Published November, 1990

# Yield and Botanical Composition of Alfalfa-Bermudagrass Mixtures

R. H. Brown* and G. T. Byrd


## ABSTRACT

**The regions of adaptation of alfalfa (*Medicago sativa* L.) and bermudagrass [*Cynodon dactylon* (L.) Pers.] overlap in the southeastern USA, but the compatibility of these species in a mixture has not been described. Two field experiments were conducted to compare the yield and botanical composition of alfalfa-bermudagrass mixtures with each species grown alone. In the first experiment 'Apollo' alfalfa was grown alone and in mixtures with 'Tifton 44' bermudagrass fertilized with 0 and 100 kg N ha$^{-1}$, and compared with bermudagrass fertilized with N at rates of 100, 300, and 500 kg ha$^{-1}$. In a second experiment Apollo alfalfa was grown alone in 15-cm rows and in 15- and 30-cm rows in mixtures with 'Coastal' bermudagrass. Bermudagrass was also grown alone and fertilized with 100, 200, and 300 kg of N ha$^{-1}$. Yields of the alfalfa-bermudagrass mixtures averaged 9.7 Mg ha$^{-1}$ over both experiments and were similar to alfalfa alone (9.2 Mg ha$^{-1}$). The mixtures also were similar in yield to bermudagrass fertilized with 200 kg N ha$^{-1}$ in the second experiment (11.2 Mg ha$^{-1}$) and between yields of bermudagrass receiving 100 and 300 kg N ha$^{-1}$ in the first experiment. Alfalfa dominated the mixture in both experiments comprising 100% of the forage in the spring harvests, except for the establishment year in the first experiment. The lowest percentage of alfalfa was in August when in 1 yr it reached 53%. Neither N fertilization nor row spacing of the alfalfa affected yield or botanical composition of the mixture.**


BERMUDAGRASS is well adapted to the southeastern USA (4) where it is the main hay crop. This grass is most often grown alone; it produces high forage yields and responds to high rates of N fertilizer (23). Alfalfa is adapted over much of the USA, but its adaptation and use is limited in the southeastern states because of acid, infertile soils, disease, and insect pests (14). The areas of adaptation of alfalfa and bermudagrass overlap sufficiently that culture of mixtures of these species should be possible. Introducing alfalfa into a mixture with bermudagrass should (i) supply N for the grass, (ii) extend the growing season, and (iii) improve the quality of the mixture compared to bermudagrass alone. Alfalfa is widely recognized for its capacity to fix atmospheric N (22) and for its high nutritive value (20).

Alfalfa is often grown in mixtures with cool-season, perennial grasses and yield and composition of such

Dep. of Agron., Univ. of Georgia, Athens, GA 30602. Supported by State and Hatch funds allocated to the Georgia Agric. Exp. Stn. Received 8 Jan. 1990. *Corresponding author.

Published in Agron. J. 82:1074–1079 (1990).

mixtures have been well described (10). However, there are few reports of research on mixtures of alfalfa with warm-season grasses. The growth response of these two species to temperature differs sufficiently that they should complement each other in a mixture. Maximum growth of alfalfa occurs at mean daily temperatures of about 20 °C (12) whereas the optimum for bermudagrass is near 30 °C (19). Thus alfalfa should be more competitive with bermudagrass in the spring and autumn and less competitive in summer. Burton (3) reported 5-yr-average yields of 8.7 to 9.9 Mg $ha^{-1}$ for alfalfa-Coastal bermudagrass mixtures in southern Georgia. Four different cultivars of alfalfa were grown with bermudagrass and alfalfa made up nearly 50% of the mixtures during the summer months. Other reports of research on alfalfa-bermudagrass mixtures could not be found.

Alfalfa has been tested with other subtropical grasses with generally favorable, but variable results. In Uganda (16) alfalfa increased from about 10% of mixtures with rhodesgrass (*Chloris gayana* Kunth.) and guineagrass (*Panicum maximum* Jacq.) in the 1st yr to 20 and 16%, respectively, in the 3rd yr. In a mixture with *Setaria anceps* [synonym *S. sphacelata* (Schumach.) Staph et C.E. Hubb] in the same experiment, alfalfa comprised about 20% of the mixture from the 1st to the 3rd yr. In central Queensland, Australia, the alfalfa portion of grazed mixtures with buffelgrass (*Cenchrus ciliaris* L.) and guineagrass ranged from about 60% in spring to less than 20% in mid-summer (8). A similar trend was observed with an alfalfa-rhodesgrass mixture (11). The percentage alfalfa in the rhodesgrass mixture in the 5th yr was similar to that in earlier years (9). Alfalfa was grown with the tall-growing grass *Sorghum almum* Parodi and the tropical legume *Glycine javanica* L. in southeastern Queensland (17). After 2 yr under grazing, cutting treatments were imposed for a period of 24 wk. When cut at a stubble height of 5 cm every 3 wk, alfalfa made up 21 to 36% of the mixture. When cut every 12 wk, only 3 to 5% of the forage was alfalfa. Thus, reports on mixtures with several species indicate that alfalfa can be successfully grown with subtropical grasses, but more information is needed on productivity and botanical composition of alfalfa-bermudagrass mixtures.

The research reported here was conducted to determine the compatibility of alfalfa and bermudagrass in mixtures and compare yields of mixtures with the two species grown alone.

## MATERIALS AND METHODS

### Experiment 1

Experiment 1 was established in 1979 at the Central Georgia Branch Station near Eatonton, GA on a Davidson loam soil (clayey, kaolinitic, thermic, Rhodic Paleudult). In April the experimental area was aprayed twice, 2 wk apart, with glyphosate [*N*-phosphonomethyl) glycine] (4.75 L $ha^{-1}$) to eliminate weeds, mostly common bermudagrass. Dolomitic limestone was applied at 4.5 Mg $ha^{-1}$ and P and K were applied at 48 and 183 kg $ha^{-1}$, respectively. The area was plowed with a moldboard plow after lime application but prior to fertilizer application. A seedbed was then prepared with a rotary tiller and smoothed with a drag harrow. On 15 May, designated plots were sprigged with Tifton 44 bermudagrass followed by simazine [2-chloro-4,6-bis-(ethylamino)-*S*-triazine] application to control weeds. On 20 September seeds of Apollo alfalfa were drilled in designated plots with a push-type planter in furrows 15 cm apart made with a grassland drill. The bermudagrass was well established but not completely covering the ground when alfalfa was planted.

The following six treatments were established on 1.5- by 6.1-m plots: (i) alfalfa alone, bermudagrass alone fertilized with (ii) 100 kg N $ha^{-1}$, (iii) 300 kg N $ha^{-1}$, and (iv) 500 kg N $ha^{-1}$, an alfalfa-bermudagrass mixture (v) without N fertilizer, and (vi) fertilized with 100 kg N $ha^{-1}$. The treatments were arranged in a randomized complete block design with four replications. Individual plots were separated by 1-m borders and borders surrounding the plots of alfalfa alone were tilled periodically during the growing season to prevent bermudagrass intrusion.

Plots were managed in a similar way each year. Bermudagrass residue in the bermudagrass plots was mowed and raked in early spring while the grass was dormant. Application of either 0-44-167 kg $ha^{-1}$ (N-P-K) or 0-39-149 kg $ha^{-1}$ (N-P-K) fertilizer was made each year in late spring. A trace element mixture which included B at a rate of 2.2 kg $ha^{-1}$ was sprayed on the plots each year. One-half of each designated N rate was applied in late spring and the other half during midsummer using $NH_4NO_3$. Alfalfa weevil (*Hyperica postica* Gyllenhal) was controlled by single applications of furadan (2,3-Dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate) each spring. Plots were harvested for 4 yr starting in 1980. Alfalfa plots, including mixtures, were harvested four to six times each year when alfalfa was in approximately one-tenth bloom. Plots of bermudagrass alone were not harvested at the first alfalfa harvest each spring but afterward their harvests coincided with the alfalfa harvests. Before plots were mowed, samples of alfalfa-bermudagrass mixtures were taken by hand to determine botanical composition. Five or six grab samples were taken at random and combined for each plot (200–300 g fresh weight). Species were separated on fresh or frozen samples. Yields were estimated by harvesting a 0.82-m strip from the center of each plot with a sickle bar or flail type mower. Subsamples (400–600 g fresh weight) were taken and dried at 70 °C for 48 h and dry matter yields were calculated. Total N was determined from finely ground, oven-dried shoot samples from each plot using micro-Kjeldhal analysis (1).

### Experiment 2

Because alfalfa comprised nearly all of the alfalfa-bermudagrass mixtures for most harvests in the first experiment, a similar experiment was conducted which included alfalfa planted in wider rows in an attempt to increase the bermudagrass percentage. At the University of Georgia Plant Science Farm near Athens, GA, an established sod of Coastal bermudagrass on a Cecil sandy loam (clayey, kaolinitic, thermic, Typic Hapludult) was used for the experiment. Plots designated for alfalfa-alone were sprayed with glyphosate (4.75 L $ha^{-1}$) on 5 September and again an 28 Sept. 1984 and the experimental area was irrigated (2.5 cm) between herbicide applications. Dolomitic limestone was applied at 2 Mg $ha^{-1}$ and P and K were applied in a mixture at rates of 44 and 66 kg $ha^{-1}$, respectively. The entire experimental area was then plowed with a moldboard plow and disked.

The following six treatments were established: (i) alfalfa alone in 15-cm rows, bermudagrass alone fertilized with (ii) 100 kg N $ha^{-1}$, (iii) 200 kg N $ha^{-1}$, and (iv) 300 kg N $ha^{-1}$, an alfalfa-bermudagrass mixture (v) with alfalfa in 15-cm rows, and (vi) with alfalfa in 30-cm rows. Alfalfa was planted 4 Oct. 1984 with a push planter at seeding rates of approximately 8 kg $ha^{-1}$ for Treatment 6 (30-cm row) and 16 kg ha$^{-1}$ for Treatments 1 and 5 (15-cm row). Individual plots were 1.5 by 6.1 m and separated by 1-m borders. There were four replications in a randomized complete block design. Borders surrounding the plots of alfalfa alone were sprayed as needed with glyphosate to prevent spread of bermudagrass.

Plowing for seedbed preparation resulted in low survival of bermudagrass in the spring of 1985, so it was necessary to plant bermudagrass during June 1985 in all plots except the plots of alfalfa alone. Because of this, only alfalfa (Treatment 1) and alfalfa-bermudagrass mixtures (Treatments 3 and 4) were harvested during 1985 and the data are not reported. In addition, a few skips in alfalfa rows were filled in with seeds during the spring of 1985.

In subsequent years, 0-44-83 kg ha$^{-1}$ (N-P-K) and 2.2 kg B ha$^{-1}$ in the form of sodium borate were applied each spring to the experimental area. In the spring of 1987, 1 Mg ha$^{-1}$ of phosphogypsum was applied to the experimental area because it has been shown to increase alfalfa yields on similar soils (21). Designated N rates were applied as $NH_4NO_3$ in two equal portions, one in late spring and one in midsummer of each year. Furadan was applied once each spring to control the alfalfa weevil.

Plots were harvested from 1986 through 1988 using a flail mower which cut a 0.82-m width. Harvests were made when alfalfa had reached the one-tenth bloom stage. Plots of bermudagrass alone were excluded from the first harvest each spring. Before each harvest, five or six grab samples of alfalfa-bermudagrass were taken randomly and combined for each plot (200–300 g fresh weight) to determine botanical composition. Subsamples were taken for moisture determination as in Experiment 1 and dry matter yields were calculated. In both experiments data were subjected to analysis of variance. Means were separated using Fisher's protected least significant difference (15).

## RESULTS

### Experiment 1

Yields of alfalfa-bermudagrass mixtures were similar to yields of alfalfa alone, except in 1980 when both mixtures had higher yields and 1981 when the mixture fertilized with 100 kg N ha$^{-1}$ yielded more than alfalfa alone (Table 1). The yields of the mixtures were similar to bermudagrass fertilized with 300 or 500 kg N ha$^{-1}$ in 1980 and 1981, but the mixtures yielded less than highly fertilized bermudagrass in 1982 and 1983. Bermudagrass fertilized with 100 kg N ha$^{-1}$ yielded less than any other treatment. Application of N to the alfalfa-bermudagrass mixture had no significant effect on yield.

Application of 100 kg N ha$^{-1}$ had no significant effect ($P > 0.05$) on botanical composition of the mixture and thus the two treatments are combined in Fig. 1. Overall alfalfa percentage was 86 and 82 for mixtures with no N and 100 kg N ha$^{-1}$, respectively (totals of all harvests across years). Weeds made up 8% or less of the forage during the experiment. The percentage of alfalfa in the alfalfa-bermudagrass mixture increased steadily over the 1st yr from about 65% in May to about 75% in early August (Fig. 1). In 1981 and 1982 alfalfa comprised over 80% of the mixture for all harvests. Alfalfa made up less of the mixtures during 1983 than in 1981 and 1982, and dropped below 60% in late August 1983. A later harvest was made in 1983, but the botanical samples were lost before separation. Plots were not harvested after August in 1980 because of severe drought. Except for 1980, alfalfa percentage was high in harvests made in May, but decreased during the summer.

**Table 1. Yields of alfalfa and bermudagrass grown alone and mixtures of the two species, and total rainfall for June, July, and August (Exp. 1).**

| Forage | Nitrogen applied | Dry matter yields 1980 | 1981 | 1982 | 1983 | Mean |
|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | Mg ha$^{-1}$ | | | | |
| Alfalfa | 0 | 4.2 | 8.1 | 10.1 | 7.4 | 7.4 |
| Mixture | 0 | 6.4 | 9.0 | 9.9 | 7.9 | 8.3 |
| Mixture | 100 | 6.8 | 9.7 | 10.4 | 7.9 | 8.7 |
| Bermudagrass | 100 | 3.0 | 4.3 | 8.2 | 5.7 | 5.3 |
| " | 300 | 5.7 | 8.2 | 15.0 | 11.6 | 10.1 |
| " | 500 | 6.1 | 9.6 | 18.2 | 16.0 | 12.5 |
| LSD (0.05) | | 0.9 | 1.2 | 1.6 | 1.2 | 0.6 |
| Rainfall, mm (June–August)† | | 182 | 224 | 227 | 140 | 193 |

† 29-yr. ave. = 306 mm.

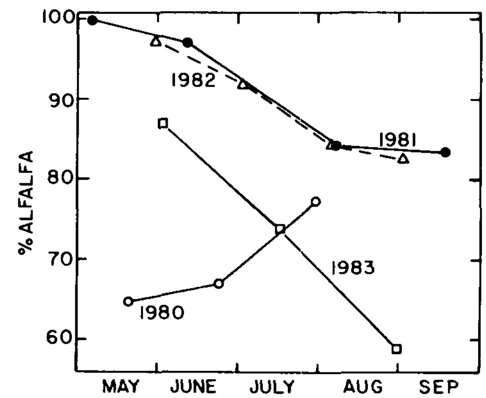


Fig. 1. The percentage of alfalfa in alfalfa-bermudagrass mixtures during four growing seasons. Experiment 1 data for no N and 100 kg N ha$^{-1}$ treatments averaged.

Nitrogen was determined on samples harvested from 1980 through 1983 (Table 2). Alfalfa grown alone had mean N concentrations higher than those in the alfalfa-bermudagrass mixtures in 1980 and 1981 but not in 1982 and 1983. Mean values for N concentration in bermudagrass ranged from 12.1 g kg$^{-1}$ when fertilized with 100 kg N ha$^{-1}$ in 1980 to 25.7 g kg$^{-1}$ when fertilized with 500 kg N ha$^{-1}$ in 1981. Significant differences were found among all treatments except the alfalfa-bermudagrass mixtures without N and with 100 kg N ha$^{-1}$ and in 1982 and 1983 alfalfa alone did not differ from the mixtures.

### Experiment 2

In 1986 yields of alfalfa alone were significantly higher than yields of the alfalfa-bermudagrass mixture with 30-cm rows (Table 3). However, during the next year, yields of alfalfa alone were lower than the alfalfa-bermudagrass mixture with 15-cm rows. In 1988 no differences were found in yields of alfalfa and the mixtures and thus the 3-yr average showed no trend with respect to these treatments. Row widths of 15 and 30 cm for alfalfa made no difference in total yield of the mixtures. Yields of bermudagrass fertilized with 100 kg N ha$^{-1}$ were lower than yields of all other treatments. Bermudagrass responded little to N fertiliza-

Table 2. Nitrogen concentration in dry herbage of alfalfa and bermudagrass grown alone and mixtures of the two species (Exp. 1).

| Forage | Nitrogen applied | N concentration in herbage 1980 | 1981 | 1982 | 1983 | Mean |
|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | g kg$^{-1}$† | | | | |
| Alfalfa | 0 | 28.9 | 30.3 | 32.0 | 27.6 | 29.7 |
| Mixture | 0 | 22.4 | 28.0 | 31.7 | 27.7 | 27.4 |
| Mixture | 100 | 23.5 | 28.9 | 31.7 | 28.1 | 28.0 |
| Bermudagrass | 100 | 12.1 | 16.4 | 15.0 | 17.0 | 15.1 |
| " | 300 | 13.8 | 22.1 | 18.1 | 18.2 | 18.0 |
| " | 500 | 16.5 | 25.7 | 23.9 | 22.8 | 22.2 |
| LSD (0.05) | | 1.7 | 1.2 | 1.5 | 2.0 | 0.7 |

† N concentrations are nonweighed averages for all harvests within years.

Table 3. Yields of alfalfa, bermudagrass, and mixtures of the two species, and total rainfall for June, July, and August (Exp. 2).

| Forage | Row spacing or N applied | Dry matter yields 1986 | 1987 | 1988 | Mean |
|---|---|---|---|---|---|
| | | Mg ha$^{-1}$ | | | |
| Alfalfa | 15 cm | 10.2 | 11.3 | 13.3 | 11.6 |
| Mixture | 15 cm | 9.1 | 12.4 | 13.2 | 11.6 |
| Mixture | 30 cm | 8.0 | 12.1 | 13.6 | 11.2 |
| Bermudagrass | 100 kg ha$^{-1}$ | 6.9 | 8.7 | 10.3 | 8.6 |
| Bermudagrass | 200 kg ha$^{-1}$ | 8.6 | 12.2 | 12.9 | 11.2 |
| Bermudagrass | 300 kg ha$^{-1}$ | 8.1 | 14.8 | 14.3 | 12.4 |
| LSD (0.05) | | 1.9 | 0.9 | 1.4 | 1.1 |
| Rainfall, mm (June–August)† | | 219 | 237 | 219 | 225 |

† 100-yr. avg. = 336 mm.

tion in 1986, but 300 kg N ha$^{-1}$ increased yields 70% in 1987 and 39% in 1988 compared to 100 kg ha$^{-1}$. Alfalfa and alfalfa-bermudagrass mixtures produced yields similar to bermudagrass fertilized with 200 kg N ha$^{-1}$.

In alfalfa-bermudagrass mixtures, alfalfa dominated the mixture with similar overall percentages for each year (80% in 1986 and 1988, and 84% in 1987). Row width of alfalfa had no influence on the composition of the mixture, and data for the two row widths are combined in Fig. 2. A similar seasonal trend in botanical composition was evident each year with alfalfa declining from 100% in spring to a low point in August then increasing again in the fall (Fig. 2). However, throughout the growing season, alfalfa made up more than 50% of the mixture. Weeds made up an insignificant percentage (<5%) of the mixtures throughout the experiment.

## DISCUSSION

Data from these experiments demonstrate that alfalfa and bermudagrass can be grown successfully in a mixture and that the mixture produces forage yields equivalent to alfalfa alone and to bermudagrass fertilized with about 200 kg N ha$^{-1}$. The results for yield and botanical composition were similar with two bermudagrass cultivars even though Tifton 44 (Exp. 1) tends to form a denser sod and Coastal (Exp. 2) is slightly taller (7). The competitiveness of alfalfa in the mixtures is indicated by the increase of alfalfa percentage during the 1st yr (Fig. 1) and by the high percentages throughout the two experiments. Burton (3) also showed that alfalfa was competitive with Coastal

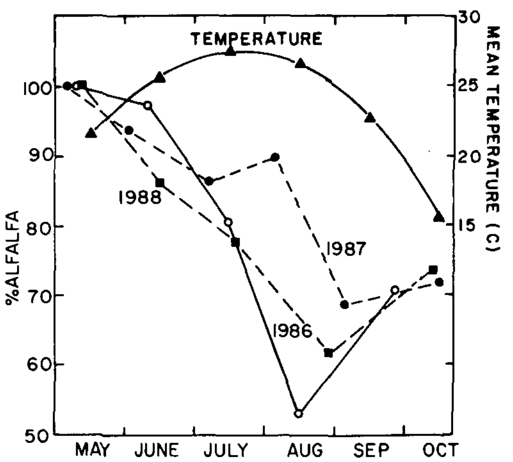

Fig. 2. The percentage of alfalfa in alfalfa-bermudagrass mixtures and the mean daily temperatures during three growing seasons. Experiment 2 data for 15- and 30-cm-alfalfa rows averaged. Temperatures are monthly averages of daily mean values for 1986, 1987 and 1988.

bermudagrass grown on the Coastal Plain of Georgia, making up nearly 50% of the mixture in summer.

The dominance of the mixture by alfalfa probably results from its lower temperature optimum and greater drought tolerance. Because of the lower temperature at which alfalfa begins growth it establishes a complete canopy in spring before bermudagrass starts growth. Alfalfa reached harvest stage each year (one-tenth bloom) in early May soon after bermudagrass began to grow. Because of the dense canopy of alfalfa and the intolerance of bermudagrass to shade (5,6), growth rate of bermudagrass is greatly reduced until the alfalfa is cut. Second, a greater drought tolerance of alfalfa is illustrated by the differential growth of the two species in pure stands during July and August of 1986 and 1987. From 14 July to 15 August, 1986 there were 106 mm of rainfall and alfalfa produced 1.40 Mg ha$^{-1}$ while bermudagrass fertilized with 200 kg N ha$^{-1}$ produced 1.79 Mg ha$^{-1}$. In a similar period in 1987 (6 July–4 August) only 54 mm of rain fell and alfalfa, although severely stunted, produced twice as much as bermudagrass (0.59 vs. 0.25 Mg ha$^{-1}$). A third factor favoring competition by alfalfa is its tendency for horizontal leaf display, especially early in the season (2) which may allow it to cast more shade per unit of leaf area than bermudagrass which has narrower and more erect leaves. This combination of factors favorable for alfalfa may make the widespread use of alfalfa in subtropical grass mixtures feasible.

As observed in other alfalfa-subtropical grass mixtures (8,11,13), alfalfa decreased in percentage in the summer. The decrease in percentage of alfalfa from spring to late summer probably is due in large part to temperatures becoming less favorable for alfalfa growth and more favorable for bermudagrass. The percentage of alfalfa began to decrease in spring when the mean daily temperature was between 20 and 25 °C and increased again in September when the mean daily temperature fell below 25 °C (Fig. 2). Growth of alfalfa has an optimum mean daily temperature near 20 °C (12) while for bermudagrass it is near 30 °C (19). Even in more temperate areas, alfalfa growth in pure stands decreases from spring to summer and the decrease has been attributed to both high temperature and drought (12). Because summer temperatures in Georgia are more favorable for bermudagrass and because the percentage of alfalfa decreased, it might be expected that the mixture would have higher yields in summer than alfalfa alone; however, this was not the case. The 3-yr total of all yields taken in July and August in Exp. 2 was 11.8 Mg ha$^{-1}$ for alfalfa alone and 11.1 Mg ha$^{-1}$ for the alfalfa-bermudagrass mixtures. Low yields in midsummer may have been due to lower than normal rainfall as discussed below.

Stand depletion is a problem in alfalfa management (10,13) and competition from aggressive grasses may hasten stand reduction. The fact that alfalfa made up over 50% of the mixture throughout both experiments indicates that the mixture is likely to be satisfactory for fairly long periods when well-managed for hay. It also suggests that alfalfa stand loss is likely to result from other causes than competition from the bermudagrass. The thinning of alfalfa that normally occurs over long periods and the stoloniferous and rhizomatous nature of bermudagrass may mean that bermudagrass will eventually dominate mixtures of these two species. However, the mixture should have a longer productive life than pure alfalfa stands because bermudagrass yields should increase as alfalfa declines and maintain high productivity over a longer period of time.

It is possible that competition from bermudagrass was minimized by the drier than normal years in which this research was conducted. Rainfall for June, July, and August in both experiments (Tables 1 and 2) averaged only 65% of normal and the range was only from 46% in 1983 to 74% in 1982. If alfalfa is favored in competition with bermudagrass during drought, then results from these experiments may not apply in wet years. There appeared to be no clear relationship in these experiments, however, between rainfall in June, July and August and percentage of alfalfa in the mixture. In fact, during the driest year (1983) the average percentage of alfalfa for the season dropped to 75% from about 90% in the two previous years (Fig. 2).

In these experiments the plants were managed as a hay crop. If the mixture were grazed, botanical composition and yield may be much different. It would be expected that grazing would shift the mixture toward bermudagrass because of its sod-forming habit and the susceptibility of alfalfa to frequent defoliation. Bermudagrass would also benefit from reduced shading under grazing. However, alfalfa has been grazed with sub-tropical grasses with some success in Queensland, Australia (8,9,11,13,17) and careful management with rotational grazing may allow the use of alfalfa-bermudagrass mixtures in a pasture.

The successful growth of alfalfa and bermudagrass in mixture indicates that bermudagrass hayfields and, perhaps, pastures could be improved by introducing this legume. Less N fertilizer would be required, and higher quality forage would result. Crude protein is only one index of forage quality, but its concentrations were highest in pure alfalfa and in the mixtures. Alfalfa had almost twice the crude protein concentration of bermudagrass fertilized with 100 kg N ha$^{-1}$ and even when fertilized with 500 kg N ha$^{-1}$ crude protein of bermudagrass was only 80% of the average of the mixtures. Even though alfalfa-bermudagrass mixtures appear to be feasible and desirable, a number of management problems need to be resolved. Among these are the interseeding of alfalfa into bermudagrass sods, optimum cutting and grazing management, and cultivar responses to interspecies competition.

## REFERENCES


1. Bremmer, J.M. 1965. Total nitrogen, p. 1149–1178 *In* C.A. Black et al. (ed.) Methods of soil analysis. Part 2. Agron. Monogr. 9. ASA, Madison, WI.
2. Brown, R.H., R.B. Pearce, D.D. Wolf, and R.E. Blaser. 1972. Energy accumulation and utilization. p. 143–166. *In* C.H. Hanson (ed.) Alfalfa science and technology. Agron. Monogr. 15. ASA, Madison, WI.
3. Burton, G.W. 1976. Legume nitrogen versus fertilizer nitrogen for warm season grasses. p. 55–72. *In* C.S. Hoveland (ed.) Biological N fixation in forage-livestock systems. ASA Spec. Publ. 28. ASA, CSSA, SSSA, Madison, WI.
4. Burton, G.W., and W.W. Hanna. 1985. Bermudagrass. p. 247–254. *In* M.E. Heath et al. (ed.) Forages: The science of grassland agriculture. 4th ed. Iowa State Univ. Press, Ames, IA.
5. Burton, G.W., J.E. Hook, J.L. Butler, and R.E. Hellwig. 1988. Effect of temperature, daylength, and solar radiation on production of coastal bermudagrass. Agron. J. 80:557–560.
6. Burton, G.W., J.E. Jackson, and F.E. Knox. 1959. The influence of light reduction upon the production, persistence and chemical composition of Coastal bermudagrass, *Cynodon dactylon*. Agron. J. 51:537–542.
7. Burton, G.W., and W.G. Monson. 1978. Registration of Tifton 44 bermudagrass. Crop Sci. 18:911.
8. Cameron, D.G., and J.D. Mullaly. 1969. Effect of Hunter River lucerne (*Medicago sativa* L.) on grasses in rain-grown pastures. Queensl. J. Agric. Animal Sci. 26:35–40.
9. Cameron, D.G., and J.D. Mullaly. 1970. The effects of Hunter River lucerne on associated grasses in raingrown pastures of central Queensland. p. 597–600. *In* M.J.T. Norman (ed.) Proc. Int. Grassl. Congr., 11th Surfer's Paradise, Australia. 13–23 Apr. 1970. Univ. Queensland Press, St. Lucia, Queensland, Australia.
10. Chamblee, D.S., and M. Collins. 1988. Relationships with other species in a mixture. p. 439–461. *In* A.A. Hanson (ed.) Alfalfa and alfalfa improvement. Agron. Monogr. 29. ASA, CSSA, SSSA, Madison, WI.
11. Christian, C.S., and N.H. Shaw. 1952. A study of two strains of Rhodes grass (*Chloris gayana* Kunth.) and of lucerne (*Medicago sativa* L.) as components of a mixed pasture at Lawes in south-east Queensland. Aust. J. Agric. Res. 3:277–299.
12. Fick, G.W., D.A. Holt, and D.G. Lugg. 1988. Environmental physiology and crop growth. p. 163–194. *In* A.A. Hanson (ed.) Alfalfa and alfalfa improvement. Agronomy Monogr. 29. ASA, CSSA, SSSA, Madison, WI.
13. Leach, G.J. 1978. The ecology of lucerne pastures. p. 290–308. *In* J.R. Wilson (ed.) Plant relations in pastures. CSIRO, Melbourne, Australia.
14. Melton, B., J.B. Moutray, and J.H. Bouton. 1988. Geographic adaptation and cultivar selection. p. 595–620. *In* A.A. Hanson (ed.) Agron. Monogr. 29. ASA, CSSA, SSSA, Madison, WI.
15. Miller, R.G., Jr. 1966. Simultaneous statistical inference. McGraw-Hill, New York.
16. Olsen, F.J., and E.R. Tiharuhondi. 1972. The productivity and botanical composition of some selected grass/legume pasture mixtures at different seeding rates. East Afr. Agric. For. J. 38:16–22.
17. Santhirasegaram, K., J.E. Coaldrake, and M.H.M. Salih. 1966. Yield of a mixed subtropical pasture in relation to frequency and height of cutting and leaf-area index. p. 125–129. *In* A.G.G. Hill (ed.) Proc. Int. Grassl. Cong., 10th. Helsinki, Finland. 7–16 July 1966. Int. Grassl. Cong., Helsinki, Finland.
18. Scateni, W.J. 1968. Effects of legumes and fertilizer nitrogen on productivity of green panic swards at Gayndah, south-eastern Queensland. Queensl. J. Agric. Anim. Sci. 25:85–91.
19. Schmidt, R.E., and R.E. Blaser. 1969. Effect of temperature, light and nitrogen on growth and metabolism of Tifgreen bermudagrass (*Cynodon* spp.). Crop Sci. 9:5–9.
20. Southern Regional Project S-45. 1. Composition and digestibility of southern forages. South. Coop. Series Bull. 165. Florida

Agric. Exp. Stn.
21. Sumner, M.E., H. Shahandeh, J. Bouton, and J. Hammel. 1986. Amelioration of an acid soil profile through deep liming and surface application of gypsum. Soil Sci. Soc. Am. J. 50:1254–1258.
22. Vance, C.P., G.H. Heichel, and D.A. Phillips. 1988. Nodulation and symbiotic dinitrogen fixation. p. 229–257. *In* A.A. Hanson (ed.) Alfalfa and alfalfa improvement. Agron. Monogr. 29. ASA, CSSA, SSSA, Madison, WI.
23. Wilkinson, S.R., and G.W. Langdale. 1974. Fertility needs of the warm-season grasses. p. 119–145. *In* D.A. Mays (ed.) Forage fertilization. ASA, CSSA, SSSA, Madison, WI.