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Row Spacing and Nitrogen: Effect on Alfalfa–Bermudagrass Yield and Botanical Composition

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ABSTRACT

Interseeding perennial legumes into bermudagrass [*Cynodon dactylon* (L.) Pers.] sods should increase forage quality. Preliminary research revealed that alfalfa (*Medicago sativa* L.) interseeded into bermudagrass (BG) rapidly reduced BG vigor, possibly because of shading by alfalfa. Grass–legume pastures should contain balanced mixtures for quality maintenance and bloat prevention. It may be possible to manipulate botanical composition with N and row spacing. The objective of this research was to examine effects of these factors on botanical composition and yield of alfalfa–BG swards. We interseeded alfalfa into 'Tifton 44' BG in 20-, 40-, and 60-cm row spacings, and included a non-interseeded check treatment. Experiments were on Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Kandiudult) and Cecil sandy clay loam (clayey, kaolinitic, thermic Typic Kanhapludult) sites. Nitrogen was applied at 0, 112, 224, and 448 kg ha^{-1} yr^{-1}. Yield of BG increased by a factor of 2.06 with 448 kg ha^{-1} of N, compared with 0 N. Alfalfa increased total yields over BG alone, at all but the highest rates of N. Nitrogen increased yields of interseeded plots an average of 11%. Yield increases from N did not result from increased grass percentage. Increasing row spacing decreased yields of interseeded mixtures, but increasing N rate sometimes compensated slightly for wide rows. Nitrogen had no effect or decreased grass percentage, whereas wide row spacing usually increased the grass component. It appears that alfalfa utilized a significant portion of applied N, and that N will not aid in retaining BG in mixtures. Increasing row spacing will aid in retaining grass in mixture, probably through reduced shading of grass.

BERMUDAGRASS is a well-adapted warm-season forage over much of the humid temperate and humid subtropical regions of the USA. It is particularly useful during summer, when cool-season forages exhibit slow growth. Forage quality of BG is usually lower than for cool-season forages at the same stage of maturity (Moore and Mott, 1973, Montgomery et al., 1983). One universal strategy for increasing forage quality of grass swards is to incorporate legumes, because of their low fiber, high protein, and high animal intake characteristics.

Clovers (*Trifolium* spp.; Laidlaw, 1984), alfalfa (Van Keuren and Heinemann, 1958), and birdsfoot trefoil (*Lotus corniculatus* L.; Forwood et al., 1989) have been used in conjunction with cool-season grasses. Much less research has been conducted with perennial legumes in conjunction with warm-season grasses. Montgomery et al. (1983) reported that red clover (*T. pratense* L.) depressed the yield of bahiagrass (*Paspalum notatum* Flügge) and bermudagrass, and the effect persisted after the clover had disappeared from the sward. Alfalfa has shown potential for establishment in BG sods (Malm et al., 1970; Burton, 1978; Stringer et al., 1988; Brown and Byrd, 1990). Stringer et al. (1988) and Brown and Byrd (1990) reported that interseeded alfalfa could provide vigorous competition for the established BG.

In cool-season forage swards the legume component is commonly less persistent than the grass, particularly when N fertilizer is applied (Laidlaw, 1984). Nitrogen has been shown to reduce legume nodulation and symbiotic N_2 fixation (Eardley et al., 1985), while stimulating growth of the grass component (Laidlaw, 1984). Bermudagrass, however, is not shade-tolerant (Burton et al., 1959), and shading from close-growing companion species may reduce productivity and competitiveness.

Our long-term goal is to create persistent BG–alfalfa mixtures for use in pastures or hay. The objective of this research was to evaluate the impact of N fertilization and alfalfa row spacings on the yield and botanical composition of interseeded bermudagrass swards.

MATERIALS AND METHODS

Tifton 44 BG sods were located on Norfolk sandy loam and Cecil sandy clay loam at Blackville and Pendleton, SC, respectively. Dolomitic limestone was applied to BG sods at 2240 kg ha^{-1} one year prior to initiating the studies. 'Cimarron' alfalfa was seeded into the established sods in 20-, 40-, and 60-cm row spacings, at seeding rates of 19, 9.5, and 6.4 kg ha^{-1} (pure live seed), respectively, using a no-tillage seeder. The seedings were made the second week of October in 1986

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Abbreviations: ANOVA, analysis of variance, BG, bermudagrass.

and 1987 at the Blackville and Pendleton sites, respectively. Plot size was 2.4 by 6.1 m, and check plots of grass sod were included. Phosphorus and K were applied at the rates of 73 kg ha^{-1} and 279 kg ha^{-1} prior to interseeding. Nitrogen fertilization rates of 0, 112, 224, and 448 kg ha^{-1} yr^{-1} were used in a complete factorial arrangement with stand type (row spacing treatments and a grass check). The experimental design was a randomized complete block with four replications.

Harvesting was initiated the spring after seeding, when alfalfa was in the 0.1-bloom stage, and ensuing harvests were made at 35-d intervals. A maximum of six cuts was possible each year. Nitrogen was applied in split applications after Cuts 1 through 4. Soil samples were taken each fall, and recommended rates of P, K, and B were applied.

Prior to each harvest, a 0.37-m^2 quadrat was hand-clipped for botanical composition determination. Total fresh forage was harvested from a 0.9-m wide strip through the plot, using a flail harvester, and a subsample was weighed fresh and after oven drying at 65 °C for 3 d. Subsample dry matter concentration was used to calculate dry matter yield. Quadrat samples were hand separated into BG, alfalfa, and weed components, oven-dried as above, and reported as BG percentage.

Analysis of variance (ANOVA) of all data was performed with the GLM procedure (SAS, Cary, NC). Percentage botanical composition data were transformed to arcsine values prior to analysis. Nitrogen rate and stand type (three row spacings and a grass check) and their interaction effects were included in the statistical model. When the interaction effect was significant, N rate effects were evaluated within each stand type using linear, quadratic, and cubic orthogonal polynomial contrasts. The interseeded treatments were also evaluated in a separate ANOVA that excluded grass check data. Nitrogen rate, row spacing, and their interaction effects were included in the statistical model. Because N rate effects were already described in the analysis that included the grass check, the purpose of this ANOVA was to determine if there was an N rate × row spacing interaction or an effect of row spacing. When interaction occurred, row spacing effects were tested within each N rate using orthogonal polynomial contrasts. All references to linear, quadratic, or cubic responses and differences are considered to be significant at the 0.05 level or lower.

RESULTS

Herbage Yield

In the initial growing season at Blackville, a heavy growth of arrowleaf clover (*T. vesiculosum* Savi) plants in early spring forced a sacrifice harvest of the first growth. Thus, the yields in Table 1 include only four harvests. Herbage yield in grass-alone treatments increased linearly with applied N up to 448 kg ha^{-1} (Table 1). The interseeded treatments, by contrast, did not respond to N. When the interseeded treatments were analyzed separately from grass alone, row spacing had no effect on yield. In the second growing season, N fertilization increased yield linearly in the grass-alone and the 20- and 60-cm row spacing treatments (Table 2), and approached significance ($P = 0.07$) in the 40-cm row spacing as well. The trend toward decreasing yield with increasing row spacing did not attain significance ($P = 0.10$).

At the Pendleton site, N fertilization in the first growing season resulted in linear increases in yields of BG alone and 20- and 60-cm row swards (Table 3). When the interseeded treatments alone were analyzed, increasing row spacing decreased yield linearly under the zero-N regime, but had no effect under the higher N rates. In the second growth season at this site, N fertilization resulted in a sharp linear increase in yield of BG alone (Table 4). In the 20-cm row swards, the N response was quadratic; in 60-cm rows, it was linear. Row spacing effects were not significant when interseeded treatments were analyzed alone.

Table 1. Total herbage yield of bermudagrass and alfalfa–bermudagrass mixtures (Blackville, SC, 1987).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	N rate means†
kg ha^{-1}	Mg ha^{-1}				
0	4.78	8.82	9.39	8.39	8.87
112	6.57	8.93	9.48	8.84	9.08
224	8.48	9.29	9.34	9.50	8.37
448	10.31	9.41	9.26	8.96	9.21
N effect‡	Lin.*§	NS	NS	NS	NS
Row spacing means†	—	9.11	9.37	8.92	NS

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. = linear effect of N rate on herbage yield.

Table 2. Total hergabe yield of bermudagrass and alfalfa–bermudagrass mixtures (Blackville, SC, 1988).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	N rate means†
kg ha^{-1}		Mg ha^{-1}			
0	7.46	12.95	12.48	10.89	11.78
112	8.60	14.59	12.70	10.48	12.30
224	11.11	13.99	14.49	12.00	13.50
448	13.23	14.91	14.58	14.00	14.49
N effect‡	Lin.*§	Lin.*	NS	Lin.*	Lin.*
Row spacing means†	—	13.86	13.34	11.85	NS

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. = linear effect of N rate on herbage yield.

Botanical Composition

Bermudagrass appeared to suffer from the heavy canopy of arrowleaf clover that developed in the first spring at Blackville. Weeds, mainly crabgrass [*Digitaria sanguinalis* (L.) Scop.], flourished for the entire season in the first year of the study. Intense shading from the clover may have reduced the vigor and early-season root growth of the BG (Burton et al., 1959). Percentage BG in the grass-alone treatments responded in quadratic fashion to added N (Table 5), and was greater at high and zero than at intermediate N rates. Grass percentage in 20-cm rows decreased at a decreasing rate as N increased, but N fertilization did not alter the botanical composition of 40- and 60-cm row swards. When the interseeded treatments were analyzed separately, in-

Table 3. Total herbage yield of bermudagrass and alfalfa–bermudagrass mixtures (Pendleton, SC, 1988).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	Row spacing effect†
kg ha^{-1}	Mg ha^{-1}				
0	8.37	12.50	12.04	10.45	Lin.*‡
112	11.07	12.85	12.17	12.08	NS
224	12.08	13.45	12.64	12.67	NS
448	14.86	13.77	12.62	12.68	NS
N effect§	Lin.*	Lin.*	NS	Lin.*	

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed a significant row spacing × N rate interaction. This interaction was evaluated by comparing the row spacing effects under different N rates using orthogonal polynomial contrasts.

‡ Lin. = linear effect of N rate or row spacing on herbage yield.

§ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

Table 4. Total herbage yield of bermudagrass and alfalfa–bermudagrass mixtures (Pendleton, SC, 1989).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	N rate means†
kg ha^{-1}	Mg ha^{-1}				
0	8.45	17.29	15.81	14.58	15.88
112	13.35	17.20	15.45	14.60	15.76
224	16.47	15.09	15.96	16.05	15.70
448	20.45	17.50	16.38	16.80	16.90
N effect‡	Lin.*§	Quad.*§	NS	Lin.*	NS
Row spacing means†	—	16.81	15.90	15.50	NS

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. and Quad. = linear and quadratic effects of N rate on herbage yield.

Table 5. Percentage bermudagrass in herbage of bermudagrass and alfalfa–bermudagrass mixtures (Blackville, SC, 1987).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	N rate means†
kg ha^{-1}	%				
0	55	14	24	30	23
112	46	11	19	35	22
224	40	7	27	36	23
448	58	6	20	33	20
N effect‡	Quad.*§	Quad.*	NS	NS	NS
Row spacing mean†	—	10	22	34	Lin.*

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. and Quad. = linear and quadratic effects of N rate or row spacing on bermudagrass percentage.

Table 6. Percentage bermudagrass in herbage of bermudagrass and alfalfa–bermudagrass mixtures (Blackville, SC, 1988).

	Stand type				
		Alfalfa row spacing, cm			
N rate	Grass alone	20	40	60	N rate means†
kg ha^{-1}	%				
0	45	5	17	16	13
112	51	4	16	23	14
224	54	3	12	20	12
448	69	2	9	16	9
N effect‡	Lin.*§	Quad.*	NS	NS	NS
Row spacing means†	—	4	14	18	Lin.*

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. and Quad. = linear and quadratic effects of N rate or row spacing on percentage bermudagrass.

creasing row spacing resulted in a linear increase in percentage BG of the sward.

Percentage BG remained low in the second growing season (Table 6). Grass percentage in the grass-alone treatments increased linearly in response to applied N. Nitrogen fertilization produced a quadratic response in 20-cm row swards, and no effect in 40- and 60-cm row swards. When interseeded treatments were evaluated apart from grass alone, increasing row spacing increased percentage grass.

Grass stands were more vigorous at Pendleton. Nitrogen fertilization did not influence composition of grass-alone swards the first year (Table 7) . The response to N in 20-cm row interseeded swards was quadratic, with percentage BG higher at intermediate rates than at the zero or high rate. There was no response of botanical composition to N in 40- and 60-cm treatments. When interseeded treatments were considered apart from grass alone, increasing row spacing increased the contribution of BG. In the second growing season at Pendleton, the grass-alone swards remained vigorous (Table 8). There was a small linear (cubic also significant) increase in grass percentage as N was increased. There was no effect of N on botanical composition in 20- and 40-cm row interseeded swards, but N fertilization produced a gradual linear decrease in grass percentage in 60-cm row swards. In interseeded treatments analyzed separately, wider row spacing produced a linear increase in BG percentage.

DISCUSSION

Bermudagrass yield with 448 kg ha^{-1} of N averaged just over twice that of the zero-N check, which is comparable with data from Monson et al. (1971). Interseeding alfalfa increased the yield of BG-based swards relative to BG with no applied N. Our results suggest that interseeding alfalfa can substitute for 224 kg ha^{-1} or more of N, in terms of dry matter production, which agrees closely with Brown and Byrd (1990). The increase in yield from interseeding was accompanied by a loss of 40 to 90% of the BG component of the sward.

Table 7. Percentage bermudagrass in herbage of bermudagrass and alfalfa–bermudagrass mixtures (Pendleton, SC, 1988).

N rate	Stand type				N rate means†
	Grass alone	Alfalfa row spacing, cm			
		20	40	60	
kg ha^{-1}	%				
0	88	9	22	39	23
112	88	15	25	39	26
224	91	13	23	35	24
448	88	7	19	35	21
N effect‡	NS	Quad.*§	NS	NS	NS
Row spacing means†	—	11	22	37	Lin.*

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. and Quad. = linear or quadratic effect of N rate or row spacing on percentage bermudagrass.

Table 8. Percentage bermudagrass in herbage of bermudagrass and alfalfa–bermudagrass mixtures (Pendleton, SC, 1989).

N rate	Stand type				N rate means†
	Grass alone	Alfalfa row spacing, cm			
		20	40	60	
kg ha^{-1}	%				
0	81	3	8	20	10
112	81	2	8	18	9
224	85	2	7	16	8
448	86	2	7	16	8
N effect‡	Lin.*§ Cub.*	NS	NS	Lin.*	NS
Row spacing means†	—	2	7	17	Lin.*

* Significant at the 0.05 probability level.

† ANOVA for interseeded treatments showed no significant row spacing × N rate interaction. Main effect means are for interseeded treatment data only, and were tested using orthogonal polynomial contrasts.

‡ Stand type × N rate interaction significant at the 0.05 probability level. This interaction was evaluated by comparing the N rate responses of different stand types using orthogonal polynomial contrasts.

§ Lin. and Cub. = linear and cubic effects of N rate or row spacing on percentage bermudagrass.

The rapid loss of BG from competition with alfalfa was unexpected. Common bermudagrass invades alfalfa fields in the South, but this may occur in response to declining alfalfa plant vigor. Malm et al. (1970) reported that BG persisted with alfalfa, even in 15-cm rows, under irrigation in the Pecos Valley of New Mexico, and that N could be used to manipulate the proportion of alfalfa. Parsons (1958) reported that alfalfa declined rapidly in orchardgrass (*Dactylis glomerata* L.). The growing season of cool-season grasses corresponds closely with that of alfalfa, which may contribute to greater competition by the grass component in cool-season grass–alfalfa mixtures than by BG. Alfalfa initiates growth 6 wk earlier than BG in the southern USA, which results in a tall dense canopy over the emerging BG spring growth. Rapid regrowth and the tall upright growth habit of alfalfa resulted in a large height advantage over BG (data not shown) throughout the growing season. The resulting long-term shading of the BG canopy, particularly in the narrow row spacings, may be largely responsible for the decline in BG productivity. It is well established that BG root and shoot growth and nonstructural carbohydrate reserves are depressed by shading (Burton et al., 1959). It is also possible that, in droughty years, the early growth of alfalfa might enable it to preempt the winter carryover supply of soil water to the detriment of the BG component. Deeper rooting of alfalfa may prolong the growth advantage of alfalfa under drought conditions.

Nitrogen fertilization commonly increased the yield of interseeded plots. Adding the highest rate of N increased the herbage yield of interseeded plots by an average of 11% over the zero-N check, when averaged over both years and locations. Proportion of grass in the mixture decreased by an average of 18 percentage units with N addition, but significantly so in only three instances (Tables 5, 6, and 8). This finding differs from published results with cool-season grasses, where legumes decline in response to added N (Laidlaw et al., 1984). Well-nodulated alfalfa can supply much of the N needs of a companion grass (Ta and Faris, 1987), but added N does not usually directly affect alfalfa yields (Eardley et al., 1985). In this study, N increased the yields of interseeded treatments, but did not increase the percentage or yield (data not shown) of the BG component of mixtures. The lack of positive response of BG in interseeded stands to added N may be an interaction with shading by the taller alfalfa. Burton et al. (1959) showed that high N increased the decline of BG under shade. Reducing the shading effects by wider row spacings increased the BG component, but resulted in lower total yields. Adding N helped to counteract yield loss from wider row spacing, but this did not occur via enhanced BG contribution, as percentage BG did not increase. Rehm et al. (1975) reported that N fertilization beyond 250 kg ha^{-1} increased alfalfa yield at the expense of grass yield, but the alfalfa was not well nodulated.

These findings suggest that alfalfa was utilizing applied N to stimulate growth. Fishbeck and Phillips (1981) showed yield increases in new alfalfa stands, but later growths did not respond to N. Lee and Smith (1972) showed no yield increases in alfalfa from N up to 900 kg ha^{-1}. Estimates of nodulation and N_2 fixation were not made in our study, but it is possible that regular additions of N may have suppressed biological N_2 fixation, particularly at high N rates, as shown by Rehm et al. (1975), thus gradually creating an N-responsive alfalfa sward. Our results suggest that wide row spacing of interseeded alfalfa will be necessary to retain a significant BG component. There may be a total herbage yield penalty from wider rows, but the savings of N fertilizer cost and the likely quality advantage from alfalfa in the mixture will help to counteract yield losses. Future research should address effects of other management factors (e.g., defoliation frequency) on yield and botanical composition of alfalfa–bermudagrass mixtures.

REFERENCES

Brown, R.H., and G.T. Byrd. 1990. Yield and botanical composition of alfalfa–bermudagrass mixtures. Agron. J. 82:1074–1079.

Burton, G.W. 1978. Legume N vs. fertilizer N for warm-season grasses. p. 55–72. *In* C.S. Hoveland et al. (ed.) Biological N fixation in forage–livestock systems. ASA Spec. Publ. 28. ASA, CSSA, and SSSA, Madison, WI.

Burton, G.W., J.E. Jackson, and F.E. Knox. 1959. The influence of light reduction upon production, persistence and chemical composition of Coastal bermudagrass. Agron. J. 51:537–542.

Eardley, B.D., D.B. Hannaway, and P.J. Bottomley. 1985. Nitrogen nutrition and yield of seedling alfalfa as affected by ammonium nitrate fertilization. Agron. J. 77:57–62.

Fishbeck, K., and D. Phillips. 1981. Combined N and vegetative growth of symbiotically grown alfalfa. Agron. J. 73:975–978.

Forwood, J.R., P. Stypinski, and J. Peterson. 1989. Forage selection by cattle grazing orchardgrass–legume pastures. Agron. J. 81:409–414.

Laidlaw, H.S. 1984. Quantifying the effect of nitrogen fertilizer application in spring on white clover content in perennial ryegrass–white clover swards. Grass Forage Sci. 39:317–321.

Lee, C., and D. Smith. 1972. Influence of N fertilization on stands, yields of herbage and protein and nitrogenous fractions of field-grown alfalfa. Agron. J. 12:527–530.

Malm, N.R., C.E. Barnes, and W.J. Russell. 1970. Forage production from bermudagrass alone and mixed with alfalfa in the Pecos Valley. New Mexico State Univ. Agric. Exp. Stn. Res. Rep. 182.

Monson, W.G., G.W. Burton, W.S. Wilkinson, and S.W. Dumford. 1971. Effects of N and simazine on yield, protein, amino acid content and carotenoid pigments of Coastal bermudagrass. Agron. J. 63:928–930.

Montgomery, C.R., B.D. Nelson, M. Allen, L. Mason, and R. Mowers. 1983. Evaluation of Pensacola bahiagrass and Alicia bermudagrass with and without interplanted ryegrass and red clover. Louisiana Agric. Exp. Stn. Bull. 748.

Moore, J.E., and G.O. Mott. 1973. Structural inhibitors of quality in tropical grasses. p. 53–98. *In* A.G. Matches (ed.) Antiquality components of forages. CSSA Spec. Publ. 4. ASA, CSSA, and SSSA, Madison, WI.

Parsons, J.L. 1958. Nitrogen fertilization of alfalfa–grass mixtures. Agron. J. 50:593–594.

Rehm, G.W., J.T. Nichols, R.C. Sorenson, and W.J. Moline. 1975. Yield and botanical composition of an irrigated pasture as influenced by fertilization. Agron. J. 67:64–68.

Stringer, W.C., D.J. Undersander, and B.C. Morton. 1988. Row spacing and nitrogen on bermudagrass interseeded with alfalfa. p. 141. *In* Agronomy abstracts. ASA, Madison, WI.

Ta, T.C., and M.A. Faris. 1987. Effects of alfalfa proportions and clipping frequencies on timothy–alfalfa mixtures: II. Nitrogen fixation and transfer. Agron. J. 79:820–824.

Van Keuren, R.W., and W.W. Heinemann. 1958. A comparison of grass–legume mixtures and grass under irrigation as pasture for yearling steers. Agron. J. 50:85–88.