed stands of adapted varieties should persist for at least three to five years in south Georgia.

The most dramatic increase in alfalfa acreage has been in the Coastal Plain region, where many plantings made on irrigated soils have produced yields ranging from five to eight tons DM per acre. Dryland alfalfa production in the Coastal Plain is riskier, as many soils in these areas are prone to drought. Although, alfalfa is relatively drought tolerant, it will be much less productive under moisture stress.

Establishment

Site and Soil Selection

Alfalfa grows best on deep, well-drained, and fertile soils with a high moisture holding capacity. Alfalfa is a deep-rooting plant if root growth is not restricted by hardpans, high water tables (poor drainage), or acid subsoils.

Sandy loam or clay loam soils in the Piedmont and sandy loam soils in the Coastal Plain may be well suited for alfalfa production. Soils that have been cropped for several years using good management practices are generally more suitable than soils that have recently been cleared and brought into production. Well-managed cropland soils usually have a history of fertilizer and lime applications. As a result, these soils will often be more fertile and have higher pH values at both the soil surface and through the soil profile.

In the Coastal Plain, it is especially important for subsoil acidity to be evaluated before considering planting alfalfa. Subsoil acidity may take years (eight or more) to remediate and should be evaluated by collecting soil samples in one-foot increments down to four feet. The pH in each of these increments should be equal to or greater than 5.5. As pH levels decline below 5.5, aluminum (Al) increases in soil solution. At sufficient concentrations, Al becomes toxic to root growth. Avoiding sites that have subsoil pH values below 5.5 is therefore critical for optimum root development and alfalfa production.

Level land is not necessarily a requirement for alfalfa; however, slopes that are not conducive to tillage, machinery operations, and/or irrigation may not be suitable for alfalfa grown for hay or silage.

Variety Selection

Variety selection is one of the most important considerations in an alfalfa production program. Many alfalfa varieties are on the market, but most were developed for use in other areas of the country and may not perform well in the Southeast. Also, varieties suitable for use in north Georgia may not perform well in south Georgia, or vice versa.

Disease Resistance

Since many disease and insect pests attack alfalfa, most varietal development has concentrated on improving overall pest resistance. Consequently, many varieties are now available that exhibit resistance to multiple pests. Such a diverse genetic base for resistance to many pests has resulted in a broad array of varieties that out-yield and are more persistent than many old cultivars. For Georgia, specific emphasis should be placed on selecting varieties that are highly resistant to as many disease and nematode problems as possible.

Dormancy

Another consideration in selecting a variety is the cultivar's growth period. Varieties differ widely in how early they initiate regrowth in late winter and when they go dormant in the fall. Alfalfa varieties are rated on a "fall dormancy" scale (Table 1) that rates the timing of when the variety ceases growth in the fall of the year. This is an important trait where winters are long and severe, because cultivars that go dormant earlier in the fall are better able to protect themselves for longer winters.

Less dormant varieties are more appropriate for alfalfa production in Georgia. The fall dormancy rating scale divides varieties into groups 1 through 9, with 1 being extremely dormant (no fall-winter growth) and 9 being non-dormant (active winter growth). For the Limestone Valley/Mountain and the Piedmont regions, varieties with a dormancy rating of 3 to 6 are recommended. Dormancy groups 5 to 9 are more suitable for the Coastal Plain region.

Table 1. Fall dormancy in alfalfa varieties.

Dormancy Group	Rating	Notes
Very Dormant	1	Very winter hardy, no fall or late winter growth
Dormant	2 and 3	Winter hardy, little fall or late winter growth
Moderate Dormant	4,5 and 6	Moderately winter hardy; moderate fall and late winter growth
Nondormant	7 and 8	Not winter hardy; good fall and late winter growth
Very Nondormant	9	Very susceptible to any winter conditions; very good fall and late winter growth.

Grazing Tolerance

Improving grazing tolerance — an important new development — was pioneered by Dr. Joe Bouton, a long-time plant breeder at the University of Georgia. Dr. Bouton's work resulted in the release of several "grazing" varieties that are tolerant of rotational grazing and "dual-purpose" varieties that are useful for hay and grazing.

Information about Specific Varieties

Most seed companies that sell alfalfa seed are members of the Alfalfa Council. This group provides a list of the varieties that their member companies offer for sale, available online at www.alfalfa.org. The Alfalfa Council's list contains information on nearly 400 distinct varieties segmented by dormancy group. It also includes ratings of each variety's resistance to seven diseases and seven insect pests, and information on traits such as winter survival, multi-foliate expression rate (leaves with more than three leaflets), and grazing tolerance.

The Alfalfa Council's list of alfalfa varieties is not completely comprehensive and may not include some information that would be pertinent to variety selection for Georgia producers. Therefore, University of Georgia forage researchers and plant breeders review recent research data on current and new alfalfa varieties and maintain a list of recommended varieties. Usually, the recommended varieties have been evaluated in yield and persistence trials conducted by scientists at the University of Georgia Agricultural Experiment Stations. These varieties are also known to have levels of disease resistance that are appropriate for the locations for which they are recommended. The current list of recommended varieties can be found on the "Forage Species and Varieties Recommended for Use in Georgia" web page at http://www.caes.uga.edu/commodities/fieldcrops/forages/species.html.

Soil Fertility at Establishment

Assessing soil fertility is the next step in gauging whether or not a site is suitable for alfalfa production. Alfalfa has a high fertility requirement and a soil test will determine the need for lime and fertilizer. Always apply the recommended quantities indicated on the soil test report. Proper fertilization and soil pH adjustment prior to establishment are critical to promoting early growth, disease resistance, and winter hardiness. Maintaining adequate fertility is equally important and is addressed in greater detail in the section titled "Fertilizing and Liming Established Stands".

Lime application prior to soil preparation.

When soil analysis indicates a pH below 6.5, apply sufficient agricultural limestone to adjust the soil pH to 6.8 to 7.0. It takes time for lime to neutralize soil acidity, so it should be applied at least **six months** prior to seeding. If possible, the lime should be incorporated into the soil to allow the amendment to affect deeper portions of the soil. If more than two tons of limestone are needed, apply one-half of the amount and incorporate it by first disking and then turning the soil. Use a plow to uniformly mix the limestone in the plow depth. Apply the remainder and incorporate it into the soil surface by disking.

Phosphorous (P) and potassium (K) are two plant nutrients critical for establishing alfalfa stands. Adequate levels of P and K are crucial for root development and seedling vigor. Boron (B) and molybdenum (Mo) play significant roles in nodule formation and nitrogen-fixation and are essential for alfalfa establishment and production. Only small quantities of these micronutrients are needed. Immediately prior to planting, 1/4 ounce of molybdenum (2/3 ounce of sodium molybdate) should be applied to each bag (60 lbs.) of alfalfa seed in just enough water to slightly moisten the seed. (CAUTION: To avoid Toxicity, do NOT exceed the recommended amount of molybdenum.)

Alfalfa is a deep-rooting forage crop when unimpeded by soil properties. Fertilizer (particularly phosphorous) should be incorporated into the soil as deeply as possible using conventional equipment. Since alfalfa will survive for several years and fertilizer and lime applications made in subsequent years will be surface-applied, uniform incorporation before establishment provides long-term benefits.

Inoculation

Many companies have begun to market pre-inoculated alfalfa seed that have been coated with an inert material, usually lime, to protect the inoculant. This saves time and helps ensure adequate and appropriate inoculation. No further inoculation before planting should be necessary, unless the inoculated seed has been stored improperly or the inoculant has expired.

If there is a question about the viability of the inoculum on pre-inoculated seed, re-inoculate the seed with fresh "Type A Inoculant" (the *Rhizobium meliloti* bacteria that are specific to alfalfa) just before seeding. Inoculants are usually packaged in plastic bags to protect the bacteria from drying. Protect bags of inoculant from direct sunlight or hot temperatures. One eight-ounce bag of inoculant will generally be enough to inoculate one bag of seed. However, always read and follow the label instructions. Inoculate only the amount of seed that will be planted each day and keep the inoculated seed in a shady location until it's placed into the planter.

Improperly inoculating alfalfa seed will likely result in poor nodulation, permanent stunting, or stand failure.

To inoculate, fill a large metal or plastic tub about half full with seed and apply enough water to moisten the seed (you will need to stir the seed). Sprinkle the recommended amount of inoculant on the moist seed and stir until the seed are uniformly coated. Moist seed tend to stick together, so let the seed dry for a few minutes before seeding.

The inoculant sticks to the seed better if a water-sugar solution or syrup-water solution is used to moisten the seed. Research indicates that a commercial sticker material significantly improves inoculation.

Establishment Methods and Considerations

Prepared Seedbed

For monoculture alfalfa stands, plant alfalfa on a well-prepared, firm, weed-free seedbed. Plowing and disking should be done as needed, incorporating pre-plant applications of lime and fertilizer, and a good, firm seedbed should be ensured. All tillage or heavy disking operations should be completed at least five weeks before the expected seeding date. Smooth the seedbed and disk lightly as needed to control weeds and incorporate preemergence herbicides prior to seeding. Use of a heavy roller or culti-packer before seeding will firm the soil and improve seedling establishment and stands. A rule of thumb for determining when the soil is appropriately firm is observing the depth of footprints in the soil. When a boot-heel leaves only a 1/4-inch indention in the soil (assuming the person is of average weight), the soil is firm enough for planting.

Sandy Coastal Plain soils may have compacted layers or hardpans, which can restrict root growth and affect water and nutrient uptake by the plant. Subsoiling or chisel plowing can be beneficial if the soil has a hardpan.

A cultipacker can help firm the soil prior to planting.

Soil that is firm enough for planting will allow a boot-heel to sink no deeper than 1/4-inch.

No-Tillage Methods

Although conventional tillage and planting into a prepared seedbed is ideal, planting alfalfa with a no-till (sod-seeding) drill can result in satisfactory stand establishment and yields. Some producers are planting alfalfa into existing stands of bermudagrass or other grass sods. This will require no-till establishment.

When planting alfalfa into a bermudagrass sod, ensure that the bermudagrass is dormant and closely mowed (and free of residue) or grazed. If the stand is to be primarily an alfalfa stand, use a row-spacing of 15 inches or less. If the stand is to managed as a mixture of bermudagrass and alfalfa with an expectation that it will eventually revert back to solid bermudagrass, use a row-spacing of 21 inches or more.

For no-till seeding into existing cool-season grass sods (e.g., tall fescue, orchardgrass), suppress the grass by closely mowing or grazing before planting with a no-till drill. If the grass is in or will be entering a rapid growth phase, chemical (herbicide) suppression of the grass immediately before planting may be necessary.

Seeding Methods and Rates

Using a cultipacking-seeder or grain drill with a small seed box to plant alfalfa into a prepared seedbed will usually result in satisfactory stands. Alternatively, seed may be broadcast and then incorporated using a double-gang, culti-packer. Regardless of the system used to plant the alfalfa, the seed should not be placed too deep (1/8- to 1/4-inches deep in loamy or clay loam soils; 1/4- to 1/2-inches deep in sandy loam or sandy soils). When seeding with grain drills, accurate depth control may be difficult to obtain. If seeding depth control will be difficult, the grain drill can be used as a broadcast seeder by disconnecting the drop tubes from the small seed attachment box and fixing it in such a way that the seed are discharged about two feet above the soil surface.

Cultipacking-seeder planting into a firm seedbed.

Cultipacking after planting with a grain drill will improve seed-soil contact.

Soil should be firm around the seed to provide proper seed-soil contact. Cultipacking or using a heavy corrugated roller after seeding will aid seed-soil contact and improve stands. An insecticide application after initial germination may be needed to control insects such as field crickets. If the seedbed is weedy (especially with ryegrass), spray with a non-selective, translocated herbicide (e.g., glyphosate) a day or two before seeding, or immediately after seeding.

When alfalfa is planted with a cultipacking-seeder or grain drill, the seeding rate should be 18 to 25 lbs. of pure live seed per acre. Higher rates should be used when seeding conditions are marginal, such as when planting with a no-till drill. When planting coated seed, some adjustment in seeding rate may be made to account for the coating weight.

Seeding Dates

In the Limestone Valley/Mountains region and the upper half of the Piedmont, a fall seeding in mid-September to late October is recommended. In the lower two-thirds of the state (Lower Piedmont and Coastal Plain), a mid-October to late November seeding is recommended. Plantings made between early March and mid-April may be successful in both locations but will likely require irrigation and a very aggressive defense against weeds. When planting into cool- or warm-season perennial grass sods, do not plant in the spring.

Always plant alfalfa when soil temperature and moisture conditions will allow rapid seed germination and establishment. This is critical for later seedings. Alfalfa seedlings need six to eight weeks of good growing conditions before the first hard freeze (temperatures below 25° F) occurs. Alfalfa seeds germinate much slower in cold soils and may benefit from a low application of N when the rhizobia are relatively inactive in cold soil.

Weed Control during Establishment

Weed competition can cause poor stands. Treatment with a pre-emergence herbicide, such as EPTC (Eptam) or benefin (Balan), that controls winter annual grass and broadleaf weeds is recommended. Common bermudagrass must be eliminated from the field before planting alfalfa. This grass is often extremely difficult to control in alfalfa stands. Further information about weed control during establishment and during the life of the stand are presented in the "Weed Control" section of this publication. Additional up-to-date information about specific herbicide options during alfalfa establishment can be found in the "Alfalfa Weed Control" section of the Georgia Pest Management Handbook http://www.ent.uga.edu/pmh/.

Crop Rotation Requirement

Alfalfa is an excellent addition to a crop rotation, particularly for crops that require high nitrogen fertilization. However, rotating out of alfalfa eventually must be done. Alfalfa produces compounds from its leaves and flowers that are autotoxic (i.e., they prevent alfalfa seed from germinating and growing). Once fully established (six to eight months), these autotoxic compounds prevent the "thickening-up" of a stand by planting more seed. This prevents alfalfa from being successfully planted into an existing or recently destroyed (within eight to 12 months) alfalfa stand. **Do not plant alfalfa into a field that contains or contained alfalfa within the last eight to 12 months.** Always allow a full growing season of another crop(s) before replanting alfalfa.

Fertilizing and Liming Established Stands

Maintaining adequate fertility is essential for successful alfalfa production, since nutrient deficiencies lead to yield losses, poor disease resistance, pest problems, and short-lived stands. If any nutrient is deficient, problems in any one or all of these areas can be expected. Thus, it is critical that a good soil fertility program be the basis of any alfalfa production system. This section briefly presents information on several aspects of soil fertility management.

Soil pH

It is critical that a soil pH of 6.5 to 7.0 be maintained in areas were alfalfa is grown. When soil pH is kept at this level, the nutrients stored in the soil will be most available to the alfalfa, and the alfalfa's ability to use applied fertilizer nutrients will be improved. Maintaining the appropriate soil pH also promotes nodulation and more efficient nitrogen fixation. Soil test each fall and apply limestone as needed.

Low soil pH in this area of an alfalfa field in South Georgia has resulted in a thin stand.

Maintaining proper soil pH also prevents toxic elements such as Al and manganese (Mn) from becoming soluble in the soil. When soil pH drops below 5.5, Al dissolves in the soil solution. Soluble Al is toxic to alfalfa roots and drastically inhibits root growth. Addiing of lime raises soil pH, and the Al returns to a solid form.

Neutralizing soil acidity deep into the soil profile is difficult. As a result, the soil surface may be neutral while the subsoil is very acidic. In this situation, the addition of gypsum ($CaSO_4$) may be helpful. Although gypsum does not alter the soil pH, it can infiltrate the soil profile and reduce the amount of soluble Al. Research with alfalfa has shown significant yield increases in response to gypsum application on some soils with acidic subsoils. A subsoil sample (soil from deeper than 15 inches) must be tested to determine whether gypsum is needed and if it will decrease toxic levels of Al.

Fertilization

Alfalfa has a high nutrient requirement, especially when the nutrients are removed from the field as hay or silage. For example, each ton of alfalfa hay may remove as much as 15 lbs. of phosphate (P_2O_5) and 60 lbs. of potash (K_2O). Productive, high-yielding stands require that these nutrients be returned to the soil through fertilizer, manure, or other sources in order to maintain yields and persist. Thus, annual alfalfa field soil sampling and testing is critical for tracking soil fertility levels and nutrient needs. Soil samples should be taken at the same time each year. It is also recommended that the soil test information be supplemented with occasional plant tissue analyses (See the "Plant Analysis" section.)

Nitrogen

In well-managed stands, the nitrogen-fixing bacteria that colonize nodules on the alfalfa roots will meet the crop's nitrogen requirement. Nitrogen-deficient alfalfa is commonly a symptom of a soil pH that is too low. Soil pH markedly affects the activity of the rhizobia bacteria that fix nitrogen. Nitrogen deficiencies will also occur if the seed was not inoculated properly before planting or if, for some other reason, nodules have not developed. When this occurs in soils that have a pH of 6.5 to 7.0, the poor nitrogen fixation may be the result of other nutrient deficiencies such as boron, calcium, magnesium, molybdenum, etc.

To diagnose nitrogen deficiencies, dig up suspect plants and check the nodules. Active nodules, when cut in half, are dark pink or red in color. A brown, black, green, or pale pink color denotes an inactive nodule. Also, determine the soil pH and analyze the plant tissue for nitrogen. Nitrogen-deficient plants turn pale green with a slight yellowish tinge. Later, leaves may become distinctly yellow.

Phosphorous

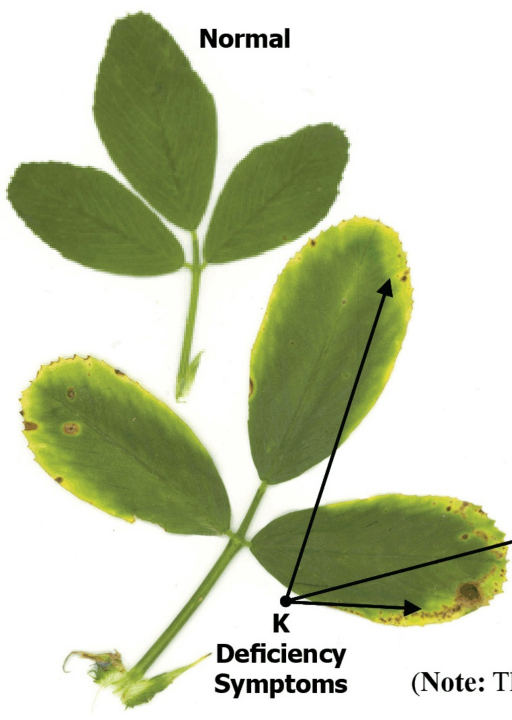
Phosphorus is an essential element for many vital alfalfa processes (e.g., root development, energy transfer, etc.). Soil phosphorous levels should be adjusted by fertilization prior to seeding and sufficient phosphorous should be applied in subsequent years to maintain adequate soil test levels. This element does not leach from the soil, so one application per year is sufficient.

Phosphorus levels in most of Georgia's soils are naturally low. Phosphorus deficiency symptoms are not as well-defined as those of many other nutrients. In general, P-deficient alfalfa stands will be stunted, the leaves may be upward-tilting and much smaller than normal, and older leaves may be stunted and dark green or purple. Symptoms may also include a decreased growth rate, reduced nodulation, and delayed maturity. Phosphorus-deficient plants may appear grayish-green and resemble drought stress, even with adequate soil moisture.

Potassium (K)

For alfalfa, potassium is essential for high yields, persistent stands, and disease resistance. This element, which is second only to nitrogen in concentration in the plant, affects plant vigor, forage quality, winter survival, and stand life.

For most sites in Georgia, K deficiency will be the most common and most problematic issue. Potassium deficiencies in alfalfa are easily recognized. White spots appearing along the margins of older leaves are an early indication of K deficiency. In time, tissue between the spots turns yellow and dies. Since potassium is a mobile nutrient in plants, symptoms first appear on leaves that are lower in the canopy, and the severity of yellowing increases from the top to the bottom of the affected shoots.



Visual symptoms of potassium (K) deficiency in alfalfa.
(**Note:** The K deficient leaf is magnified slightly to provide greater detail.)

Potassium deficiencies can be prevented and stand life prolonged by a good K fertilization program. Soil test K levels should be high or supplemented with K_2O fertilizer when alfalfa is planted. Annual soil testing and recommended K fertilizer applications will be crucial to ensuring that this critically important nutrient is not deficient. Tissue analyses taken prior to early summer harvests will help verify that K levels in the plant are maintained at or slightly above sufficiency levels (1.8 to 2.0 percent).

Multiple K applications will be more efficiently used by plants and will ensure that an adequate supply is available throughout the growing season. On heavy soils in the Piedmont and Mountain regions, two (spring and fall) or three (spring, summer, and fall) applications during the growing season are recommended. Sandy soils in the Coastal Plain do not hold K as well as the heavier soils in north Georgia. As a result, more frequent K applications are recommended. Four applications (late winter, early summer, late summer, and fall) should be sufficient. The fall application will ensure that the plants have adequate K for winter survival.

Sulfur

Sulfur (S) is critical to protein formation, N-fixation, and maintaining root growth. Sulfur may become a limiting nutrient in plants like alfalfa that have high levels of nitrogen in their tissues. In Georgia, the need for S varies considerably. In the soil, S is held and released from organic matter and, once mineralized, can easily leach out of sandy soils.

Much of the S available to the plant results from atmospheric deposition of S being released during the burning of fossil fuels (coal, gas, diesel, etc.). Sulfur is absorbed through the roots as sulfate (SO_4) or through the leaves as sulfur dioxide (SO_2) gas. Another substantial source of S has historically been blended fertilizers that contained S as a by-product. Deficiencies of this nutrient have occurred more frequently in recent years because of a shift to the use of high-analysis phosphate fertilizers that contain only small quantities of sulfur and because of S removal from the emissions of coal- and lignite-burning electricity generation plants.

When alfalfa is grown on soils deficient in S, protein formation is retarded and upper leaves (including veins) turn light yellow. Growth is stunted and maturity is delayed as deficiencies become more severe. Leaves may become long and slender. Sulfur deficiencies are similar to nitrogen deficiencies except that with nitrogen deficiencies, the younger leaves turn yellow before the older leaves.

Sandy soils are more likely to be deficient in S than heavier soils. Sulfur may be deficient on soils that contain little organic matter or where such factors as cool soil temperatures, drought, or low pH cause slow decomposition of organic matter. If these conditions exist or S deficiency is suspected, a tissue analysis can assess S levels. If needed, applying 10 to 30 pounds of S per year should be adequate for alfalfa.

Boron

Alfalfa needs very small quantities of boron (B), but a severe deficiency of this nutrient can cause yield reductions of more than two tons of dry matter per acre. If soil B levels are inadequate, deficiencies may appear. Symptoms of B deficiency appear first at the shoot tips (terminal portion of shoots) where rapid growth is occurring. The leaves turn yellow and sometimes red at the tips, while the lower leaves remain green. Retarded growth at the shoot tips causes growth at buds located lower on the shoot. This growth pattern causes the plant to exhibit a rosette appearance.

Boron deficiency in alfalfa may be prevented by applying boron to the soil. An annual application of B (three lbs. of B per acre) is recommended and should be applied with other fertilizer materials as a topdressing in the late winter. Boron may also be applied as a foliar spray using a soluble source of B such as Solubor (20.5 percent B) in 25 to 30 gallons of water per acre. Do not apply more than 1/2- to one lb. of B per acre as a foliar spray. Higher rates can cause leaf burn.

Molybdenum
Molybdenum (Mo) is required for adequate nodulation and nitrogen fixation. Deficiencies are frequently observed on acid soils because Mo becomes less available as the soil pH decreases. Deficiency symptoms are similar to those of nitrogen deficiency. Growth is reduced and plants turn a pale yellow. Lower leaves may die and drop prematurely. Molybdenum is the only plant-essential micronutrient that becomes increasingly available as soil pH is raised by liming. To prevent Mo deficiency, lime the soil to increase pH to recommended ranges. An application of Mo (eight oz. of sodium molybdate in 25 gallons of water per acre is recommended) should be made every other year in the spring when alfalfa is six to eight inches tall.

Calcium
Calcium (Ca) deficiencies are rare under field conditions if soil pH is above 6.0. Compared with grasses, Ca levels in alfalfa are relatively high. Older leaves contain a higher percentage of the element than younger ones. Calcium deficiency results in leaves that are distorted at the growing points and shoot tips that wither and die. If limestone is applied to correct soil pH before planting and if soil test recommendations are followed in succeeding years, Ca deficiencies are unlikely.

Magnesium
Magnesium (Mg) deficiency is most likely to occur on acid, sandy soils low in Mg. Magnesium deficiency causes yellowing between the veins of leaves and generally is first observed in older leaves. Use of dolomitic limestone as the liming material will increase soil magnesium and reduce the possibility of deficiencies. In fields with an optimum or high soil pH and low soil Mg, apply 25 to 50 lbs. of Mg per acre. Sulfate of potash-magnesia contains 22 percent K_2O, 22 percent S, and 11 percent Mg, and is a good material for soil applications of Mg, as well as K and S. An Mg deficiency could be confused with iron deficiency in plants, except that iron deficiency is first observed in newer leaves.

Manganese
Most soils with a pH of 6.5 to 7.0 supply adequate manganese (Mn) for alfalfa. As a result, Mn deficiencies are rare in alfalfa, except when a stand is subjected to poor drainage. This may occur in depressions in the field where the soil pH may be higher than in surrounding areas. Applying 10 to 15 lbs. of Mn per acre on mineral soils will usually correct known deficiencies. Foliar applications will be required if the deficiency is severe. Leaves of Mn deficient plants exhibit a mottled yellowing between the veins similar to iron or Mg deficiencies, but the veins never turn yellow.

Zinc
Most soils contain adequate zinc (Zn) for alfalfa production. Deficiencies are more likely to occur on the more weathered, coarse-textured soils in the Coastal Plain. Soil test to determine the Zn level in the soil and apply three lbs. of elemental Zn per acre if the soil level is low. Zinc deficiencies may cause abnormal root tips and dwarfed vegetative growth. Bronze spots that later become white and necrotic may appear around the leaf margin. Moderate Zn stress in alfalfa may be difficult to recognize because symptoms appear erratically and growth is only moderately stunted.

Detecting Deficiencies
Nutrient deficiencies may be caused by several factors, including a lack of nutrients in the soil or a lack of nutrient uptake due to restricted root absorption. Deficiency symptoms may also occur even though the plant is able to absorb the nutrients. This results when transport or utilization of the nutrient within the plant is blocked.

Remember: At least 16 nutrient elements are essential for healthy plant growth, but a deficiency of only one of these can negatively affect plant growth. Nutrient deficiencies may show up in one of several ways: Some alfalfa fields may not show any change in appearance even though deficiencies are present; some may only have reduced yields; and still others may have both visible deficiency symptoms and reduced yields. It is better to prevent nutrient deficiencies through a balanced, proactive fertility program than to correct deficiencies once symptoms appear.

Plant Analysis

Annual soil sampling and testing provides the basis for the soil fertility program. However, it is also recommended that the soil test information be supplemented with occasional plant tissue analyses. Tissue samples should be obtained from alfalfa fields in late June or early July within one to two weeks of a harvest. Analyzing samples at the time of the growing season can help assess macro- and micro-nutrient levels and identify potential deficiencies in time to correct them before they have lasting effects. In severe cases of nutrient deficiency, plant analysis should only be viewed as a diagnostic aid.

Sampling Procedures

Samples should be obtained by clipping the top six inches of growth prior to or at 1/10 bloom stage (i.e., when 10 percent of the shoots have one or more flowers). Obtain clippings in this way from 40 to 50 areas in the field or from each management zone. Combine the clipped material into one sample and air-dry for one-half day. **Do not put fresh plant tissue into polyethylene or tightly-sealed paper envelopes.** Moisture loss from plants in tightly-sealed containers will transfer nutrients out of the plants and distort the analytical results of the plant tissue. If a plant analysis kit is not available, an ordinary paper bag or envelope is a suitable container. The sample should be relatively free of dust and soil particles. Wash the fresh tissue gently with clean tap water and a clean rag or sponge and blot dry. **Plants that are diseased, damaged by insects, or under moisture stress should not be sampled for plant analysis.** Dead plant tissue should not be collected with a sample or used for diagnostic purposes.

The University of Georgia has an excellent plant analysis service. Information and plant analysis mailing kits are available from your county Extension office.

Irrigation Management

Alfalfa uses a substantial amount of water to produce high yields. Fortunately, alfalfa is exceptionally deep rooted and can access water stored deep in the soil profile. However, very few sites will have soils that are capable of holding and providing the amount of water necessary to maximize alfalfa production, unless the crop is irrigated or consistently receives adequate rainfall.

Evapotranspiration (ET), or the amount of water that evaporates from plant surfaces and the soil, is affected by many weather-related variables such as temperature and relative humidity, and by the growth rate/maturity of the plant. In Georgia, ET rates during the summer generally are 0.20 to 0.25 inches of water per acre per day. This means that alfalfa may use one acre inch of water every four to five days at peak demand. Despite relatively high precipitation rates, irrigation will be needed to supplement rainfall during the summer in most cases.

Yield losses in alfalfa may occur when soil moisture content drops below 50 percent of the soil's available water-holding capacity. This yield loss cannot be recovered by additional irrigation after the damage has been done. Therefore, it is important to maintain soil moisture above this level.

To prevent unnecessary irrigation, alfalfa producers should schedule their irrigations. Irrigation scheduling can be accomplished by estimating soil moisture using the water balance method, wherein water inputs (rain or irrigation) are balanced against water outputs (the ET demand).

The number of factors that must be considered when scheduling irrigation using the water balance method can result in substantial errors when too many "guesstimates" and bad assumptions are made. Therefore, it is critical to use irrigation scheduling calculators, the best available weather data and ET estimates (e.g., from www.georgiaweather.net), and routine checks of actual field conditions using a soil probe or shovel. Additionally, soil moisture can be directly measured by properly installing and calibrating soil moisture monitoring devices in representative locations within the field. More information about developing an irrigation scheduling system for alfalfa or other crops can be found at the University of Georgia's Stripling Irrigation Research Park website www.nespal.org/sirp/.

Irrigation practices also must factor in the timing of alfalfa harvests, especially if the crop is to be dried for hay. Excess soil moisture will severely delay curing rates of hay crops. Wet soils may also lead to substantial damage and soil compaction from heavy machinery operations or hoof traffic. For heavy-textured, clay-type soils, do not irrigate for at least four to five days prior to cutting the alfalfa hay. In lighter-textured, sandy soil types, this interval may only need to be two to three days. Irrigation (as required) should begin again as soon as possible after harvest. If moisture stress occurs during early regrowth, severe yield losses can occur.

A center pivot irrigation system sits ready to irrigate one-week-old regrowth on an alfalfa field in Coffee County, GA

Harvest Management

Alfalfa can produce high yields of high-quality forage for several years. However, the yield, quality, and persistence of alfalfa are all highly dependent upon several harvest management factors.

Harvest Timing Affects Yield, Quality, and Persistence

Harvest management of alfalfa requires the manager to balance yield, quality, and persistence. Maximum forage yield in alfalfa will occur at about the time the plant reaches the full-flower maturity stage (Figure 1). However, this is **NOT** the ideal stage for cutting alfalfa because forage quality declines as the plant matures. One reason for this is that the more highly-digestible leaf material makes up less of the total yield. Secondly, as alfalfa matures, the forage becomes more fibrous and harder to digest (Table 2).

When to Harvest

Alfalfa should be harvested at the early bloom/flower stage of growth (when 10 percent of plants have flowers). Harvesting at this growth stage represents the best compromise between forage yield, forage quality, and maintaining healthy stands. After the first cutting is taken, alfalfa will usually reach the early bloom stage every 28 to 35 days. The first cutting depends on weather and the variety's dormancy rating. In general, alfalfa growers in south Georgia may be able to make their first cutting in early April, while it may be as late as mid-May before the first cutting occurs in the north Georgia Mountains. Because of the differences in the length of growing season, alfalfa is usually cut five to seven times per year in south Georgia but only four to five times per year in north Georgia. In the seedling year, the first cutting likely will be delayed about one month behind older-growth stands.

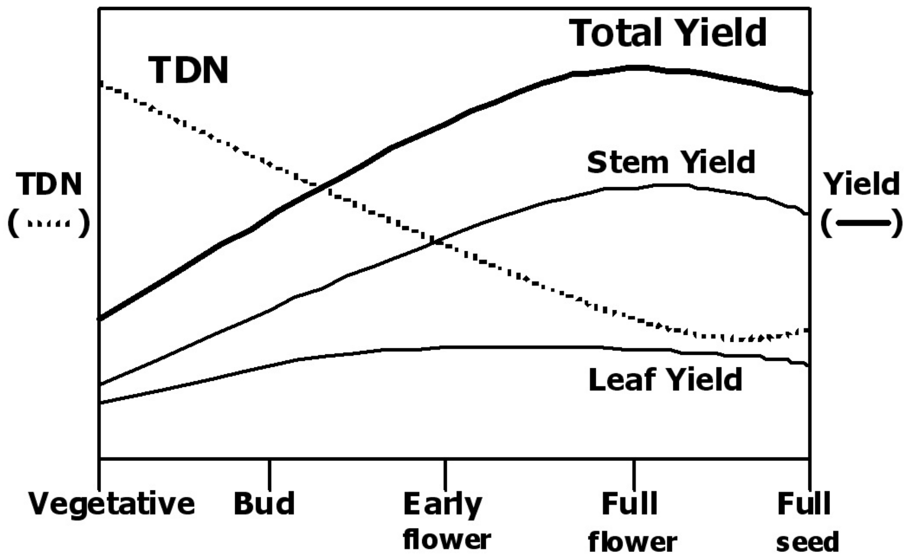


Figure 1. The relative effect of advancing alfalfa maturity stages on total digestible nutrients (TDN) and leaf, stem, and total yield.

Table 2. Expected range in forage quality† for alfalfa at various maturity stages.‡

Stage of Maturity	CP	NDF	ADF	TDN	RFQ
Vegetative	24-27	25-37	20-27	68-75	230-300
Bud	22-26	38-47	28-32	64-67	160-250
Early bloom	18-22	42-50	32-36	61-64	125-180
Mid-bloom	14-18	46-55	36-40	58-61	100-150
Late bloom	9-13	56-60	41-43	50-57	90-110

† Alfalfa will often be higher in fiber concentration, less digestible, and have lower relative forage quality when subjected to higher temperatures or soil moisture stress.

Abbreviations: CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; TDN = total digestible nutrients; RFQ = relative forage quality.

‡Adapted from Ball et al, 2007. Southern Forages, 4th Edition.

Exceptions to harvesting at the early bloom growth stage:

1. The first cutting of a stand that was planted the previous fall should not be taken until the plants are in the mid-bloom stage (25 percent of plants have flowers). This will allow the root system and crown to be more fully developed and will prevent excessive losses early in the stand's life. If the root system and crown were well developed prior to the onset of winter, cutting at the early bloom stage will be acceptable.
2. The first harvest in spring can be made from mature stands at the bud growth stage (just before flowers appear) without negatively affecting the stand. Do NOT harvest at the bud stage when the stand was planted the previous fall.
3. During late summer (July and August) in south Georgia, delay one harvest until the mid-to-late bloom stage (25 to 50 percent of plants have flowers). Delaying harvest will allow the plants to fully rebuild root carbohydrate reserves. Growing conditions are usually very stressful during this period, and a delayed harvest can be made with little effect on annual yield of digestible nutrients.

The Effect of Harvesting Too Soon

Alfalfa plants store carbohydrates, protein, and other nutrient reserves in the crown and upper part of the tap root (Figure 2). Carbohydrate and protein reserves are required by the plant for rapid regrowth after it has been harvested. The plant mobilizes these reserves and will continue to live off of these nutrients until enough leaf area is created to sustain the plant's growth. As a plant matures, it replenishes these nutrient reserves in preparation for the next regrowth. This cycle is repeated each time the crop is cut.

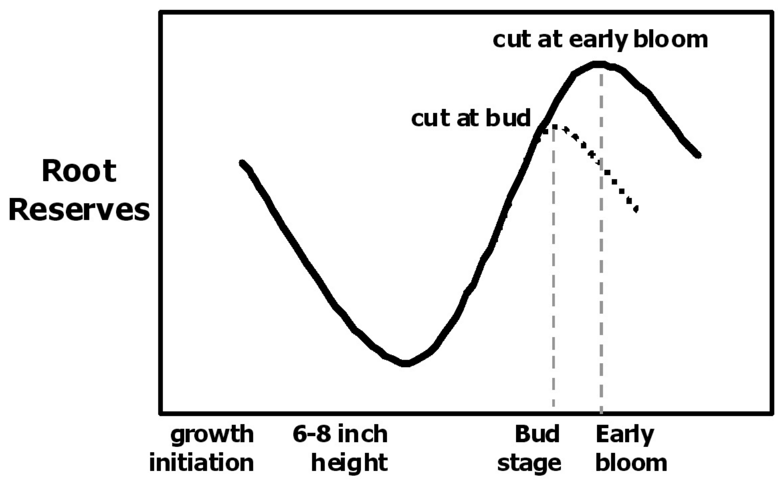


Figure 2. The relative effect of advancing alfalfa maturity on the root reserves when alfalfa is harvested at early bloom or bud stage.

Cutting too early, before root carbohydrate reserves are replenished, will result in alfalfa that has not built up enough root reserves to support vigorous regrowth. If the alfalfa is continually harvested before the bud stage and continually unable to replenish the root reserves, the plants may fail to initiate regrowth or over-winter and the stand will be reduced.

Harvesting too soon is most damaging to the crop during the hottest part of the summer. When under heat stress (particularly when nighttime temperatures are in excess of 80° F), alfalfa does not efficiently produce and store carbohydrates. This is the primary reason why delaying at least one harvest during this period can improve stand vigor.

Regrowth after Harvest

Regrowth after harvest may occur from two sites. The first site is at the crown buds, which elongate and form new shoots. Usually, some crown buds will start to grow and may be one to two inches tall before the crop is ready to harvest. If they are not clipped when the crop is harvested, regrowth will be very rapid. This is the reason a cutting height two to four inches above the soil surface is recommended. The second site for regrowth is the axillary buds on the lower portion (below the cutting height) of stems that were harvested. Unless the mowing height is too low, these buds can provide significant regrowth.

It is critical to get alfalfa that is cut for hay cured and removed promptly. Alfalfa hay that fails to cure within four to six days of cutting may slow the rate of regrowth. Similarly, alfalfa should be irrigated (as required) as soon as possible after the previous crop has been removed. Moist soil conditions at the initiation of regrowth helps to determine the number of shoots per square foot — a key component of alfalfa yield.

When to Make the Last Harvest in the Fall

Because Georgia does not normally experience the same severe winters and long-term snow cover as other alfalfa-producing regions, there is more flexibility in fall management programs. However, some considerations differ substantially between north and south Georgia.

North Georgia

Winters in the Limestone Valley, Mountains, and Piedmont regions can be relatively cold, and low temperatures occur earlier in the fall than in south Georgia. Varieties in dormancy groups 4, 5, and 6 will usually not go completely dormant (except at higher altitudes in the mountains) in north Georgia. However, the frequent low temperatures greatly restrict alfalfa growth in the winter and early cold snaps can greatly impact root reserves prior to the onset of winter.

Fall management for alfalfa in north Georgia is critical and should be done in a way that allows the plant to store enough root reserves to survive the winter. In general, this is done by not harvesting after late September in the Mountains or early October in the Piedmont.

A final "freeze-down" harvest can be made after plant tops have been killed by temperatures of 25° F or lower. Since forage quality deteriorates rapidly after freezing, harvest within two weeks of plants freezing. Evidences of freezing are yellowing, browning, and curling of leaves and permanent wilting.

Harvesting residue after a killing frost can be beneficial for preventing insect and disease problems in the spring. Alfalfa weevil eggs are deposited in stems during the late fall and many will be removed by a freeze-down harvest, reducing alfalfa weevil populations and damage in the spring. Removing this residue also tends to reduce the severity of some cool-season foliar and stem diseases that affect the spring regrowth.

South Georgia

Most alfalfa varieties grown in the Coastal Plain are in dormancy groups 7 and 8, with some 9s along the Florida border. These cultivars will usually maintain active growth well into late November or early December, slow (but not go completely dormant) in January and February, and initiate regrowth in mid-February or early March. Cold temperatures (less than 25° F) will kill back top growth but regrowth occurs from the crown with the return of warmer weather. Frequently, only the taller stems will be frozen. Temperatures are usually warmer near the soil surface and shorter growth is not severely damaged.

Going into the winter with a high level of root reserves is a good idea. Schedule the last harvest to allow about 30 days of regrowth before temperatures below 25° F are expected. As a rule of thumb, targeting between November 1 and 15 as the cut-off date for the post-freeze harvest works well.

Curing and Producing High-Quality Alfalfa Hay

Producing high-quality alfalfa hay requires excellent management, especially since hay production in Georgia is often a race against the weather. In addition to cutting the crop at the correct stage of growth, it is important to utilize tools that lessen the time it takes to dry the forage. These tools also must be used in ways that minimize the loss of the high-quality leaves.

Cutting Method

Strategies for drying alfalfa begin with the harvest implement. Alfalfa harvested for hay should be cut with a mower-conditioner, which usually allows the forage to dry 20 to 30 percent faster than when no conditioning is used (Table 3). The effect on drying rate is greatest during the first one to two days after the forage is cut. To maximize drying on the day of cutting, alfalfa to be cured for hay should be cut as soon as the dew is off in the morning.

Table 3. The average relative drying rate of alfalfa during the first two days after cutting if it was subjected to a rubber crimping roll-, steel flail-, or plastic flail-type conditioner and subsequently tedded or allowed to dry without tedding.*

	Relative Drying Rate	
	Not-Tedded	**Tedded**
	———— difference from control ————	
No conditioner	**	+17%
Rubber crimping roll	+18%	+48%
Steel flail	+24%	+50%
Plastic V-flail	+14%	+35%

* Adapted from Borreani et al., 1999. Agron. J. 91:457–463.
** The changes in drying rates are set relative to the control treatment (no conditioner, not-tedded).

For alfalfa, it is best to use a mower-conditioner that presses and crimps the forage between two inter-meshing, chevron-shaped rollers. These crimping rollers crush the stems and allow the drying rate of the stem to more closely match the faster-drying rate of the leaves. This creates more uniformity in the drying rate of the forage, which helps to reduce leaf losses during other hay curing steps.

A mower-conditioner cutting alfalfa.

The most common mower-conditioner in Georgia is the steel flail-type conditioner, which uses V-shaped flails to help strip away some of the waxy coating from the plant material as the forage is being harvested. Although this works well for fine-stemmed grass crops, flail-type conditioners can cause significant leaf losses that lower yield and crop quality (Figure 3, page 18).

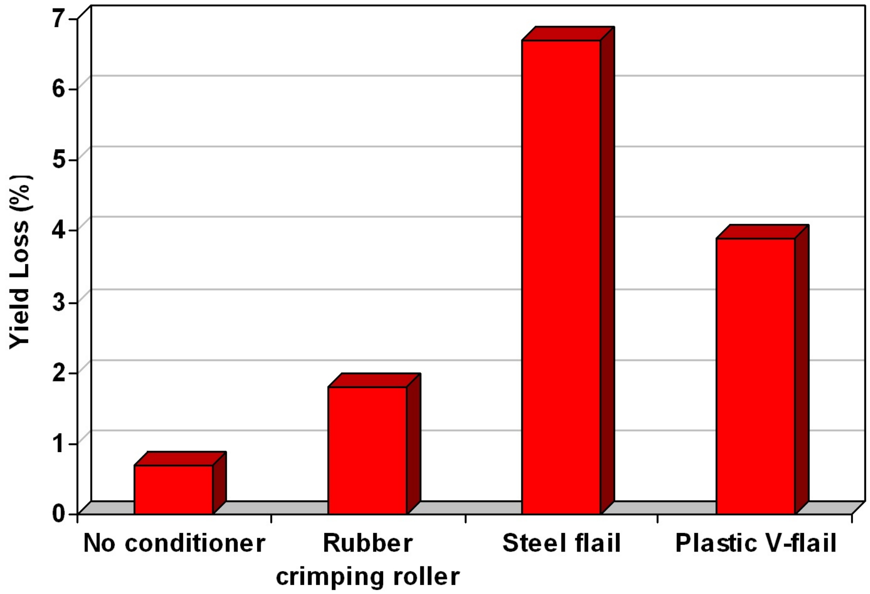


Figure 3. The effect of conditioning treatment (disc-mower with no conditioner, rubber crimping roller-, steel flail-, or plastic flail-type conditioner) on average yield losses, as a percent of the total yield.*

* Adapted from Borreani et al., 1999. Agron. J. 91:457–463.

What is the Right Time of Day to Cut Alfalfa?

The time of day when alfalfa is cut may seem unimportant, but it has significant implications for drying time and, in some cases, forage quality. Therefore, for Georgia conditions, it is recommended that alfalfa be cut early in the day (as soon as the dew is off). Three key facts need to be considered to understand this recommendation:

1. Respiration by the plant (and any microbes acting on the plant) will continue to use sugars and other carbohydrates until the plant moisture drops below 48 percent.
2. Moisture loss from the plant occurs primarily via open stomata (tiny holes in the leaf that allow moisture, O_2, and CO_2 exchange with the surrounding air), even after the plant is cut.
3. Alfalfa stomata are open during the day and close at night or when they are excessively shaded.

Because of respiration losses, it is critical to dry the alfalfa crop down to below 48 percent moisture as soon as possible. If alfalfa is cut during the morning, the stomata will be open and the crop will lose moisture faster than if the crop is cut late in the day or at night. This rapid moisture loss will be even greater if the swath is laid out as wide as possible to maximize surface area and to minimize shading (which will cause stomata to shut). If the crop is cut in the morning and the forage is spread out, alfalfa may actually drop below the 48 percent moisture level by the end of the first day or early on the following day.

Since the later drying phase (from 48 percent down to 16 to 18 percent moisture) can be rather slow, anything that can allow the crop to enter into the last phase of drying sooner will help the crop dry out more quickly. Cutting alfalfa early in the morning will take full advantage of alfalfa's physiology to get it to dry. Catching several days in a row that grant good drying weather in Georgia is generally rare. Consequently, any drying advantage that can be gained should be taken.

Tedding

The process of tedding (turning and fluffing the forage) greatly accelerates the drying rate of alfalfa, especially when used in combination with a mower-conditioner (Table 3). However, tedders can cause leaf loss if the crop is too dry. Therefore, it is important to appropriately time the use of the tedder and prevent excessive quality losses. Usually, it is best to ted alfalfa hay in the morning the day after the forage is cut. When tedded at this time, the forage will still be relatively moist (greater than 50 percent moisture) and tedding should have a minimal effect on leaf loss. Additional teddings may be useful; however, care should always be taken to minimize leaf losses retain forage quality. This risk is best minimized when tedding operations are performed in the morning and completed before or soon after the dew is off.

Tedding must be done carefully, otherwise the high-quality *leaves may be knocked off and yields and quality will suffer.*

Raking

Raking accumulates the forage swaths into windrows for baling. Like tedding, raking operations can cause excessive leaf losses if they are improperly timed. For alfalfa, it is critical to rake when the forage is at approximately 40 percent moisture. The curing process will be completed in the windrow and the crop will retain more leaves than if it is raked dry. If the hay becomes too dry before windrowing, excessive shattering of leaves will occur. Under these conditions, rake at night or early in the morning when the leaves have absorbed moisture from the air. Parallel-bar rakes usually result in less damage to the crop than wheel rakes, but must be operated at a relatively slow ground speed.

A wheel rake parked at the edge of an alfalfa field in Coffee County, GA after the hay has been harvested.

Baling

Baling packages the hay in a transportable form; however, bales must be sufficiently dry before they are formed. Baling when the moisture is too high will increase mold growth, reduce quality, and cause excessive heating or even spontaneous combustion.

A square baler baling alfalfa in a field in Coffee County, GA

Weight square bales in the field with a calf scale to ensure they are hitting the target weight for your market.

Most alfalfa hay in Georgia is baled in small rectangular ("square") bales. Square bales of alfalfa are typically more acceptable in the commercial hay market because of their lighter weight (usually less than 75 lbs.) and ease of handling in small lots. Small square bale systems can be more labor intensive than the larger package hay systems, though numerous labor-saving devices exist for handling, loading, and unloading small bales. Square bales usually are less dense than larger bale systems. As a result, they can be baled at slightly higher moistures than the large bale systems. Even so, to prevent excessive heating during storage, alfalfa should not be baled in small squares until the crop has dried to a moisture content of 18 percent or less.

Large round balers that produce cylindrical bales are commonplace in Georgia grass hay operations. These balers can also be used to bale alfalfa. However, the major disadvantage to these bales is that their marketing options are more limited. Also, these bales should not be formed until the forage moisture is less than 15 percent, since these bales are dense and less able to allow moisture and heat to diffuse from the forage once the bale is formed.

Similarly, alfalfa may also be baled in large rectangular bales. These bales are usually as dense as the large round bales. As a result, alfalfa should be less than 15 percent moisture when large rectangular balers are used. Handling and marketing problems are comparable to those of the large round bales.

Hay Preservatives

Alfalfa can be baled at higher moisture levels (20 to 25 percent) when a hay preservative is used. Fewer leaves will be lost from shattering during baling operations at 20 to 25 percent moisture than at 15 to 18 percent moisture. Hay preservatives are usually sprayed or spread on the windrow via an applicator mounted on the baler. When the preservatives are applied according to manufacturer recommendations, treated hay is safe to feed to all livestock.

There are three general types of hay preservatives: organic acids, ammonia and ammonia-based products, and microbial additives. The use of propionic acid has been proven effective. Newer formulations contain buffering solutions that minimize the corrosive effect that these chemicals have on equipment. Ammonia and ammonia-based preservatives are generally used on lower-quality forage crops to obtain a crude protein increase and are not economically feasible for alfalfa. Many microbial products have been promoted recently for use as hay preservatives, but the effectiveness of these products under conditions in Georgia remain relatively unknown and are therefore not recommended.

Hay preservative being applied to alfalfa hay as it is being baled.

Hay preservatives can cause excessive corrosion on equipment.

Storage

Alfalfa hay should always be stored under a shelter. Alfalfa bales will not shed water as well as bales of grass hay, and excessive storage losses occur when bales are stored outside. Also, bales should be stacked in a way that allows for some air movement through the stack.

Alfalfa as a Silage Crop

Ensiling alfalfa has certain advantages for producers who can use silage in their feeding programs. Unfavorable weather conditions that can cause significant losses in hay production are less of a problem. Fewer field losses (from leaf losses and respiration of plant tissue during drying) occur and a higher percentage of the nutrients in the forage can be preserved. Silage can be preserved for a long time and feeding can be mechanized to reduce labor requirements.

Crops such as corn have a naturally high level of soluble carbohydrates and ferment rapidly. This produces a great deal of lactic acid which lowers the pH and stabilizes the silage. Alfalfa, like other legumes, does not contain a high level of carbohydrates for natural fermentation, which limits the amount of lactic acid produced. Compounds within the alfalfa also act as a buffer, making the attainment of a low and stable pH even more difficult.

Under unfavorable conditions, poor fermentation resulting in low palatability, unpleasant odors and excessive storage losses can occur. However, alfalfa can achieve a good natural fermentation when properly managed.

Types of Silage

Alfalfa silage is generally created in one of three ways: direct cut, wilted and chopped, or wilted and baled. Standing alfalfa can be directly chopped and ensiled in conventional silos, but the high moisture content (80 percent or greater) will result in excessive effluent, and unpalatable silage may result from unfavorable fermentation. Adding a carbohydrate source such as crushed corn or molasses to the silage during the filling operation will usually improve fermentation and reduce seepage losses.

Wilted alfalfa being chopped for silage.

Cutting alfalfa and letting the crop wilt in the field to 65 to 70 percent moisture before chopping and ensiling will improve preservation. Only one to four hours of wilting will be required under average drying conditions.

Alfalfa being baled for silage.

Wilted silage packs well and produces little or no effluent. Silage in this moisture range can be stored in horizontal silos, but losses of dry matter and nutrients will be greater than when silage is stored in upright silos.

Alternatively, alfalfa can be wilted and then baled using a large round baler. These bales can be wrapped with stretch-wrap plastic to exclude oxygen and then be ensiled. It is critical that the wrapper applies sufficient plastic to the bales. In-line wrappers that form a tube need to apply six to eight layers of stretch-wrap to each bale, with up to 10 layers applied at the locations where bales abut one another in the tube. Individual bale wrappers should apply a minimum of four layers, but six layers are recommended for bales that will be stored for more than six months. Silage bales should not be moved or handled until they are to be fed. Silage bales can be handled like large round hay bales, but silage bales are usually twice as heavy as the same size hay bales. Therefore, care should be taken to ensure that all equipment (balers, bale forks/spears, bale slicers, tub grinders, etc.) are capable of handling the heavier weight. Also, bale wrapping for hay must be done on-site where storage and feeding will occur. Dropping these wrapped bales off the wrapper and into a storage row with no additional handling is preferred. If wrapped bales must be moved to the storage site, any holes or damage to the plastic must be patched and sealed immediately.

In-line hay wrapper.

Individual bale wrapper.

Grazing Alfalfa

For many years, alfalfa was not considered capable of withstanding substantial grazing pressure. However, forage breeding efforts by Dr. Joe Bouton at the University of Georgia between the late 1980s and 2000s resulted in several grazing-tolerant varieties and "dual-use" (grazing or hay) alfalfa varieties that are now available. However, these varieties still must be correctly managed to maintain productive stands.

Grazing alfalfa provides high-quality pasture.

When managing any alfalfa for grazing, some fundamentals must be kept in mind to ensure success. First, carefully select the grazing-tolerant variety. Any grazing-tolerant variety should have data showing its grazing performance. Ask for this information and use it to decide which variety to select.

Secondly, obtain a strong alfalfa stand. Any grazing-tolerant variety will be subject to the same soil and management needs of hay-type alfalfas and must be treated as such. Use recommended establishment and management procedures for alfalfa in your area.

Thirdly, **prevent bloat by never allowing hungry animals onto alfalfa**. Ruminants can bloat on alfalfa. This usually occurs when an animal that has either been without feed or has an empty rumen is allowed to gorge on fresh alfalfa. It is best to feed a supplement containing monensin (Rumensin) and/or a chemical bloat preventative (Bloat Guard) to minimize the risk of bloat.

Finally, use some type of managed grazing (i.e., management-intensive grazing or rotational grazing). If a variety is truly grazing-tolerant, it should survive and perform well even under fairly substantial grazing pressures. However, the efficiency of alfalfa production is greatest when the stand is allowed to accumulate 10 to 16 inches of growth (usually early bloom stage), grazed to a stubble height of two to four inches in less than four days, and then allowed to rest for 15 to 30 days (or the time it takes to reach the grazing initiation height or early bloom stage). Longer grazing periods will cause stand loss, as grazers trample new growth buds.

The use of easy-to-move electric fences has made managed grazing easier for many producers. Managed grazing allows better control over the forage supply and reduces waste. In managed grazing, the efficiency of the system and the level of management increase when animals are rotated among more and smaller pastures (paddocks). However, if rotating animals among several small pastures is not feasible, using alfalfa for creep and limited grazing can allow the producer to give access only to those livestock that need it, with very little routine management effort.

For more information about managed grazing systems, visit our "Management-intensive Grazing" Web site at http://www.caes.uga.edu/Topics/sustainag/grazing/index.html.

Alfalfa pastures in Tift County, Ga.

A creep-grazing gate allows calves to access an alfalfa field in Tift County, Ga.

Weed Control

Alfalfa is a vigorous, long-lived perennial forage that provides good ground cover from early spring until late fall. The plant recovers rapidly after harvesting and is a good competitor with most weeds.

Weeds are likely to be a problem during the establishment year and in subsequent years as stands thin or growth is slowed due to unfavorable moisture, low fertility, or poor harvest management. A good weed control program will increase stand productivity and, in many cases, extend the useful life of the stand.

Pre-Emergence

Fall-planted alfalfa is susceptible to competition from winter annual grasses (e.g., little barley, rescuegrass, annual ryegrass, etc.) and winter annual broadleaf weeds (e.g., chickweed, henbit, various mustard species, Carolina geranium, etc.). Though these weeds may seriously interfere with stand establishment in fall-planted alfalfa, summer annual and perennial weeds are much more aggressive in Georgia and make it difficult for spring-planted alfalfa to compete. This is one of the major reasons spring plantings of alfalfa are NOT recommended in Georgia, while northern and mid-western states recommend spring plantings.

Pre-plant herbicides that are incorporated into the soil immediately before planting are recommended in the Georgia Pest Management Handbook (http://www.ent.uga.edu/pmh/). These herbicides can provide excellent control of both grass and broadleaf weeds. The response of specific weeds to specific herbicides can be found in weed response tables in the Georgia Pest Management Handbook.

Some herbicides may cause temporary injury to seedling alfalfa but plants usually recover quickly with no lasting effects. Injury, which is expressed as stunted plants with leaves that do not unfold (margin leaf-sealing), is most likely to occur on sandy or coarse-textured soils.

Post-Emergence

Weed populations may interfere with the growth and development of alfalfa seedlings, particularly if pre-emergence treatments were omitted or if environmental conditions reduced the effectiveness of pre-emergence treatments. A limited choice of herbicides may be safely used on alfalfa seedlings after the three-leaf stage during the winter or early spring of the year of establishment. Apply treatments to small weeds as soon as alfalfa reaches minimum size, provided temperatures are warm enough to permit good activity (50° to 55° F minimum). Consult the current Georgia Pest Management Handbook for specific treatments and suggestions for proper use.

Post-emergence herbicide application on alfalfa.

Weeds may encroach on alfalfa stands after hay harvesting begins, especially after the stand is three to four years old. Winter weeds may be especially troublesome, as alfalfa growth is less vigorous during the winter and less competitive in preventing weed establishment. A good selection of contact and translocated herbicides is available for post-emergence application to dormant or semi-dormant alfalfa. Applications are usually made in January or early February to control winter annual grasses and broadleaf weeds, in order to eliminate weed contamination in the first hay harvest each year.

During summer periods after hay harvest, alfalfa is especially vulnerable to germination and establishment of annual grasses and broadleaf weeds. Summer annual grasses or broadleaf weeds are usually best controlled by applications between the time the forage is harvested and the alfalfa begins to regrow. Selected herbicides, outlined in the Georgia Pest Management Handbook, are available that can kill the weeds with minimal impact on alfalfa regrowth rate or yields.

Common bermudagrass is a particularly troublesome weed in established alfalfa. Currently-labeled chemicals may suppress this weed, but at labeled application rates will not kill common bermudagrass, even with sequential applications up to the allowable maximum application rate. Therefore, this weed should be well-controlled before planting alfalfa, and must be followed by application of a reliable pre-emergent herbicide.

Diseases

A number of diseases that affect alfalfa can kill seedlings, limit yields, reduce the quality of the forage, and shorten stand life. This section offers a brief overview of eight diseases (or disease complexes) that have been summarized from a number of other publications that describe these and other diseases in greater detail and aid diagnosis. These publications include the *Alfalfa Analyst* (published by the National Alfalfa and Forage Alliance and available at http://www.alfalfa.org/pdf/AlfalfaAnalyst.pdf); the Kentucky Integrated Pest Management: Alfalfa Diseases Page (http://www. uky.edu/Ag/IPM/scoutinfo/alfalfa/disease/dislist.htm) and the more detailed *Compendium of Alfalfa Diseases* (published by APS Press).

Anthracnose

Affected Areas	Stems (initially), crowns (eventually).
Symptoms	Large, sunken, oval- to diamond-shaped lesions on stems. Lesions enlarge, join other lesions, and can girdle the stem(s).
Scouting Recommendations	Examine fields every 4 weeks in mid-summer and fall (July 15 to Oct. 1). Examine plants within a 20 foot radius.
Disease Severity Scale	0 = no symptoms on stems or crowns of any plants. 1 = a few lesions found on some stems of a few plants, but no crown infections, little or no death of plants. 2 = lesions found on a number of plants, some dead, straw-colored stems scattered throughout the area. 3 = lesions observed on most stems of most plants, numerous dead stems found, thinning of stand apparent with anthracnose symptoms associated with crowns of dead or dying plants. (If entire crowns are dead, indicate as such.)
Comments	Infected crowns turn blue-black, produce fewer stems per plant, and the plant eventually dies. Moderate or higher resistance is available in many varieties.

Aphanomyces Root Rot

Affected Areas	Seedlings
Symptoms	Seedlings (usually in wet soils) develop yellow cotyledons, chlorosis of other leaflets. Underside of leaflets may be reddened.
Scouting Recommendations	Examine plants in the field about 6 to 8 weeks after seeding. Examine five sites at least 10 to 20 feet from the field edge, especially in wetter areas of the field.
Disease Severity Scale	0 = no plants diseased. 1 = less than 25% of plants in the site have modest stunting and yellowing. 2 = more than 25% of plants are showing symptoms; some scattered plants may show severe stunting. 3 = more than half of the plants at the site are extremely stunted (less than two inches tall) six weeks after seeding.
Comments	Avoid poorly-drained sites. Select resistant varieties. There are two races. Most resistance is to Race 1. Occasionally, resistance to Race 2 is needed.

Crown and Root Rot Complex

Affected Areas	Crowns and taproots
Symptoms	Infected plants have leaves that wilt, turn yellow, then become bleached, often with a reddish tint. Crowns and roots contain reddish or brown rotting tissue.
Scouting Recommendations	Examine plants every 4 weeks from April to October. Examine any suspicious-looking plants within 100 feet of the monitoring site.
Disease Severity Scale	0 = no infected plants; good, healthy stand. 1 = one plant has symptoms, appearance of some missing plants in stand. 2 = between 2 and 10% of plants infected; several areas where stand slightly thinned. 3 = more than 10% of plants infected, severe thinning of stands.
Comments	Minimize crown injury by avoiding traffic or grazing when soil is wet. Maintain good soil fertility (esp. K). Allow adequate regrowth between cuttings (4 to 6 weeks). Control leaf-feeding insects.

Leaf Spot Complex

Affected Areas	Leaves and stems
Symptoms	Leaf spots that are tan, brown, or black; circular to oblong; may be raised above the leaf surface. Several types of leaf spots are common in alfalfa (e.g., common leaf spot, lepto leaf spot, etc.). Leaves with several or many spots may turn yellow and fall to the ground.
Scouting Recommendations	Examine plants in the field every week after the plant reaches late vegetative stages between mid-March and Sept.
Disease Severity Scale	0 = no affected plants. 1 = a few lower leaves contain spots, but little or no defoliation. 2 = many leaves contain spots, some premature defoliation. 3 = leaves and stems peppered with spots, many leaves fallen on ground, all plants affected.
Comments	Fields receiving an average rating of 2 or more should be harvested early (but not before bud stage). Currently available varieties have little resistance.

Sclerotinia Crown and Stem Rot

Affected Areas	Leaves and stems (initially), crowns (eventually).
Symptoms	Brown spots on leaves and stems, affected stems wilt and die, and the fungus infects the crown. When moist, a cottony fungus grows over diseased areas. Black bodies called sclerotia, about the size of BBs, form in this fungus growth or on dead stems.
Scouting Recommendations	Examine plants in the field every 2 to 4 weeks from mid-Feb. - April.
Disease Severity Scale	0 = no affected plants. 1= only 1 to 2% of plants show typical symptoms. 2 = 2 to 15% of plants affected. 3 = more than 15% of plants affected.
Comments	Damage is least severe in fields established using conventional tillage. Use Sclerotia-free seeds when planting. More likely in the Georgia Mountains or in very mild winters and springs.

Spring Black Stem and Leaf Spot

Affected Areas	Leaves and stems
Symptoms	Small, irregularly-shaped, black to dark brown spots develop on the lower leaves and stems. Diseased leaves turn yellow, wither, then fall. Lesions on the stems may girdle and blacken large areas near the base of the plant.
Scouting Recommendations	Examine plants in the field every week after the plant reaches late vegetative stages from mid-Feb. to April.
Disease Severity Scale	0 = no affected plants. 1 = a few lower leaves contain spots, but little or no defoliation. 2 = many leaves contain spots, some premature defoliation. 3 = leaves and stems peppered with spots, many leaves fallen on ground, all plants affected.
Comments	Fields receiving average rating of 2 or more should be harvested early (but not before bud stage). Early harvest will reduce leaf loss. Spring black stem is favored by cool, moist weather and the first cutting in the spring is usually the most damaged. Varietal resistance is highly variable.

Summer Black Stem and Leaf Spot

Affected Areas	Leaves and stems
Symptoms	Leaf spots are somewhat larger than those of spring black stem, usually 1/8- to 1/4-inch in diameter. Spots are reddish brown to light gray and often surrounded by a yellow halo. Stem lesions are dark brown.
Scouting Recommendations	Examine plants in the field every week after the plant reaches late vegetative stages from mid-May to Sept.
Disease Severity Scale	0 = no affected plants. 1 = a few lower leaves contain spots, but little or no defoliation. 2 = many leaves contain spots, some premature defoliation. 3 = leaves and stems peppered with spots, many leaves fallen on ground, all plants affected.
Comments	Fields receiving average rating of 2 or more should be harvested early (but not before bud stage). Early harvest will reduce leaf loss. Summer black stem is favored by hot, humid weather. Currently, available varieties have little resistance.

Southern Blight or Stem Rot

Affected Areas	Leaves and stems (initially), crowns (eventually).
Symptoms	One or more individual branches turn yellow, wilt, and die. Disease lesions are light tan to brown and often develop into a dry rot. In humid conditions, the fungus produces a white moldy growth over infected stems similar to Sclerotinia. Produces tan to brown, mustard seed-sized sclerotia.
Scouting Recommendations	Examine plants in the field every 2 to 4 weeks from mid-May to Sept.
Disease Severity Scale	0 = no affected plants. 1= only 1 to 2% of plants show typical symptoms. 2 = 2 to 15% of plants affected. 3 = more than 15% of plants affected.
Comments	Southern stem rot is a hot weather disease.

Disease Management

The occurrence and severity of these diseases depend on soil conditions, crop management, and environmental stresses. Since no chemical control options are available, the only way to control these diseases is to practice good management. Cultural practices that maintain healthy growth can be achieved by abiding by the following recommendations:

- Select varieties that have a "Resistant" (R) rating (or higher) to as many diseases as possible.
- Select a well-drained, deep, and fertile site for alfalfa production.
- Use high-quality and, when possible, fungicide-treated seed.
- Maintain an appropriate soil pH and adequate levels of soil nutrients.
- Control insects and weeds to prevent wounds, stress, competition, or reductions in air circulation.
- Minimize crown injury by avoiding the use of heavy equipment or grazing when the soil is wet.
- Cut alfalfa at the early-bloom stage to prevent the buildup of foliar diseases.
- Harvest young stands before older ones to prevent the spread of disease from old to new stands.
- Cut only when foliage is dry.
- Cure, bale, and remove hay promptly.
- Practice good fall harvest management and remove freeze-damaged stems in a “freeze-down” harvest after a killing frost.
- Rotate crops and ensure that alfalfa does not follow other legume crops.

Nematodes

Several species of parasitic nematodes infect alfalfa. Nematodes can affect stand establishment, promote increased susceptibility to root and crown diseases, reduce stand life, and cause yield losses.

Alfalfa is generally classified as being affected by root-knot, lesion, stubby root and lance nematodes. Although not confirmed by research, nematologists suspect that the sting nematode will also injure alfalfa. Nematodes are more likely to affect alfalfa on the sandy soils of the Coastal Plain and on sandy river bottoms in north Georgia.

Nematode damage appears as stunted, yellow to light green areas in a field. Root damage symptoms include stunted root systems, stubby feeder roots, and knots on the roots similar to nodules. No nematicides are registered for use on alfalfa. Avoid planting in fields where damaging populations of nematodes occur. Nematologists can determine nematode population levels by extracting and counting juvenile nematodes found in soil samples taken for that purpose. Contact your county Extension agent for more information on sampling for nematodes.

Insects

Alfalfa grown in Georgia is subject to attack by a wide variety of insect pests. However, only a few of these pests occur at population levels capable of causing economic damage to the crop in most years. Knowledge of the seasonal occurrence of insect pests, their appearance and damage symptoms, and means by which they can be controlled will help growers minimize economic losses to their alfalfa crops.

Foliage Feeding Insects

Alfalfa weevil tip feeding damage.

Alfalfa Weevi

The alfalfa weevil is considered the most serious alfalfa pest in Georgia. Both larval (worm or grub) and adult stages attack the plants. Larvae are most damaging to the first crop of the season and adults can be present in damaging numbers during regrowth of the second crop. Their feeding causes loss of both yield and quality.

Alfalfa weevils overwinter as both adults and eggs. Eggs are deposited within alfalfa stems in the fall through early spring. Eggs hatch, depending on temperatures, in late February to early March and the larvae move to the tips of the plants. If left uncontrolled, larvae will feed for two to three weeks. The small larvae feed within the plant terminals, causing a "ragging" of leaves emerging from the terminal buds. Larger larvae usually feed more on the leaves that have already emerged. When present in large numbers, larvae cause severe defoliation and fields appear frosted or grayish. In very mild winters, weevil larvae can begin feeding in early winter and control measures may be needed.

Alfalfa weevil (Photo by Jack Kelly Clark, courtesy of UC Statewide IPM Program).

Alfalfa weevil larvae (Photo courtesy of Marlin Rice, Iowa State University).

As the first harvest approaches, most weevil larvae spin cocoons in debris on the soil surface and enter the pupal stage. An adult will emerge from each of these cocoons after two to three weeks of pupation and begin feeding on alfalfa. They normally feed for a short time to build up food reserves and then move into vegetation along field margins, where they remain inactive during the summer months. With the return of cool weather conditions in the fall, the adults return to the alfalfa fields.

In Georgia, at least one insecticide application will be needed in most fields every year to control alfalfa weevils in established alfalfa. In most years, alfalfa larvae can be present in damaging numbers early in the first growth cycle (late February through mid-March) when stems may still be short. In cool springs, larvae may occur later in the first growth cycle. Sample larvae with either a sweep net or a shake-bucket technique. Insecticide control is justified if larval numbers exceed 20 larvae per sweep and 30 percent of terminals show damage. For the bucket technique, carefully pick 30 stems randomly per field, place them in a white plastic bucket, and beat stems against the side of the bucket. Count the larvae and divide by the number of stems. Shake-bucket thresholds are based on stem heights (Table 4). If stems are very short and most larvae are very small (1/16-inch long), most likely the eggs are still hatching and treatment should be delayed to allow most eggs to hatch before treatment.

Table 4. Treatment thresholds for control of insect pests of alfalfa.

Pest	Threshold level(s)
Alfalfa weevil larvae Sweep net Shake bucket (based on stem height)	20 or more larvae per sweep 5-8 inches: 0.5 larva per stem 9-14 inches: 1.0 larva per stem 15 inches or more: 1.5 larvae per stem
Clover leaf weevil and lesser clover leaf weevil larvae	30% infested stems
Aphids (based on stem height)	Less then 15 inches: 40 aphid per stem 15 inches or more: 80-100 aphids per stem
Potato leafhopper (based on stem height)	3-7 inches: 0.5 hopper per sweep 8-10 inches: 1.0 hopper per sweep 11-14 inches: 2.0 hoppers per sweep 14+ inches: 4.0 hoppers per sweep or cut early
Leaf-feeding caterpillars, cutworms	10% defoliation
Grasshoppers	10% defoliation or 10 nymphs per square yard
Soil insects or Green June beetle larvae	2 per square yard
Three-cornered alfalfa hopper	10% infestation of seedling stands or Girdling of 10% of stems in established stands

In Georgia, alfalfa weevils almost always need control several weeks before normal harvest. Sometimes, in cool springs or in the northern part of the state, damaging populations may occur near harvest them bud stage to first bloom stage. At this point, consider harvesting early with a mower-conditioner, which will kill most larvae. Grazing cattle also can be used as a weevil larvae control measure for the first harvest. Check stubble four to six days after mowing or grazing for possible damage by surviving larvae or new adults. Stubble sprays may be required, especially in fields not sprayed before harvest, to prevent damage during regrowth of the second crop.

When selecting an insecticide for alfalfa weevil, carefully consider the product harvest interval. Some older products at higher rates can have a very long harvest interval.

Aphids

Aphids also can be a serious alfalfa pest in Georgia. They are often especially damaging during years with cool, wet conditions that allow for maximum aphid population development. Aphids insert their mouthparts into plants and feed directly on plant juices. Their feeding usually does not cause obvious yellowing or stunting, but large numbers can reduce plant vigor and growth.

Two aphid species typically attack alfalfa in Georgia: the pea aphid and the spotted alfalfa aphid. A third species, the blue alfalfa aphid, has been found in Georgia but rarely is a problem in the state. The pea aphid is light green and larger than the spotted alfalfa aphid. It usually occurs on the first crop of the season. Damage symptoms include yellowing of infested foliage and possible wilting of plants due to removal of plant fluids.

The spotted alfalfa aphid is pale yellow to white with several rows of dark spots along its back. Damage symptoms appear as a yellowing of the foliage between the leaf veins.

Pea aphids (Photo by Jack Kelly Clark, courtesy UC Statewide IPM Program).

Spotted alfalfa aphids (Photo by Jack Kelly Clark, courtesy UC Statewide IPM Program).

Initiate control against aphids when heavy infestations begin to cause yellow and/or loss of vigor. Treatment thresholds are not well established but consider insecticidal control if numbers exceed 40 aphids per stem when alfalfa is less than 15 inches tall or 80 to 100 aphids per stem if alfalfa is 15 inches taller. If alfalfa is close to harvest maturity, harvest early and treat stubble as needed. Natural enemies such as lady beetle larvae and adults and various parasites usually keep the aphid population in check. Lady beetles are not active during the winter, so large aphid populations may build up in late winter on non-dormant alfalfa before lady beetles become active. If spotted alfalfa aphids appear in seedling stands, treat when they can be easily found in the field. This aphid is capable of severely stunting or destroying alfalfa seedlings.

Potato Leafhopper

Potato leafhoppers sometimes reach damaging levels in later alfalfa growth cycles between July and September in Georgia. They feed on leaves and stems by sucking plant fluids. Their feeding causes a toxic reaction that typically causes the tips of leaves to turn yellow. This injury forms an inverted V-shape from the tip and is called “hopperburn.” Severe damage will stunt plants and make the stand appear yellowed.

Potato leafhopper adult (Photo courtesy of Marlin Rice, Iowa State University).

Potato leafhopper nymph and “hopperburn” caused by feeding injury (Photo courtesy of Oklahoma State University).

Potato leafhopper nymphs are very small, 1/16- to 1/32-inch long, and adults are 1/4-inch long. Both are greenish yellow and elongated. Sampling is based on sweep net samples. Take 10 sweeps per spot in five spots per field. Insecticide treatment thresholds are based on stem height and range from 0.5 to four hoppers per sweep, depending on stem height (Table 4). Several insecticides are available; pyrethroid insecticides usually provide good control.

Alfalfa varieties with resistance to potato leafhoppers have been developed and may be available. These varieties generally are more tolerant of leafhopper damage, with damage usually being reduced to a point where treatment is not needed. However, potato leafhopper resistance has not been extensively evaluated in Georgia.

Three-cornered Alfalfa Hopper

Three-cornered alfalfa hoppers are so named because adults have a large triangular shield over their back. Nymphs are teardrop-shaped and have a line of small spines along the back. Both nymphs and adults are green and have piercing-sucking mouthparts. They feed on alfalfa stems, often girdling the stem less than one inch above the soil surface and causing the stem to wilt and die. In Georgia, this insect also causes similar damage to soybean and peanut. Three-cornered alfalfa hopper usually does not need to be controlled in alfalfa. Treatment threshold is 10 percent of stems being girdled and dying.

Three-cornered alfalfa hopper (Photo by Jack Kelly Clark, courtesy UC Statewide IPM Program).

This stem was girdled by the three-cornered alfalfa hopper and the leaves show the effects.

Blister Beetles

Several species of blister beetles may infest alfalfa in Georgia. Blister beetles feed on foliage but rarely cause significant defoliation. Instead, their bodies contain a very toxic chemical that contaminates hay. This compound, cantharidin, can be toxic to livestock especially horses. The striped blister beetle is the species usually associated with alfalfa hay poisonings. Generally, the first cutting is at low risk of infestation; beetles usually occur after that time and peak in late summer. Blister beetles can aggregate in very large numbers, often along the field margin. For more detailed information on blister beetle management in alfalfa see UGA Extension Circular 917 (http://pubs.caes.uga.edu/caespubs/pubcd/C917/C917.htm).

Striped blister beetle (Photo courtesy of Marlin Rice, Iowa State University).

Others

Later in the growing season, lepidopteran (caterpillar) larvae, including green cloverworm, velvetbean caterpillar, alfalfa butterfly larvae, and various armyworm species, may cause defoliation. These caterpillars can be considered as a group and control considered when defoliation exceeds 10 percent. Grasshoppers also may cause defoliation, especially in dry years. Several other weevil species (such as clover leaf weevil) may occasionally infest alfalfa and cause damage similar to the alfalfa weevil. Check Table 4 for treatment thresholds for these and other alfalfa pests.

Soil Insects

Various soil insects such as white grubs, wireworms, or whitefringed beetle larvae may cause stand losses when establishing new alfalfa plantings. Inspect fields before planting to determine whether soil insects are present. Since these insects bury themselves quickly in the soil (within seconds), inspection should be made immediately after turning the soil. If any of these pests are found at an average of two larvae per square yard, a pre-plant or at-planting insecticide may be beneficial. The only insecticide currently available for soil insect control during alfalfa planting is chlorpyrifos (Lorsban, Chlorfos and other brands). The liquid formulation (4E) can be applied pre-plant and incorporated, or the granular formulation (15G) can be applied in-furrow at planting. Control may be variable depending on soil conditions and infestation size.

If alfalfa is to be planted following grass sods, inspect the sod for infestations of mole crickets or green June beetle larvae. Infestations are indicated by fluffiness of the top one to two inches of the soil and the presence of holes (1/4- to 3/4-inch in diameter). No effective chemical controls are available for use against mole crickets in alfalfa, but green June beetle larvae can be controlled with recommended insecticides.

Management

A proper crop management program can ensure high alfalfa yields and quality. Follow recommended agronomic practices (fertilization liming, weed control, seeding, etc.) to achieve and maintain vigorous crop stands. Healthy plants tend to tolerate and/or outgrow insect damage more efficiently than plants not receiving proper care. Check fields for insect problems at least weekly during the growing season. Maintaining a field report at each sampling may help determine whether a population is increasing or decreasing.

Inspect each field; insect populations differ among various locations. Examine plants at three to four locations for every five to 10 acres in a field. A sweep net may be used in these examinations, but use the "bucket method" when scouting for alfalfa weevil. In the "bucket method," entire stems from the sample locations (a total of 30 stems from representative areas of the field) are collected and shaken inside a bucket to dislodge the weevils from the stems, and the alfalfa weevils are counted. If a damaging population is present, early cutting can be a very effective means of control. Check stubble for surviving pests within four to six days after cutting and treat the stubble if regrowth is delayed. Specific treatment threshold levels and insecticide recommendations for all alfalfa pests are updated annually in the Georgia Pest Management Handbook (http://www.ent.uga.edu/pmh/) and may be obtained from your county Extension office.

Use insecticides judiciously in alfalfa. Numerous beneficial insect predators and parasites can be found in alfalfa fields during the entire growing season. These beneficials help suppress many different insect pests. Also avoid applying insecticide to flowering alfalfa to prevent killing bees. In addition, be aware of the restrictions for individual insecticides with regard to the interval between spray and harvest when you select the best insecticides for your situation.

Alfalfa Utilization

Alfalfa is one of the highest-quality forages available to livestock producers in Georgia. It is high in crude protein and above average in energy. As a result, it is sometimes used as the primary forage for grass-fed livestock systems where pastured animals require high levels of nutrition from their pasture rather than from grain-based supplements.

For conventional livestock systems, however, alfalfa normally supplies more protein and energy than is required for most classes of animals. For this, as well as economic reasons, good quality alfalfa is typically used as a supplement in feeding programs in Georgia rather than as the primary forage in livestock rations. This supplement can be provided by allowing animals to limit-graze alfalfa or alfalfa/grass pastures, but most commonly is provided by using alfalfa hay as an ingredient in a balanced ration.

The following examples provide the considerations necessary for feeding alfalfa hay as a high-quality forage supplement. In the interest of brevity, these sections only consider the use of alfalfa hay in rations for the three major forage-based livestock systems in Georgia: beef cow-calf, dairy cows, and horses.

Certainly, there are many other livestock enterprises where alfalfa can be utilized. The following suggested rations are meant only as guidelines. There will be substantial differences in each scenario, even within the examples detailed here. Thus, it is best to consult with your county Extension agent or animal nutritionist about how to use alfalfa in your specific livestock feeding program(s).

Using Alfalfa Hay in Livestock Feeding Systems

When alfalfa is harvested for hay following best management practices (see previous sections), the forage will generally contain 61 to 64 percent TDN and 18 to 22 percent protein (Table 5). By virtue of being comparatively higher in quality than grass hay, alfalfa is most often used as a substitute for grass hay in the ration.

Table 5. Comparison of the typical forage quality of grass and alfalfa hay when harvested at the recommended stage of maturity.

Nutrient	Grass Hay	Alfalfa Hay
CP	9 – 11%	15 – 18%
TDN	55 – 58%	61 – 64%
RFQ	90 – 115	125 – 180

Although it can be exceptionally high, alfalfa quality varies considerably (as do most other feedstuffs). Unfortunately, quality cannot be adequately assessed without a forage analysis (see the “Your Senses Can Be Deceiving” inset). It is critical that an analysis be used to determine the true nutritive value before the forage can be most effectively used in the ration.

Additionally, animals that have been switched to a diet that contains relatively high amounts of alfalfa (more than 25 percent) may need time to adjust to the change in quality. In these transitions, alfalfa may have a mild laxative effect on some animals. In general, animals acclimate to alfalfa-rich diets within two weeks.

Your Senses Can Be Deceiving

Green color in a hay crop does not equal high quality. Alfalfa hay that is produced in western states is often a bright green color. This side effect of more arid curing conditions is not very indicative of energy content, fiber digestibility, or protein level. Thus, the use of color as an indicator of forage quality is overrated and can be quite deceiving. This essentially cosmetic trait is sought by hay buyers, but it is more important to the person than to the animal (cattle and horses are unable to distinguish green from brown).

However, **the smell of hay can be used to identify problems** not seen in analyses of forage quality. As with all hay crops, alfalfa hay can contain excessive mold or dust when baling conditions were less than ideal. Good alfalfa hay should have a fresh, pleasant smell rather than a moldy or dusty odor. Moldy or dusty smelling hay is a reasonable (but still rather subjective) indicator of mold or dust. However, mild odors or the lack of hay odor should not be thought of as conclusive indicators of mold or dust content. For example, if the hay was recently baled (less than three weeks), its mold content (and smell) may change in time.

Beef

Alfalfa can serve as a good supplement resource for beef cattle producers in Georgia because it provides an excellent source of protein and energy. Alfalfa hay that does not meet dairy/horse specifications may be purchased cheaper than many typical supplements. However, as with any supplementation strategy, feedstuffs should be evaluated on a per-nutrient basis to assure the most economical decision is made.

A typical supplement for a 1,000 lb. lactating cow is a 50:50 blend of corn gluten feed and soyhulls fed at sevens lbs. a day (77 percent TDN, 15 percent CP). In order to compare the value of alfalfa hay to this supplement we need to define the amount of alfalfa hay needed to equal the amount of supplement (Table 6). Currently, energy is the most expensive nutrient to feed cattle and should be the first nutrient balanced.

Table 6. Comparison of a 50:50 blend of corn gluten feed and soyhulls to medium-quality alfalfa hay.

	TDN	CP
	—— % ——	
Corn Gluten Feed/Soyhull (50:50 blend)	77	15
Alfalfa Hay (medium-quality)	62	15

Alfalfa hay (medium-quality) contains approximately 80 percent of the energy (TDN) of the corn gluten: soy hull supplement. Therefore, alfalfa's value is 80 percent of the typical supplement (based on energy content).

Guidelines for Feeding

Feeding alfalfa as a supplement to other forages may present problems that should be considered. Care must be taken to ensure that the alfalfa supplement is equally available to all animals. The following guidelines will help in planning how to properly use alfalfa in your program.

Frequency of feeding. It is best to feed on at least a daily basis. A suitable alternative would be to feed double the amount on alternate days. Feeding alfalfa less frequently (every third or fourth day) may cause digestive problems and reduce performance.

Form of feeding. Alfalfa is best handled in square bales. Feeding as long-stemmed hay is preferred. Provide hay in troughs or racks, not on the ground. Hay fed on the ground will cause high losses due to leaf shatter and trampling. Round bales of alfalfa can be fed, but limiting access to the forage is more challenging. Grinding bales in a tub grinder is a suitable alternative if it is not ground too finely. A grind of 1/2 to one inch is best.

Trough space. Since alfalfa hay should be hand-fed, adequate trough space is a must. Provide 1 1/2 to two linear feet per head so all cattle can eat at once.

These suggestions are meant as guidelines. There are many ways to feed alfalfa successfully. The key is to know the nutrients available in pastures and grass hay, and to allow all animals adequate alfalfa supplement on a regular basis without overfeeding.

Dairy Cow

The dairy cow is a ruminant that requires a large amount of forage (fiber) in her diet. Alfalfa is a high-quality, highly-digestible forage that is relatively high in calcium and energy content, relative to other forage crops. Alfalfa is known for its ability to meet most of the cow's nutrient requirements and, as a result, has been used in dairy rations for several decades. It has proven to be a forage that aids milk production and is adapted to many feeding schemes.

For the dairy cow, fiber, protein, energy, and calcium are critical nutrients. Adherence to several ration balancing rules of thumb should ensure that there is adequate fiber in the dairy cow's diet. These requirements include at least 40 percent of her dry matter intake (DMI) to be roughage, 17 percent crude fiber (CF), 33 percent neutral detergent fiber (NDF), 23 percent acid detergent fiber (ADF), and 75 percent of the NDF should be from forages. All of these percentages are required to get enough fiber in the ration to maintain rumen microbial activity and slowly release volatile fatty acids (VFA) from the fermentation of cellulose and hemicellulose. The major VFA produced in the rumen is acetate. Acetate is critical to the dairy cow because it is used by the mammary gland to produce milk fat. Fifty percent of the cow's milk fat is synthesized in the mammary gland. If too much grain is fed, less acetate will be produced and milk fat depression will occur. If this continues, rumen pH will decrease and acidosis will occur. Adequate forage in the diet is the best prevention of acidosis.

The protein content for the lactating dairy cow should be 14 to 17 percent, depending upon her level of production. Having more protein available in the forage allows more flexibility in balancing rations and less need to purchase protein supplements. The protein content in alfalfa is relatively high for a forage crop, and it is readily available to the dairy cow.

Energy is often limiting in the ration of the early-lactation or high-producing dairy cow. The cow cannot eat enough feedstuffs to meet her milk production demands. Because of the need to maintain the fiber level for milk fat production, energy will be limited because of intake restrictions. The higher the energy in forage, the closer the ration can come to meeting the dairy cow's energy need. Alfalfa is a high-energy forage that can be used to balance the cow's need for fiber and energy.

Milk is an excellent source of calcium for humans. To provide this level of calcium, the dairy cow has a high calcium requirement. To produce 50 lbs. of 3.5 percent milk, the cow must have 0.13 lbs. of calcium in her diet above her needs. Alfalfa is high in calcium and can help to meet this requirement.

Feeding Systems

Alfalfa is often fed as the sole forage in the West and Midwest. In the Southeast, alfalfa is typically fed in limited amounts as supplemental forage. This means it is most effectively used when it can be blended in a mix to ensure all cows have access to the alfalfa. The way alfalfa is fed to dairy cows will depend upon the form of preservation chosen for the forage. Alfalfa can be harvested and stored as silage, low-moisture silage (haylage), or hay. The form chosen will depend upon harvest time, equipment, storage facilities, feeding system, labor, and capital. Silage, haylage, or chopped hay can be used in total mix rations (TMR) for dairy cows. The interactions of these variables will determine which form a dairy producer will use.

For many producers, the flexibility to harvest their alfalfa in different forms is essential to managing the crop. Harvest time, drying time, and competition with the harvest of other crops will determine how the farmer will harvest and store the crop. As alfalfa production has increased in the Southeast, more alfalfa hay is grown as a cash crop to sell. Competition from the horse market will determine the availability of alfalfa for dairy cattle.

Table 7 lists feed ingredients for a basic corn silage ration using feed ingredient prices averaged from the 2000s and the prices for 2008. Recent prices have increased dramatically due to ethanol demand for corn, global demand for U.S. feed stocks, increased energy prices, increased fertilizer costs, and other economic challenges.

Table 7. Prices for feed ingredients in a base ration with average 2000s prices and 2008 prices.

Feed	Avg 2000s	2008
Corn Silage	$30/ton	$45/ton
Corn	$3.50/bu	$7.00/bu
SBM 48	$260/ton	$350/ton
Whole Cottonseed	$145/ton	$275/ton
Limestone	$65/ton	$90/ton
Dical	$320/ton	$425/ton
Trace Mineral Salt	$140/ton	$185/ton
Dynamate	$180/ton	$240/ton

Table 8 lists the competitive price for alfalfa hay with the base ration, 2000s average, and 2008 prices, and milk production at 50, 70 and 90 lbs. If the competitive price is above the cost of production, then the production of alfalfa could be economically feasible for the dairy producer. If the market price to purchase is higher than the competitive prices, then it may not be economically feasible to buy and feed alfalfa.

Table 8. Competitive price for alfalfa hay with average 2000 feed prices and 2008 feed prices.

Milk Production	Avg 2000s	2008
lbs./day	———— ($/ton) ————	
50	$116.20	$144.61
70	$103.27	$137.84
90	$102.17	$137.24

Rations

Several example rations were calculated to show how alfalfa can be used in dairy rations. A wide range of ingredients were used to allow as much flexibility as possible. The rations in Table 9 were all calculated for a cow weighing 1,350 lbs., producing 60 lbs. of milk daily, with 3.6 percent fat, and at a $21.00 per hundredweight milk price. The alfalfa was early bloom and priced at $150 per ton. The silages were priced at $35 per ton.

Ration 1 is a corn silage-based ration. When alfalfa is substituted as the forage, there is a decrease in protein feeds fed and an increase in energy feeds as seen in Ration 2. Rations 3 and 4 are sorghum silage-based. Adding alfalfa decreased the amount of sorghum silage, corn, and soybean meal, and decreased the feed cost. This is a reflection of the nutritive value of sorghum silage. Rations 5 and 6 are wheat silage-based. The addition of alfalfa to wheat silage is similar to the corn silage rations. These rations maximize the amount of forage as concentrate prices have increased.

Table 9. Rations with corn silage, sorghum silage, and wheat silage with or without alfalfa hay, balanced for 60 lbs. of milk per day.

Feed	**1**	**2**	**3**	**4**	**5**	**6**
Corn Silage	96.2	85.4	—	—	—	—
Sorghum Silage	—	—	78.1	65.8	—	—
Wheat Silage	—	—	—	—	88.0	77.8
Alfalfa	—	5.0	—	7.0	—	5.0
Corn	3.1	3.9	10.7	9.9	5.3	6.1
SBM48	7.8	6.6	7.3	5.2	4.4	3.6
WCS	—	—	6.0	6.0	6.0	5.1
Minerals	0.9	0.9	0.9	0.8	0.9	0.8
Feed $/cow/day	$3.38	$3.45	$4.61	$4.49	$3.79	$3.77
IOFC	$9.22	$9.15	$7.99	$8.11	$8.86	$8.83

Abbreviations: SBM48 = soybean meal, 48% crude protein; WCS = whole cottonseed; IOFC = income over feed costs.

Rations 7 to 12 (Table 10) are balanced for 80 lbs. of milk. To meet the increased nutrient demand, less forage and more concentrate are fed. The response of adding alfalfa is similar to the rations balanced for 60 lbs. The higher the level of milk production, the more valuable alfalfa becomes. The higher levels of forage also help to maintain rumen function and cow health.

Table 10. Rations with corn silage, sorghum silage, and wheat silage with or without alfalfa hay, balanced for 80 lbs. of milk per day.

Feed	**7**	**8**	**9**	**10**	**11**	**12**
Corn Silage	94.3	81.9	—	—	—	—
Sorghum Silage	—	—	59.0	48.7	—	—
Wheat Silage	—	—	—	—	70.7	61.5
Alfalfa	—	5.0	—	7.0	—	5.0
Corn	3.1	4.0	19.3	18.1	15.3	14.6
SBM48	10.8	9.9	11.8	9.6	7.8	7.2
WCS	6.0	6.0	6.0	6.0	6.0	6.0
Minerals	1.2	1.1	1.2	1.1	1.3	1.2
Feed $/cow/day	$4.68	$4.78	$5.95	$5.81	$5.10	$5.14
IOFC	$12.12	$12.02	$10.85	$10.99	$11.70	$11.66

The better the quality of alfalfa, the better returns will be to the dairy producer. Even though alfalfa is the "queen of forages," its quality can vary tremendously. The dairy cow can use alfalfa effectively but, as seen from the rations, the better the quality of alfalfa, the better the cow's needs can be met.

Horse

The high nutrient content and high digestibility of alfalfa make it an excellent feed for horses. Alfalfa hay can serve as the sole roughage for horses, but may be best used as a supplement to lower-quality grass hay in some cases. For maintenance and gestating mare diets, it is typically more economical to use alfalfa as a supplement to a grass hay rather than feeding only alfalfa. However, alfalfa is often fed as the sole roughage to lactating mares, young horses (weaning to two years), and active or working horses. The suggested use of alfalfa for various classes of horses is listed in Tables 11, 12, and 13. (Note: A high phosphorus mineral supplement may be needed to balance the Ca:P ratio.)

Table 11. Feeding guidelines for the maintenance of recreational horses and early- and late-lactating mares with (Diet A) or without (Diet B) the use of alfalfa hay.†

	Maintenance		**Early-Lactating Mare**		**Late-Lactating Mare**	
	Diet A	Diet B	Diet A	Diet B	Diet A	Diet B
	(lbs./animal/day)		**(lbs./animal/day)**		**(lbs./animal/day)**	
Early Bloom Alfalfa Hay	15.00	—	17.50	—	17.00	—
Good Quality Grass Hay	—	20.50	—	20.50	—	18.00
Commercial Concentrate (10% CP)	—	—	11.00	—	8.00	—
Commercial Concentrate (14% CP)	—	0.10	—	13.25	—	11.00
Mineral Supplement	0.05	0.10	—	—	—	—
Expected Feed Intake	15.05	20.60	28.50	33.25	25.00	29.00

† Average body weight of the horses in these examples is assumed to be 1,100 lbs.

‡ Mineral supplement to contain: Calcium: 12-14%, Phosphorus: 12%, Copper: 2,500 ppm, Zinc: 10,000 ppm, and Selenium: 15 ppm.

Table 12. Feeding guidelines for weanling and yearling horses when the animal is (Diet A) or is not (Diet B) provided alfalfa hay.

	Weanlings†		**Yearlings**‡	
	Diet A	Diet B	Diet A	Diet B
	(lbs./animal/day)		**(lbs./animal/day)**	
Early Bloom Alfalfa Hay	6.00	—	9.00	—
Good Quality Grass Hay	—	6.00	—	11.00
Commercial Concentrate (10% CP)	—	—	7.00	—
Commercial Concentrate (12% CP)	6.50	—	—	8.00
Commercial Concentrate (14% CP)	—	8.00	—	—
Mineral Supplement††	0.06	—	0.10	—
Expected Feed Intake	12.56	14.00	16.10	19.00

† Body weight range of 475 to 600 lbs.

‡ Body weight range of 600 to 880 lbs.

†† Mineral supplement monosodium phosphate containing 25% phosphorus.

Table 13. Feeding guidelines for horses performing moderate or heavy work when the animal is (Diet A) or is not (Diet B) provided alfalfa hay.[†]

	Moderate Work		**Heavy Work**	
	Diet A	Diet B	Diet A	Diet B
	(lbs./animal/day)		**(lbs./animal/day)**	
Early Bloom Alfalfa Hay	14.00	—	16.00	—
Good Quality Grass Hay	—	16.50	—	16.50
Commercial Concentrate (10% CP)	6.00	7.75	7.00	10.00
Mineral Supplement[‡]	0.15	—	0.15	—
Expected Feed Intake	20.15	24.25	23.15	26.50

[†] Average body weight of the horses in these examples is assumed to be 1,100 lbs.
[‡] Mineral supplement monosodium phosphate containing 25% phosphorus.

Economics of Alfalfa Production

An economic analysis of any crop involves (1) an estimate of production costs, and (2) the expected receipts for the crop. Once production costs are known, the producer is in a better position to evaluate the market alternatives for the crop.

Cost Outlays Vary

Costs of producing alfalfa will vary among farms as the result of many factors (e.g., soil fertility, climate, life of establishment, and yield level). When considering alfalfa production, be aware of the inputs needed, expected yield, and production costs under the specific set of conditions on the farm in which alfalfa would be produced.

Purpose of Budget

The cost estimates in the accompanying tables are intended to assist with individual farm estimates. These data are not costs associated with a given type of farm, but reflect inputs likely to be associated with the stated outputs. They are designed to permit producers to best estimate their costs to be incurred in the production systems. These budgets can be modified to reflect individual growing conditions.

Types of Costs

Cost determination is the most important part of any marketing or production plan. Until cost is determined, it is impossible to conduct any meaningful economic analysis, regardless of price.

Production costs should be calculated on a marketing unit basis. That is, if alfalfa hay will be marketed on a per-ton basis, then costs should be calculated on a "dollars-per-ton" basis. If the hay will be sold on a per-bale basis, then costs should be calculated in terms of "dollars-per-bale."

In practice, the best way to calculate costs on a per-unit basis is to determine the cost per acre, then divide that cost by the number of units per acre. For instance, if total costs are $1,200 per acre and a producer is planning on marketing six tons of hay per acre; then the cost per ton is $200.

There are two types of costs. Variable costs, often referred to as cash or direct expenses, include items that are used annually for production. Changing levels of variable costs will directly impact production. These costs can be eliminated by not producing the crop.

Fixed costs occur regardless of production. They include items such as prorated establishment costs, depreciation, interest on investment, taxes, and insurance. Fixed costs per unit of output may be reduced by producing more output with a fixed set of equipment.

Production Cost Estimates

Annual Costs

The three largest production cost items are fertilizer, irrigation, and prorated establishment costs (Table 14).

Because of the high investment cost in alfalfa, irrigation is recommended to reduce production risk. If producers choose not to use irrigation, they should lower their annual average yields. Irrigation costs account for approximately 18 percent of total production costs. These costs are based on applying eight acre-inches of water at $16.50 per acre-inch as well as $90 per acre fixed costs for the irrigation and pumping equipment. The irrigation operational costs are based on diesel-powered pumps and diesel at $4 per gallon. Costs for electric-powered systems will save approximately 50 percent in variable irrigation costs.

Table 14. Estimated irrigated alfalfa hay production costs assuming a yield of six tons of hay per acre annually from 120 acres under center pivot irrigation and baled as square or round bale hay.

ITEM	UNITS	UNITS/ ACRE	TOTAL UNITS	COST ($/UNIT)	TOTAL COST	COST ($/ACRE)	COST ($/TON)
Variable Costs							
Fertilizer:							
Phosphate	lb.	70.00	8,400.00	$1.00	$8,400.00	$70.00	$11.67
Potash	lb.	250.00	30,000.00	$0.60	$18,000.00	$150.00	$25.00
Boron	lb.	3.00	360.00	$0.67	$241.20	$2.01	$0.34
Lime	ton	0.75	90.00	$33.00	$2,970.00	$24.75	$4.13
Crop Protection:							
Gramoxone	pints	2.00	240.00	$12.00	$2,880.00	$24.00	$4.00
Pursuit	ozs	2.00	240.00	$12.25	$2,940.00	$24.50	$4.08
Poast	pints	3.20	384.00	$8.90	$3,417.60	$28.48	$4.75
Furadan 4f	pints	1.00	120.00	$9.66	$1,159.20	$9.66	$1.61
Sevin Xlr Plus	quarts	1.50	180.00	$9.80	$1,764.00	$14.70	$2.45
Machinery:							
Fuel	gal.	14.31	1,717.45	$4.00	$6,869.81	$57.25	$9.54
Repairs & Maint.	acre	1.00	120.00	$24.22	$2,906.40	$24.22	$4.04
Twine	bale	0.26	31.20	$25.00	$780.00	$6.50	$1.08
Hay Hauling	ton	6.00	720.00	$14.00	$10,080.00	$84.00	$14.00
Irrigation	inches	8.00	960.00	$16.50	$15,840.00	$132.00	$22.00
Land Rental	acre	1.00	120.00	$0.00	$0.00	$0.00	$0.00
Labor	hrs.	3.78	453.60	$10.00	$4,536.00	$37.80	$6.30
Other	$	0.00	0.00	$0.00	$0.00	$0.00	$0.00
Interest On Op. Cap.	$		$82,784.21	8.50%	$3,518.33	$29.32	$4.89
Total Variable Cost					**$86,302.54**	**$719.19**	**$119.86**
Fixed Cost							
Establishment Costs	year	0.33	120.00	257.44	$30,893.12	$257.44	$42.91
Annual Fixed Costs	year	1.00	1.00		$14,923.65	$124.36	$20.73
Annual Fixed Costs for Irrigation	year	1.00	1.00		$10,800.00	$90.00	$15.00
Management	% of vc	1.00	86,303	6.00%	$5,178.15	$43.15	$7.19
Land	acre	1.00	120	$0.00	$0.00	$0.00	$0.00
Total Fixed Cost					**$61,794.92**	**$514.96**	**$85.83**

Expenditures for labor, machinery, and twine will depend in part on yield levels. Varying levels of these inputs are taken into account in the cost-per-unit estimates in Table 14. Higher yields usually mean higher outlays. More labor is required, extra twine is needed, and machinery is used more, but the result is usually a lower cost per unit of the output. Lower yields will tend to have the opposite effect.

Establishment Costs

For fixed costs, the largest item is the establishment cost. To account for stand establishment in an economic analysis, total establishment costs are prorated over the useful life of the stand. As a result, a longer stand life will reduce annual fixed costs.

Establishment costs shown in Table 15 are estimated to be $772 per acre, excluding irrigation. Almost 2/3 of this amount consists of expenditures for lime and fertilizer. Lime requirements will likely be less in the Coastal Plain area, and fertilizer inputs can vary depending on the fertility level of the soil. Costs for other establishment inputs should be added to reflect individual conditions.

Table 15. Estimated alfalfa establishment costs per acre.

ITEM	UNIT	UNITS PER ACRE	TOTAL QUANTITY (units)	UNIT PRICE ($/unit)	TOTAL AMOUNT
Variable Costs:					
Seeding	lbs.	25.00	25.00	$4.50	$112.50
Lime	ton	2.00	2.00	$33.00	$66.00
Fertilizer: Seeding					
Phosphate	lb.	130.00	130.00	$1.00	$130.00
Potash	lb.	200.00	200.00	$0.60	$120.00
Boron	lb.	3.00	3.00	$0.67	$2.01
Gypsum	ton	2.00	2.00	$50.00	$100.00
Fertilizer: After 1st Cutting					
Phosphate	lb.	0.00	0.00	$1.00	$0.00
Potash	lb.	150.00	150.00	$0.60	$90.00
Herbicides - Preplant					
Eptam	pints	3.50	3.50	$4.24	$14.84
Other	pints	0.00	0.00	$5.85	$0.00
Herbicides - Post					
Pursuit	ozs.	2.00	2.00	$12.25	$24.50
Poast	pints	1.50	1.50	$8.90	$13.35
Insecticides					
Lorsban	pints	2.00	2.00	$6.54	$13.08
Other	pints	1.50	1.50	$8.90	$13.35
Other	pints	0.00	0.00	$8.90	$0.00
Machinery:			0.00		
Fuel	gal.	6.42	6.42	$4.00	$25.68
Repairs & Maint.	acre	1.00	1.00	$7.14	$7.14
Land Rental	acre	0.00	0.00	$0.00	$0.00
Labor	hrs.	1.45	1.45	$10.00	$14.50
Other	$	0.00	0.00	$0.00	$0.00
Interest On Op. Cap.	$	634.45	634.45	8.00%	$25.38
Total Establishment Cost					**$772.33**

In addition to prorated establishment costs, there are other fixed costs for alfalfa production, including tractors and harvesting equipment, irrigation equipment, and management.

Equipment and Irrigation Fixed Costs

Fixed costs for tractors and harvesting equipment are included because these items eventually have to be replaced. Fixed costs for tractors and harvesting equipment include depreciation, interest on investment, and storage and housing.

For equipment that may be shared with other enterprises such as crops (for tractors) or grass-hay production (for cutters, rakes, balers, etc.), producers should assign fixed costs to alfalfa based on the percentage of time the item is actually used in alfalfa production. For instance, if a round-baler is used 50 percent of the time in the alfalfa enterprise and 50 percent of the time in other hay enterprises, then only half of the annual fixed costs should be counted toward the alfalfa enterprise. However, if a square baler is used exclusively for alfalfa, then 100 percent of the square baler's fixed cost should be counted toward the alfalfa enterprise.

In these example budgets, fixed costs for irrigation are estimated to be $90 per acre per year. This figure is based on 2008 UGA crop enterprise budgets and assumes a 130-acre center-pivot powered by a diesel pump. Readers with different irrigation systems should adjust their irrigation fixed costs accordingly.

Management Charges

Management charges are a fixed cost that many operators mistakenly overlook. The purpose of including management charges is to place a value on the operator's decision-making role as well as rewarding them for investing the capital into the enterprise. There are several ways to calculate management charges, but in this budget they are estimated to be 6 percent of variable costs.

Land Charges

As land costs depend on individual circumstances, no specific land charge is included in the cost estimate.

Computerized Budget Spreadsheet

As an aid to developing a budget that is tailored to a specific scenario, a computerized version of this budget is available in a spreadsheet. This and other downloadable spreadsheet-based enterprise budgets are located on the Department of Agricultural and Applied Economics' Web site (http://www.ces.uga.edu/Agriculture/agecon/agecon.html).

Calculating Break-even Prices

The break-even price is the price a producer must receive to break even or not lose money on a particular venture. Break-even prices are affected by costs and production. A helpful formula to determine the break-even price for alfalfa sold on a per-ton basis is:

$$\text{Breakeven Price} = \frac{\text{Production Costs}}{\text{Tons of Hay Sold}}$$

Potential alfalfa growers should calculate two break-even prices: the price to cover variable costs and the price to cover total costs. The break-even price to cover total costs is the price that MUST BE ACHIEVED virtually every year because the returns left over after covering variable costs are what are used to pay fixed costs. The break-even price to cover total costs is the price that covers all variable plus fixed costs and provides a return to the owner for his management and risk. Break-even prices for different yield levels for variable, fixed, and total costs are shown below in Table 16.

Table 16. Break-even price per ton to cover the variable, fixed, and total costs of producing alfalfa hay at varying levels of alfalfa yield.

Yield	Variable Costs	Fixed Costs	Total Costs
(tons/acre)	———————— ($/ton) ————————		
8	$93.53	$64.37	$157.90
7	$102.74	$73.57	$176.31
6	$119.86	$85.83	$205.69
5	$143.84	$102.99	$246.83
4	$172.54	$128.74	$301.28

To interpret this table, choose a yield level and then see what the break-even prices for the appropriate costs (variable, fixed, or total) are at that level. For instance, at six tons, the sales price will need to be approximately $120/ton just to cover the variable costs. Fixed costs, including management, add another $86/ton to costs to make the break-even price to cover all expenses $205.69.

One key item of note is that the yield mentioned here refers to tons marketed. So, any alfalfa that is lost due to spoilage, harvest loss, storage loss, etc. should not be included in the yield number.

Returns from Alfalfa

Most alfalfa that is produced will be for sale. As such, potential net returns can be estimated for varying yields and prices. Estimates for net returns above variable and total costs are shown below in Tables 17 and 18. The cost estimates used in this analysis indicate a sale price of $100 to $200 per ton is necessary to cover variable expenses. To cover all costs, prices will need to be in the $200 to $300 range.

Table 17. Returns above variable costs ($/acre) at various price and yield combinations for alfalfa hay.

Yield	Net Sales Price					
(tons/acre)	———————————— ($/ton) ————————————					
	$600.00	$500.00	$400.00	$300.00	$200.00	$100.00
8	$4,051.78	$3,251.78	$2,451.78	$1,651.78	$851.78	$51.78
7	$3,480.81	$2,780.81	$2,080.81	$1,380.81	$680.81	($19.19)
6	$2,880.81	$2,280.81	$1,680.81	$1,080.81	$480.81	($119.19)
5	$2,280.81	$1,780.81	$1,280.81	$780.81	$280.81	($219.19)
4	$1,709.84	$1,309.84	$909.84	$509.84	$109.84	($290.16)

Table 18. Returns above total costs ($/acre) at various price and yield combinations for alfalfa hay.

Yield	Net Sales Price					
(tons/acre)	———————————— ($/ton) ————————————					
	$600.00	$500.00	$400.00	$300.00	$200.00	$100.00
8	$3,536.82	$2,736.82	$1,936.82	$1,136.82	$336.82	($463.18)
7	$2,965.85	$2,265.85	$1,565.85	$865.85	$165.85	($534.15)
6	$2,365.85	$1,765.85	$1,165.85	$565.85	($34.15)	($634.15)
5	$1,765.85	$1,265.85	$765.85	$265.85	($234.15)	($734.15)
4	$1,194.88	$794.88	$394.88	($5.12)	($405.12)	($805.12)

Factors Impacting Sales Price

The sales prices used here are "blended" net sales prices that assume some of the hay is sold as square bales and some as round bales. As a rule, small square bales bring more on a dollars-per-ton basis than round bales. Because of this, most producers would like to sell all of their hay as square bales. However, this is not always possible. Weather, insect, weed, and other problems will most likely make it necessary to put up at least some of the hay produced as round bales. As a result, potential alfalfa growers should be realistic in their price expectations and use a projected sales price that accurately reflects the sales prices for round and square bales and the amounts of each type of hay that is sold.

Alfalfa Feeding Values

If the hay is to be used for feed on the farm where it is produced, compare the feed value of the hay with the cost of a feed that can be purchased. As alfalfa can be a very high-quality feed, it is usually considered a cost-effective feed when grown on farm.

Summary

Alfalfa is a perennial legume forage crop that can be successfully grown on well-drained and fertile soils throughout the state. Alfalfa forage has a high energy value and protein content and can be used as a cost-effective feedstuff in many forage-based livestock systems in Georgia.

Good management is critical to successful alfalfa production. The crop must be harvested at the correct stage of growth to produce quality feed and maintain healthy, productive stands. Lime and fertilizer requirements must be met and insects and weeds must be controlled. Well-managed alfalfa fields may produce more than six tons of hay per acre in a good growing season, and stands should persist for three to five years in south Georgia and four to seven years in north Georgia.

When well-managed, alfalfa is a high-value crop that can be profitably produced for the cash hay market or stored as hay or silage for on-farm use.

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THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Alfalfa Variety Trials 2008-2010

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Table of Contents

Introduction to Alfalfa

Adaptation:	Entire state. Very drought tolerant. Requires well drained soil and does not tolerate low soil fertility or acidity.
Establishment:	Seed 18 to 25 lb/A drilled with a cultipacker seeder, 22-25lb/A broadcast on a prepared seedbed in September.
Recommended Varieties:	**NORTH GA** – **BaraWet 501,** Bara-503, **Bulldog 505, CW 500,** Evermore, HybriForce 600, HybriForce 700, **Phoenix.** **SOUTH GA** – Attention II, **BaraWet 501**, Bulldog 505, Bulldog 805, **HybriForce 600**, HybriForce 700, **PGI 801**, TS 8031. * Bolded entries indicate superior yielding and stand ratings after 3 years.

Alfalfa is often referred to as the "Queen of Forages" because it produces high yields that are highly digestible and high in protein. Alfalfa can be effectively utilized in managed grazing, hay, or silage systems. It is often used in rations when nutritional needs are very high.

Alfalfa requires a combination of proper soil characteristics (well-drained, fertile, low acidity, etc.) with outstanding management (appropriate variety selection, timely harvests, pest control, etc.) to maintain long-lived, productive stands. Alfalfa requires deep, well-drained soils. It develops a deep root system if root growth is not restricted by hardpans, high water tables, or acid subsoil.

Alfalfa (*Medicago sativa*)

Alfalfa can be grown throughout the state where suitable soils occur. In general, well-drained bottomlands in the Limestone Valley/Mountains and Piedmont regions will provide the best results. Within the Coastal Plain region, the sandy loam soils provide good sites, especially if irrigation is available. Most sites in the Atlantic Coast Flatwoods and Tidewater areas will not be sufficiently well-drained to successfully produce alfalfa.

Alfalfa requires a relatively neutral soil pH (6.5-6.8) and non-limiting levels of essential nutrients. Alfalfa is especially sensitive to potassium (K), phosphorus (P), boron (B), and molybdenum (Mo) deficiencies. Close adherence to soil test recommendations during and after establishment are critical.

Alfalfa stands eventually thin to a point where the land must be rotated out of alfalfa. However, the lack of sufficient soil fertility is the most common contributor to accelerated stand declines. Disease pressure, insect damage, poor weed control, overgrazing, and improper cutting management also contribute to poor persistence. Stands in the Coastal Plain region generally have a shorter life (two – five years) than stands on the heavier soils in north Georgia. It is not uncommon for stands to persist for four – seven years (or longer) in the Piedmont and Limestone Valley/Mountains regions.

Description of the Variety Trials

Alfalfa variety entries were solicited from the companies who sell them. These companies were charged an entry fee for each variety they entered and for each location in which the variety was tested. This entry fee helped to cover some of the costs of the variety trial.

The tests were planted at Georgia Agriculture Experiment Station (GAES) facilities near Athens and Midville and on the USDA-ARS's Bellflower Research Farm near Tifton. Plots were established and maintained using standard, UGA-recommended practices. The trial was conducted by experienced research technicians and other GAES staff under the supervision of the State Forage Extension Specialist. The alfalfa trials were established by drilling the alfalfa seed into a well-prepared seedbed at the rate of 25 lbs of pure live seed (PLS) per acre. Specific planting dates for individual locations are described in the Yield by Harvest Date sections. Soil fertility was maintained in accordance with soil fertility recommendations.

Yield-type variety trials simulate forage productivity under a hay production regimen or a well-managed rotational grazing regimen. Alfalfa variety trials are generally continued until the stands of the majority of the entries deteriorate below 60% basal area coverage (60% stand). Tables that indicate a summary of data from 2008 through 2009 are preliminary datasets and will likely be continued in 2010 (and perhaps beyond).

Alfalfa trials are also assessed annually (typically just before the plants go fully dormant for the winter). This stand assessment is made using a quantitative measure of the plot area that is covered by living alfalfa plants after harvest (basal area coverage).

Statistical analyses were performed on all data to determine if the numerical differences were truly the result of varietal differences or just random differences. To determine if two varieties are truly different, compare the difference between them and the LSD (Least Significant Difference) at the bottom of the column. If the difference is equal to or greater than the LSD, the varieties are truly different when grown under the conditions at the given locations. The comparison is aided by the fact that the values in bold font are not significantly different from the best variety at that time and location. In addition, values sharing the same letter are not different. NS indicates no significant differences were observed. The Coefficient of Variation (CV) is a measure of the variability of the data and is included for each column of means when differences exist. Low variability is desirable (generally, a CV less than 15%).

Alfalfa Yield Trial Summary

Table 1. Forage yield of some alfalfa varieties averaged over the 2008-2010 growing seasons in Athens, Midville, and Tifton, GA.†

	2 yr average (2008-2009)	**3 yr average (2008-2010)**	
Variety	**Midville**	**Athens**	**Tifton**
		---------- dry lbs/acre ----------	
Attention II	6430 bc	9468 bcde	8612 bc
Bara - 503§	**7243** a	9757 bcd	7950 cd
BaraWet 501§	**7108** ab	**10592** a	**8946** ab
Bulldog 505	**7233** a	**9861** abc	**9361** a
Bulldog 805	**6561** abc	9213 cde	8202 cd
CW 35160§	-	8074 f	-
CW 36106§	6223 c	-	-
CW 500	-	**10114** ab	-
Evermore	-	9788 bc	-
Hybri Force 600	**7117** ab	8950 e	**8909** ab
Hybri Force 700	6462 bc	9036 de	8508 bc
PGI 801	**6760** abc	-	8537 bc
PGI 909	-	-	7635 d
Phoenix	-	**9940** abc	-
TS 4010§	-	9531 bcde	-
TS 8031§	-	-	8590 bc
CV%	10	9	10
LSD	710	735	674

† Planted on October 10, 2007 in Athens; November 1, 2007 in Midville, and February 21, 2008 in Tifton.

‡ Values within a column that are labeled with the same letter were not significantly different ($\alpha=0.05$) from one another. Values that are in **bold** font are not significantly different from the best variety at that time.

§ Experimental variety (not available).

Stand Assessments (Yield Trial)

Table 2. Percent basal cover of alfalfa varieties in the yield trials located at Athens, Midville, and Tifton, GA. 2008-2010.†

	Percent basal cover within row					
	Athens			Midville	Tifton	
Variety	Dec. 1, 2008	Dec. 14, 2009	Dec. 15, 2010	Jun. 18. 2008	Nov. 4, 2009	Jan. 15, 2011
BaraWet 501§	91	88	81.3 ab	85	**84** a‡	86.3 a
Bulldog 805	89	78	67.5 bcd	88	**83** a	81.7 ab
Hybri Force 700	96	92	80.6 abc	91	**77** a	77.0 b
Hybri Force 600	86	80	71.9 abcd	81	**80** a	75.0 b
PGI 801	-	-	-	89	**74** a	73.8 b
Bara – 503§	91	88	65.0 cde	88	**78** a	65.0 c
TS 8031§	-	-	-	84	**77** a	63.8 c
Attention II	86	84	83.8 a	78	58 b	63.3 c
Bulldog 505	88	81	76.3 abc	86	**74** a	60.0 c
PGI 909	-	-	-	86	**82** a	60.0 c
CW 35106§	93	86	49.5 e	-	-	-
CW 500	92	86	72.5 abcd	-	-	-
Evermore	85	84	66.3 bcd			-
Phoenix	87	76	73.1 abcd	-	-	-
TS 4010§	91	83	58.1 de	-	-	-
CV %	-	-	17	-	13	8
$LSD_{\alpha=0.05}$	NS	NS	15.85	NS	13.5	8.12

† Planted on October 10, 2007 in Athens; November 1, 2007 in Midville, and February 21, 2008 in Tifton. Stand deterioration at the Midville location led to the termination of the trial at that location in the fall of 2009.

‡ Values within a column that are labeled with the same letter were not significantly different (α=0.05) from one another. Values that are in **bold** font are not significantly different from the best variety at that time.

§ Experimental variety (not available).

Yield by Harvest Date – Athens

Table 3. Forage yield of alfalfa varieties at Athens, GA. 2008-2010.†

Year	Variety	Dry Matter Yield					
		dry lbs/acre					
		Harvest Date					
2008		**May 6**	**June 20**	**Aug.28**	**Dec.5**		**Total**
	TS 4010§	4031	931	195	1527		**6684** a‡
	BaraWet 501§	3320	1125	240	1573		**6258** a
	Bulldog 505	3365	1026	207	1493		**6091** a
	Bulldog805	3654	711	205	1393		**5963** ab
	Phoenix	3299	931	176	1374		**5780** ab
	Evermore	3067	1076	233	1316		**5692** ab
	Attention II	3211	928	246	1110		**5495** abc
	Bara- 503§	3139	992	225	1443		**5799** ab
	CW 500	2961	1164	196	1416		**5737** ab
	Hybri Force 600	3022	901	167	1261		**5351** abc
	Hybri Force 700	2443	821	185	1213		4662 bc
	CW 35106§	2245	591	136	1222		4194 c
	CV %						16
	LSD$_{\alpha=0.05}$	NS (.10)	NS	NS	NS		1337
2009		**May 6**	**June 26**	**Aug.6**	**Sept. 8**	**Oct. 22**	**Total**
	BaraWet 501§	2739	**2898** a*	2599	2117	2161	**12514** a
	Bulldog 505	2624	**2460** abc	2037	1909	2221	**11251** ab
	CW 500	2636	**2494** abc	2012	2166	1864	**11172** ab
	Evermore	2536	**2292** abc	2242	1990	1967	**11027** ab
	Phoenix	2529	**2445** abc	1873	1958	1974	10779 b
	Bara- 503§	2407	**2656** ab	2000	1795	1735	10593 b
	Attention II	2578	**2554** abc	1723	1596	2089	10540 bc
	Bulldog805	2565	2024 bcd	1959	1746	2109	10403 bc
	Hybri Force 700	2578	1987 cd	1718	2104	2104	10222 bc
	TS 4010§	2278	**2258** abc	1841	1675	1795	9847 bc
	Hybri Force 600	2636	2056 bcd	1822	1649	1607	9770 bc
	CW 35106§	2371	1517 d	1625	1718	1748	8979 c
	CV %		19				10
	LSD$_{\alpha=0.05}$	NS	645	NS(.08)	NS(.06)	NS	1578
2010		**Apr. 23**	**June 16**	**July 13**	**Aug. 20**	**Nov. 1**	**Total**
	BaraWet 501	1427 ab	2702 bc	2150	5216 a	1508	13002 abc
	CW 500	1566 a	3077 a	2294	5161 ab	1335	13432 a
	Phoenix	1268 ab	3051 ab	2812	4959 abc	1170	13260 ab
	Bulldog 505	1216 b	3080 a	2403	4395 bcde	1175	12269 abcde
	Evermore	1391 ab	3088 a	2225	4676 abc	1265	12645 abc
	Bara - 503	1202 b	2820 abc	2342	5268 a	1247	12879 abc
	TS 4010	1221 b	2785 abc	1964	4935 abc	1156	12061 bcde
	Attention II	1346 ab	3100 a	2424	4336 cd	1162	12369 abcd
	Bulldog 805	825 c	2848 ab	2531	3767 e	1303	11274 de
	Hybri Force 700	1298 ab	2867 abc	2242	4599 abcd	1197	12203 abcde
	Hybri Force 600	1215 b	2555 c	2085	4608 abcd	1266	11730 cde
	CW 35160	1119 bc	2576 c	2237	3838 de	1279	11050 c
	CV %	17	9		12		9
	LSD$_{\alpha=0.05}$	317	357	NS	783	NS	1274

† Planted on October 10, 2007.
‡ Values within a column that are labeled with the same letter were not significantly different (α=0.05) from one another. Values that are in **bold** font are not significantly different from the best variety at that time.
§ Experimental variety (not available).

Yield by Harvest Date – Midville

Table 4. Forage yield of alfalfa varieties at Midville, GA. 2008-2009.[†]

Year	Variety	Dry Matter Yield					
		------ dry lbs/acre ------					
		Harvest Date					
2008		**May 6**	**June 9**	**July 23**	**Sept.5**	**Nov.20**	**Total**
	PGI 801	2625	2392	2277	2344	761	10399
	Bara 503[§]	2674	1906	2704	2069	761	10114
	BaraWet 501[§]	2101	2276	2525	2196	570	9668
	Hybri Force 600	2371	2202	2728	1910	454	9665
	Bulldog 505	2179	2358	2493	2019	615	9664
	Bulldog 805	2262	1926	2312	2073	842	9415
	CW 36106[§]	2309	2424	2142	1745	604	9224
	Attention II	2425	2305	2075	1948	445	9198
	Hybri Force 700	2112	2101	2379	1908	571	9071
	CV %						
	$LSD_{\alpha=0.05}$	NS	NS	NS (.11)	NS	NS	NS
2009		**April 15**	**May 15**	**June 25**	**Aug. 14**		**Total**
	Bulldog 505	**1596** a[‡]	**1376** ab	705	**1124** ab		**4801 a**
	Hybri Force 600	**1544** a	1432 cd	473	**1120** ab		**4570 a**
	BaraWet 501[§]	**1617** a	**1414** ab	490	**1028** ab		**4549 a**
	Bara 503[§]	**1411** ab	**1284** abcd	450	**1225** a		**4371 ab**
	Hybri Force 700	1163 bc	**1400** ab	420	871 bc		3854 bc
	Bulldog 805	1251 bc	1183 bcd	406	868 bc		3708 bcd
	Attention II	1202 bc	**1301** abc	354	806 bc		3663 cd
	CW 36106[§]	1116 c	1053 d	388	665 c		3223 cd
	PGI 801	1057 c	1126 cd	274	663 c		3119 d
	CV %	14	12		23		12
	$LSD_{\alpha=0.05}$	266	232	NS (.09)	318		693

[†] Planted on November 1, 2007. Stand deterioration led to the termination of this trial location in the fall of 2009.

[‡] Values within a column that are labeled with the same letter were not significantly different (α=0.05) from one another. Values that are in **bold** font are not significantly different from the best variety at that time.

[§] Experimental variety (not available).

Yield by Harvest Date – Tifton

Table 5. Forage yield of alfalfa varieties at Tifton, GA. 2008-2010.[†]

Year	Variety	Dry Matter Yield (dry lbs/acre) — Harvest Date							
2008				**Jun. 18**	**Jul. 30**	**Sept.10**	**Nov.11**		**Total**
	Hybri Force 600			1791	1399	**2464** ab[‡]	1010		6664
	Bulldog 505			1250	1644	**2623** a	883		6400
	TS 8031[§]			1219	1577	**2592** a	716		6104
	Hybri Force 700			1391	1304	**2414** ab	974		6083
	PGI 801			1289	1218	**2054** abc	1092		5653
	Bulldog 805			1156	1276	**2314** ab	787		5533
	Attention II			1240	1499	1943 bc	834		5516
	BaraWet 501[§]			1296	1168	**2105** abc	844		5413
	Bara – 503[§]			927	1279	**2166** abc	668		5040
	PGI 909			1332	826	1723 c	963		4844
	CV %					17			
	$LSD_{\alpha=0.05}$			NS(.09)	NS	574	NS		NS
2009		**Apr. 7**	**May 7**	**Jun. 17**	**Jul. 30**	**Sept. 18**	**Nov. 4**	**Dec. 17**	**Total**
	BaraWet 501[§]	2047	1678	2598	2534	1921	942	127 cd	11847
	PGI 801	1973	1967	2589	2406	1638	930	**311** a	11671
	Attention II	2117	1755	2577	2758	1474	835	101 de	11399
	Bulldog 505	2235	1551	2824	2635	1613	907	80 de	11356
	Hybri Force 700	1935	1547	2538	2507	1759	813	156 cd	11256
	TS 8031[§]	2168	1532	2521	2484	1547	815	170 cd	11087
	Bulldog 805	2018	1610	2299	2514	1464	881	214 bc	10812
	Hybri Force 600	1849	1573	2618	2330	1636	838	28 e	10460
	PGI 909	1592	1614	2245	2208	1498	802	**278** ab	9866
	Bara – 503[§]	1627	1147	2305	2448	1467	762	34 e	9791
	CV %							43	
	$LSD_{\alpha=0.05}$	NS	NS	NS	NS	NS	NS	92	NS
2010		**May 6**	**June 20**	**July 30**	**Sept. 13**	**Oct. 12**	**Nov. 17**		**Total**
	Bulldog 805	2559 de	2550	1279	1368 bc	195 bcd	121 b		**9841** a
	PGI 801	2347 ef	2610	1326	**1426** abc	**257** a	**178** a		8144 cd
	Attention II	2667 cd	2912	1283	**1561** ab	192 cd	88 c		8784 bcd
	TS 8031	2577 de	2678	1359	**1549** ab	188 cd	79 cd		8429 cd
	Hybri Force 600	2943 cd	3093	1350	**1572** ab	175 cd	60 cd		**9192** abc
	Hybri Force 700	2531 de	2462	1438	1354 bc	**259** a	138 b		8183 cd
	BaraWet 501	2847 bc	3212	1663	**1580** ab	**219** abc	56 cd		**9577** ab
	Bulldog 505	**3168** a	3178	1609	**1678** a	158 d	50 d		8075 cd
	PGI 909	2162 f	2649	1342	1255 c	**243** ab	**174** a		7825 d
	Bara - 503	**2987** ab	2754	1474	**1584** ab	164 d	55 d		**9019** abc
	CV %	6			12	16	22		9
	$LSD_{\alpha=0.05}$	249	NS	NS	271	49	33		1127

[†] Planted on February 21, 2008.

[‡] Values within a column that are labeled with the same letter were not significantly different (α=0.05) from one another. Values that are in **bold** font are not significantly different from the best variety at that time.

[§] Experimental variety (not available).

Weather Data during Trials:

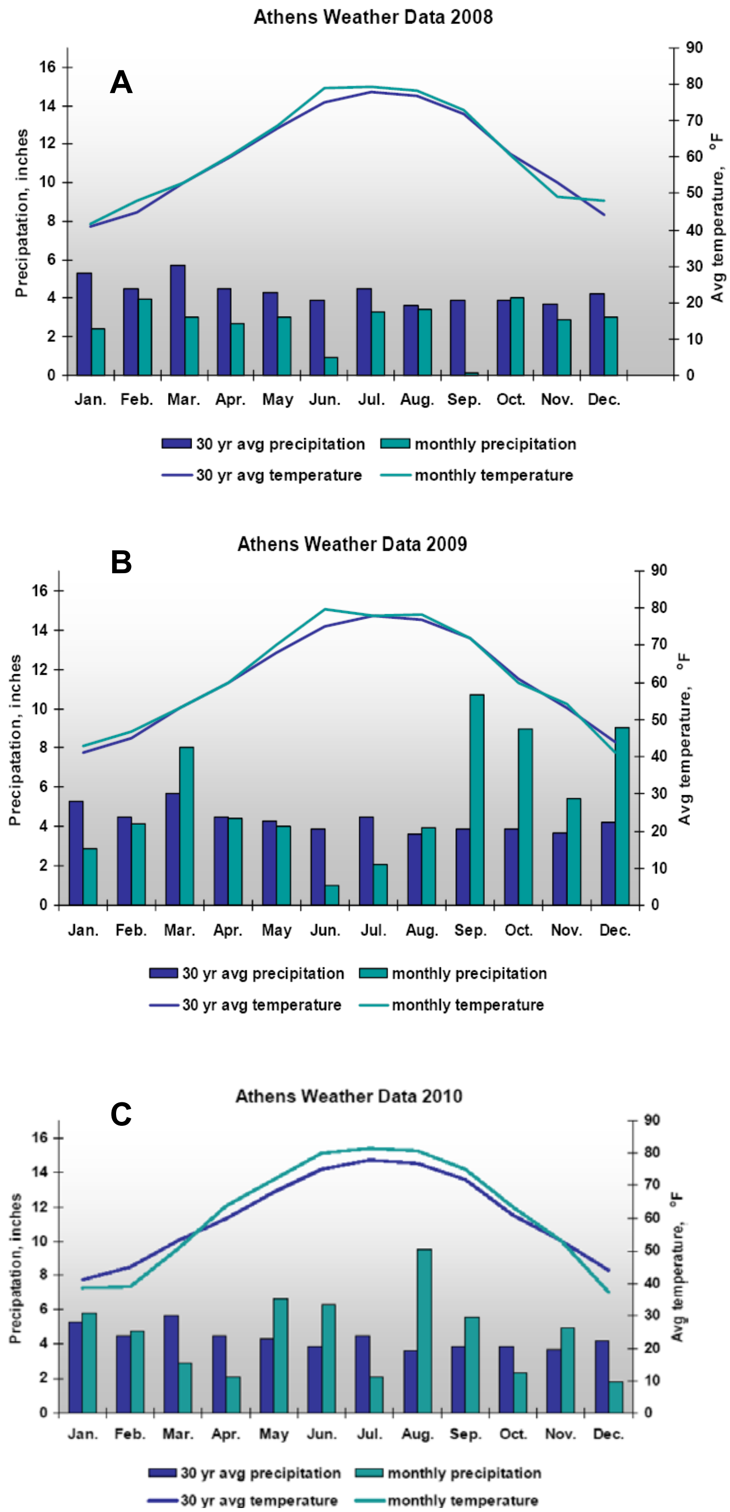


Figure 1. Weather data during the 2008 (A), 2009 (B), and 2010 (C) growing seasons in Athens.

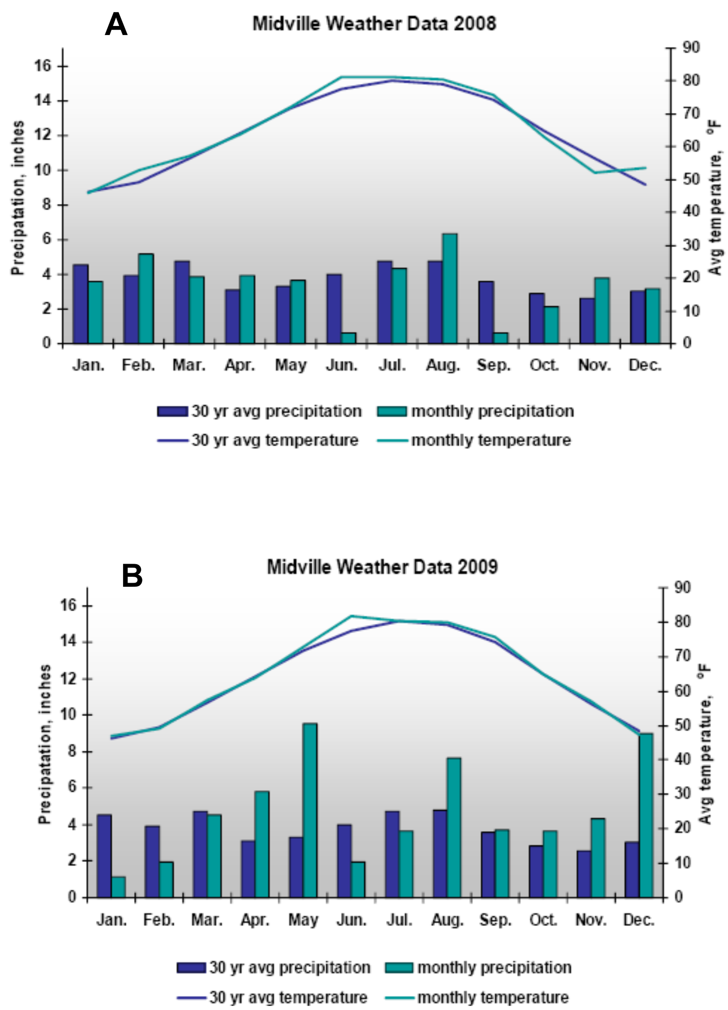
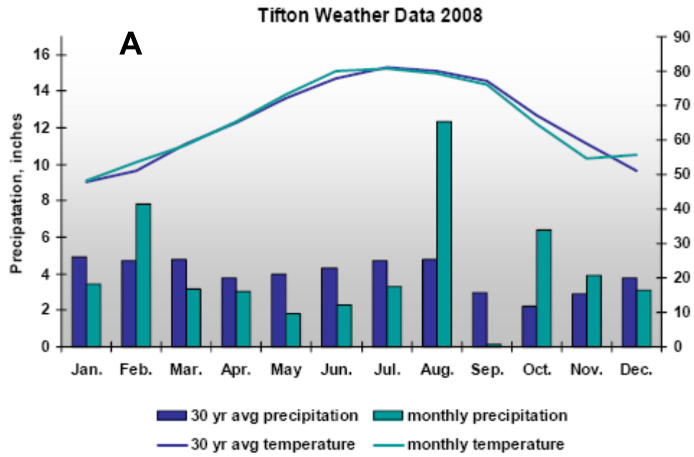
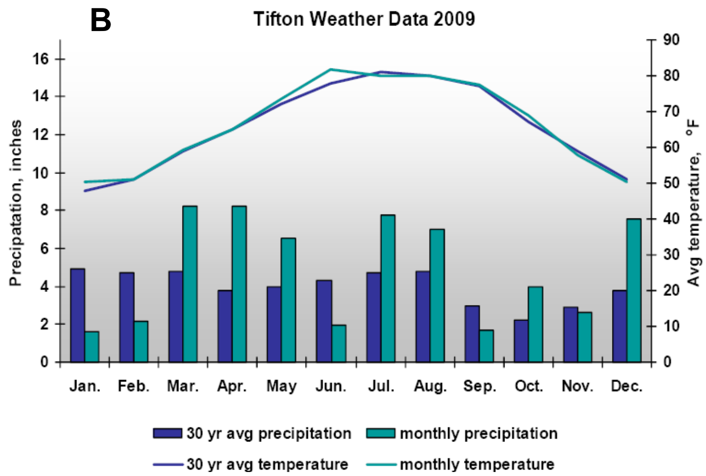


Figure 2. Weather data during the 2008 (A), and 2009 (B) growing seasons in Midville.





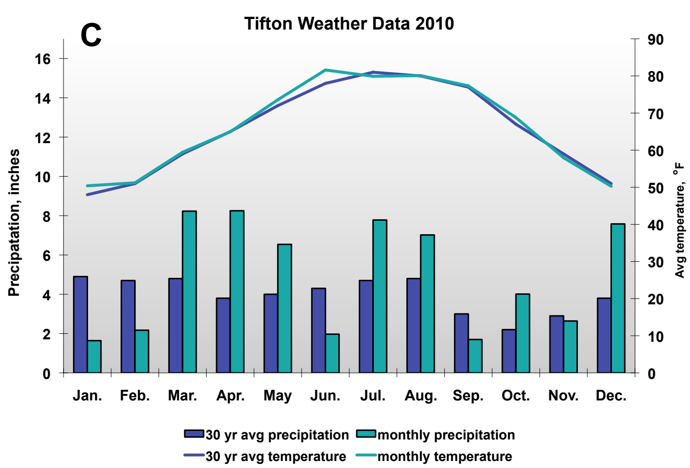


Figure 3. Weather data during the 2008 (A), 2009 (B), and 2010 (C) growing seasons in Tifton.

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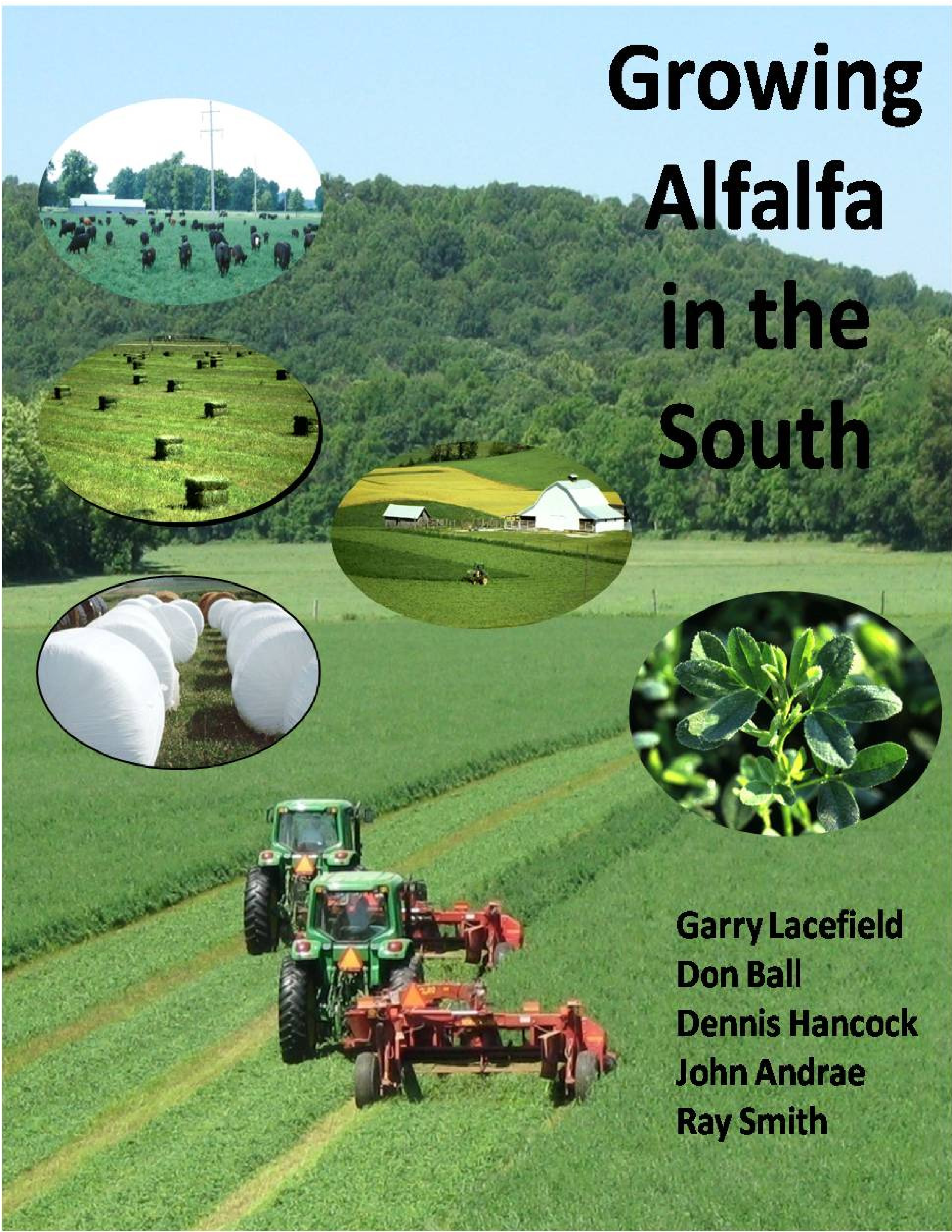

Growing Alfalfa in the South

Garry Lacefield
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Growing Alfalfa in the South

Garry Lacefield, Don Ball, Dennis Hancock, John Andrae and Ray Smith[1]

Alfalfa, often called "The Queen of the Forages," is one of the most widely grown crops in the United States and is one of the most important forage crops in the world. It has a high forage yield potential, and can produce these high yields without nitrogen fertilization. Furthermore, alfalfa is high in digestible energy and protein, which makes it an extremely valuable feed. When alfalfa is included in a livestock ration, it can reduce or eliminate the need for protein supplements while providing high levels of digestible energy. In addition, its relatively high levels of calcium, phosphorus, and magnesium help to minimize mineral supplementation costs.

Alfalfa: The World's most important forage crop.

Alfalfa is a versatile crop that can be used for pasture, or as hay, silage, or greenchop. As a result of its versatility, yield potential, and quality, alfalfa can be used successfully in many types of livestock feeding programs. Consequently, it is highly sought after and can be a profitable cash crop. It can also play an important role in crop rotations since it supplies substantial amounts of organic nitrogen to subsequent crops and has numerous other positive effects on soil fertility, soil structure, and soil health.

Economic conditions have increased the demand for high-quality forage in the Southern USA, which has spurred an expansion of alfalfa production in the region. This expansion has been supported by several new and on-going plant breeding, research, and extension efforts by scientists at various Land Grant universities and private companies. New alfalfa varieties, more efficient harvest and curing systems, and improved production practices have been developed. These efforts have resulted in the sustainability of high alfalfa yields, forage quality, and persistence in the South.

Alfalfa is not a new crop in the South. It has been grown in the region since the late 1800's and continues to be recognized as a superb forage species. Nonetheless, to date alfalfa has not attained the status in the South that it has in other parts of the nation. Like other regions, alfalfa acreage moved slowly upward for several decades in the early 1900's. Then, with the arrival of the alfalfa weevil in the late 1950's and an abundant supply of inexpensive nitrogen fertilizer, alfalfa acreage fell sharply in the early 1960's.

[1] Extension Forage Specialists, University of Kentucky, Auburn University, University of Georgia, Clemson University and University of Kentucky, respectively.

Since then, southern alfalfa acreage has remained relatively low. Production problems, such as a lack of modern well-adapted varieties and pest infestations, limited alfalfa yields and stand persistence. Low fertilizer and transportation costs during this era made it impractical for livestock producers in the South to grow their own alfalfa. If they needed alfalfa hay or other protein supplements, it was more cost effective to import them from other regions.

However, fertilizer and transportation costs have increased substantially in recent years. This has resulted in increased demand for high quality forage produced at the local level. As a result, alfalfa acreage in the South is increasing once again.

The potential for further acreage expansion is great. It is estimated that the region could easily produce and benefit from over 5 million acres! In the region as a whole, around 80% of the alfalfa is harvested as hay. Most of the remainder is harvested for silage or baleage, with a minor amount being harvested as greenchop. Approximately 45% of this alfalfa is used by horse producers, around 40% in the dairy industry, and 15% by beef cattle enterprises. A small quantity is used for sheep, goats and other farm animals. Though grazing alfalfa has historically been a very minor harvest method, this has become a significant option for some livestock producers in the region, especially those who market "grass-fed" meat and dairy products.


Alfalfa is a high yielding, high quality perennial legume

Steady progress is being made in overcoming the problems with alfalfa production in the South. The alfalfa weevil now can be effectively controlled, seed of southern-adapted varieties is now readily available, and yields are increasing. In the upper South, alfalfa is usually harvested 3 to 5 times per year, while the long growing season in the lower South often allows as many as 6 to 8 harvests. On-farm yields average between 3 and 4 tons of hay (or equivalent) per acre, with top producers often getting 6 or more tons per acre without irrigation and 8 or more tons per acre when irrigated. Yields of over 9 tons per acre have been attained in research trials in several southern states, with a record 10.13 tons/A in Kentucky research trials without irrigation.

Alfalfa is no longer a neglected crop in the South! Dozens of research studies and demonstrations are currently in progress. In addition, there are numerous publications on alfalfa available from Land Grant universities and commercial firms within the region, and various training programs on alfalfa are performed by Extension personnel in many states. In view of the current interest, enthusiasm, and effort that alfalfa is presently receiving, as well as the known need and potential for acreage expansion, the future of this magnificent forage crop in the South appears bright!

PRODUCTION REQUIREMENTS

Profitable alfalfa production requires obtaining high yields of high quality forage, a long stand life, and skillful marketing of the product. This requires attention to details, timely action, and planning. There are four basic prerequisites for successful alfalfa production:

1) Selection of a well-drained site that allows for the development of a deep and healthy root system
2) A willingness to apply fertilizer and lime (as necessary) and control pests as required
3) The ability to harvest in a timely manner
4) A viable strategy for marketing or otherwise utilizing the alfalfa

Because of the wide range in soil and climatic conditions throughout the South, specific recommendations will not be offered here, but important general principles will be reviewed that have been documented through research and farmer experiences. Specific recommendations on varieties, fertility, seeding dates and rates, herbicides, insecticides, and harvest management should be obtained from the appropriate Land Grant University.

■ Site Selection

Alfalfa requires a well-drained soil for optimum production and long stand-life. Root rot diseases and winter heaving damage (upper South) are greater on poorly-drained than on well-drained sites. Progress has been made in variety improvement; however, varieties are not available that persist under waterlogged soil conditions. A soil map is useful in locating fields suitable for growing alfalfa. Level land is not a requirement for alfalfa, but safe operation of machinery must be considered. Sites with a high water table, a shallow hardpan, bedrock, or other impediment to root development are also not well suited for alfalfa production. It is common in the South for an acidic subsoil to inhibit sufficient root development. In the Coastal Plain regions in the lower South, subsoil acidity should be evaluated by collecting soil samples in 1-ft increments down to 4 ft. The pH in each of these increments should be $\geq$ 5.5.

■ Soil Test and Fertilize

Soil test and fertilize according to recommendations for good yield, persistence, and profit

A soil test is the most economical investment in an alfalfa fertility program. A soil test should be used as a guide to determine application rates of lime, phosphorus, and potassium. Tissue analyses taken within 10 days of a summertime harvest can also fine-tune fertilizer needs.

Alfalfa grows best and sustains longer-lived stands when the soil pH is maintained at 6.5-6.8. Nitrogen fixation in the root nodules will be reduced as pH decreases. Micronutrients may be required in some areas. Consult state fertilizer recommendations for specific elements and rates.

■ Variety Selection

Proper variety selection can have a dramatic impact on yield, quality, and stand longevity. Select adapted, high yielding, and pest-resistant varieties. Consider using more than one variety if the planting involves a large acreage. Most states in the South publish recommended alfalfa varieties based on yield and persistence trials. Plant breeders at Land Grant universities and within private companies continue to release varieties specifically for the South. As more new varieties with improved adaptability, yield potential, pest resistance, and persistence are made available to southern growers, the feasibility of alfalfa production within the region will be further enhanced.

■ Inoculation

Most companies market pre-inoculated alfalfa seed that have been coated with an inert material, usually lime, to protect the inoculant. Use of pre-inoculated seed saves time and helps to ensure adequate and appropriate inoculation has occurred. No further inoculation before planting should be necessary, unless the inoculated seed has been stored improperly or the planting date recommendation has expired. Coated seed normally flows faster through most seeding equipment. If the seed is not pre-inoculated or the inoculant coating is suspected of being ineffective, inoculate the seed just before planting with fresh inoculant specific to alfalfa. Protect packages of inoculant from direct sunlight or hot temperatures. Use a commercially available adhesive or some type of sticking agent to ensure that sufficient inoculant is stuck to each seed. One 8-ounce bag of inoculant will generally be enough to inoculate one bag of seed. However, always read and follow the label instructions.

Poor inoculation

■ Weed Control during Establishment

Weeds can drastically reduce alfalfa stands, yields, and forage quality. Alfalfa stands are especially susceptible to weeds during establishment. Fortunately, there are preplant incorporated herbicides available that control many grassy weeds that germinate and compete with alfalfa. However, these herbicides generally do not provide much control of broadleaf weeds, thus post-emergence herbicide applications may be necessary.

Do not seed grass with alfalfa if a pre-emergence herbicide is used to control grass weeds. If an alfalfa-grass mixture is desired when using pre-emergents, drill grass into established alfalfa in late summer or fall (i.e., six months or more after the alfalfa has been seeded). Always read and follow the herbicide label, especially for residuals that could affect establishment.

■ Seeding in Tilled Seedbeds

A firm seedbed, which will hold moisture close to the seed for rapid germination and prevent new roots from drying out, is an important factor in successful establishment of new stands. Plowing and preparing the soil 30 to 60 or more days before seeding is ideal. This allows lime and fertilizer to be incorporated into the plow layer and gives time for rains to firm the soil and build up a moisture supply. When spring seedings (recommended only in the upper South) are to be made on soils with a high clay content, fall plowing is desirable to allow freezing and thawing to break down the large clods.

Alfalfa can be sown successfully with a cultipacker-seeder, using a grain drill with a small seed attachment, or by broadcasting the seed followed by use of a cultipacker. Seeding into a firm seedbed and cultipacking will ensure proper seed-soil contact. Regardless of seeding method, the seed must not be planted too deep (1/8 to 1/4 in. in loamy or clay loam soils; 1/4 to 1/2 in. in sandy loam or sandy soils).

Seeding in Tilled Seedbeds

■ No-Till Seeding

Alfalfa can also be planted with a no-till drill into sods or other vegetative cover that is dormant or that has been suppressed with herbicides. By seeding no-till rather than in tilled seedbeds, soil erosion is drastically reduced, rocks remain below the surface, soil moisture is conserved, less time and fuel is expended, and seedings can be made in a more timely manner. Calibration of seeding equipment is very important regardless of seeding method.

Research and experience have shown that the vegetative cover must be dormant or dead before seeding. When planting into dead or dormant sod, insects must be controlled to prevent stand loss. Lime and fertilizer applications should be made well in advance of seeding, and perennial weeds need to be controlled prior to seeding.

■ Fertilizing Established Stands

Alfalfa stands must have adequate soil fertility to be vigorous. Well-nodulated stands need no nitrogen, but lime, phosphorus, and potash must be added according to soil test recommendations. Boron, molybdenum, and possibly other micronutrients may also need to be applied. Check state and local recommendations for amounts and timing. Alfalfa, like any other high yielding crop, is a heavy user of soil nutrients. For example, each ton of alfalfa hay may remove as much as 15 lbs of phosphate and 60 lbs of potash. Productive, high-yielding stands require that these nutrients be returned to the soil (via fertilizer, manure, or other sources) in order to maintain high yields and to persist. Since grass competes vigorously with alfalfa for potassium, higher potassium rates may be necessary for alfalfa-grass mixtures.

Soils differ in their capacity to supply nutrients, so annual soil tests should be made to monitor fertility changes and avoid the occurrence of critical deficiencies. For high yields, the pH level should be maintained at 6.5-6.8. Corrective fertilization can be practiced at any time during the year. However, a good time to lime and fertilize the stand is after the last harvest of the growing season and before growth begins the next growing season. In soils where leaching is possible (sandy soils), one-half of the annual potassium fertilizer should be applied after the second cutting of the growing season.

■ Weed Control

The most important and effective weed control factor is a dense, thick, vigorous stand of alfalfa. Harvesting alfalfa at the appropriate stage of maturity will also help prevent weed encroachment. Proper cutting height (leaving a 2-3 inch stubble) can kill or reduce the vigor of many weeds, but will not injure alfalfa. Many different weeds can become a problem in alfalfa, but herbicides are available for control of most weeds in alfalfa stands. In addition to selective herbicides used during regrowth, some broad-spectrum and non-selective herbicides can be used in dormant stands and, in some cases, immediately following harvest.

Weed Free Alfalfa Field

■ Insect Control

Alfalfa weevil and potato leafhopper control is often necessary for high yields, high quality, and long-lived stands. Other insects may, at times, attack alfalfa. These include meadow spittlebugs, aphids, clover-root curculios, three-cornered alfalfa hoppers, and grasshoppers. In the South, blister beetles will occasionally infest alfalfa, but are rarely problematic. Use of resistant varieties, proper harvest and fertility management, routine scouting, biological control, and selective use of insecticides are important factors in insect control.

■ Disease Control

Bacterial wilt, leaf spot, anthracnose, and phytophthora are the diseases that generally cause the most serious damage to alfalfa stands, although several other diseases can reduce yields or damage stands. Practices that help control alfalfa diseases are:

a) Use certified seed of a recommended variety. If a particular disease is known to be present on the farm, select a variety known to have resistance to that disease.

b) Avoid seeding alfalfa in soils where alfalfa or clover was grown during the preceding two years. This will reduce damage from sod- or plant debris-borne disease organisms. When possible, plant into a site that has produced a cultivated crop for the previous 2 or 3 years.

c) In the upper South, make summer seedings before August 15 to provide stands with sufficient growth before cold weather to withstand winter injury and reduce the risk of Sclerotinia crown and root rot and heaving. Early spring seedings also are successful in this area. Depending on location, alfalfa may be seeded as late as early November in the Deep South.

d) Allow alfalfa to go into the winter after the last cutting with enough growth (usually 6-8 inches) to develop sufficient root reserves.

e) Follow the recommended practices for liming, fertilizing, seeding, and cutting.

f) Control insects to prevent weakening the plants and making them more susceptible to diseases.

Alfalfa Weevil Damage

■ Harvesting for Quality

Alfalfa, alone or in grass mixtures, may be used as hay, baleage, or silage. The latter two methods are increasing in use. A higher quality feed, better suited for mechanized handling and feeding, can be preserved by making silage or baleage, particularly from the spring growth. Since less drying is required than for hay, fewer leaves are usually lost and there is less risk of rain damage. Under favorable drying conditions, the forage can be mowed, chopped, and placed in the silo or possibly even baled (as baleage) on the same day.

Research has proven the effectiveness of some chemical preservatives and microbial inoculants that permit hay to be safely stored at higher moisture contents. These products allow more flexibility in producing hay and are now commercially available. Additional information on these products are available from your state's Cooperative Extension Service.

Climate-based recommendations for harvest dates and schedules vary among and within states. Additionally, these recommendations may need to be changed to meet yield, forage quality, and stand persistence goals. In general, the quality of alfalfa decreases as the plant transitions from vegetative (leafy) to reproductive (flower) stages (Table 1). However, yields increase during this transitional phase. Furthermore, repeatedly harvesting alfalfa in a vegetative stage of maturity can reduce stand longevity. In general, alfalfa cut in the range of late bud to early bloom will result in acceptable yields of high quality feed with a minimal effect on stand persistence.

Good quality alfalfa should contain from 17-20% crude protein (CP) and 60-65% total digestible nutrients (TDN). Six tons of good alfalfa hay contains more digestible energy than 150 bushels of corn and more protein than 2 tons of soybean meal.

Of course, the ultimate test of forage quality is animal performance. Forage must be palatable (readily consumed by animals) in addition to containing sufficient energy and protein. Research and farmer experience have shown alfalfa to be a superior feed that is readily consumed. In fact, high quality alfalfa may actually stimulate intake by livestock that are consuming low quality forages.

Table 1. Expected range in forage quality† for alfalfa at various maturity stages.‡

Stage of Maturity	CP	NDF	ADF	TDN	RFQ
Vegetative	**24-27**	**25-37**	**20-27**	**68-75**	**230-300**
Bud	**22-26**	**38-47**	**28-32**	**64-67**	**160-250**
Early bloom	**18-22**	**42-50**	**32-36**	**61-64**	**125-180**
Mid-bloom	**14-18**	**46-55**	**36-40**	**58-61**	**100-150**
Late bloom	**9-13**	**56-60**	**41-43**	**50-57**	**90-110**

† Alfalfa will often be higher in fiber concentration, less digestible, and have lower relative forage quality when subjected to higher temperatures or soil moisture stress.

Abbreviations: CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; TDN = total digestible nutrients; RFQ = relative forage quality.

‡Adapted from Ball et al, 2007. Southern Forages, 4th Edition.

MANAGEMENT GREATLY AFFECTS QUALITY OF THE FORAGE HARVESTED AND STORED

Harvest at proper stage and save leaves for highest quality.

□ Stage of maturity - Stage of maturity at harvest has the most significant influence on forage quality. Fortunately, this factor can largely be controlled by management. As alfalfa plants advance from the vegetative to the reproductive (flowering) stage, they become higher in fiber and lignin, lower in protein content and digestibility, and less acceptable to livestock (Table 1).

□ Leafiness - Fiber digestibility and protein, energy, and mineral content are much higher in leaves than in stems. Thus, leaf loss during the cutting, raking, and baling processes can greatly reduce alfalfa quality (Table 2).

□ Color - A hay crop with bright green color indicates proper curing, high carotene content, and good palatability. However, a slight color change usually does not indicate significantly reduced forage quality. Hay that has been either sunbleached or has had a small amount of rain damage still can be good quality feed, despite some discoloration. Regardless of cause, some hay buyers discount hay that is discolored.

□ Odor and condition - The smell of newly- mowed hay is the standard with which to compare all hay odors. Musty or putrefied (rotten) odors indicate poor quality. Foul odors and dustiness can lower

Table 2: The Effect of Handling Conditions on Alfalfa Hay Losses.

Nutrient Factors	Raked and Baled Correctly (lbs/acre)	Losses (lbs/acre)			
		Baled Too Dry	Raked Too Dry	Raked and Baled Too Dry	Total (%)
Dry Matter	2900	-100	-700	-1000	34
Crude Protein	660	- 60	-210	- 290	44
T.D.N.	1710	- 90	- 480	- 680	40

Source: Adapted from materials compiled by USDA-Univ. of California

palatability and reduce hay value, especially in horse markets. Common causes of odor problems are weather damage during curing or baling, and storing at moisture levels that are too high.

■ Grazing

Alfalfa or alfalfa-grass mixtures can provide exceptionally high quality pasture. Alfalfa's high forage quality allows for beef stocker and finishing gains that exceed 2.5 pounds per day. It is best to use some type of managed grazing (i.e., rotational stocking) system. The efficiency of alfalfa production is greatest when a stand is allowed to accumulate to the bud to early bloom stage, grazed to a stubble height of 2 – 4 inches, and then allowed to rest for 25 – 30 days.

The first rotation cycle of the grazing season is typically the most difficult to manage due to rapid forage growth. It is often necessary to initiate grazing at an early growth stage and defer some paddocks in the rotation. Deferred paddocks can be harvested as hay at its optimal maturity or can be grazed at a more mature stage. Grazing-tolerant varieties are recommended.

Alfalfa as a grazing crop.

The commercial development of temporary, portable fence and water systems has made controlled grazing practices affordable and practical for producers to implement. Managed grazing allows better control over the forage supply and reduces waste. In managed grazing, forage utilization efficiency improves when the animals are rotated among more and smaller pastures (paddocks). Alfalfa can also be effectively utilized as a creep grazing crop. This is most effective when mature animals with relatively low nutrient requirements (i.e. beef cows) are mixed with animals with high nutrient needs (i.e. nursing calves). Construction of a creep gate that allows calves to pass into an adjacent alfalfa pasture while restricting cow access is a simple and often cost-effective supplementation strategy.

Ruminants can occasionally bloat when grazing alfalfa, but this risk can be minimized by following some simple management practices. Bloat normally occurs when hungry animals are turned into vegetative paddocks and are allowed the opportunity to gorge on fresh alfalfa. It also may occur when cattle are introduced to an alfalfa pasture in early morning hours to dew-laden paddocks. Bloat risk can be minimized by introducing animals to fresh paddocks only when they are not hungry. This can be easily accomplished by closely monitoring alfalfa residue height and moving animals before forage supply is limited. Rotating animals in late morning or early afternoon is also beneficial. Older stands of alfalfa can be interseeded with cool season grasses to minimize bloat risk and improve production potential. Mixed grass and alfalfa stands are often higher yielding than pure alfalfa pastures and may also provide a more consistent forage growth pattern so that forage surplus and deficits are more easily managed. In circumstances where bloat risks are high, it may be necessary to feed an energy supplement containing monensin or a chemical bloat preventative like poloxalene.

■ Alfalfa in a Crop Rotation

Alfalfa often can be effectively used in rotation with other crops. On farms with land too steep for continuous corn, a rotation of silage corn and alfalfa, either in strips or whole fields, will often produce more forage than any other rotation. Alfalfa helps stabilize the soil, reduces erosion, and improves soil structure. Alfalfa usually provides 100 or more pounds of nitrogen per acre to the crop that follows it in a rotation.

A 3 to 5 year rotation allows utilization of alfalfa during its most productive period. The stand may then be plowed or planted no-till to another crop before it becomes more susceptible to disease and weed problems and begins to thin. Alfalfa should never be replanted into the same field for at least one year due to the alleopathic effect of mature plants on development of new seedlings and minimal risk of disease for the new planting.

■ Alfalfa As A Wildlife Plant

In one sense alfalfa has always been a wildlife plant; after all, wild animals use alfalfa fields and other forage plantings anytime they choose. However, in recent years there has been a substantial amount of alfalfa planted specifically for wildlife, especially deer. This has occurred largely because of the development and commercial availability of grazing-tolerant varieties that hold up much better under continuous and/or close grazing than do hay type varieties.

Advantages alfalfa offers are mostly the same as those it offers to livestock: high forage quality, excellent palatability, good dry matter yield, and drought tolerance. Also, a particularly valuable trait of alfalfa in wildlife food plots is its long growing season, which helps ensure that wild animals will have access to good quality forage whenever they need it. For birds of many species, including quail and wild turkey, insects found within an alfalfa stand provide an excellent source of protein.

Alfalfa requires more precision during planting, higher pH and fertility, and more management in general than most plants commonly established for wildlife. However, the excellent nutrition it provides helps increase body weights, facilitates rebreeding, and favors antler development in buck deer. Many wildlife enthusiasts who have tried alfalfa, particularly those who are serious about providing year-around high levels of nutrition to animals, have had outstanding success, assuming they have followed the basic agronomic principles known to be important in growing the crop.

ECONOMIC CONSIDERATIONS

Recent price increases in supplemental feeds, minerals, and transportation costs have placed a premium on high quality, locally-produced forage. This has made alfalfa production in the South increasingly attractive. Now, with new alfalfa varieties, more efficient harvest and curing systems, and improved production practices, it has become increasingly feasible to grow alfalfa in the South.

A thorough look at the costs and benefits is an important first step in determining if alfalfa is right for your farm. Extension economists at several Land Grant universities in the South have developed budgets for alfalfa production that are downloadable from the internet. These budgets are usually done assuming that the existing soil fertility levels in the field are moderate. Consequently, almost 2/3 of the establishment cost consist of expenditures for lime and fertilizer. Certainly, more fertile sites and soils that are more responsive to lime will decrease these initial expenditures.

The total annual cost of producing and harvesting alfalfa also depends on the fertility level. Furthermore, the annual "per-unit" cost of alfalfa is also influenced by the crop's yield, the harvest method used (i.e., grazing, square-baled hay, round-baled hay, silage, etc.), pest and disease pressure, the life expectancy of the stand, and other production considerations. As a result, each production system will be different. Therefore, it is recommended that a budget be developed for each specific production system being evaluated.

Though alfalfa has a relatively high production cost when compared to other forage crops, it is similar to the cost of producing many southern row crops. However, the potential return on investment for alfalfa enterprises can be quite high.

A Swathed Field of Alfalfa

■ Alfalfa's Value

It is also important for a producer to consider what he (or she) is getting for their money and effort when growing alfalfa. The forage quality of alfalfa is excellent, often containing over 16% crude protein and 60% total digestible nutrients (TDN) on a dry matter basis. Some southern farmers have realized that alfalfa has excellent cash crop potential and routinely sell all of the hay they have produced.

The economics of producing alfalfa become increasingly attractive at high yield levels and/or a long stand life. Fixed costs per acre and the establishment costs are relatively high, but once these expenses have been offset, additional increases in yield or increased length of stand life of this high-value crop tend to rapidly increase net profit. Thus, it is very important to manage alfalfa in a way that emphasizes high yields and a long stand life.

■ Value in Crop Rotations

The amount of nitrogen available to a crop planted behind alfalfa can easily exceed 100 pounds per acre. With current nitrogen prices, 100 lbs of nitrogen is valuable! Alfalfa also is a deep-rooted crop that leaves root channels in the soil, thus allowing the roots of the following crop to penetrate more deeply than would otherwise be possible. Reduced pest problems in row crops planted in rotation with alfalfa, as compared with continuous row cropping, adds additional value. Though it is difficult to estimate the true value of the contribution that alfalfa makes to a succeeding crop, research and experience has shown that (for example), corn yields typically increase by at least 10-15% when following alfalfa.

Alfalfa is a Deep Rooted Crop

■ Alfalfa's Value to the Soil

Data from the University of Missouri indicate that the average soil losses per acre for various crops from fields having a 5% slope 200 feet long would be as follows: soybeans - 14 to 35 tons; corn or grain sorghum - 13 to 25 tons; wheat - 8 to 13 tons; and alfalfa - 2 to 4 tons. This loss is again difficult to quantify in terms of dollars, but every good farmer is acutely aware of what such soil losses will mean to him and his family in the long run.

■ The Importance of a Diverse Marketing Plan

The best laid plans do not always come to fruition. For example, alfalfa hay producers quite commonly have (in fact likely will have) some cuttings that are too low in quality, too weedy, or too damaged to be acceptable to the premium cash hay market. A diversified marketing plan will help one deal with such eventualities. If a producer's primary outlet is the premium hay market, then it may be helpful to have a side market for marginal or rain-damaged hay lots. This may include selling the lower quality forage to neighboring livestock operations or marketing it through their own livestock. Regardless of the situation, it is advisable to have more than one outlet for the product.

Conclusion

Alfalfa is not for everyone. However, alfalfa could be a tremendous asset on many farms in the South. When farmers in this region objectively consider the facts with regard to the economics of growing alfalfa and the recent developments that make alfalfa production in the South more feasible, they often find that it has great potential on their farms. In fact, some might find that alfalfa has the potential of being the most profitable enterprise on their farms.

Resources:

Resources are available through local, state and national sources including many universities and organizations and industry.

Many websites also have valuable alfalfa information as well as links to other resources.

Examples include:
- NAFA - http://www.alfalfa.org/
- NAAIC - http://www.naaic.org/
- Kentucky - http://www.uky.edu/Ag/Forage/
- Georgia - http://www.georgiaforages.com/
- Alabama - http://www.aces.edu/department/forages/

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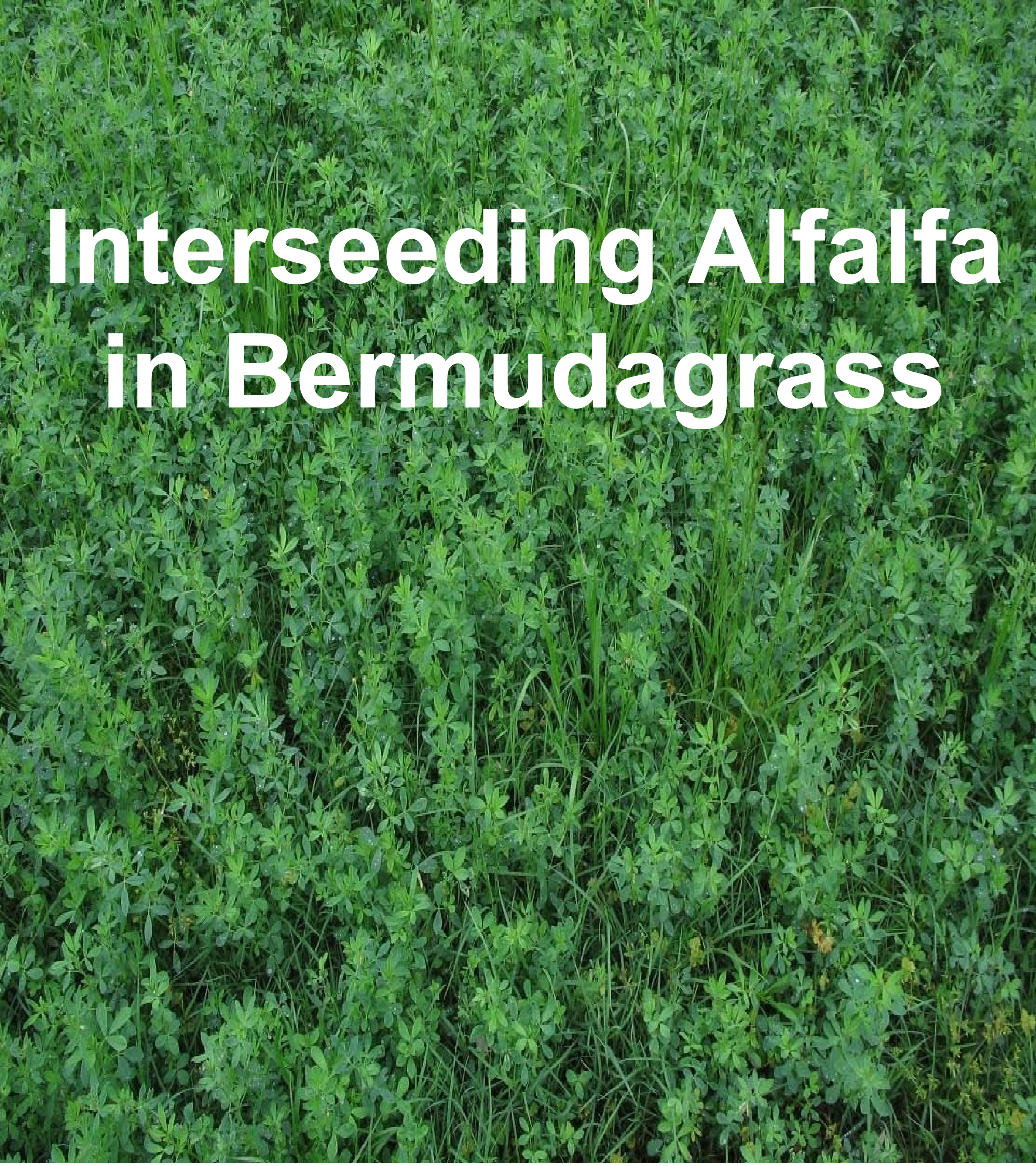
Lacefield, G.D., D.M. Ball, D. Hancock, J. Andrae, and R. Smith. 2009.
Growing Alfalfa in the South.

National Alfalfa and Forage Alliance.

Interseeding Alfalfa in Bermudagrass



: Grow Your Own N Fertilizer

: Increase The Value Of Your Hay

: Management Simplification

Why Interseed Alfalfa into Bermudagrass?

1. Grow your own nitrogen
2. Increase the quality of your forage (+ 30 or more RFQ points)
3. Makes excellent supplemental feed and/or cash hay crop
4. Growing with bermudagrass allows alfalfa to dry faster and be harvested clean
5. If all else fails, you still have bermudagrass.

Keys to Successfully Establishing Alfalfa into Bermudagrass

1. Select a well-drained site for planting.
2. Soil test the site and lime and fertilize according to the recommendations.
   a. Ideal levels are: pH 6.5, High P, and High K. pH at 1 ft depth should be greater than 5.5.
   b. Pay attention to micronutrient fertilization needs (B and Mo, as needed)
3. Plant at the right time of the year:
   a. Mountains and Piedmont area, Sept.15th - Oct. 15th.
   b. Coastal Plains region Oct.15th- Nov.15th.
4. Have bermudagrass very short (1-2 in.) whenever planting.
   a. Spray with a non-selective herbicide:
      i. paraquat (Gramoxone) at 1 qt./ac or
      ii. glyphosate (Roundup) at 9 oz./ac if 5.5 lb. a.i. formulation or at 12 oz./ac if 4 lb. a.i. formulation.
   b. It is ok to burn off with fire after the chemical burn down.
5. Plant with a no-till drill
   a. Seeding rate = 22-25 lbs/ac
   b. 7-9 in. rows
   c. Plant no deeper than ½ in.
6. After emergence, spray with insecticide to control mole crickets and other insect pests (Mustang or Karate at the highest labeled rate).
7. Irrigate if available and necessary.

Keys to Maintaining Alfalfa in Bermudagrass

1. Applying K fertility as recommended
2. Following K fertility recommendations
3. Fertilize with K as recommended
4. Apply B and Mo as recommended
5. Take a tissue sample 1 wk prior to the second cutting of each year to determine other fertility needs
6. Scout and spray for alfalfa weevils in Feb./Mar. and fall armyworms in summer.

More Information:

For more information about growing alfalfa in Georgia, see the following publications and websites:

1. Alfalfa Management in Georgia (http://www.caes.uga.edu/Publications/pubDetail.cfm?pk_id=7788)
2. Growing Alfalfa in the South (http://www.alfalfa.org/pdf/alfalfainthesouth.pdf)
3. The Georgia Forages Website (www.georgiaforages.com)

Forage Bermudagrass Varieties for Southeastern Hay Producers

Dr. Dennis Hancock, Extension Forage Agronomist

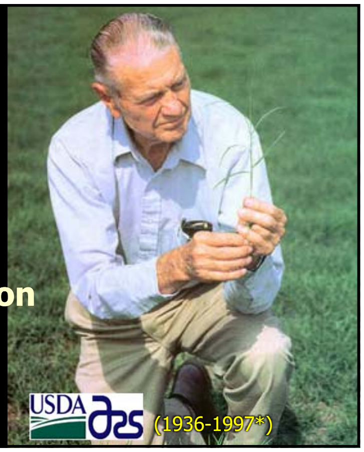
Forage Bermudagrass Varieties for the SE

Forage Bermudagrass Varieties for Southeastern Hay Producers

Dr. Dennis Hancock
Extension Forage Specialist
Crop and Soil Sciences – UGA

Bermudagrass

- Common (seeded)
- Hybrids (sprigged)
  - Tifton (USDA-ARS & UGA)



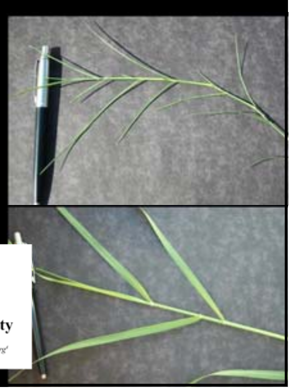
Dr. Glen Burton
"Father" of forage & turf bermudagrasses
(1910-2005)

Bermudagrass

- Common (seeded)
- Hybrids (sprigged)
  - Tifton (USDA-ARS & UGA)
- Typically very drought tolerant
- Aggressive and persistent
- Requires high fertility

Bermudagrass

- Varieties differ in quality
- Vigor
- Coarseness & drying rate



THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION

Selecting a Forage Bermudagrass Variety

Dennis W. Hancock, Norman R. Edwards, T. Wade Green, and Deron M. Rehberg
University of Georgia Cooperative Extension

Selecting the appropriate variety.

Variety	Overall Rating	Yield*	Digestibility**	Winter Hardiness	Persistence	Leaf Spot Resistance
Alicia (Alecia)	★★½	100	P	G	P	P
Coastal	★★★½	100	F	G	G	E
Coastcross II	★★★★½	135	E	G	ND	ND
Russell	★★★★½	130	G	E	E	G
Tifton 44	★★★★	90	G	E	G	E
Tifton 78	★★★	120	E	F	F	E
Tifton 85	★★★★★	135	E	F	E	E

Forage Bermudagrass Varieties for the SE

Coastal

- Released 1943 (1st hybrid forage bermudagrass)
- F_1 hybrid a South Africa x an ecotype found in a S. Georgia cotton patch.
- Named for Exp. Station
- On ~15 million acres in the SE US.
- Gold standard against which other varieties are measured.

Coastal

- Tall-growing, intermediate coarse-stemmed type
  - Rhizomes and stolons
  - Produces few viable seed
  - Excellent drought tolerance.
  - Moderate forage quality
- Establishes well from both sprigs and clippings (tops).
- Best adapted to the Coastal Plain and Piedmont areas.
- Not as cold tolerant as Tifton 44 or Russell.

Tifton 44

- Winter-hardy hybrid released in 1978.
  - Cross between Coastal and a winter-hardy bermudagrass from Germany.
- Produces rhizomes, but few stolons
- Fine stems, dark green, and dense sod.
- Higher quality than most
- Slower to establish

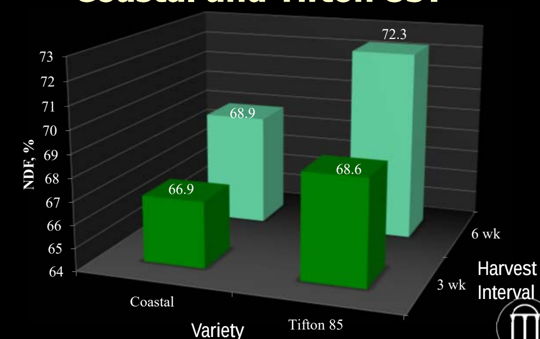
Russell

- Natural hybrid found in a field in Russell Co., in eastern AL in 1970's
  - CP & digestibility similar to or slightly lower than Coastal
  - Finer stems than Tifton 85,
  - Yields well but slightly lower than Tifton 85
- Russell spreads very rapidly, with impressive establishment growth
- Emerges early – similar to Tifton 44

Tifton 85

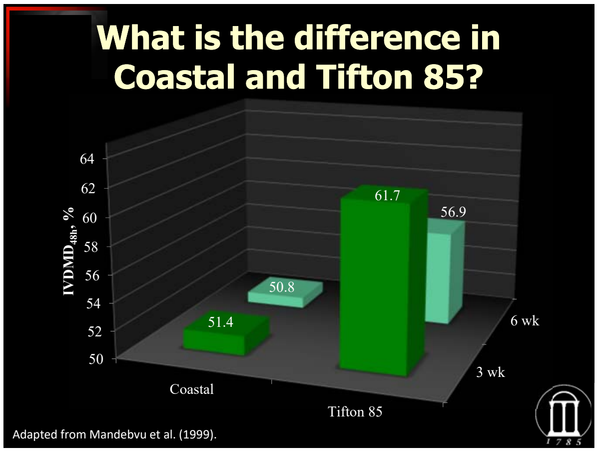
- Released in 1993
  - Fast growing,
  - Highest yielding & quality
- Larger stems, wider leaves, and is darker green than other cultivars.
- Tifton 85 is higher in digestibility than other cultivars, despite having higher fiber (NDF).

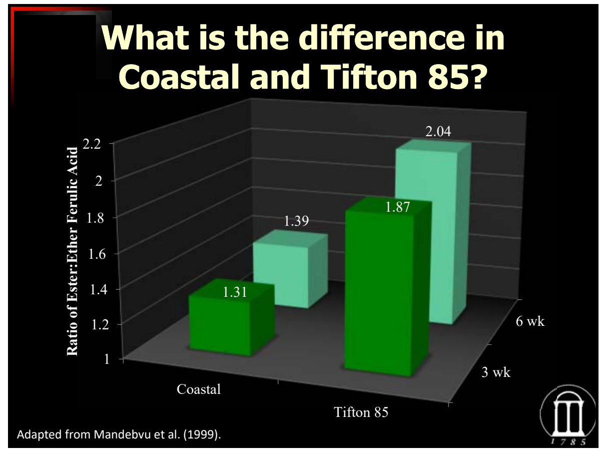
What is the difference in Coastal and Tifton 85?

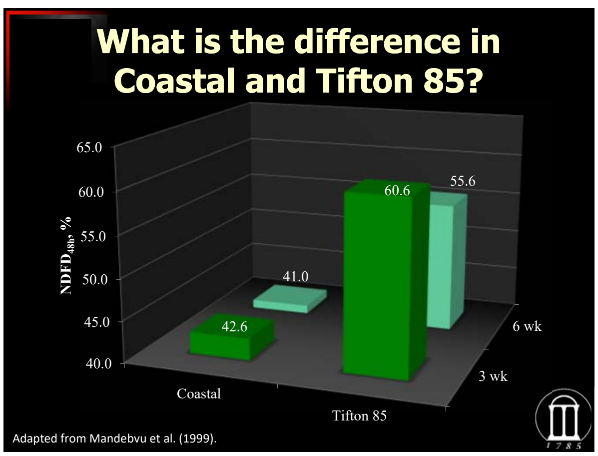


Adapted from Mandebvu et al. (1999).

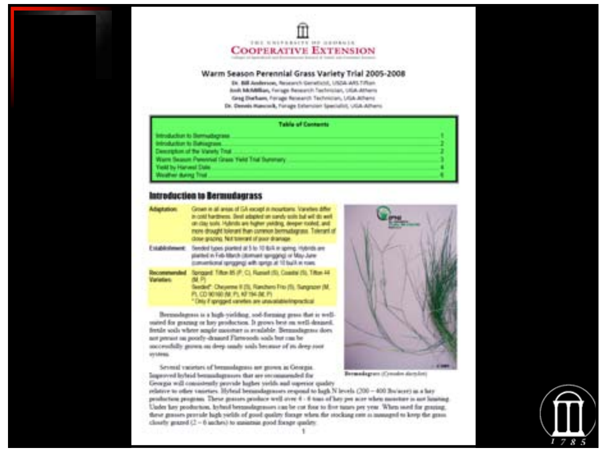
Forage Bermudagrass Varieties for the SE

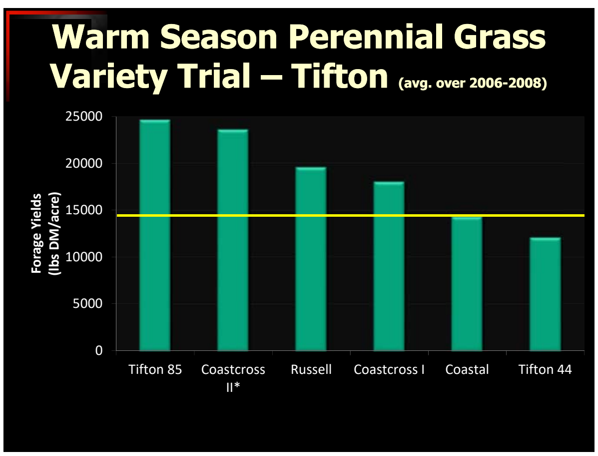


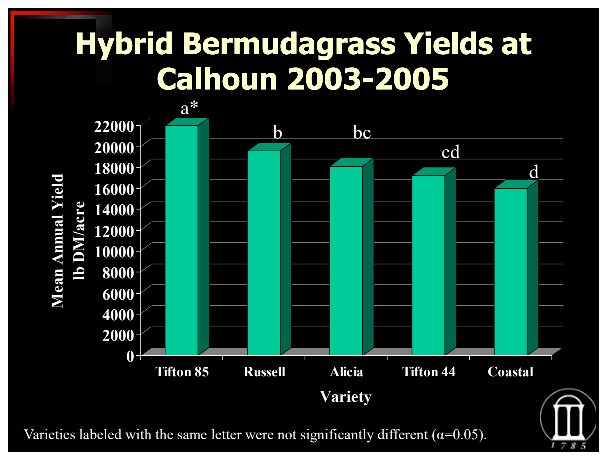


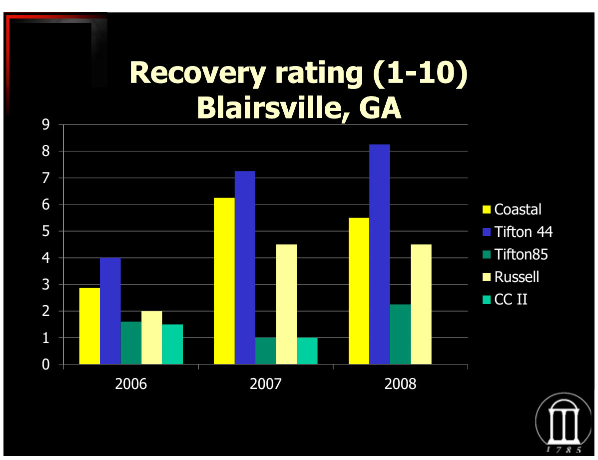


Forage Bermudagrass Varieties for the SE

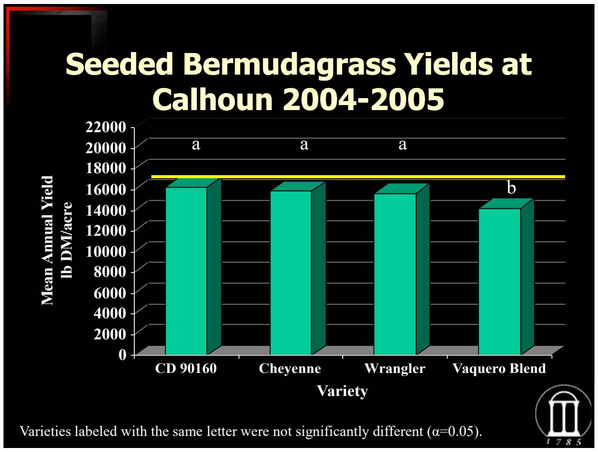


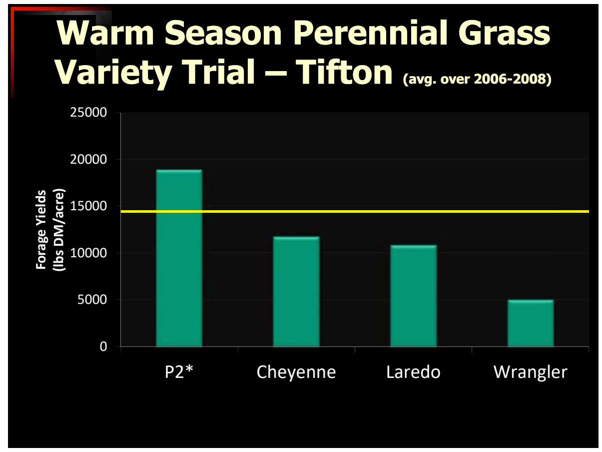


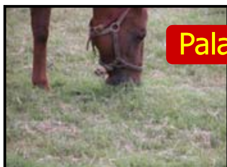




Forage Bermudagrass Varieties for the SE



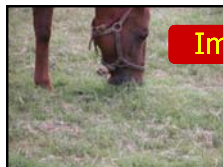




Palatability of Bermudagrasses

Highly acceptable:
Coastal = Tifton 44 = Tifton 78
(= Russell)

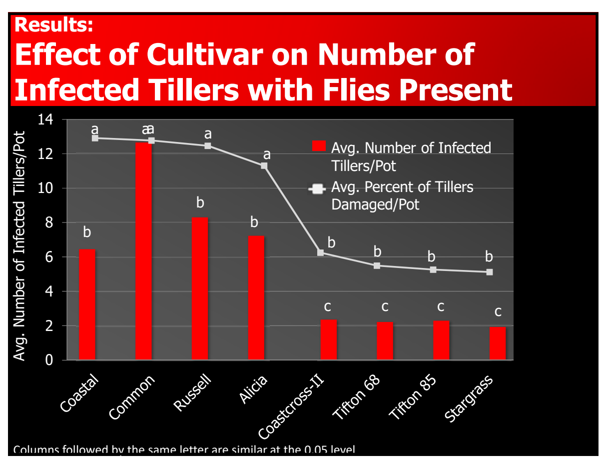
Acceptable if given no other choice:
- Tifton 85
- Coastcross



Impaction on Bermudagrass

Myth or Truth?

- High NDF Content
  - Somewhat related to bermudagrass variety
  - As a rule of thumb for bermudagrass hay, keep NDF < 65%.
- Insufficient Water Availability
- Insufficient Mastication (chewing)
  - Fed only 1-3 times per day
  - Horses in stall
- Inactivity/lack of exercise



Dr. Dennis Hancock
Extension Forage Agronomist

GRASS

THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Selecting a Forage Bermudagrass Variety

Dennis W. Hancock[1], Norman R. Edwards[2], T. Wade Green[3], and Deron M. Rehberg[4]
University of Georgia Cooperative Extension

Unlike most other agronomic crops, the selection of a bermudagrass cultivar is a long-term commitment. Bermudagrass is a warm-season perennial grass that can persist and withstand the rigors of grazing and hay production for decades. Establishing it, however, is a significant investment that pays off over the long-term. It is important to understand the characteristics of the different cultivars. This publication shares the collective experience of research and extension personnel on bermudagrass cultivars that are (or could be) grown in Georgia. The recommendations and descriptions of these cultivars are the result of numerous research experiments and on-farm observations within Georgia and surrounding states since the late 1930s.

Vegetatively Propagated (Sprigged) Varieties

Recommended Cultivars

Tifton 85 is a hybrid from a cross between cold-susceptible but higher digestible Tifton 68 and an introduction from South Africa with greater cold tolerance. It was released in 1993 by Dr. Glenn W. Burton, principal geneticist with the USDA-ARS at the Coastal Plain Experiment Station (CPES) in Tifton. Tifton 85 can be established from sprigs or from clippings ("tops"). It is one of the few varieties that is easily distinguishable from other bermudagrass varieties, since it has larger stems, broader leaves, a darker green color, and is taller than most bermudagrass hybrids. It develops few rhizomes but many very large, rapidly spreading stolons. It consistently provides the highest yields in variety trials throughout Georgia and retains the high digestibility traits of Tifton 68. Tifton 85 is the most digestible of the recommended bermudagrass varieties (Tables 1a & 1b). However, the combination of heavy yields and thick stems slows hay curing, and Tifton 85 will often take one-half to one day longer to dry to suitable baling moistures than other varieties under similar conditions. Since it is not highly winter-hardy, it is common for a Tifton 85 stand to be substantially thinned during winter in the Piedmont region. Thus, Tifton 85 is currently recommended only for the southern two-thirds of Georgia (roughly south of Athens and I-20). It can be successfully grown farther north if you are willing to accept the increased risk of stand loss.

Russell, a vegetatively propagated bermudagrass, was jointly released by Auburn University and Louisiana State University in 1994. Russell was discovered in the late 1970s in Russell County, Alabama, by local County Agent Donald Bice. The field had originally been planted to Callie, a variety very susceptible to winter-kill. The excellent winter-hardiness of Russell made it clear this grass was indeed unique (likely either a mutation or hybrid of Callie). When moisture is not limited, Russell

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may out-yield all bermudagrasses in the first harvest and match the high seasonal yield totals of Tifton 85. Russell is also noted to spread rapidly and has been rated higher for winter-hardiness than Coastal. Forage height at the appropriate harvest intervals is typically shorter than other high-yielding bermudagrass hybrids, but the forage is quite dense. Despite its high-yield potential, Russell is somewhat less drought tolerant than Tifton 85. Furthermore, Russell is substantially less digestible than Tifton 85 and slightly less than or equal to Coastal. Russell produces both rhizomes and stolons, develops one of the best root systems of all the hybrids, and forms a dense sod that holds up well under grazing. Russell can be established from sprigs or clippings (tops) and often is quicker to establish than Tifton 85. Russell is a solid variety that is recommended throughout Georgia.

Tifton 44, a winter-hardy hybrid bermudagrass, was released in 1978. Tifton 44 is a cross between Coastal and a winter-hardy bermudagrass found near a railroad track in Berlin, Germany. Its winter-hardiness allows successful growth as far north as Kentucky and Virginia, more than 100 miles north of the recommended range of Coastal bermudagrass. This hybrid produces more rhizomes, has finer stems, is darker green, and forms a denser sod than Coastal. It is better adapted to the northern areas of the bermudagrass growing regions of the country than many other varieties. Though it can perform well in the Coastal Plain, Tifton 44 will likely yield less in this area than the other recommended hybrids. It is slower to establish than many other varieties and may not establish well if propagated from clippings (tops). As a result of this slow establishment, it usually will not provide any significant grazing/haying during the establishment year. Tifton 44 bermudagrass produces a higher-quality forage than Coastal or Alicia, averaging 7 percent higher in digestibility than Coastal and 10 percent higher than Alicia. Hay yields of Tifton 44 are similar to Coastal. Tifton 44 starts growing in early spring and grows later into the fall than Coastal or Alicia in northern latitudes.

Coastal, released in 1943, is the first hybrid forage bermudagrass from Dr. Burton's work at the CPES. It is an F_1 hybrid between an introduction from South Africa and a prolific bermudagrass found in a south Georgia cotton patch. Named for the experiment station where it was bred, Coastal is among the most successful forage variety releases in the past century as it makes up some 15 million acres of the hay and pasture land in the southern United States. It is the standard against which other varieties are measured. Coastal is a tall-growing, intermediate, coarse-stemmed type, has both rhizomes and stolons, produces few viable seed, and has excellent drought tolerance. Coastal establishes well from both sprigs and clippings (tops). In Georgia, Coastal is best adapted to the Coastal Plain and lower Piedmont areas. It is not as cold tolerant as Tifton 44 or Russell and could winter-kill in the mountains. Coastal produces twice as much forage as common bermudagrass, and its forage quality is superior to common Alicia and a few other varieties when properly managed.

Noteworthy Upcoming Release

Coastcross II is a mutant selection from Coastcross I, a bermudagrass that had very poor winter-hardiness. Coastcross II is currently in the process of being released by Dr. William Anderson, Research Geneticist with the USDA-ARS's Crop Genetics and Breeding Research Unit at the CPES. Coastcross II grows taller and has broader, softer leaves. Though it is less winter-hardy than Coastal, it is similar to Tifton 85 in that it produces very high yields, and has superior quality and improved digestibility. This hybrid can be established from sprigs and tops; it has rapidly spreading stolons but develops few rhizomes.

Other Varieties

Alicia was selected from introductions from Africa and marketed by a Texas businessman in the early 1970s. Alicia is relatively easy to establish from sprigs or clippings (tops) and produces high hay yields similar to Coastal and Tifton 44. Its forage is much less digestible and lower in quality than Tifton 85 and even Coastal. Alicia is very susceptible to leaf-spot and may not consistently provide a thick stand. As a result, Alicia is not recommended in Georgia.

Callie, released by Mississippi State University, is a selection from a group of highly digestible bermudagrasses introduced from Kenya. Callie produces good quality forage and yields well where it is adapted, but it is not cold tolerant and will winter-kill in Georgia during severe winters. Therefore, Callie is not recommended in Georgia.

Coastcross I, released by Dr. Burton in 1967, is a hybrid of Coastal and a very digestible bermudagrass from Kenya. Coastcross I grows taller, has broader, softer leaves and produces higher quality forage than Coastal, but it is not winter-hardy. Coastcross I will winter-kill in south Georgia during severe winters and, therefore, is not recommended in Georgia.

Grazer was bred at Tifton as a hybrid of a selection found in the Alps of north Italy and introductions from Kenya. Yield performance was poor (10-15% less than Coastal) in Tifton. Excellent digestibility and performance in Louisiana led to the release of Grazer there in 1985. Poor yields prevent its recommendation for Georgia.

Midland was released in 1953 by Dr. Burton and colleagues in Oklahoma. A hybrid of Coastal and a winter-hardy common from Indiana, it is similar to Coastal in yield, growth habit, and forage quality. Some Midland stands still exist in north Georgia; however, the variety has largely been replaced by Tifton 44. It is more widely grown north of the Coastal bermudagrass belt. Midland 99, a newer selection from this line, has a wider geographic range of adaptation. For Georgia, Midland fails to yield or persist as well as Tifton 44, so it is not recommended.

Tifton 68 was released from Dr. Burton's breeding program at the CPES in 1984. It is a hybrid of two highly digestible plant introductions. It has large stems and stolons (no rhizomes) that spread rapidly. However, Tifton 68 has poor winter-hardiness and is not recommended.

Tifton 78, released in 1984, is a hybrid bermudagrass. Tifton 78 is the best of many crosses made between Tifton 44 and Callie. Compared with Coastal, Tifton 78 grows taller, has larger stems and a similar rhizome system, spreads much faster, is more easily established (sprigs and tops), and starts growth earlier in the spring. In tests at Tifton, this hybrid produced 25 percent more dry matter (hay yields) than Coastal and averaged 7.4 percent higher in digestibility. It has excellent resistance to leaf-spot, a foliage disease that destroys leaf tissue and reduces yields and quality. Tifton 78 is less winter-hardy than Tifton 44. It is well-adapted throughout the Coastal Plain and may be grown to a limited degree in the lower Piedmont. Plantings in the Piedmont may experience some stand thinning during winter, so Tifton 78 is recommended only for areas south of the Fall Line. Tifton 85 was released soon after Tifton 78. Tifton 85 has higher yields and quality than Tifton 78. As a result, Tifton 85 is a better choice for new plantings than Tifton 78 in South Georgia and the Coastal Plain region.

World Feeder, a naturally-developed, vegetatively propagated bermudagrass, was found by a producer in Oklahoma and has been marketed by Agricultural Enterprises of Oklahoma City. World Feeder is winter-hardy, but has demonstrated poor yields and digestibility in trials and demonstration plots in Georgia and several other states. It is very susceptible to leaf-spot diseases leading to many reports of stand decline/failure in World Feeder plantings in Georgia. Therefore, it is not recommended for Georgia.

Several other vegetatively propagated bermudagrass varieties are available, many of which are releases from university or USDA breeding efforts. Among these, Brazos, Hardie, Oklan, and Quickstand have not performed well in Georgia or are known to not be well-adapted. Of course, many others have not been adequately evaluated in Georgia including Florakirk, Greenfield, Hill Farm Coastcross-I, Jiggs, Lancaster, LeGrange, Luling, Naiser, Scheffield, Summerall, Suwannee, Zimmerly, and any others not listed here.

Seed Propagated Varieties

Seeded bermudagrass varieties generally have low yields and low forage quality when compared to improved hybrids. However, sprigging an improved hybrid bermudagrass is expensive and risky, especially where small acreages drive up the cost per acre and rolling terrain leaves soil prone to erosion for a significant period of time. Producers often find that planting seed is the most feasible establishment option.

Ironically, the most hardy and persistent varieties will often produce little seed. These varieties can be expensive. Seed companies will often help offset this problem by offering seed blends, so it is important to closely evaluate and compare seed tags. These blends usually contain one or more of the top varieties in mixtures with varieties that are more prolific seed producers (Table 2). Though these more prolific seed producers (such as Giant and Jackpot) grow very well in the establishment year, they are not usually persistent and are often very short lived in Georgia. However, by the time these components of the mix die out, the more persistent varieties may be capable of filling in the gaps. Unfortunately, these gaps often exist in early spring when weeds are growing but the bermudagrass is not. Alternatively, companies may fill out a blend by mixing in common bermudagrass, some or all of which may have been hulled to remove the seed husk for faster germination. These blends may be prone to revert to common (that is, common will ultimately dominate the stand). Despite the expense, seeding recommended cultivars alone (not in a blend) is more likely to lead to better results over the long-term because these varieties are more hardy, produce higher yields, limit weed intrusion, and maintain better quality.

Recommended Cultivars

Cheyenne, a seeded bermudagrass cultivar, has exceptionally good persistence, is winter-hardy in Georgia, and consistently performed well in yield trials throughout the state (Tables 3a and 3b). The forage quality (protein, fiber, and digestibility) of Cheyenne is quite similar to Coastal, but it is slightly lower than CD90160 and KF-194. Cheyenne has not been a prolific seed producer. This has limited the availability of seed from this cultivar. Recently, clones of Cheyenne were selected for improved seed production by Texas A&M University and Seeds West. The product of this selection, Cheyenne II, has been shown to match the yield and persistence of Cheyenne in initial evaluations. Cheyenne II is now being sold and used in seed blends such as Ranchero Frio.

CD90160, a seeded bermudagrass cultivar, is most often sold in seed blends such as Vaquero, Gaucho, Sungrazer Plus, and Sungrazer 777. When grown alone, this cultivar matches the yield, winter-hardiness, and persistence of Cheyenne. CD90160 has also shown to have higher protein (increased by 20%) and digestible nutrients (increased by 14%) than Cheyenne.

KF-194 is often sold in seed blends such as Sungrazer Plus and Sungrazer 777. Like CD90160, this cultivar also matches the yield, winter-hardiness, and persistence of Cheyenne. KF-194 shares the high forage quality characteristics of CD90160.

Other Varieties

Common bermudagrass is certainly well-adapted to the humid South and quickly became a widespread weed in cultivated crops after its introduction in the 18th century. Common produces viable seed and spreads by stolons and rhizomes. Once established, it is difficult to eradicate. Common bermudagrass is present, usually in combination with fescue or as a contaminant in improved bermudagrass pastures, on more than 400,000 acres in Georgia. It is hardy, forms a dense sod, and can be established from seed and maintained on infertile soils. Although Common does not provide high yields (often 50% as much hay per acre as Coastal), it can be effectively used in forage programs to provide summer grazing. In north Georgia, it is best used in combination with fescue and clover. Though Common bermudagrass is an important part of pastures and hayfields in Georgia, it is not recommended for new seedings simply because improved seeded varieties (recommended above) will consistently out-yield and provide higher quality forage than Common.

Many other seeded bermudagrass varieties are available. Most of these releases are from private companies and turfgrass breeding efforts. Many have been shown to have persistence problems or yield poorly, such as Giant, Guymon, Jackpot, and Wrangler, and are therefore not recommended. Mirage, Mohawk, Pyramid, and many other varieties not listed have not been adequately evaluated under Georgia's conditions.

Tables

Table 1a.
Summary of the characteristics of the primary vegetatively propagated (sprigged) bermudagrasses in Georgia.

Variety	Overall Rating	Yield*	Digestibility**	Winter Hardiness	Persistence	Leaf Spot Resistance
Alicia (Alecia)	★★½	100	P	G	P	P
Coastal	★★★½	100	F	G	G	E
Coastcross II	★★★★½	135	E	G	ND	ND
Russell	★★★★½	130	G	E	E	G
Tifton 44	★★★★	90	G	E	G	E
Tifton 78	★★★	120	E	F	F	E
Tifton 85	★★★★★	135	E	F	E	E

Ratings: E = Excellent, G = Good, F = Fair, P = Poor.
* Yields are expressed as a percent of yields from Coastal.
** Based on *in vitro* dry matter digestibility.
ND Insufficient data exists to accurately estimate these parameters. Coastcross II remains a relatively new variety and has not yet been evaluated as rigorously as other hybrids.

Table 1b.
Summary of the characteristics of the primary vegetatively propagated (sprigged) bermudagrasses in Georgia.

	Recommended for:			
Variety	**Mountain**	**Upper Piedmont**	**Lower Piedmont**	**Coastal Plain**
Alicia (Alecia)				
Coastal		√	√	√
Coastcross II	ND	√	√	√
Russell	√	√	√	√
Tifton 44	√	√	√	
Tifton 78				
Tifton 85		√	√	√

ND Insufficient data exists to accurately estimate these parameters. Coastcross II remains a relatively new variety and has not yet been evaluated as rigorously as other hybrids.

Table 2.
Blends of seeded bermudagrasses.

Trade Name	Components
Morhay	Common, Giant
Pasto Rico	Common, Giant
Pasture Supreme	Common, Giant
Ranchero Frio	Cheyenne, Mohawk, Giant
Sungrazer 777	KF 194, CD90160, Jackpot
Sungrazer Plus	KF 194, CD90160, Giant
Texas Tough	Common, Giant
Tierra Verde	Common, Giant
Vaquero	Mirage, Pyramid, CD90160

Table 3a.
Summary of the characteristics of the primary seeded bermudagrasses in Georgia.

Variety	Overall Rating	Yield*	Winter Hardiness	Persistence
Giant (NK37)	½★	55	P	P
Cheyenne**	★★★	60	G	E
CD90160	★★★	60	G	E
KF-194	★★★	60	G	E
Wrangler	★½	55	E	F
Common	★	50	G	G

Ratings: E = Excellent, G = Good, F = Fair, P = Poor.
* Yields are expressed as a percent of yields from Coastal.
** The original Cheyenne is no longer being sold. Cheyenne II, a variant of Cheyenne (selected for higher seed yield), is currently being marketed. Cheyenne II is expected to have characteristics similar to Cheyenne.

Table 3b.
Summary of the characteristics of the primary seeded bermudagrasses in Georgia.

Variety	Recommended for Georgia	Comments
Giant (NK37)		Fast growing, but short-lived seeded variety. Northrup King has the only named variety of Giant.
Cheyenne**	√	Most reliable of seeded varieties grown Georgia.
CD90160	√	Solid performer, but most commonly sold as one of three components in a blend.
KF-194	√	Another solid performer that is primarily sold as a component in seed blends.
Wrangler		Good variety for northern-most counties, but it has not persisted well in variety trials in most of Georgia.
Common		Default pasture species throughout most of Georgia, but it suffers from poor yields and susceptibility to disease.

Ratings: E = Excellent, G = Good, F = Fair, P = Poor.
* Yields are expressed as a percent of yields from Coastal.
** The original Cheyenne is no longer being sold. Cheyenne II, a variant of Cheyenne (selected for higher seed yield), is currently being marketed. Cheyenne II is expected to have characteristics similar to Cheyenne.

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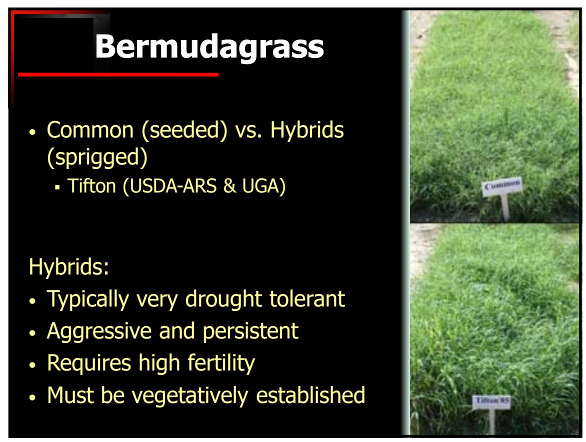
J. Scott Angle, Dean and Director

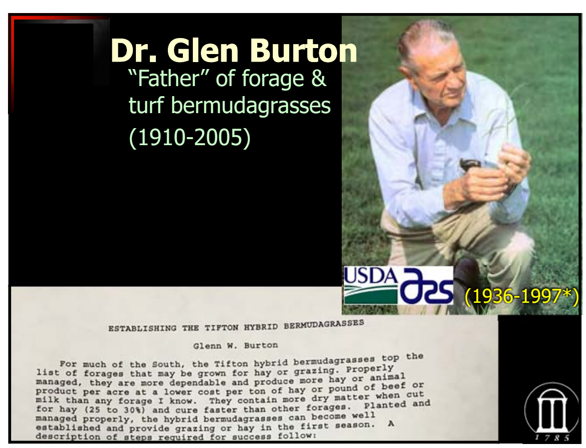
Methods for Vegetative Establishment

Dr. Dennis Hancock, Extension Forage Agronomist

Methods of Vegetative Establishment

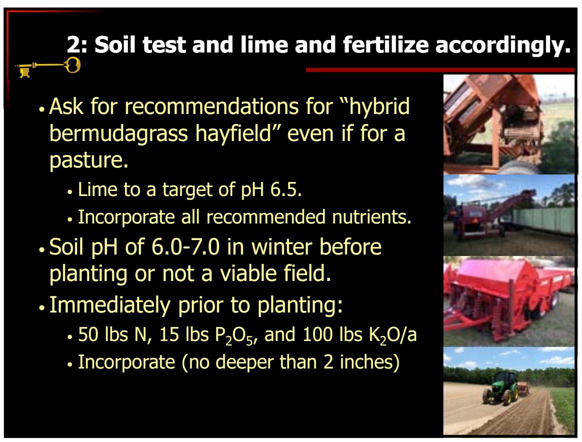
Methods of Vegetative Establishment





2018 Hay and Baleage Short Courses

Methods of Vegetative Establishment



Methods of Vegetative Establishment

3: Use the false or stale seedbed preparation method.

- In the 4-6 weeks between tillage and planting, weed seeds will germinate.

False seedbed prep:

- Kill the weeds by lightly tilling the soil with a light drag or shallow disking, then immediately firm with a roller.
  - Downside: moisture loss

Stale seedbed prep:

- Kill the weeds with non-selective herbicide, wait 1-7 days and plant.

Minimum Till ("No-till") Options

- Acceptable for vegetative establishment (sprigging), but will leave the field very rough.
- Weed control?

4: Choose an establishment method and timing.

Three primary methods

1) Dormant sprigs – 40-70 bu of LS/acre
   - Jan. to early Mar.
   - Less desirable for Tifton 85
   - Cover with at least 2" of soil to protect sprigs from freezing
   - 50%+ of dormant sprigs fail to emerge
   - Fall prior: do not allow the nursery area to be cut or grazed after Labor Day
   - Excessive winter rainfall limits dormant sprig survival
   - Estimate sprig survival by grow-out and adjust sprigging rate accordingly

4: Choose an establishment method and timing.

Three primary methods

2) Spring sprigs – 40-70 bu of LS/acre
   - Spring (after last freeze) to early Aug.
   - Early sprigging increases likelihood of establishment by end of the first year
   - Avoid planting before early April
   - Sprigs should be vigorously growing before digging.
   - Stand development is directly proportional to sprigging rate

Methods of Vegetative Establishment

4: Choose an establishment method and timing.

Three primary methods

3) Tops/green stems – 60-100 bu/A
- June until early Aug.
- Tops need 6+ nodes on the stolons
  - Fine-textured varieties: 10-12”
  - Coarse-textured varieties: 18-24”
- Nursery area should receive: 100 lbs N, 25 lbs P_2O_5, and 100 lbs of K_2O/acre in late March to produce tops by June
- Not recommended for Tifton 44
- Usually not planted with sprig planter.

Methods of Vegetative Establishment

Methods of Vegetative Establishment

5: Plant ONLY in moist soil.

- Sprigs will die if they drop below **~50-55% moisture** or if they heat above **120°F** for extended period.
- If soil is dry, especially if hot, it will draw moisture out of the sprigs even after they have been planted.
- Ideal: planting on cool, cloudy day, preferably with a misty rain or imminent rainfall.
- Irrigation before and after can add flexibility, but do not over irrigate.
  - ~1"/wk (0.5" x 2x/wk) for first 4 wks

Heat Damage to Sprigs:
Lessons from the Turfgrass World

- **Temp. of sprigs inc. 1.0-2.5°F/hour of storage, depending on O_2 intrusion and density of pack.**
- **Sprigs can survive 110°F for extended period and 120°F for up to 6 hrs with minimal damage.**
- **If exposed to 130°F for 4 hrs, sprig survival is 30-60%. If 140°F for 1 hr, 100% sprig death.**
- **No difference in sprig survival among turf varieties.**

Source: Elsner and McWhorter, 1999. USGA Green Sec. Rec.

Photo credit: ChechesseeCreekClub.com

6: Plant pure sprigs or tops.

- Recommended to buy only certified planting material
  - GA Crop Improvement Assoc. certified (www.georgiacrop.com)
- If none available in your area, ask to see the nursery field
  - 'Common' contamination is common complaint.
  - Be proactive!

7: Plant fresh sprigs or tops from a well-fertilized nursery.

Recommended nursery protocol:

- If dormant sprigs to be harvested
  - 100 lbs N, 25 lbs P_2O_5, and 100 lbs K_2O/acre in Sept. prior to dig.
- If spring sprigs to be harvested
  - 100 lbs N, 25 lbs P_2O_5, and 100 lbs K_2O/acre at spring green up or within 6 weeks of digging or top harvest.

What Does a "Good Sprig" Look Like?

- **Crown, rhizome, and stolon size are an indicator of CHO storage and.**
- **Crown and rhizomes should be 3/16 – 3/8" in diameter.**
- **Stolons in sprigs should have 2-4+ nodes and be 1/8 – 1/4"+ in diameter at nodes.**
- **Stolons as tops should have 6+ nodes and be 1/8 – 1/4"+ in diameter at nodes.**
- **Dormant and spring sprigs should be planted ASAP (at least <24 hr after digging).**
- **Tops should be planted < 4 hr of cutting.**

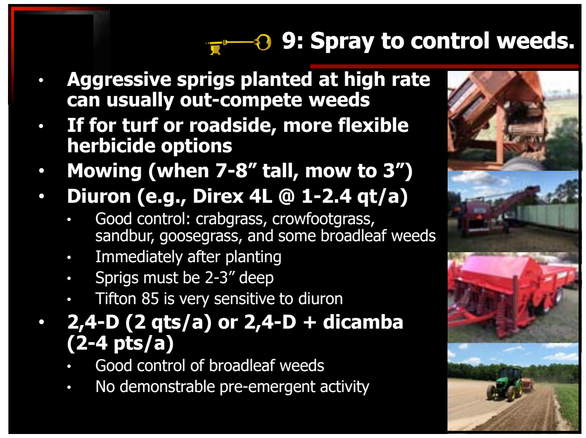
Dennis Hancock, UGA

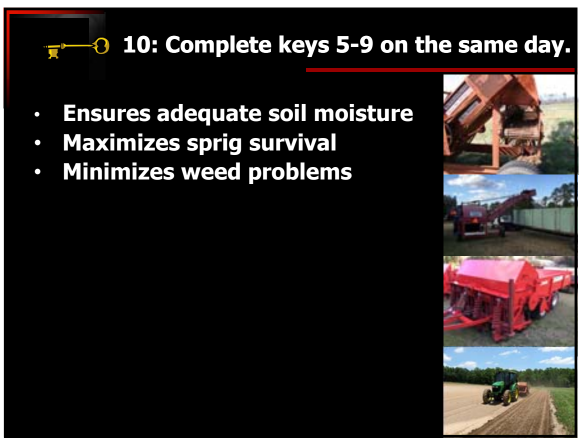
8: Pack the soil well after planting.

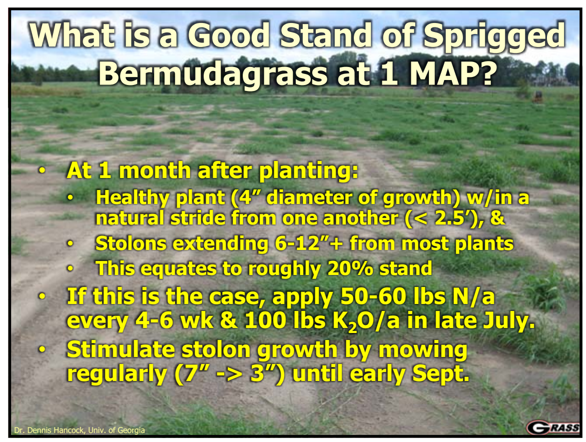
Dr. Dennis Hancock, Univ. of Georgia

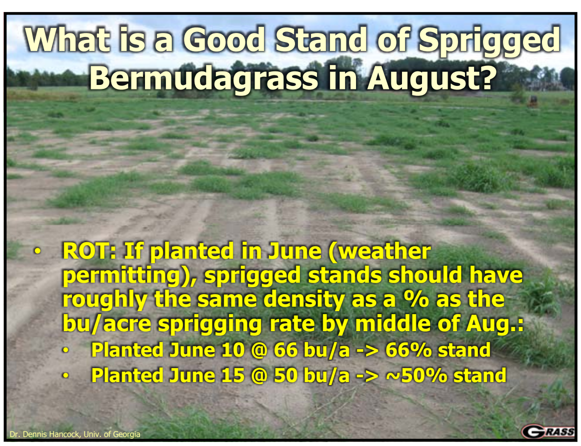
Dr. Dennis Hancock
Extension Forage Agronomist

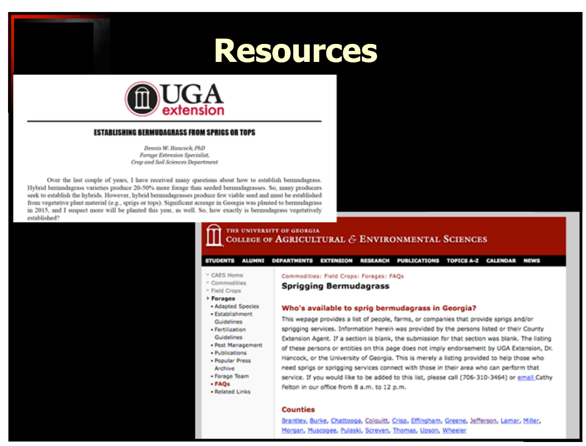
Methods of Vegetative Establishment











Methods of Vegetative Establishment

ESTABLISHING BERMUDAGRASS FROM SPRIGS OR TOPS

Dennis W. Hancock, PhD
Forage Extension Specialist,
Crop and Soil Sciences Department

Over the last couple of years, I have received many questions about how to establish bermudagrass. Hybrid bermudagrass varieties produce 20-50% more forage than seeded bermudagrasses. So, many producers seek to establish the hybrids. However, hybrid bermudagrasses produce few viable seed and must be established from vegetative plant material (e.g., sprigs or tops). Significant acreage in Georgia was planted to bermudagrass in 2015, and I suspect more will be planted this year, as well. So, how exactly is bermudagrass vegetatively established?

The Origins of Vegetative Establishment

It is important to recognize those who have painstakingly worked out the challenge of vegetatively establishing bermudagrass. Dr. Glenn Burton, plant breeder with the USDA-Agricultural Research Service at the Georgia Coastal Plain Experiment Station (GCPES) in Tifton from 1936-1997 and informally until his death in 2005, was the person who developed nearly all of the hybrid bermudagrasses we now use (e.g., 'Coastal,' 'Tifton 44,' 'Tifton 85,' etc.). In 1942, one of Burton's USDA-ARS bosses from Washington, DC visited Tifton and saw common bermudagrass full of seed heads growing next to Coastal with no seed heads. Coastal, like all hybrid bermudagrasses, produces few viable seed and must be established from vegetative plant material. Burton's boss wanted to know how he planned to propagate 'Coastal.' Burton said, "vegetatively." The USDA boss laughed and said, "whoever heard of planting pastures vegetatively!" Burton accepted the challenge to make vegetative propagation of forage practical. Initially, Burton used a wooden stick shaped like a putty knife on one end that allowed him to push sprigs (stolons and rhizomes) into the soil like planting sweet potato vines. Sprigs have also been broadcast onto a prepared seedbed and immediately lightly-disked into the soil. This method is still used in some cases today, but it requires a large volume of sprigs (50 – 75 bushels of sprigs) from a nursery to plant a single acre of land. In this case, one acre of nursery can only sprig 4 – 6 acres. Consequently, James Stephens, a UGA agricultural engineer at the CPES, developed a precise two-row planter that allowed the sprigging rate to be cut in half (20 – 40 bu./acre). As more 'Coastal' bermudagrass acreage was planted, farmers innovated and developed their own methods and machines. Now, modern sprig diggers and sprigging machines do the work (Figure 1).

Figure 1. Modern sprig digging (above) and sprigging equipment (below).

10 Steps to Establishing Bermudagrass

Dr. Burton was frequently asked to provide producers with a recipe for establishing bermudagrass vegetatively. He wrote an article entitled "Establishing the Tifton Hybrid Bermudagrasses," which provided a 10-step recipe for success. In the decades since, nearly all of his advice has remained as valid today as it was when he wrote that article. However, there have been a few advancements that have been found to increase the chances of success. Below are updates to Dr. Burton's 10 steps.

1. Choose an appropriate site for establishment. First, the soil must be well-drained. Bermudagrass does not do well on Flatwoods soils or other land that tends to hold water or flood. Also, choose a site that is free of other bermudagrass varieties and bahiagrass and that has minimal weed pressure. Land that has been recently cropped is usually ideal. If the site currently has bermudagrass or bahiagrass on it, one would ideally grow a summer and fall crop on the land and use appropriate herbicides or chemically fallow the land (i.e., use a non-selective herbicide 2 – 4 times during the summer and fall) in the year before the bermudagrass is to be established so that it will completely eliminate the existing stand. At a minimum, one should apply a non-selective herbicide to the existing stand of bermudagrass or bahiagrass in the fall prior to establishing bermudagrass in the spring or summer. Fall applications of an herbicide are more likely to translocate to the roots, thereby improving efficacy.

2. Soil test, lime, and fertilize accordingly. Submit a soil sample and ask for recommendations for a hybrid bermudagrass hayfield, even if it is to be a pasture. If a field does not already have a soil pH of 6.0 or higher, it is not yet a candidate for being established to bermudagrass. Apply all lime (target pH of 6.5) and fertilizer that is recommended from the soil test prior to land preparations so the amendments can be worked into the soil. Ensure that 50 lbs of N, 15 lbs of P_2O_5, and 100 lbs of K_2O/acre are incorporated (no deeper than 2 inches) immediately before the bermudagrass is planted.

3. Use the false or stale seedbed preparation method. For best results, bermudagrass sprigs or tops should be planted into a conventionally-tilled, prepared seedbed. The seedbed should be prepped 6 weeks or more prior to planting. To start the seedbed preparation process, chisel or moldboard plow the soil and then disc harrow the field. Allow the soil to settle for 4 – 6 weeks. During this time, weeds will likely begin to germinate. The "false seedbed preparation method" involves killing germinated weeds by tillage. In that method, kill the weeds by lightly tilling the soil with a light drag or very shallow disc harrowing, then immediately plant the sprigs or tops, and firm the soil with a cultipacker or roller immediately to minimize moisture loss. This step can be conducted closer to the actual planting date if soil moisture can be maintained. Tillage prior to planting may cause the soil to dry excessively, cause sprigs to be planted into dry soil, and, thereby, reducing establishment success. Alternatively, one can use the "stale seedbed preparation method," which involves herbicidal weed suppression instead of tillage. In this method, any germinated weeds are killed with a non-selective herbicide 1-7 days prior to sprigging. This requires no additional tillage and assists in the retention of soil moisture.

Though there are some so-called "no-till" sprigging machines, these implements still do significant tillage with the shank that opens a slot for the sprigs to be dropped into a furrow. These no-till spriggers can be successful, but ensuring weeds are chemically suppressed before, during, and after establishment will be crucial. No-till sprigging also tends to result in a field surface that is rough, which can cause challenges for the operation of hay equipment and be a nuisance to the equipment operator.

4. Choose an establishment method and timing. There are three establishment methods: dormant sprigging, spring sprigging, and tops.

Dormant sprigs, which include the crowns, corms, or rhizomes of bermudagrass, should be planted at a rate of at least 40 – 70 bushels of viable sprigs per acre in late winter (January – March). Most varieties can be established this way, but dormant sprigging of Tifton 85, at least above the fall line, has proven to be more risky. Dormant sprigs should be covered with at least 2 inches of soil to protect them from freezing. Delaying dormant sprigging until February will reduce the chances of winter injury and competition from winter weeds. Dormant sprig plantings may not begin to grow until March or April. It is likely that 50% or more of the dormant sprigs planted will fail to emerge. Those that do emerge may not have enough reserves to establish a live plant. Therefore, dormant sprigs should come from plants that had maximum reserves going into the winter. This can be accomplished by not allowing the stand from which sprigs will be dug to be cut or grazed after Labor Day in the fall preceding sprig digging. In addition, excessive moisture in winter limits dormant sprig survival. To estimate dormant sprig survival, dig some of the sprigs and place a known number of them in 2 – 3 buckets of soil 1 month prior to dormant sprigging. Keep the soil in the buckets moist (not wet) and in an area that is warm and subjected to at least 12-hours of light during the day. Adjust the sprigging rate based on the percentage of sprigs planted in the buckets that emerge after 14 – 21 days.

Spring sprigs with green tops and stolons are planted at a rate of 40 – 70 bu./acre. Spring sprigs can be planted anytime after the danger of a heavy freeze has passed, up until August. Early planting of spring sprigs can help that ensure the sprigs become well established during the first year and increases the likelihood they will survive a severe winter. However, planting too early (March and early April) is stressful on sprigs, as they are already low on reserves after emerging from winter dormancy. So, make sure that the sprigs are vigorous and healthy before digging. If buried too deeply, spring sprigs may not have enough reserves to emerge from the soil and will die. Planting sprigs with green leaves and stolons can help ensure sprig survival, as they can more quickly begin to photosynthesize and manufacture carbohydrate reserves.

Tops (green stolons) are planted at a rate of 60 – 100 bushels of fresh tops/acre. Tops can be planted from June until August. Stolons planted as tops must have 6 or more nodes. This usually means the stolons are 18 – 24 inches in length. A nursery area provided with 100 lbs of N, 25 lbs of P_2O_5, and 100 lbs of K_2O/acre in late March will usually produce such tops by early June. Cuttings of tops later in the season will require approximately 8 weeks of regrowth for stolon development to be sufficient. Nearly all of the recommended varieties of bermudagrass can be established from tops, but Tifton 85 ranks first and Tifton 44 last in the success obtained with such plantings. Because of their length, tops are usually not planted in the ground by a sprig planter. Tops are spread across a prepared seedbed, lightly disked into the ground, and the soil is firmed around them with a cultipacker or roller. To facilitate handling, tops are often cut with a disc hay mower (no conditioner) and immediately baled, either in small square or round bales. Small square bales of tops can be spread by hand or using a tops spreader such as the ground-driven implement pictured in Figure 2. Round bales must be unrolled and spread out (usually using a tedder) before they are harrowed into the soil. Tops that are baled must be handled and planted quickly (within 2 hrs for best results) to prevent them from overheating and dying before they are planted.

Figure 2. Square bales of bermudagrass tops are being scattered over a prepared seedbed (top) using a ground-driven tops spreader.

5. Plant only in moist soil. Sprigs or tops must be planted in moist soil to prevent them from wilting. If tops are scattered on dry soil, they can die in a few minutes. It is best to plant sprigs or tops on a cool, overcast or cloudy day, preferably with a misty rain or an imminent rainfall. Irrigation can assist spring sprigs or tops, but this is not a necessity unless planting occurs during a prolonged drought.

6. Plant pure sprigs or tops. It is recommended to buy certified planting material of the variety you want to grow. The Georgia Crop Improvement Association certifies the fields from which such planting material is taken, and they ensure that proper protocols are followed to prevent contamination from off varieties and weeds. A list of certified planting material providers is located on their website (http://www.georgiacrop.com). One of the most frequent complaints is that the provider of planting material used the wrong variety or it was contaminated with common bermudagrass. A proactive stance on the part of the buyer in using certified planting material can help prevent these mistakes.

7. Plant freshly harvested sprigs or tops from a well-fertilized nursery. A nursery area where dormant sprigs are to be harvested should receive 100 lbs of N, 25 lbs of P_2O_5, and 100 lbs of K_2O/acre in the September prior to harvest. This same amount of fertilizer should be added at spring green up or within 6 weeks of harvesting of either spring sprigs or tops. The size of the crown, rhizomes, and stolons are an indicator of carbohydrate storage in and, therefore, the viability of the planting material. Sprigs of the plant's crown and rhizomes should be 3/16 – 3/8 inch in diameter. Sprigs of the plant's stolons should have at least 2 nodes (preferably 4) and be at least 1/8 – 1/4 inch in diameter at the nodes. Stolons used for establishment by tops should have at least 6 nodes and be at least 1/8 – 1/4 inch in diameter at the nodes. Dormant and spring sprigs should be planted as soon as possible but at least within 24 hours after digging. Tops should be planted within 4 hours of cutting.

8. Pack the soil well. Immediately after planting, use a cultipacker or heavy roller to firm the soil around the sprigs or tops. This will ensure that the planting material has good contact with the soil so that it can stay moist. Irrigation can help, but it is usually not necessary if these rules are followed closely.

9. Spray to control weeds. It is likely that significant weed pressure will occur after planting bermudagrass. Good weed control during the establishment phase is essential. Newly-established bermudagrass cannot compete with rapidly growing annual grasses and broadleaf weeds. A thick cover of weeds slows stand establishment by shading the emerging bermudagrass plants and preventing the bermudagrass stolons from pinning down. An application of diuron, a pre-emergence herbicide, will provide fair to good control of crabgrass, crowfootgrass, sandbur, and goosegrass, as well as providing residual control of certain annual broadleaf weeds. Diuron should be applied immediately after planting. However, diuron can severely injure bermudagrass sprigs and (especially) tops. Any green or emerged bermudagrass at the time of treatment may be significantly injured. Tifton 85 appears to be very sensitive to diuron, so its use on plantings of this variety should be avoided unless weed pressure is expected to be high. Bermudagrass planting material should be planted 2 – 3 inches deep to lessen chance of injury. If diuron is not used, an application of 2,4-D + dicamba (WeedMaster) should be applied at a rate of 2 – 4 pts/acre within 7 – 10 days after planting. This can provide excellent control of most broadleaf weeds and significant suppression of some grassy weeds. See the Georgia Pest Management Handbook (http://www.ent.uga.edu/pmh/) for herbicide recommendations and follow rate guidelines and grazing restrictions on product labels. Check with your County Extension Agent for additional information and current recommendations.

10. Complete steps 5 – 9 on the same day. This will ensure adequate soil moisture is available to the planting material and ensure that weeds are adequately controlled.

Learning for Life

CSS-F053 **February 2016**

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J. Scott Angle, Dean and Director.

HOW MANY LIVE BERMUDAGRASS SPRIGS IN A BUSHEL?

Glenn W. Burton

As a buyer of a bushel of bermudagrass sprigs, I would like an answer to that question. As a sprigger who plants sprigs on a custom basis, I need that answer. I will need it to adjust my planter that is usually calibrated in "bushels per acre".

The bushel has been the unit used to measure bermudagrass sprigs for a long time. Yet at the first bermudagrass spriggers workshop, February 26, 1992, there was no consistent answer to the question, "what is a bushel?" Certainly, that question must be answered before a count of live sprigs can mean very much.

Since February, 1992, we have been trying to answer that question. Here are the results of our efforts:

What is a bushel?

1. It is a volume measurement.
2. It contains 32 quarts or 8 gallons or 1.25 cubic feet.
3. Length x width x depth in feet divided by 1.25 or multiplied by .8 will indicate the number of measured bushels a truck or trailer box can hold.

The problem is that sprigs are fluffy and vary in size. Size will be determined by the amount of tops (above ground) growth and the adjustment of the digger. Other than sprig sizes, compaction to reduce fluffiness will determine the number of sprigs that can be put in a bushel.

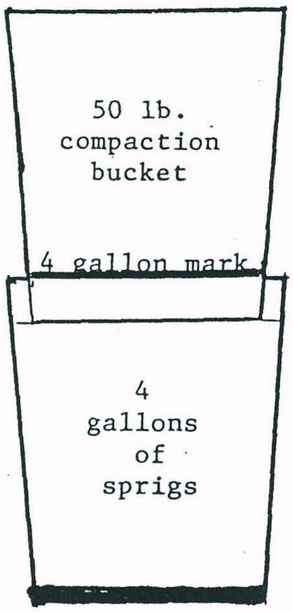
We think there is a need for a standard bermudagrass sprig bushel that is restricted by volume and compaction and defined as follows.

STANDARD BERMUDAGRASS SPRIG BUSHEL

contains

Two times the sprigs in a 5-gallon bucket compacted to the 4-gallon mark on a similar 5 gallon bucket. A practical measuring procedures follows:

1. Obtain 2 empty 5-gallon buckets (such as those used to sell farm chemicals) that measure about 9 7/8 inches in diameter at the bottom, 11 1/4 inches in diameter at the top and about 14 1/4 inches deep. One bucket will be used to measure 4 gallons of sprigs. The second bucket will be inserted in it to apply compaction.



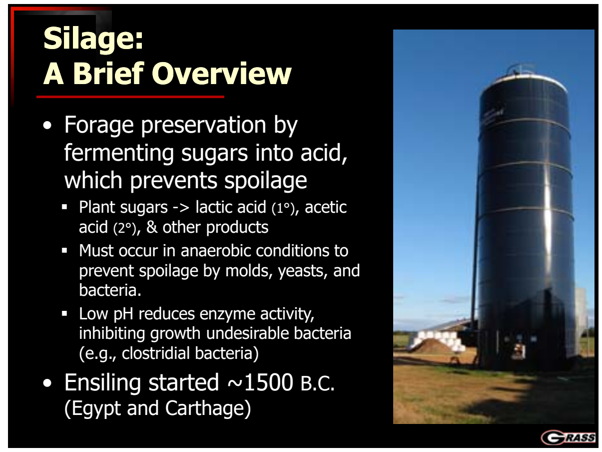
2. Put 4 gallons of water (one-half bushel) in the sprig-bucket and measure the distance from the water to the top of the bucket. It will be about 4 inches.
3. Mark that 4 inches on the outside near the bottom of the packing-bucket so when it is inserted in the sprig-bucket to that mark it barely touches the water.
4. Fill the packing-bucket with 50 pounds of sand and use it to pack sprigs in the sprig-bucket. Add sprigs until packing bucket reaches that 4-inch mark on its outside. Multiply the number of live sprigs in the sprig-bucket by 2 to get the number of live sprigs in a standard-bermudagrass-sprig-bushel. Do several of these and use an average to indicate the number of live sprigs in the standard-bermudagrass-sprig-bushel that you will sell, buy or plant.
5. To determine the weight of a standard-bermudagrass-sprig-bushel, weigh the sprigs in each standard-bermudagrass-sprig-bucket prepared as described in 4 before counting the live sprigs. The amount of soil left on the sprigs and the amount of green leaves will no doubt cause different lots of sprigs to vary in weight.
6. To estimate the number of standard-bermudagrass-sprig-bushels in a trailer or truck box, subtract its empty weight from its weight full of sprigs and divide by the average weight of a standard-bermudagrass-sprig-bushel of the same kind of sprigs. Dormant sprigs will weigh about 4 lb/half bushel.
7. To estimate the number of live sprigs in a standard-bermudagrass-sprig-bushel of dormant sprigs, put 1/2 lb. in a 6 lb. brown (kraft) paper bag, fill it with water, pour it off quickly and place bag and sprigs in a plastic grocery bag. Put in a warm place, count sprigs with live shoots. Live sprigs/bushel = live sprigs per 1/2 lb. x 2 x pounds per standard bushel.

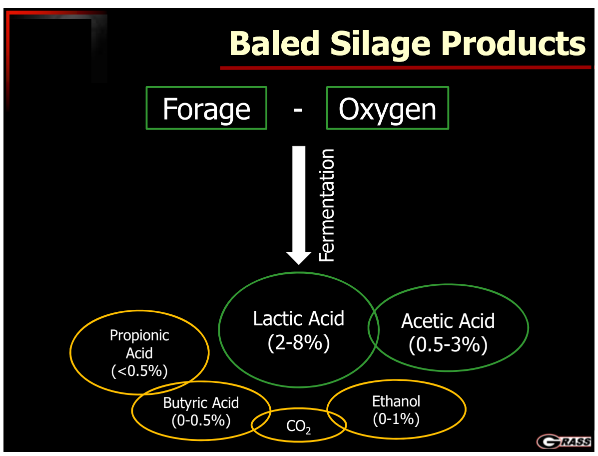
Keys to Making Baled Silage

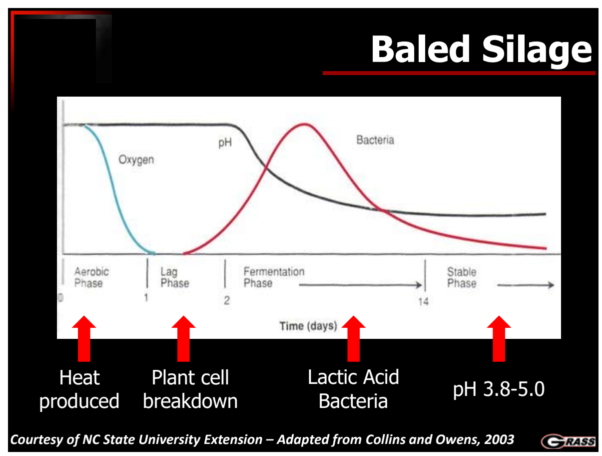
Taylor Hendricks, PhD Student

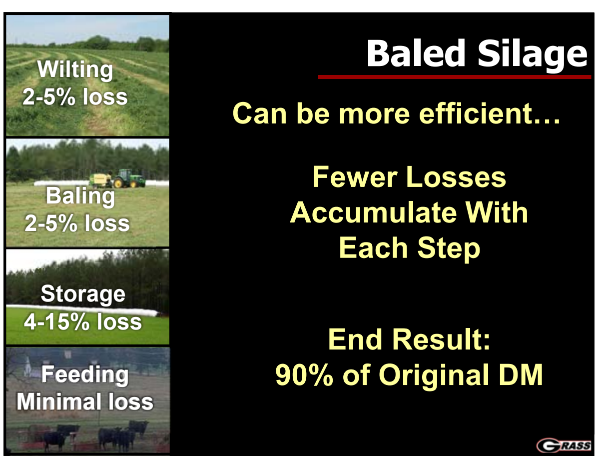
2018 Hay and Baleage Short Courses

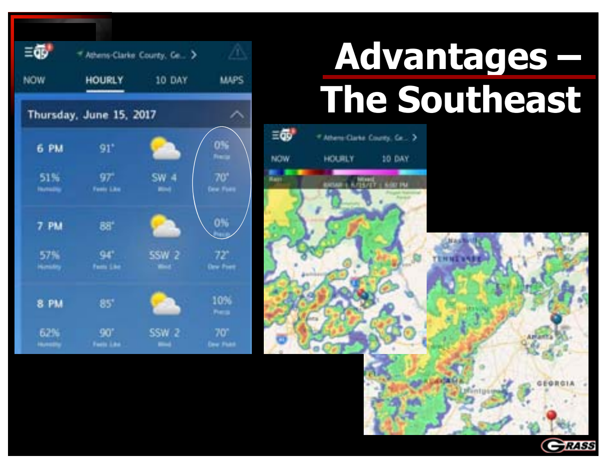
Keys to Making Baled Silage











Keys to Making Baled Silage

Quality Advantages

- Enables timely harvest
  - Reduces drying time
  - Lowered risk of rain damage
  - Less shatter loss
- Higher forage quality[1]
  - Lower NDF, ADF, ADL
  - Higher CP
  - Increased digestibility
  - Increased palatability

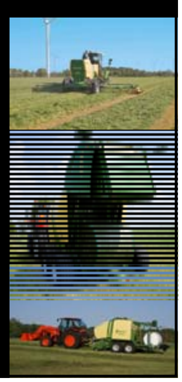
[1] Han, et al. 2005; Hancock and Collins, 2006.

But Remember . . .

"Garbage in = Garbage Out"

1: Cut down no more than you can handle.

- Lay down an appropriate amount of forage for wilting, baling and wrapping.
  - Cut mid-afternoon on one day, bale & wrap the next day.
- Amount cut = how much can be baled and wrapped on same day.
- Bales should be wrapped w/in 12 hrs of baling.



Effects of Delaying Wrapping on Internal Bale Temperature (63% M)

Wrap Delay	At Wrapping	Day 1*	Day 2	Day 4	Day 6	Day 14
h	---------- °F ----------					
No wrap	99	121	127	150	145	135
0	91	93	95	89	84	76
24	110	119	114	101	92	75
48	136	142	130	109	95	72
96	147	145	133	110	92	73

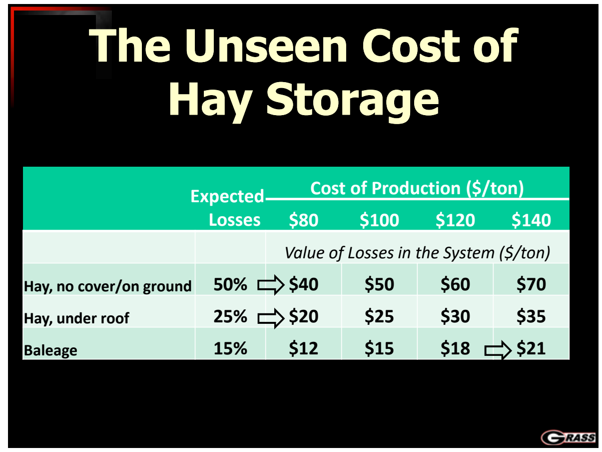
Vough et al. (2006): data adapted from Undersander et al. (2003); all square bales of alfalfa wrapped with eight mils of plastic film.

* Denotes days from wrapping.

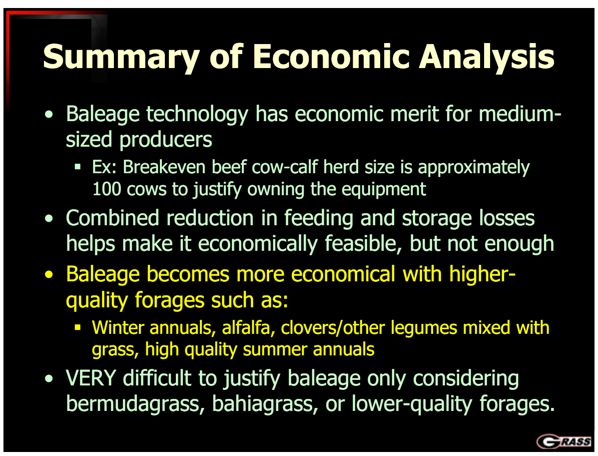
Slide credit: Dr. Wayne Coblentz, USDA-ARS

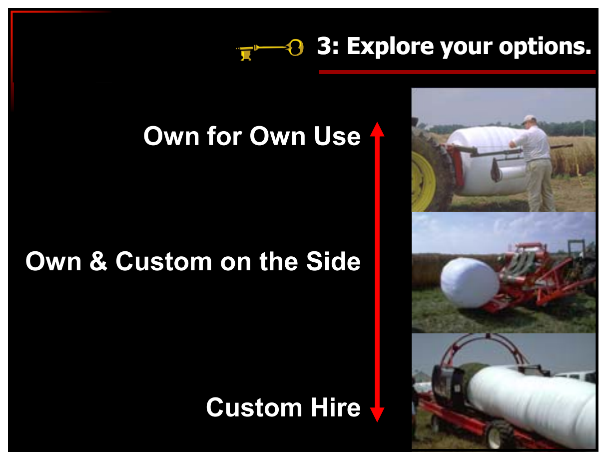
Keys to Making Baled Silage

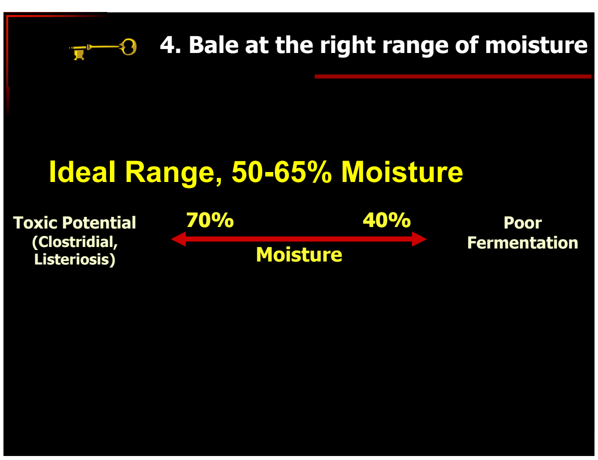
Keys to Making Baled Silage

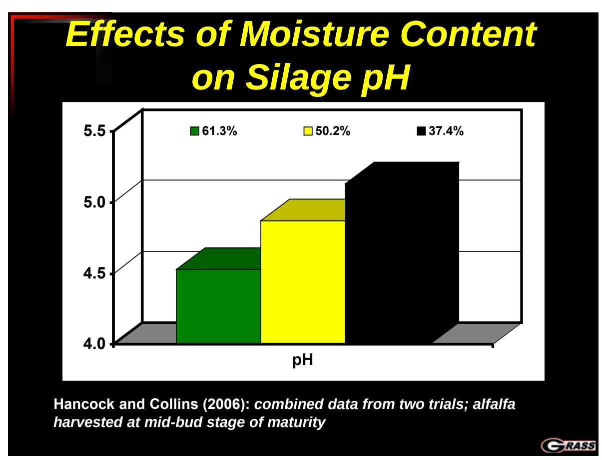


	Expected Losses	Cost of Production ($/ton) $80	$100	$120	$140
		Value of Losses in the System ($/ton)			
Hay, no cover/on ground	50%	⇨ $40	$50	$60	$70
Hay, under roof	25%	⇨ $20	$25	$30	$35
Baleage	15%	$12	$15	$18	⇨ $21



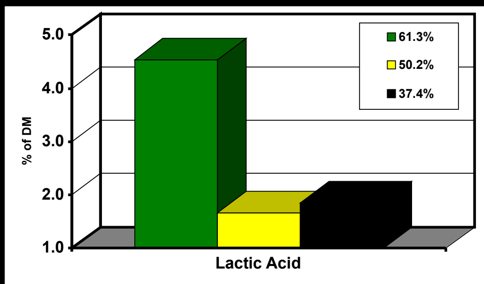






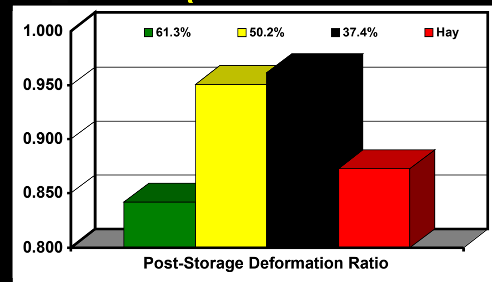
Keys to Making Baled Silage

Effects of Moisture Content on Lactic Acid



Hancock and Collins (2006): *combined data from two trials; alfalfa harvested at mid-bud stage of maturity*

Effects of Moisture Content on Bale Deformation (ft vertical/ft horizontal)

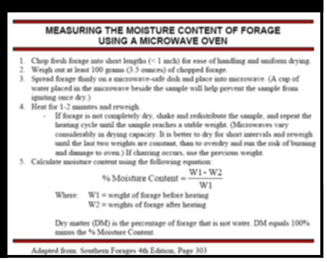


Hancock and Collins (2006): *combined data from two trials; alfalfa harvested at mid-bud stage of maturity; estimate for hay is mean of bales made at 16.6 and 19.8% moisture, and stored outdoors, uncovered.*

Determining Moisture

Methods:

4. Hay Moisture Testers/Probes
3. By feel (if calibrated).
2. Microwave moisture test



MEASURING THE MOISTURE CONTENT OF FORAGE USING A MICROWAVE OVEN

1. Chop fresh forage into short lengths (< 1 inch) for ease of handling and uniform drying.
2. Weigh out at least 100 grams (3.5 ounces) of chopped forage.
3. Spread forage thinly on a microwave-safe dish and place into microwave. (A cup of water placed in the microwave beside the sample will help prevent the sample from igniting once dry.)
4. Heat for 1-2 minutes and reweigh.
   - If forage is not completely dry, shake and redistribute the sample, and repeat the heating cycle until the sample reaches a stable weight. (Microwaves vary considerably in drying capacity. It is better to dry for short intervals and reweigh until the last two weights are constant, than to overdry and run the risk of burning and damage to oven.) If charring occurs, use the previous weight.
5. Calculate moisture content using the following equation:

$$\% \text{ Moisture Content} = \frac{W1 - W2}{W1}$$

Where: W1 = weight of forage before heating
W2 = weights of forage after heating

Dry matter (DM) is the percentage of forage that is not water. DM equals 100% minus the % Moisture Content.

Adapted from: Southern Forages 4th Edition, Page 303

http://bit.ly/MicroMoisture

Determining Moisture

Methods:

4. Hay Moisture Testers/Probes
3. By feel (if calibrated).
2. Microwave moisture test
1. Moisture tester (e.g., Koster)

5. Make good bales

Effects of Bale Density on Fermentation

Moisture	------- 58.7% ------		------- 52.4% -------	
Density, lbs/ft^3	12.9	10.9	12.4	10.4
pH	*4.7*	4.9	*4.8*	5.1
lactic acid, %	*7.0*	6.5	*7.1*	6.3
acetic acid, %	2.4	3.8	3.3	2.0
max temp, °F	107	109	108	106
DM REC, %	98.6	98.6	97.8	98.3

Han et al. (2004): high density bales created at 842 x 10^3 Pa of chamber pressure; lower density bales made at 421 x 10^3 Pa.

Slide credit: Dr. Wayne Coblentz, USDA-ARS

Keys to Making Baled Silage

6. Choose an appropriate site for wrapping

- Wrap at the storage site
  - reduces handling
  - reduces risk of spoilage
- Where feed out is easy
- Store individual bales on flat end

Effects of Plastic Layers and Storage Side on Mold Coverage

Plastic Layers	Store Position	Surface Mold Coverage (%) Side	End	Total
4	End	4.5	26.0	12.6
4	Side	27.7	5.1	19.2
6	End	6.7	6.8	6.7
6	Side	20.1	0.0	12.6

** P < 0.01; ** P < 0.001*

Bisaglia et al. (2011): Bales consisted of half Italian Ryegrass, half Lucurne; storage period 180 days

7. Apply enough plastic but no more.

Remember - The plastic is not impermeable to oxygen.

Application Amount – Inline Wrapper

- Eight+ layers (+ double on joints)
  - 12.5 – 16.7% overlap
  - two rolls rotating around bales
- Pre-stretched to 50-70%
- Tacky side towards the bale
- 60-80+ bales per hour

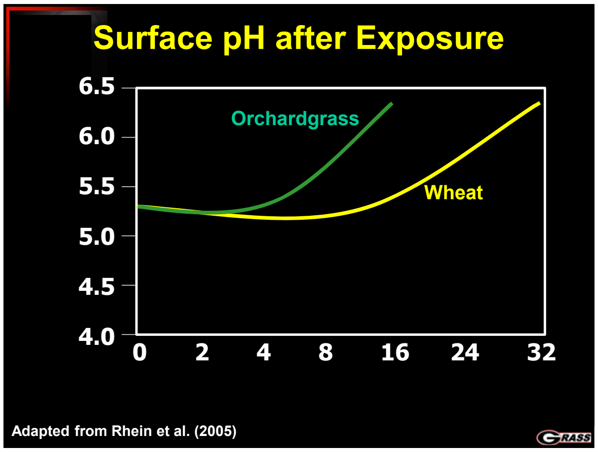
Application Amount – Ind. Wrapper

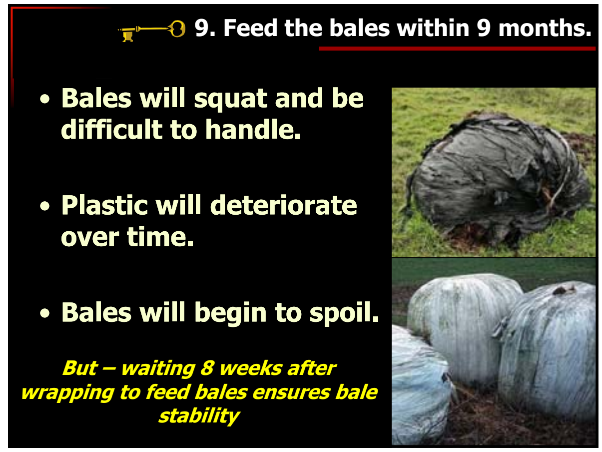
- Six+ layers (2 + 2 + 2 system)
  - 50% overlap
  - Three full bale rotations
  - If short term, 4-layers may be ok
- 15-40 bales per hour

8. Feed it in an appropriate way.

- Match quality to animals needing that quality
- Use a ring (or cone) feeder
- OK for mixed rations
  - Bale grinder
  - May need to be sliced

Dr. Dennis Hancock
Extension Forage Agronomist


Surface pH after Exposure
6.5
6.0
5.5
5.0
4.5
4.0
0 2 4 8 16 24 32
Orchardgrass
Wheat
Adapted from Rhein et al. (2005)


9. Feed the bales within 9 months.
• Bales will squat and be difficult to handle.
• Plastic will deteriorate over time.
• Bales will begin to spoil.
But – waiting 8 weeks after wrapping to feed bales ensures bale stability


10. Have a plan for handling the plastic.
• Recycling is not currently an option
• Reduce the bulk to aid in handling


Questions?
GRASS
www.georgiaforages.com

Baled Silage: Frequently Asked Questions

Dr. Dennis Hancock, Forage Extension Specialist

Increasingly, producers have recognized the potential of baled silage to reduce the losses associated with harvesting and storing forage, as compared to conventional haying methods and provide an alternative method of silage production to conventional silos. Inevitably, a new technology has many questions associated with it. Hopefully, the answer to these questions, along with the information in the enclosed Extension publication "Baling Forage Crops for Silage," will aid in the introduction of the baled silage technology.

Common Questions About Baled Silage

1) What will I need?
The requirements for baled silage are much the same as those for round baled hay. However, there are some additions. The minimum requirements are a mower, rake, baler, tractor of sufficient horsepower to make and carry these bales safely, bale handling equipment, and wrapper. Usually, the variable chamber balers (belt balers) are capable of baling wet forage into a dense package. Most variable chamber balers also allow the control of bale size. New, specially designed fixed chamber balers are also capable of making dense bales, but are not able to change bale size. Many balers have some type of chopping mechanism that aids in increasing bale density as well as reducing particle size for use in mixing rations. Bale spears are inexpensive ways of moving the bales. However, spears will make holes in the plastic if they are used after wrapping. Therefore, use the spears only in moving the bales to the wrapping/storage area and the feeding site. Many types of wrappers exist. Wrappers range in cost $3000-18,000 or more and differ considerably in labor and equipment requirements. Also, there are round bale wrappers, large rectangular bale wrappers, and even small square bale wrappers. Some custom operators are wrapping silage and some counties have purchased wrappers that can be rented, thus offering alternatives to the large capital investment of purchasing a wrapper.

2) What should I use to mow?
Mower-conditioners are the most popular and easiest to use for baled silage. This is mainly due to faster wilting and evenly formed swaths. Raking can be avoided if a narrow swath is formed. Other mowers can also be used very successfully.

3) When do I cut?
The crop should be cut at the optimum maturity stage that provides good yields and the quality needed for your feeding situation. This generally means that legumes should be cut at one quarter bloom and grasses at the late boot stage. Other crops such as oats, rye, triticale, and barley should be cut before the boot stage for the best results. These crops are hard to dry at this maturity but lose feed value quickly as they mature. Cutting at these earlier stages will produce good silage and excellent feed value per acre.

4) When should I bale?
Baling at the proper moisture content is important to success in producing baled silage. Forage containing less than 40% moisture or much above 65% moisture should not be baled for silage in order to avoid excessive molding or spoilage. Producing bales with too much moisture reduces the feed quality of the forage, increases the chance of undesirable, butyric acid fermentation, and reduces the amount of dry matter stored per storage unit, greatly increasing storage costs. Baling with inadequate moisture reduces fermentation and increases mold production, greatly increasing storage losses. Considering all factors, the optimum range for baled silage is probably in the 50-65% range.

5) How should I make the bales?
A slow ground speed during baling helps make tight, dense bales which are less likely to spoil. Plastic twine is recommended, but net-wrap or nontreated sisal twine can be used successfully. Sisal twine should be avoided since the oils and rodenticides applied during its manufacturing often degrade the plastic film and can result in large storage losses. The most popular bale size is 4 feet wide and 4 to 5 feet in diameter. These bales weigh 900-1300 lbs. or more, depending on density and moisture concentration, and are best for handling and feeding. Larger bales, which use relatively less film, can be made; however, handling difficulties may outweigh the advantages.

6) Should I apply additives?
Experimental work has shown that excellent baled silage can be made with or without the use of additives. This is true even when ensiling legume crops which have more difficulty reaching the pH range of stabilized fermentation. Therefore, inoculants can be added, but probably will not be necessary in baled silage.

7) How soon should I wrap the bales?
Unnecessary delay between the baling and wrapping processes may lower the quality of the bale because of microbial activity and excessive heating that may occur while the bale is exposed to oxygen. Too much time between the baling and wrapping process may also cause the bale to sag. A sagging bale is difficult to wrap, uses more wrap and wastes time. Ideally, wrapping should be carried out as soon as possible after bailing. However, instantaneous wrapping may not be economically feasible or efficient. Bales should always be wrapped within 12 hours of baling.

8) Where should I wrap?
Wrapping at the storage site ensures that handling of the bales, and likely damage to the individually wrapped bales, is kept to a minimum. Mishandling wrapped bales risks damage and spoilage of part or all of the bale. However, there is a wide range of special equipment available for transporting and stacking silage bales. Individually wrapped bales can be laid or stacked on their sides or ends. It is thought that stacking the bales on their flat ends may reduce potential damage to the plastic. Small holes in the bale's plastic can be patched using a repair tape that has been treated with a UV inhibitor. UV deterioration of other types of tapes, such as duct tape, makes them unacceptable for repairing holes. To avoid degradation of both the silage and the plastic, store the bales on a well-drained sod and away from trees. Spray the perimeter of the stack to kill weeds which harbor rodents and insects that might damage the plastic.

9) What kind of wrap should be used?
The plastic wrap used in baled silage is a polyethylene plastic film that is pre-stretched by the wrapper as it is applied to the bale. The plastic must be able to withstand the local environmental conditions such as UV radiation and changes in ambient air temperatures. Tear strength and the amount of tack or "stickiness" may also vary among brands of wrap. Most farm supply stores either carry or can obtain stretch-wrap plastic for baled silage. Check with the supplier and/or local producers to see which brands promote proper fermentation and are economically viable in your area. The use of white plastic wrap, to aid in preventing excessive heating, is recommended.

10) How much plastic needs to be applied?
Stretch-wrap plastic usually is one mil (0.001 in) thick and comes in 20 or 30 in. rolls which are 5,000 or 6,000 ft in length. The plastic is typically pre-stretched 50 to 55% on the wrapper's film dispensing unit to get the correct tension on the bale surface. Always ensure that the tension of the wrap (tacky side toward bale) is such that it is stretched uniformly on the bales. At least four layers should be applied to each bale if an individual (spinning platform) bale wrapper is used. If an inline wrapper is used, apply six layers of wrap to each bale with additional wrapping were bales butt-up against one another. The plastic used in baled silage does not create an airtight seal. Fortunately, this low density polyethylene plastic is four times more permeable to carbon dioxide gas than it is to oxygen gas, allowing the bales to vent excess carbon dioxide as fermentation begins.

11) How many bales can be wrapped per hour?
Depending on the type of wrapper used, experienced workers can wrap 25-30 bales, or more, per hour. This is about the same number of bales covered by a 20 in x 6,000 ft or 30 in x 5,000 ft roll of stretch-wrap plastic. However, plastic use will also be dependent on the wrapper type.

12) How much does it cost?
Since each roll is approximately $60-90 (1999 prices) and will cover 25-30 bales, the average cost per bale is $3-4. Because the cost of the wrapper varies and the type of wrapper determines the amount of labor and plastic that will be required, the total cost of baled silage per ton of dry matter (DM) is highly dependent on the type of wrapper used. The more expensive wrappers are usually less labor intensive and can use less plastic than the less expensive models. Producers should use a wrapper that will minimize the capital investment, the amount of plastic used, and labor costs for their specific system. The cost of baled silage, therefore, will vary from $9-11 per ton of DM. This is much less expensive than conventional silage methods and is very competitive with the cost of conventional

hay, when the losses associated with making and storing hay are taken into account.

13) What if I feed a molded bale?

Despite the best efforts of the producer to limit the amount of mold growth in silage bales, many bales will develop some white mold. This usually occurs on the flat ends of the bale and around previously undetected pinholes in the plastic. This type of mold is usually just surface mold, caused by a fungal colony's access (though limited) to oxygen, and rarely penetrates more than a few inches into the bale. The animal will usually eat around or even discard this portion. Even if ingested, this type of mold will not harm the animal. Severely spoiled, putrid bales can, however, contain harmful bacteria such as Listeria and botulism organisms and molds, and should not be fed. Such severe cases only occur when there was an excessive amount of topsoil in the bale, there was an extremely excessive amount of moisture, or the plastic hadn't sufficiently prevented oxygen entry.

14) Is baled silage higher in quality?

The feed value of the baled silage will be no better than the quality of the forage at the beginning, and can be worse if the bale was too wet and/or spoilage has occurred. As with conventionally prepared hay, quality is a function of forage maturity at harvest, handling during harvest, and storage. The adage "garbage in - garbage out" is very true concerning baled silage quality. Relative to hay, however, the forage going in is higher in quality due to decreased harvest losses, and the resulting silage will not exhibit the same degree of losses during storage. Therefore, baled silage will be higher in quality than a comparable hay.

15) How many bales will I need?

In order to justify the costs associated with storing forage, one should wrap as many bales as possible in a season. However, because of the possibility of less DM per bale in baled silage (depending of baler type and setting), one might be putting up more bales (up to 20% more) of the same size to feed the same number of animals, relative to the number of hay bales required. Yet, the amount of DM harvested will be approximately the same, and, therefore, from an acreage standpoint, the number of acres put up as stored forage will probably be approximately the same.

16) What kind of feeding system do I need?

With the costs associated with each wrapped bale, or any other type of stored forage, it is essential to control feeding losses and refusals. Some studies have shown that a considerable amount of forage was lost when large round silage bales were fed to cattle without placing the bales in a ring feeder. Use of a ring feeder, especially if the bale is elevated, can reduce losses such that only refused forage will remain. When feeding whole silage bales to any species, it is best to feed a sufficient number of animals that will eat the entire bale within about two days. Silage bales may also be integrated into rations if cut before grinding and mixing the ration.

17) What can I feed it to?

Traditionally, baled silage has been fed to beef and dairy cattle. However, there is no reason, physiological or otherwise, that it cannot be fed to sheep, goats, or even horses. Feeding molded silage bales to horses, as in hay, should be avoided. When prepared properly, baled silage can represent up to one third of a horse's ration, on a dry matter basis. To ensure the most efficient use of the quality in a silage bale, it is important to match the bale's quality to the animals' economic productivity.

18) What should I do with the used plastic?

Because the plastic can be used for baled silage only once, plastic disposal is a potential environmental problem. Every effort should be made to prevent this. Currently, there are no standard policies in Georgia for collection and disposal of used baled silage plastic, beyond landfill disposal. Used plastic, in the future, may be baled and collected for recycling. Such efforts have been successful in those areas that have enough plastic to warrant its collection and recycling. Check with your local government on applicable statutes in your area for disposal or recycling.

REDUCING LOSSES AND GETTING HIGH QUALITY FORAGE

April 2010 Georgia Cattleman

Dennis Hancock, Forage Extension Specialist
The University of Georgia

Perhaps this long winter is finally drawing to a close. I don't think I have ever wanted spring to come so badly, and I know you are anxious for it, too. The silver lining is that this past winter has reminded us of several things. First, high quality hay is necessary to keep flesh on cows that are weathering low temperatures, cold rains, and mud. Secondly, storage losses in hay are a major issue affecting our beef cattle industry. In previous articles and as I speak to cattlemen all around the state, I have provided information about each of these subjects. But in this month's article, I hope to present an option that can kill both of those birds with one stone: baleage.

What is Baleage?

Round bale silage (or baleage) is simply baled forage that has been ensiled. The process of making baleage includes cutting the forage crop with conventional hay harvesting equipment, allowing the forage to wilt to 50 – 65% moisture, baling the forage into dense and well-formed bales, and quickly wrapping the bales in plastic so that oxygen is excluded. In the absence of oxygen, the wet forage in the bale does not rot. Instead, it goes through an ensiling process where microorganisms (mainly *Lactobacillus* sp.) ferment the feed and stabilize it by forming lactic acid and other mild organic acids. These acids give the bales the sweet smell of silage and, more importantly, inhibit the growth of other microorganisms (mainly yeasts and mold) that cause rot and deterioration.

Baleage Reduces Total Forage Loss

The ensiling process uses up some of the carbohydrates in the forage, but this loss is inconsequential relative to the savings made as a result of substantial reductions in the losses associated with making, storing, and feeding hay (Table 1). Because baleage is prepared from moist forage, it has much less risk of leaf shatter losses and rain damage (as it usually is cut one afternoon and baled and wrapped the next day). Further, the forage is wrapped in plastic, which prevents losses due to weathering or rot. Finally, cattle usually do an excellent job of eating all of the available baleage that they are given and feeding losses are minimal. As a result, the total losses associated with producing, storing, and feeding baleage are typically far less than that of either hay system.

Table 1. The typical losses of dry matter associated with producing, storing, and feeding grass hay and baleage.[†]

	Harvesting & Baling	Storage	Feeding	Total Losses
Hay, no cover/on ground	7-15%	20-40%	5-25%	30-60%
Hay, under roof	7-15%	2-10%	5-15%	15-35%
Baleage	3-10%	3-10%	4-10%	10-25%

[†] Adapted from data from eight distinct studies performed in the US.

The estimates of total loss in Table 1 enable one to compare the costs associated with these losses in each of the systems. In Table 2, I have listed the amount of total loss that I believe to be typical for these three systems in Georgia. From this, I calculated the value of these losses for forage valued from $80 up to $140/dry ton. This table reinforces the concept that no hay storage system is cheap! But, this table also allows one to better understand the value of baleage.

Table 2. The value of typical total dry matter losses associated with producing, storing, and feeding grass hay and baleage in Georgia.

	Anticipated Losses	Cost of Production ($/ton)			
		$80	$100	$120	$140
		Value of Losses in the System ($/ton)			
Hay, no cover/on ground	50%	$40	$50	$60	$70
Hay, under roof	25%	$20	$25	$30	$35
Baleage	15%	$12	$15	$18	$21

One could take this a step further by examining Table 2 a little closer. Let's say that the cost of production is $100/ton. If the only option a producer has is to store the forage outside (i.e., barn storage is not an option), then the baleage system will prevent $35 worth of losses per ton of stored forage relative to hay stored outside on the ground (i.e., $50 - $15 = $35). This would suggest that as long as the baleage system added less than $35/ton to the cost of production, it may be a feasible alternative to storing hay outside on the ground. Of course, these calculations include very broad generalizations and cannot account for all the differences between hay and baleage production systems. Thus, each producer should thoroughly examine the potential impact of this production change using a partial budget analysis.

Baleage Allows Timely Harvesting of High Quality Forage

The second major advantage to baleage is that it allows harvests to be very timely. A good example for this, particularly in the context of the current time of the year (April), is the harvest of excess annual ryegrass. It is frequently difficult for producers in Georgia to cut annual ryegrass at the proper maturity (early boot stage) because hay drying conditions are very poor at that time of year. Our research crew at the NW Georgia Research and Education Center's facility in Red Bud has helped Dr. Lawton Stewart and I evaluate the potential of ryegrass baleage in feeding replacement heifers. Last spring, they cut a pasture of ryegrass that was extra, took part of it off as ryegrass baleage, and let the remainder dry out for hay. We then compared the forage quality and average daily gain (ADG) of weanling replacement heifers provided either the ryegrass baleage, ryegrass hay, or a good crop of 'Russell' bermudagrass hay that was harvested later in the summer. The results are summarized in Table 3.

Table 3. The forage quality and average daily gain (ADG) of replacement heifers fed bermudagrass hay or ryegrass baleage or hay (unpublished data, Calhoun, GA. 2009).

Treatment	*CP*	*TDN*	*RFQ*	*ADG*
	%	*%*		*(lbs/hd/d)*
Bermuda Hay	16.1 a†	62.9 b	116 c	1.56 b
Ryegrass Baleage	16.3 a	65.9 a	174 a	1.94 a
Ryegrass Hay	14.7 b	62.4 c	133 b	1.26 b

† Averages within a column with a different letter are different ($P < 0.10$). The heifers were provided no additional supplementation.

The ryegrass hay was substantially lower in quality than the baleage. This is largely the result of two light showers (total of ~0.5 inches) that it unexpectedly received while we attempted to dry the hay to a moisture level appropriate for hay storage. Of course, this is a quite common occurrence when attempts are made to make ryegrass hay in the Southeast. By using baleage, the ryegrass was successfully harvested in a way that was mostly independent of the rainfall. Plus, the gains that these replacement heifers made without any supplementation are quite remarkable.

Baleage is NOT for Everyone

There certainly are a number of benefits to utilizing baleage as a system for conserving forage. However, it is important to recognize that baleage is NOT appropriate for everyone. The costs associated with baleage can be quite substantial, and a certain amount of scale is necessary for one to make the system cost-effective. Adopting baleage as a production practice should only be done after a thorough economic analysis has shown it to be cost-effective and practical in the farm operation.

Learn More About Baleage

There will be two events in April that will allow one to better understand how baleage fits within their farm operation. Baleage will be discussed at length at UGA's Hay Production School on April 8-9th in Moultrie at the Sunbelt Ag Expo site. We will also be discussing and demonstrating baleage as part of the Annual Ryegrass Field Day on Saturday, April 10, 2010 at Greenview Farms (Mr. Jonny Harris) near Odum, GA. Registration and program details are available for both of these events on the "Upcoming Events" page on www.georgiaforages.com. Of course, you also are encouraged to learn more about baleage as an alternative forage conservation method by visiting our website at www.georgiaforages.com or by contacting your local University of Georgia Cooperative Extension office at 1-800-ASK-UGA1.

Some Points on Feeding Baled Silage

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Silage makes an excellent feed for ruminant animals. However, feeding silage is much different than feeding hay. Silage, because it is much wetter than hay, is much more susceptible to deterioration. When sealed from oxygen during storage, the forage undergoes fermentation. However, when it is once again exposed to air when it is fed, it can still deteriorate quickly. Because of this, baled silage must be managed slightly different than hay.

Whether it is in an upright, bunker, pit, or bag silo or as a wrapped bale, the process of fermentation is very similar. Essentially, lactic acid forming bacteria that occur naturally on the surface of plant leaves undergo massive population buildups once oxygen is excluded from their environment. They derive energy from the sugars that are inherent in plant cell sap and tissue via a fermentative process. They undergo many, many cycles of feeding and reproduction until their populations become so high that the waste of their fermentation processes leads to a buildup of acid. This is why silage has a low pH. The smell of silage is also the by-products of the fermentation process. Whether the forage is ensiled in bulk in a silo or in a wrapped bale, the fermentation that occurs is essentially the same process that happens on a smaller scale when a ruminant animal such as a cow, sheep, or goat ingests forage. This is one of the reasons this feed is such a natural fit for dairy, beef, sheep, and goat production. Essentially silage is“pre-ruminated” forage.

But, there in lies the major issue with feeding silage: instability. An analogy to our eating habits would be potato salad. Pre-cooked and prepared, it doesn't need to set out very long before we eat it. This is especially true at a summer picnic where temperatures can speed the deterioration. But, this can also occur in the wintertime, even though it may take longer for it to spoil. In either case, it is not worth the chance of eating it if it has set out very long.

Thus as a "rule of thumb," never leave silage exposed to the air more than two days during feeding. If the daytime temperature exceeds 60° F, don't leave it exposed more than one day. This rule of thumb is especially important for producers who feed baled silage. It is extremely critical to those who use an in-line bale wrapper, since this determines the feed-out rate. If you have made baled silage using an in-line bale wrapper, you must be feeding enough animals that you can feed at least one bale per day in the winter. This is because as a bale is fed, the next bale is being exposed to air. Individually wrapped

Fig. 1. When feeding bales wrapped by an in-line wrapper, feed at least one bale per day during the winter.

bales are usually not subject to exposure before they are fed, and thus the feeding schedule is somewhat more flexible.

Here are some additional "rules of thumb" on how to feed silage bales or, in some cases, what not to do.

- Ensure that the storage site doesn't increase the chances of exposure to air. Some storage sites increase the likelihood of punctures to the plastic wrap. Examples would be areas near trees that have dropped limbs, rodent and other varmint dens, or that are freshly mowed and have coarse weed stubble. Many of these may create punctures that go unnoticed until it is too late.
-
- Ensure that the forage is between 50-65% moisture before it is wrapped and ensiled. Baling when the crop is too dry is the most common problem because a field may start out at the right moisture and end up being too dry. Dry forage doesn't provide the bacteria enough moisture to allow sufficient fermentation. But, it does allow fungi to grow during storage and feeding that can lead to deterioration. Baling too wet is less common. However, high moisture silage spoils quickly when exposed to air. Take care to avoid excessive moisture in the forage (e.g., little or no wilt before baling, etc.) as this may lead to clostridial spoilage or botulism.

- Don't spear into bales after they have been wrapped. Squeeze carriers or handlers are better, but may still stretch, tear, or puncture bales. Any hole in the plastic barrier can lead to small areas or even entire bales that deteriorate.

- To feed a bale that has been wrapped using an in-line wrapper, simply spear into the bale, lift, and pull away. The plastic between it and the next bale will tear away. Then cut over the top and peel the plastic off in one large section. To feed an individually wrapped bale, cut a large X in the end to be speared and pull back the flaps. Spear the bale, lift, and cut across the top and down the other flat side to peel the plastic off in one piece. In both cases, the netwrap or twine should then be removed before feeding the bale.

- Wastage and refusal is rarely an issue when feeding baled silage, unless a bale is being fed to too few animals. If silage remains when the time frame for feeding has been exceeded, put out a fresh bale. Forcing animals to eat waste or refused silage may force them to eat deteriorated material and can lead to poor performance or animal health issues. Bale size, which can usually be adjusted on the baler, should be determined during the growing season by considering the number of animals and the feed out rate that will be needed during the feeding period.

- The ensiling process usually completes within 3-6 weeks, depending on a large number of factors. At essentially any point, the forage can be fed, but this should only be done in an emergency situation. The partial ensiled product will heat excessively and spoil very quickly. Bales wrapped with an in-line bale wrapper should not be fed until at least 4-6 weeks after wrapping, unless the plan is to feed the whole line of bales in just a few days.

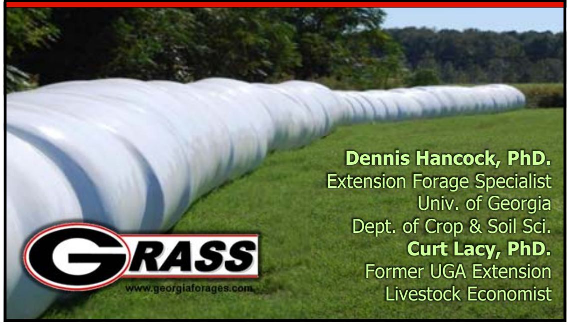
Economics of Baled Silage

Dr. Dennis Hancock, Extension Forage Agronomist

2018 Hay and Baleage Short Courses

Economics of Baled Silage

Economics of Baled Silage



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Curt Lacy, PhD.
Former UGA Extension
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Background

- Pasture, feed, and forage costs are approximately 2/3 of cash operating expenses in beef cow-calf operations
- Goal is to reduce these costs while minimizing losses in the hay production/feeding phases
- Interest in baleage has increased due to recent droughts and extended wet periods

Economics of Baleage

- Baleage has the potential to be more economical than conventional hay production
- Much of this is driven by herd size
- Analyze 3 scenarios w/ yield held constant:
  - Scenario 1: Reduced feeding and storage losses
  - Scenario 2: Reduced purchased feed costs due to feeding higher quality forages
  - Scenario 3: Combination of reduced feeding losses and reduced purchased feed costs
- Analyze a scenario w/ yield increased and increased number of cuttings:
  - More timely harvest, better quality, and more yield

Wrapper Costs

Wrapper Styles

- **3 point hitch** (**$8,000 - $22,000**)

- **individual** (**$14,000 - $26,000**)

- **in-line** (**$20,000 - $42,000**)

Baled Silage Costs

Plastic Cost:
$6.00 - $8.00/ton DM

Wrapper cost:
$2.00 - $5.00/ton DM

Fuel & Repairs:
$0.50 - $5.00/ton DM

Labor:
$0.75 - $2.00/ton DM

Dr. Dennis Hancock
Extension Forage Agronomist

Economics of Baled Silage

Data and Methods

- Compare the direct costs of use of in-line bale wrapper to conventional hay production
- Compare costs of bermudagrass and winter annuals in these scenarios
- Use UGA Extension forage budgets
  - 1,200 pound cow fed for 120 days at 2% of body weight (1.8 tons per cow)

Assumptions – Equipment Costs

	Conventional Round Baler	High Moisture Round Baler	In-Line Wrapper	Individual Wrapper
Purchase Price	$31,500	$36,500	$30,000	$22,500
Estimated Useful Life	8 Years	8 Years	15 Years	15 Years
Estimated Annual Use	200 Hours	200 Hours	48 Hours	96 Hours
Repair and Maintenance Rate	90%	90%	5%	5%
Bales Wrapped in 1 Hour	N/A	N/A	48 Bales	15 Bales
Bales Wrapped per Plastic Roll	N/A	N/A	35 Bales	22.5 Bales
Length of Loan	5 Years	5 Years	5 Years	5 Years
Interest Rate	5.25%	5.25%	5.25%	5.25%
Annual Loan Payment	$7,326.06	$8,488.93	$6,977.20	$5,232.90

Pruitt and Lacy, 2013.

Assumptions – Variable Costs for Wrapping (per ton)

	In-Line Wrapper	Individual Wrapper
Tractor Operating Cost ($3.30/gal. diesel)[1]	$0.30	$0.93
Bale Wrapper Repair and Maintenance	$0.04	$0.05
Plastic Costs ($89/roll)	$2.54	$3.96
Gas Costs ($3.30/gal.)	$0.07	$0.00
Labor ($9.60/hour)	$0.22	$1.40
Direct Tractor and Bale Wrapper Costs	$3.16	$6.35
Indirect Tractor and Bale Wrapper Costs	$1.35	$1.94
Total Wrapping Costs	$4.51	$8.29
Total Wrapping and Harvesting Costs[2]	$10.03	$13.81

Pruitt and Lacy, 2013.

Economics of Baleage

- Baleage has the potential to be more economical than conventional hay production by virtue of 3 scenarios:
  - Scenario 1: Reduced feeding and storage losses

The Unseen Cost of Hay Storage

	Expected Losses	Cost of Production ($/ton) $80	$100	$120	$140
		Value of Losses in the System ($/ton)			
Hay, no cover/on ground	50%	$40	$50	$60	$70
Hay, under roof	25%	$20	$25	$30	$35
Baleage	15%	$12	$15	$18	$21

Variable Costs for Baleage: In-Line Wrapping (per ton)

Total Tons of Baleage Harvested (As Fed Basis)	Savings Due to Reduced Hay Losses[1]	Annual Ownership Cost[2]	Increase in Operation Costs	Cost Increase Per Ton (As Fed Basis)
90	$3,390.25			
180	$6,780.50			
270	$10,170.75			
360	$13,561.00			
450	$16,951.25			
540	$20,341.49			
630	$23,731.74			
1,000	$37,669.43			

[1] Hay costs =~$125/ton; storage and feeding losses = 30%.
[2] Added ownership cost of bale wrapper and silage baler.

Breakeven tons of baleage to cover hay losses = 216 tons/year

Pruitt and Lacy, 2013.

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Economics of Baled Silage

Variable Costs for Baleage: Individual Bale Wrapping (per ton)

Total Tons of Baleage Harvested (As Fed Basis)	Savings Due to Reduced Hay Losses	Annual Ownership Cost[1]	Increase in Operation Costs	Cost Increase Per Ton (As Fed Basis)
90	$3,103.60			
180	$6,207.20			
270	$9,310.80			
360	$12,414.40			
450	$15,518.00			
540	$18,621.60			
630	$21,725.20			
1,000	$34,484.45			

[1] Hay costs =~$125/ton; storage and feeding losses = 30%.
[2] Added ownership cost of bale wrapper and silage baler.

Breakeven tons of baleage to cover hay losses = 186 tons/year

Pruitt and Lacy, 2013.

Scenario 2 Results

- Baleage technology economically justifiable on improved forage quality compared to purchased feed costs
  - Used UGA Basic Balancer (Stewart, Hancock, and Lacy, 2013)
  - Assumed zero feeding losses
  - Ration of whole cottonseed, corn, and a mixture of corn gluten feed and soy hulls

Ration Costs

	Good Hay	Average Hay	Poor Hay	Bermuda Baleage	Winter annuals Baleage
Amount of DM pounds fed	3,540	3,072	2,292	3,540	3,696
Crude Protein	12%	12%	6%	12%	16%
Total Digestible Nutrient	58%	53%	45%	58%	62%
Bales needed	4.2	3.6	2.7	5.9	6.2
Supplemental feed (tons)	0.40	0.62	0.98	0.40	0.00

Net Savings from Bermuda Grass Baleage Excluding Cost of Baler and Bale Wrapper

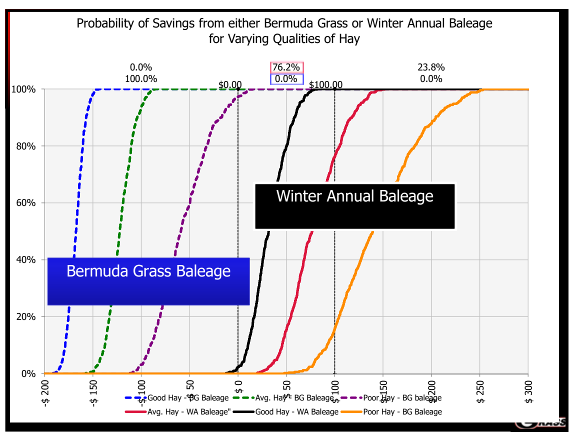
Number of Beef Cows	Good Hay	Average Hay	Poor Hay
25	($4,180.93)	($3,192.21)	($1,1718.60)
50	($8,361.85)	($6,384.42)	($3,437.20)
100	($16,723.71)	($12,768.84)	($6,874.40)
250	($41,809.27)	($31,922.10)	($17,185.99)
500	($83,618.53)	($63,844.20)	($34,371.98)

- There is not a scenario in this analysis where bermudagrass baleage is more economical than bermudagrass hay – even hay from a year like 2013!

Winter Annual Baleage Cost Savings Excluding Cost of Baler and Bale Wrapper

Number of Beef Cows	Good Hay	Average Hay	Poor Hay
25	$28.48	$1,017.20	$2,490.81
50	$56.97	$2,034.40	$4,981.63
100	$113.94	$4,068.81	$9,963.25
250	$284.85	$10,172.01	$24,908.13
500	$569.70	$20,344.03	$49,816.25

- With equipment fixed costs of $7,000 to $15,000, breakeven herd size is 75 to 150 beef cows.



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Economics of Baled Silage

Scenario 3 Results

- Improved feeding quality and reduced storage losses results in purchase of baleage technology being more economically feasible
  - Savings of:
    - $8/cow/year for bermudagrass baleage
    - $100/cow/year for winter annual grass baleage
- Viable herd size of 50 to 75 beef cows to purchase baleage technology if growing winter annuals.

Economics of Baleage

- Baleage has the potential to be more economical than conventional hay production
- Much of this is driven by herd size
- Analyze 3 scenarios w/ yield held constant:
  - Scenario 1: Reduced feeding and storage losses
  - Scenario 2: Reduced purchased feed costs due to feeding higher quality forages
  - Scenario 3: Combination of reduced feeding losses and reduced purchased feed costs
- Analyze a scenario w/ yield increased and increased number of cuttings:
  - More timely harvest, better quality, and more yield

Timely Harvest, Higher Quality, Greater Yields - Bermudagrass

Item	Hay	Baleage
Number of Cuttings	3	5
Tons of Dry Matter per Acre	4.05	6.25
Crude Protein (Percentage)	10.1	12.9
TDN (Percentage)	53.8	57.1
Cost (Dollars per Acre)	$400.00	$452.50
Cost (Dollars per Ton of Dry Matter)	$100.00	$72.40
Ration Cost (Dollars per Day)	$1.86[1]	$1.26[2]

Balanced ration for lactating beef cow using 50:50 CG:SH supplement ($225/ton) requiring 1) 6.8 lbs and 2) 3.7 lbs/hd/d, respectively.

Hersom et al., 2007.

Conclusions

- Baleage technology has economic merit for Southeastern U.S. beef cow-calf producers
  - Breakeven herd size is approximately 50 cows if already own hay equipment
- Combined reduction in feeding and storage losses make it economically feasible
- Baleage becomes more economical with higher-quality forages such as:
  - Winter annuals
  - Alfalfa
  - Clovers/other legumes mixed with bermudagrass

Conclusions

- VERY difficult to justify baleage if primary storaged forage is bermuda, bahia, or lower-quality forages.
  - Unless, a significant inc. in yield along with improved quality can be realized.

Economics of Baleage
for Beef Cattle Operations

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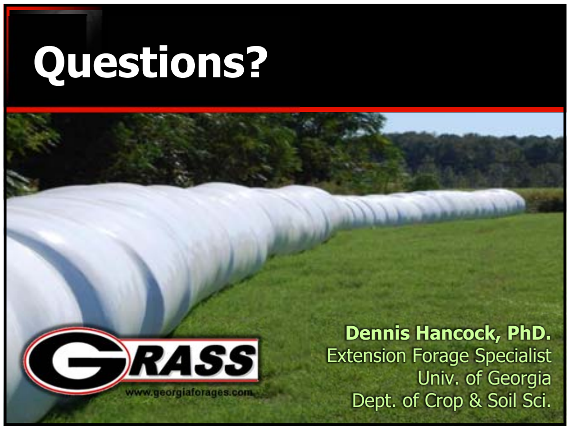
Economics of Baled Silage



Economics of Baleage *for Beef Cattle Operations*

Introduction and Overview

In recent years, there has been considerable interest from beef cattle producers in using baled silage or baleage as a way to reduce feeding expenses. This publication will discuss the costs of incorporating baleage into an existing beef cattle operation.

Since pasture, feed and forage costs constitute two-thirds of the operating expenses in a beef cow-calf operation, this examination certainly is warranted. Baleage is produced by baling higher moisture forage (typically 45-65 percent moisture) and wrapping the bales in plastic to exclude oxygen and allow the forage to ferment/ensile. Conserving forage as baleage reduces the risk of field curing, harvest and storage losses; retains more nutritive value; and makes the forage more palatable compared to conventional dry hay production and storage. As a result of the increased nutritional value of the baleage, the need to purchase supplements may be reduced. Use of baleage also may increase the opportunity to sell higher quality forage in a value-added venture for beef cattle producers.

Addition of baleage into a beef cattle operation will result in few operational changes, provided the operation is effectively managing its soil fertility and forage programs. The major difference producers will experience by choosing to begin baleage production is that the moisture content of hay at harvesting will be higher than for normal hay production. A moisture level target of 55-60 percent is desirable for baleage compared to 14-18 percent for normal hay production. The desired weight for bales to be converted into baleage is 1,500 to 2,000 pounds.

Due to the increased moisture levels needed to effectively store baleage, existing round balers may not be appropriate. Round balers that are manufactured to be able to harvest high-moisture forage will work best for baleage. Some manufacturers sell kits, however, that will convert balers to be able to handle hay that has higher moisture content. These kits are available for $300 to $1,000 but may not be available from every manufacturer or for all balers. The difference in purchase price between a conventional round baler and a high-moisture round baler is approximately $5,000, but these differences also can vary by manufacturer.

There are two major ways to store forage as baleage: through use of an individual bale wrapper (Figure 1) or an in-line wrapper that continuously wraps bales (Figure 2). Significant differences exist between the two systems. Most notably, the individual bale wrapper generally costs less and runs on the hydraulics of the tractor towing the wrapper, but it does not wrap bales as quickly (three to six minutes per bale), requires more labor, and uses more plastic (20-25 bales per roll of plastic). In contrast, the in-line bale wrapper costs significantly more, runs on its own gasoline-powered engine, wraps bales substantially quicker, and uses less plastic (30-40 bales per roll of plastic). Trailed versions of the individual bale wrappers can be operated with a 45-50 horsepower tractor or more. A 75 horsepower tractor is recommended, however, for the in-line wrappers, because the

Figure 1. Picture of individual bale wrapper. Photo credit: Dr. Michael McCormick, LSU AgCenter.

Figure 2. Picture of in-line baleage wrapper. Photo credit: Dr. Dennis Hancock, University of Georgia.

bale must be loaded into the machine. Some manufacturers suggest plastic caps be purchased to properly seal the ends of a row when using an in-line wrapper.

The purchase price for bale wrapping machines is nearly equivalent to a new round baler. Individual bale wrappers typically can be purchased for $20,000 to $25,000, but industry professionals suggest individual wrapping machines are difficult to find due to lack of popularity. An in-line wrapping machine is more expensive at $28,000 to $33,000. While the in-line initially may be more expensive to purchase, it has advantages in needing less labor, wrapping more bales per hour and not using as much plastic per bale as an individual bale wrapper.

Figure 3. Qualitative comparison of in-line and individual baleage wrappers.

Comparison of Major Wrapping Systems

In-line Wrapper

- More bales per hour
- Less labor
- No additional tractor required
- Can use less plastic
- Once a bale is exposed to air, must be fed very soon
- Higher purchase price

Individual Wrapper

- Lower purchase price
- Fewer bales per hour
- Bales can be transported individually while wrapped

Methods and Procedures

The following comparison of ownership and operating costs of the bale wrapping machines does not include any costs associated with forage production but does include the costs associated with the use of operating a round baler. This allows for one of three scenarios to be analyzed: 1) conventional round bale production, 2) high moisture baler used with an in-line wrapping system and 3) high moisture baler used with an individual bale wrapper. Costs associated with cutting, raking and tedding of hay are assumed to occur regardless of scenario and are not included in this analysis. Additional expenses of hauling from the field to a storage site also are not included since these costs likely will occur regardless of how hay is stored. It is highly recommended that producers choosing to produce baleage wrap all bales at the storage site and that the storage site is clean and well-drained. This will reduce wear and tear on all equipment and pastures.

Table 1 contains basic assumptions that will be used throughout the comparison of the costs of owning and operating a conventional round baler relative to an in-line or individual bale wrapping machine that is used in conjunction with a high-moisture baler. The annual loan payment is sizable, but the total operating costs (direct and indirect) may make it appealing to purchase this haying equipment. A 75 horsepower tractor is assumed to be used regardless of which wrapping machine is used, with diesel fuel costs assumed to be $3.30 per gallon. Cash costs of diesel fuel and repair and maintenance (excluding labor) are assumed to be $14 per hour to operate a tractor with this level of horsepower, and indirect costs (depreciation and interest) are $7.71 per hour, for a total cost of $21.71 per hour. For a conventional round baler, cash costs are $17.72 per hour ($3.74 per acre), and indirect costs are $22.16 per hour ($4.68 per acre). A high-moisture baler will have slightly higher cash costs ($20.53 per hour; $4.33 per acre) and indirect costs ($25.68 per hour; $5.42 per acre).

Operating costs ultimately are determined by how many hours per year the bale wrapper is used. An in-line wrapper is assumed to wrap 7.5 tons (as-fed basis) per hour compared to 3.75 tons (as-fed basis) per hour for an individual wrapper. A 100 cow operation feeding hay for 150 days, assuming a 1,200 pound cow eats 2 percent of body weight a day in dry matter, would need roughly 180 tons

Table 1. Equipment and Labor Assumptions for Conventional Round Baler and In-Line and Individual Bale Wrappers.

	Conventional Round Baler	High Moisture Round Baler	In-Line Wrapper	Individual Wrapper
Purchase Price	$31,500	$36,500	$30,000	$22,500
Estimated Useful Life	8 Years	8 Years	15 Years	15 Years
Estimated Annual Use	200 Hours	200 Hours	48 Hours	96 Hours
Repair and Maintenance Rate	90%	90%	5%	5%
Bales Wrapped in 1 Hour	N/A	N/A	48 Bales	15 Bales
Bales Wrapped per Plastic Roll	N/A	N/A	35 Bales	22.5 Bales
Length of Loan	5 Years	5 Years	5 Years	5 Years
Interest Rate	5.25%	5.25%	5.25%	5.25%
Annual Loan Payment	$7,326.06	$8,488.93	$6,977.20	$5,232.90

of dry matter for the winter. Approximately 48 hours would be needed to wrap the baleage using an in-line wrapper compared to 96 hours for an individual bale wrapper. Assuming a yield of 1.5 tons dry matter per acre and three cuttings of hay (1.76 tons of hay on an as-fed basis per cutting), 40 acres would provide enough dry matter, given the above feeding assumptions.

Costs associated with baling of hay are shown in Table 2. Per bale costs assume hay bales weigh 1,200 pounds on an as-fed basis to calculate the per bale cost.

Table 3 lists the estimated operating costs per ton on an as-fed basis for each of the two bale wrapping systems. Direct tractor and bale wrapper operating costs are $4.51 per ton on an as-fed basis ($215.59 per hour) for the in-line wrapper and $8.29 per ton on an as-fed basis ($122.39 per hour) for the individual wrapper. Anecdotal evidence from current owners of bale wrappers suggests this type of equipment is not prone to expensive repairs, but users should expect some repair costs, even if not to the level estimated in Table 3. Labor costs with the individual wrapper are higher because two people are needed to wrap baleage (one to load the bales on the wrapper and the second to operate the wrapper). Note that bales of baleage are assumed to weigh 2,000 pounds (as-fed basis) and contain 50 percent moisture. Assuming a cow would consume 3.6 tons of forage on an as-fed basis (1.8 tons dry matter basis) per winter feeding period, total wrapping and harvesting costs per cow would be $36.11 for the in-line wrapper and $49.70 for the individual wrapper, using 2,000 pound bales on an as-fed basis.

Information on costs associated with a conventional round baler compared to an in-line wrapper and individual wrapper are contained in Table 4. Readers should note the annual loan payments are higher with use of a wrapping machine but reflect inclusion of the payment associated with use of a round baler that can handle hay that is higher in moisture content. The cost differential between the two types of round balers is assumed to be $5,000 and results in an annual loan payment of $1,162.87 more for

Table 2. Estimated Hourly and Per Acre Costs for Conventional and High-Moisture Round Hay Balers.

	Conventional Baler	High-Moisture Baler
Per Hour Tractor Cost ($3.30/gal. diesel)	$14.00	$14.00
Labor ($9.60/hour)	$9.60	$9.60
Per Hour Baler Repair and Maintenance	$17.72	$20.53
Per Hour Direct Tractor and Baler Costs	$41.32	$44.13
Per Hour Tractor Indirect Costs	$7.71	$7.71
Per Hour Round Baler Indirect Costs	$22.16	$25.68
Total Tractor and Baler Costs Per Hour	$71.19	$77.52
Total Tractor and Baler Cost Per Acre	$15.22	$16.56
Total Tractor and Baler Cost Per Ton (As-Fed Basis)	$8.63	$9.38
Total Tractor and Baler Cost Per Ton (Dry Matter Basis)	$10.15	$11.04

Note: Labor costs increased by 10 percent when converted to per acre and per bale basis to account for preparation of equipment.

Table 3. Estimated Per Ton As-Fed Basis Costs for In-Line and Individual Bale Wrappers.

	In-Line Wrapper	Individual Wrapper
Tractor Operating Cost ($3.30/gal. diesel)[1]	$0.30	$0.93
Bale Wrapper Repair and Maintenance	$0.04	$0.05
Plastic Costs ($89/roll)	$2.54	$3.96
Gas Costs ($3.30/gal.)	$0.07	$0.00
Labor ($9.60/hour)	$0.22	$1.40
Direct Tractor and Bale Wrapper Costs	$3.16	$6.35
Indirect Tractor and Bale Wrapper Costs	$1.35	$1.94
Total Wrapping Costs	$4.51	$8.29
Total Wrapping and Harvesting Costs[2]	$10.03	$13.81

[1] Total diesel and repair and maintenance costs associated with operating a 75 horsepower tractor.
[2] Sum of total wrapping costs and $5.52 per ton as-fed basis cost with high moisture round baler use.
Note: Labor costs increased by 10 percent when converted to per bale basis to account for preparation of equipment.

the high-moisture round baler compared to a conventional round baler.

General Results, Break-even Herd Size and Sensitivity Analysis

Ultimately, the economics of purchasing a baleage wrapper are most influenced by improvements in forage quality and forage utilization. Forage quality from baleage, when compared to hay, generally is improved for two main reasons: 1) the ability to harvest at target crop maturity levels more consistently and 2) less dry matter loss and prevention of weathering.

One of the primary benefits of using baleage is reduced forage loss due to exposure to the elements. As a result, the forage maintains a higher nutritional value when fed to cattle. The other primary benefit is that by using bale-wrapping technology, producers can harvest and store higher quality forages such as winter annual grasses, legumes and Bermuda grasses. While theoretically these higher quality forages can be harvested using conventional hay equipment, it is difficult to do this on a routine basis because of the risk of weather damage. During the spring, a sequence of days that provide adequate drying conditions to safely and properly put up winter annual hay is rare. Moreover, during summer months, producers inevitably end up delaying cutting hay or have hay get wet after cutting due to random summertime rainfall events. In either case, forage quality is decreased. Depending on the length of the delay, the quality can deteriorate to the point it becomes the nutritional equivalent of straw.

By using baleage technology, less time is needed between cutting and baling and that decreases the risk of rain damage. As a result, declines in forage quality due to rain-induced delays in harvesting are reduced greatly. Consequently, the conserved forage is of higher quality and also can produce higher yields due to more frequent cuttings.

The practical implication for cattle producers from all of these factors is that the need for supplementation also may be reduced and can result in additional cost savings for the operation. The following discussion examines the effects of the factors from several perspectives.

Table 4. Comparison of Costs Associated with Conventional Hay Production and Use of Bale Wrapping Machines.

	Conventional Hay Baler	In-Line Wrapper and High-Moisture Baler[1]	Individual Wrapper and High Moisture Baler[1]
Total Investment Costs	$31,500.00	$66,500.00	$59,000.00
Annual Loan Payment	$7,326.06	$15,466.13	$13,721.83
Difference in Loan Payment[2]	N/A	$8,140.07	$6,395.77
Total Direct Costs Per Hour	$41.32	$195.04	$152.28
Total Indirect Costs Per Hour	$29.87	$98.07	$143.65
Total Costs Per Hour	$71.19	$293.11	$199.91
Total Direct Costs Per Ton, As-Fed Basis	$5.05	$6.34	$9.52
Total Indirect Costs Per Ton, As-Fed Basis	$3.57	$3.70	$4.29
Total Costs Per Ton, As-Fed Basis	$8.63	$10.04	$13.81

[1] Includes costs of purchasing (operating) high-moisture round baler and bale wrapping machine.
[2] Annual loan payment of bale wrapper and high-moisture round baler less annual loan payment for conventional baler.

Savings from Reduced Losses

Cost savings for the operation through use of a bale wrapper depend upon how much additional forage will be saved through wrapping bales in plastic. Hay that is harvested and stored without protection from the elements can result in 25 percent or more of the crop's dry matter being lost prior to being fed, while dry matter loss for plastic wrapped bales typically is about 5 percent.

In the following example, a hay field is expected to produce 4.5 tons of hay (dry matter basis) per acre over three cuttings (1.5 dry matter tons per acre per cutting). As previously mentioned, a cow is expected to consume 1.8 tons of hay (dry matter basis) during a 150-day winter feeding period. Direct costs per acre are expected to be $525 per acre when accounting for fertilization, labor, fuel and repair and maintenance costs for equipment using a conventional round baler. This cost is adapted from the annual LSU AgCenter and University of Georgia enterprise budgets and does not include interest on operating capital[1]. The direct cost per acre translates into $116.67 per ton of dry matter ($99.17 per ton, as fed). Cows are assumed to consume 1.8 tons dry matter during the winter, resulting in cost per cow of $210, but that does not account for hay loss. Assuming 25 percent hay loss, this raises the cost per cow to $280.

[1]Repair and maintenance costs often are calculated as a percentage of purchase price and theoretically should result in higher production costs per acre when using a high-moisture round baler compared to a conventional round baler. In practice, this often is not the case, so we assume equal hay production costs regardless of which type of round baler is used.

Direct per bale costs for the in-line wrapper are $3.16 compared to $6.35 for the individual wrapper. Assuming that hay loss is only 5 percent for bales wrapped in plastic, total per cow costs are $233.04 and $245.11 for the in-line and individual wrapper, respectively. Cost savings are then $46.96 per cow for the in-line wrapping system and $34.89 per cow for the individual wrapping system compared to costs with a conventional round baler. Based on these cost savings, an operation would need to have 173 cows to pay for the annual loan payment on the high-moisture round baler and in-line wrapping system compared to 183 cows for an individual wrapper. Supplementation costs may be reduced as a result of the use of bale wrapping systems and could result in further cost savings, which would reduce the number of cows needed to pay for the annual payment on the loan.

Many operations are not of sufficient size to generate cost savings to pay the note on the equipment purchase, but purchase of a bale wrapper still may be feasible. The following tables illustrate the estimated total savings for operations of different sizes. Per cow cost increases are shown, with assumptions about hay loss under each scenario as they were described previously.

This analysis uses a standard assumption that 25 percent of stored hay is lost between when it is cut in the field and fed to the herd. Numerous research trials conducted around the country, however, have demonstrated losses range from 10 percent to greater than 70 percent when field curing, storage and feeding losses accumulate. Since these losses will vary not only by operation, but also by year, it is helpful to look at various combinations of total losses from harvesting to feeding.

The following chart shows the total net savings from purchasing an in-line wrapper at various hay feeding losses. The calculations used in the chart are based on a 5 percent storage and handling loss for using baleage. This number is widely reported by producers, Extension Service agents and Extension Service

Table 5. Additional Per Ton (As Fed Basis) Costs for In-Line Bale Wrapper.

Total Tons of Baleage Harvested (As Fed Basis)	Savings Due to Reduced Hay Losses[1]	Annual Ownership Cost[2]	Increase in Operation Costs	Cost Increase Per Ton (As Fed Basis)
90	$3,390.25	$8,140.07	$4,749.82	$52.78
180	$6,780.50	$8,140.07	$1,359.57	$7.55
270	$10,170.75	$8,140.07	($2,030.68)	($7.52)
360	$13,561.00	$8,140.07	($5,420.93)	($15.06)
450	$16,951.25	$8,140.07	($8,811.18)	($19.58)
540	$20,341.49	$8,140.07	($12,201.43)	($22.60)
630	$23,731.74	$8,140.07	($15,591.68)	($24.75)
1,000	$37,669.43	$8,140.07	($29,529.37)	($29.53)

[1] Savings calculated as difference in feeding efficiency due to reduced feeding losses.
[2] Annual loan payment of bale wrapper and high-moisture round baler less annual loan payment for conventional baler.

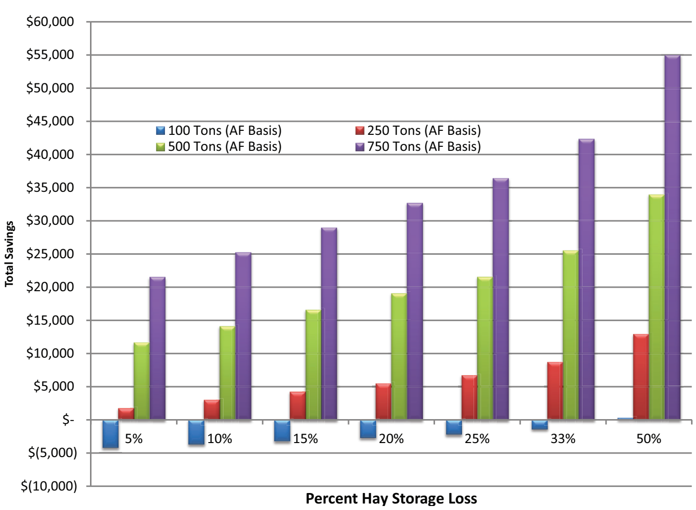
Table 6. Additional Per Ton (As Fed Basis) Costs for Individual Bale Wrapper.

Total Tons of Baleage Harvested (As Fed Basis)	Savings Due to Reduced Hay Losses	Annual Ownership Cost[1]	Increase in Operation Costs	Cost Increase Per Ton (As Fed Basis)
90	$3,103.60	$6,395.77	$3,292.17	$36.58
180	$6,207.20	$6,395.77	$188.57	$1.05
270	$9,310.80	$6,395.77	($2,915.03)	($10.80)
360	$12,414.40	$6,395.77	($6,018.64)	($16.72)
450	$15,518.00	$6,395.77	($9,122.24)	($20.27)
540	$18,621.60	$6,395.77	($12,225.84)	($22.64)
630	$21,725.20	$6,395.77	($15,329.44)	($24.33)
1,000	$34,484.45	$6,395.77	($28,088.68)	($28.09)

[1]Annual loan payment of bale wrapper and high-moisture round baler less annual loan payment for conventional baler.

specialists as being representative of losses expected from baleage. Interested readers will want to know that each additional 5 percentage point increases in dry matter loss in the baleage system lowers expected savings by about $1,106 per year across the herd sizes shown in Figure 4.

Figure 4. Total Savings from Purchasing an In-Line Bale Wrapper at Various Hay Storage Losses and Baleage Losses of 5 Percent.



Savings From Increased Forage Quantity and Quality

One of the primary advantages of baleage is the ability to harvest and store higher quality forage and/or harvest more often due to diminished weather concerns. Improved forage quality can result in heavier weaning weights for cow-calf producers or decreased need for supplementation to produce the same size calves. Using this approach, it is possible to estimate the savings from feeding higher quality forage.

Data from a one-year study conducted by the University of Florida at the Santa Fe Research Station were used in the UGA Basic Balancer to estimate dollars per feeding day for Bermuda grass hay and baleage. The forage quality and quantity results reported in the study were combined with the previously described per acre forage production costs to arrive at a dollar per ton (dry matter basis) for hay and baleage. The results from the University of Florida study and the resulting cost assumptions are listed in Table 7.

Table 7. Results From the University of Florida Baleage Research Trial and Assumptions Used in Baleage Versus Hay Comparison. *

Item	Hay	Baleage
Number of Cuttings	3	5
Tons of Dry Matter per Acre	4.05	6.25
Crude Protein (Percentage)	10.1	12.9
TDN (Percentage)	53.8	57.1
Cost (Dollars per Acre)	$400.00	$452.50
Cost (Dollars per Ton of Dry Matter)	$100.00	$72.40
Ration Cost (Dollars per Day)	$1.86[1]	$1.26[2]

* Adapted from Hersom, et al. "Utilization of Round Bale Silage as a Compliment to Hay Production." 2007 University of Florida Beef Report.
[1] Ration figured as peak lactation for 1,000 pound cow. 22 pounds of hay (AF) and 6.80 pounds 50:50 corn gluten and soybean hull mixture costing $225 per ton.
[2] Ration figured as peak lactation for 1,000 pound cow. 45.4 pounds of baleage (AF) and 3.70 pounds 50:50 corn gluten and soybean hull mixture costing $225 per ton.

If no allowance is made for storage and feeding losses, it costs 60 cents per day less to feed a cow using baleage as opposed to hay. As a result, we can calculate the number of feeding days required per year to justify purchasing an in-line baleage wrapper. These results are shown in Column A of Table 8.

Table 8. Number of Days Required and Dollars per Day Savings Required to Break Even on Purchase of In-Line Wrapper Under Various Feeding Scenarios and Cow Herd Sizes.

Herd Size	Annual Feeding Days Required to Break Even on Purchase of In-Line Wrapper at 60 Cents per Head Savings From Improved Forage Quality Only (Column A)	Dollars per Day Differential Required to Break Even on Purchase of In-Line Wrapper With 150-day Feeding Period (Column B)	Annual Feeding Days Required to Break Even on Purchase of In-Line Wrapper at 60 Cents per Head Savings From Improved Forage Quality Plus Savings From Reduced Storage and Feeding Losses (Column C)
25	426	$1.71	284
50	213	$0.85	142
75	142	$0.57	95
100	107	$0.43	71
125	85	$0.34	57
150	71	$0.28	47
175	61	$0.24	41
200	53	$0.21	36
225	47	$0.19	32
250	43	$0.17	28
500	21	$0.09	14

In general, we can say cow-calf operations with less than 100 cows will find it difficult to justify purchasing an in-line baleage wrapper if storage and feeding losses are similar to those assumed in this analysis. Conversely, the results of this analysis indicate producers with herds larger than 150 cows should strongly consider purchasing an in-line baleage wrapper since it takes only a very few feeding days to recoup the additional operating costs and amortized payments.

Since forage and supplement costs can be highly variable, another perspective to consider when evaluating the economics of baleage is to determine the daily feed cost differential between baleage and hay for a 150-day feeding period. These differentials are presented in Column B of Table 8. For example, a herd with 25 cows would need to experience a feeding cost differential of $1.71 per day to cover the additional cost of the bale wrapper. Alternatively, a herd of 150 cows will only need to see a difference of 28 cents per head per day to justify purchasing a bale wrapper.

The final consideration would be the combination of lower feeding costs and reduced losses. This scenario is presented in Column C of Table 8. If hay losses are about 25 percent and baleage losses are approximately 5 percent, then producers with herd sizes as small as 75 cows rationally can consider purchasing an in-line bale wrapper on the basis of improved forage quality and reduced losses, since a relatively short feeding period of 95 days will pay for the additional operational and ownership costs of the bale wrapper.

Other Comparisons

Another scenario that may be considered is the cost of this equipment compared to a hay barn that could be constructed. While a complete analysis of this scenario is beyond the scope of this publication, a few items are worth considering.

A simple pole barn can be constructed for roughly a third to half of the combined cost of a bale wrapping machine and high-moisture round baler. Building a hay barn serves a useful function by providing shelter for hay and adding value to your property. But it also can increase property taxes and require the purchase of additional insurance to cover the potential loss of the barn. Barns can be depreciated for tax purposes, however, as can a bale wrapper.

Forage dry matter losses will occur regardless of whether a barn or bale wrapper is used on the farm. The exact percentage of hay loss that occurs when stored in a barn can vary. Use of a barn to store hay, however, requires that the hay is dry to prevent mold and/or fires. Producers can't always cut, harvest and store hay when it is dry. Use of a bale wrapper does not require that hay be dry when cut and wrapped. This results in the stored forage being of higher nutritional quality and can result in reduced supplementation costs. Over time, the cost of a hay barn and additional supplementation can exceed the costs of owning and operating a bale wrapper.

In the end, producers should determine whether reduced storage losses or increased forage quantity and quality are their limiting factors. If storage and feeding losses are the primary concern, a hay barn likely will be more cost-effective. If improved timeliness of forage harvest and the resulting increases in quantity and quality are of primary importance, however, some type of bale wrapper likely would make the most sense.

Summary

For beef cattle producers who have been affected by lack of winter forage in recent years, use of baleage systems to harvest and store forage may be a worthwhile investment. Producers may need to focus on increasing the nutritional value of the baleage for the decision to purchase a bale wrapper and high-moisture baler to be economical. The high per hour costs of operation may make it cost-prohibitive for smaller cattle operations to purchase, but use in a custom wrapping situation can bring down the hourly costs and help a bale wrapper and/or high-moisture baler pay for itself. Use of a wrapping machine for hire or to sell may necessitate the purchase of additional equipment to prevent disfiguration of wrapped bales.

In general, producers with cow-calf operations that have at least 150 cows in the herd will find the decision to purchase a bale wrapper and high-moisture baler to be cost-effective compared to employing conventional hay-making systems. In contrast, producers with cow-calf operations of less than 100 cows are less likely to find such a purchase to be economical, unless they use the machinery in a custom hire enterprise. Cow-calf producers, particularly those with less than 200 cows, should use the information in this publication to fully evaluate the economics of a decision to purchase a bale wrapper and high-moisture baler.

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