THE INFLUENCE OF SEEDING RATES ON BOTANICAL COMPOSITION AND YIELD OF FORAGE MIXTURES UNDER TWO DIFFERENT CUTTING TREATMENTS

Thesis for the Degree of Ph. D.

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William F. Hueg, Jr.

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This is to certify that the

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THE INFLUENCE OF SEEDING RATES ON BOTANICAL COMPOSITION AND YIELD OF FORAGE MIXTURES UNDER TWO DIFFERENT CUTTING TREATMENTS

presented by

William F. Hueg, Jr.

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AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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ABSTRACT

In a greenhouse experiment, Alfalfa (Medicago sativa), Red Clover (T. pratense), Ladino clover (T. repens L) and Bromegrass (Bromus inermis) were planted at varying seeding rates in mixtures, and subjected to two and five cutting treatments. As the rate of seeding of the individual species was increased, the number of plants of that species and total plants in the mixture increased.

Under both cutting treatments the yield of the individual species in mixtures was not higher than the yield of the species seeded alone. In only four of the thirty-three mixtures that were cut twice, were total yields greater than alfalfa seeded alone, and eleven mixtures had total yields lower than red clover seeded alone. Total yields from mixtures with Ladino clover and bromegrass were greater than either species seeded alone.

The increased rate of individual species in the mixtures had less influence on total yield of tops and roots than the two different cutting treatments. Higher total yields of forage and roots were produced from the mixtures cut twice. Ladino clover and bromegrass were less affected by frequent cutting than red clover or alfalfa. Alfalfa yields decreased when the recovery period was of short duration, but the other species showed increased yields with successive cuttings.

The dependence of new growth on carbohydrate reserves was shown by the roots from those mixtures cut frequently. The vigor of alfalfa roots as seen in weight, length and diameter determinations, was reduced markedly by frequent cutting. Red clover and bromegrass roots were also retarded by frequent cutting but less than alfalfa. Ladino clover produced more vigorous roots and slightly higher root yields under frequent cutting.

In the mixtures for pasture, higher total yields were obtained at the higher rates of seeding, while the medium seeding rates produced the highest yields of hay. Mixtures of two compatible species gave as much or more yield than those mixtures with more than two species. The inclusion of Ladino clover to an alfalfa-bromegrass mixture for hay purposes did not add to the total yield in this experiment, and the rapid recovery attributed to Ladino under frequent cutting was overshadowed in mixtures cut for hay by competition from other species. When red clover was used in the mixtures, total yields were not increased and the yield of component species was less than when only two or three species were in the mixture.

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Introduction

When Cato, the Roman philosopher, was asked over 2000 years ago what was the most profitable thing a farmer could have, he replied, "A first class meadow." This somewhat startled his questioners who then asked what the second most prized possession might be. "A second class meadow", was his ready reply.

Today, as in the times of ancient Rome, a dependable supply of high quality forage from meadows is still necessary for successful and economical livestock production. A first step to adequate supplies of forage is the establishment of the stand.

Between states and regions there are broad variations in the recommended forage species, but most noticeable are the wide range of seeding rates, especially in mixtures. In their book, "Forages", Hughes, et al [10] cite recommended mixtures and rates for ten north central states. Sixteen of these involve alfalfa at rates from 3 to 15 pounds per acre; 12 include red clover at rates from 1 to 10 pounds per acre; eight include ladino clover at rates from ½ to 2 pounds per acre; and 11 recommend bromegrass either alone or in combination with other grasses at rates from 3 to 10 pounds.

Some mixtures include from four to eight legumes

and as many grasses. The seeding rate for most of these "shot gun" mixtures will approach forty pounds per acre.

Recent experimental work has shown an advantage to reducing the number of species in a mixture, not only because of cost, but for ease of planting and management once the meadow is established. When mixtures are composed of many species it is virtually impossible to establish and maintain all of the species. Therefore, the more aggressive species, and those few species best adapted to the grazing or cutting management will dominate the stand.

Farmers continue to request information on the best species or mixture of species for their meadows. Are there evident differences in species to be used for hay or pasture? What is the best seeding rate for hay and pasture? What is the effect of time and number of cuttings on forage yield, botanical composition, and persistence of stand?

An experiment was established in the greenhouse at Michigan State University, East Lansing, on January 28, 1956, to learn more about the influence of seeding rate and frequency of cutting on the establishment, yield and botanical composition of meadow stands.

Review of Literature

Many volumes have been written dealing with the factors under consideration in this experiment. The effect of varying the total amount of seed planted has been studied,

but very little is reported where seeding rates of only one mixture component were varied. In addition, many of the reports are contradictory because of environmental differences, species combination, and methods of management studied. Somewhat general agreement exists, however, that the more simple the mixture used the easier to approach the goal of maintaining vigorous, high yielding stands of superior quality forage.

Blaser, et al (1) (2) have thoroughly examined the physiological factors to be considered in compounding seed mixtures. Particular emphasis was given to seedling competition. By weighing seedlings of each species, alfalfa was found to be very aggressive, while red clover and ladino clover were less aggressive. Bromegrass was rated to be more aggressive than red clover, but less than alfalfa. Their work suggests that several simple mixtures of different maturity are useful and can be manipulated during the season according to growth to obtain a uniform distribution of grazing.

A report from Wales by Milton (10) shows that the yield from mixtures composed of two grasses were about as good as yields from mixtures with more than two grasses. Legume species in the mixture were held constant.

Dennis (3) found in a Michigan field experiment that yields of alfalfa were directly associated with cutting interval; the oftener the plants were cut, the less productive they became. Root production and winter survival were curtailed by frequent cutting. Frequent cutting stimulated

regrowth for a short period, after which new growth was definitely limited. These findings confirm the earlier work of Hodgson, (7) with greenhouse grown bromegrass, bluegrass and orchard grass, which showed that frequent close cutting stimulated growth for a short time, but severely reduced root and top production ultimately.

Sprague and Sullivan (13) reported that reserve carbohydrates in grasses were not only stored in the roots and rhizomes but primarily in the lower leaf sheaths that comprise the stubble of plants in the vegetative stages of growth. When forage was cut back to near ground level, a large portion of the stored carbohydrates was removed. The rate of recovery and vigor of grasses were reduced as they were cut or grazed closer to ground level.

In later work, Sprague, et al (14) found that the carbohydrate content of grass and legume plants decreased rapidly for 7 to 10 days following cutting, and then increased for about four weeks to its original level.

In legumes, the reserve food used by the plant for recovery is stored in the roots and stolons which are not removed in grazing or cutting. Moran (11), and Stewart and Bear (15), reported that frequency of cutting rather than height of cutting affected carbohydrate reserves in alfalfa and ladino clover. Hildebrand (6) showed that frequent cutting of alfalfa reduced food reserves and resulted in large decreases in yield and plant vigor. Graber, et al (5),

concluded that depleted food reserves caused by frequent cutting at immature growth stages resulted in reduced productivity and vigor of perennial plants.

Harrison and Hodgson (7) found under greenhouse conditions that the combination of frequent cutting at 1 inch heights produced severe damage to grasses. Wagner (16), at Beltsville found that the greatest reduction in growth occurred when the grass was clipped back to 2 inches during the later stages of development. He reported bromegrass to be more sensitive than orchard grass in this respect. This data suggests that moderate clipping in the early stages should help the legumes and less aggressive grasses to compete against weeds and result in their faster establishment.

Experimental Procedure

Seedings were made in sand in ten inch clay pots. The species used were Alfalfa (Medicago sativa, var. Vernal); Red Clover (Trifolium pratense, var. Pennscott); Ladino Clover (Trifolium repens L.); and Bromegrass (Bromus inermis). They were grown as single species and in mixture. In the mixture only one of the components was varied in each of the four series. Details of the seeding rates are as follows:

Single Species

Alfalfa - 8 lbs. per acre

Red Clover - 8 lbs. per acre

Ladino Clover - 1 lb. per acre

Bromegrass - 3 lbs. per acre

Species Mixtures

Alfalfa - 1,2,4,6,8,10,12,16, and 20 pounds per acre
Bromegrass - constant rate at 3 pounds per acre

Bromegrass - 1,2,4,5,6,7,8,9, and 10 pounds per acre
Alfalfa - constant rate at 8 pounds per acre

Ladino Clover - 1/8, 1/4, 1/2, 3/4, 1,2,3,4, and 5 pounds per acre
Alfalfa - constant rate at 8 pounds per acre
Bromegrass - constant rate at 3 pounds per acre

Red Clover - 1,2,4,6,8, and 10 pounds per acre
Alfalfa - constant rate at 8 pounds per acre
Bromegrass - constant rate at 3 pounds per acre
Ladino Clover - constant rate at 1 pound per acre

The seeds were carefully weighed and counted before planting.

The experiment was set up in a split plot design and replicated three times within each of the cutting treatments. One-half of the cultures in the experiment were cut when growth reached a ten inch height to simulate a grazing or pasture treatment. The other half of the cultures were allowed to go to the hay stage (approximately one-fifth bloom) before cutting. An aftermath cutting was taken at the completion of the experiment in early June.

The seedings were watered daily for the first six weeks, then as required. After emergence a standard nutrient solution was applied weekly for the first five weeks, then each 3½ days until the end of the experiment. The pH of the medium remained fairly constant at 7.2, and regular

flushing with water prevented excessive salt accumulation.

The greenhouse temperature fluctuated between 65 and 70 degrees F. for the first three months, but was more irregular in May, when it sometimes reached 90 degrees F.

Stand counts were made on March 1. All of the seed had not germinated by this first count as there were increased plant numbers in some treatments at the time of the final harvest. The first clipping in the pasture treatment was made on March 28. Clippings were taken two inches above the sand level. The species were hand separated for botanical analysis and the green and oven dry weight recorded. The hay treatment was harvested on May 8, and the aftermath growth on June 1.

After the final harvest, the root systems were carefully washed free of sand, and individual plants were counted before green and oven dry weights were taken.

Legume roots of each species were separated into three groups based on length and diameter. From each group three representative roots were selected for sectioning.

The nine roots were washed and a portion one-half inch long was cut from the alfalfa roots at 3½ inches below the crown. The selected portion was taken two inches below the crown from red clover and 1 inch in ladino clover.

The root sections were pickled in formalin alcohol. After imbedding in paraffin, cross sections approximately 10 microns in thickness were prepared and stained

with triple stain.

Statistical significance was determined by analysis of variance and use of Duncan's (4) Significant Studentized Range Test. Any difference less than the corresponding L.S.D. value was not considered significant at that level. Any difference greater than the corresponding R.E. value was considered significant at that level. All differences between the corresponding L.S.D. and R.E. values were considered questionable as to their significance. R.E. (6) is the range of equality based on a maximum number of means in the table.

EXPERIMENTAL RESULTS

1. Influence of Seeding Rate on Establishment

Seedling emergence was most rapid the first two weeks, although later emergence did occur. Alfalfa was first to emerge, followed by red clover, Ladino clover and bromegrass. The greatest rate of growth was shown by alfalfa and bromegrass, followed by red and Ladino clover. Development of Ladino clover was very slow until after the first trifoliate leaf had expanded. Figures 1 and 2 show that the average height of all species, six weeks after seeding, was four to five inches, with a range from two to eight inches, with bromegrass being the tallest.

As the rate of the varied or single species was increased the number of plants of that species increased

steadily as shown in Tables 1 through 5. The same pattern was noted in total plant numbers, but the increases were not always proportional. With single species the difference in plant numbers between groups in the cutting treatments was not significant.

In the alfalfa-bromegrass series, alfalfa dominated the mixtures above the two pound rate. (Table 2) At the higher rates there were differences in plant numbers between cutting treatments. There were no significant differences in bromegrass numbers. Total plant numbers increased at about the same proportion as alfalfa.

Bromegrass did not dominate the bromegrass-alfalfa mixtures at any rate. (Table 3) There were significant differences in bromegrass numbers in the group to be cut five times at most rates. Alfalfa showed large differences between cutting treatment groups but not between rates. The total number of plants in the group which was to be cut five times were significantly different than the group to be cut twice between rates of bromegrass.

Ladino clover was the dominant species in those mixtures above the two pound rate. (Table 4) There were significantly more Ladino clover plants between rates within cutting treatment groups at the higher rates of Ladino. Total plant numbers were significantly different between rates only in the group to be cut five times.

Red clover dominated that series where red clover

was the varied species only at the highest rate. (Table 5) Alfalfa, bromegrass, Ladino and mixture totals were not significantly different between rates or cutting treatment groups.

The competitive effect of red clover on alfalfa establishment can be seen by comparing alfalfa numbers in Tables 3 to 5. In the bromegrass-alfalfa mixtures, alfalfa averaged 18.0 and 18.3 plants for the five and two cutting groups;18.3 and 16.8 respectively in the Ladino clover mixtures; but only 13.4 and 12.8 respectively in the red clover series.

Table 1. Influence of Seeding Rate on Establishment

Single Species

Species	Pounds per acre	Seeds per culture	Number of plants (average of 3 cultures on Mr.1) 5X*	2X*	Diff.
Alfalfa	8	22	19.0	20.0	+1.0
Bromegrass	3	6	5.0	6.0	+1.0
Ladino clover	1	9	8.0	8.0	--
Red clover	8	22	14.3	15.0	+0.7
					no sig. diff.

* Seedings set up in groups to be cut 5 and 2 times respectively

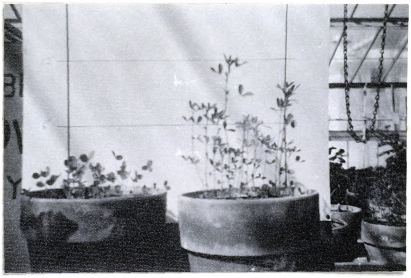


Figure 1. Growth six weeks after seeding
L. - Red Clover 8 lbs; R. - Alfalfa 8 lbs.

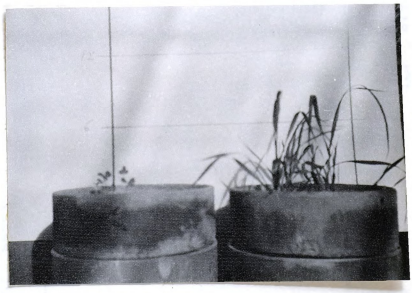


Figure 2. Growth six weeks after seeding
L. - Ladino Clover 1 lb; R. - Bromegrass 3 lbs.

Table 2. Influence of Seeding Rate on Establishment

Alfalfa varied - bromegrass constant at 6 seeds per culture

Alfalfa in lbs. per acre	Alfalfa seeds per culture	Number of Plants by Species (Average of 3 cultures on March 1)								
		Alfalfa			Bromegrass			Total		
		5X*	2X*	Diff.	5X	2X	Diff.	5X	2X	Diff.
1	3	2.0	2.3	+0.3	5.3	4.3	-1.0	7.3	6.6	-0.7
2	7	5.3	5.3	--	5.0	5.3	+0.3	10.3	10.6	+0.3
4	11	10.0	10.3	+0.3	5.0	4.0	-1.0	15.0	14.3	-0.7
6	18	15.3	17.0	+1.7	4.3	4.7	+0.4	19.6	21.7	+2.1
8	22	19.0	15.3	-3.7	5.0	4.0	-1.0	24.0	19.3	-4.7
10	28	20.3	25.3	+5.0	6.0	5.0	-1.0	26.3	30.3	+4.0
12	34	27.3	31.0	+3.7	5.7	4.0	-1.7	33.0	35.0	+2.0
16	45	38.3	35.0	-3.3	5.7	5.3	-0.4	44.0	40.3	-3.7
20	55	44.0	44.0	--	5.3	5.0	-0.3	49.3	49.0	-0.3
RE_9 = 5%		5.6	3.4		no sig. diff.			4.7	3.9	
1%		7.8	4.8					6.6	5.5	
LSD = 5%		4.9	3.0	3.9				4.2	3.5	3.7
1%		6.8	4.2	5.3				5.7	4.8	5.0

*Seedings set up in groups to be cut 5 and 2 times respectively

Table 3. Influence of Seeding Rate on Establishment

Bromegrass varied - alfalfa constant at 22 seeds per culture

Bromegrass in lbs. per acre	Bromegrass seeds per culture	Number of Plants by Species (Average of 3 cultures on March 1)								
		Bromegrass			Alfalfa			Total		
		5X*	2X*	Diff.	5X	2X	Diff.	5X	2X	Diff.
1	2	1.3	2.0	+0.7	17.3	19.0	+1.7	18.7	21.0	+2.3
2	4	3.3	2.7	-0.6	16.7	20.3	+3.6	20.0	23.0	+3.0
4	7	5.7	6.3	+0.6	17.0	21.4	+4.4	22.7	25.7	+3.0
5	8	5.7	5.3	-0.4	16.6	18.4	+1.8	22.3	23.7	+1.4
6	11	8.7	7.7	-1.0	21.6	17.3	-4.3	30.3	25.0	-5.3
7	12	8.7	10.3	+1.6	18.0	19.0	+1.0	26.7	29.3	+2.6
8	14	10.3	8.7	-1.6	19.0	16.6	-2.4	29.3	25.3	-4.0
9	16	12.7	12.0	-0.7	18.6	17.0	+1.6	31.3	29.0	-2.3
10	17	9.7	12.7	+3.0	16.6	16.6	--	26.3	29.3	+3.0
RE_9=5%		1.4	2.3		no sig. diff.			4.1	no	
1%		2.0	3.2					5.7	sig.	
LSD=5%		1.3	2.0	1.6			3.7	3.6	diff.	4.3
1%		1.8	2.8	2.2			5.0	5.0		5.7

*Seedings set up in groups to be cut 5 and 2 times respectively

Table 4. Influence of Seeding Rate on Establishment

Ladino varied - alfalfa constant at 22 seeds, bromegrass at 6 seeds per culture

Ladino Clover in lbs. per acre	Ladino Clover seeds per Culture	Number of Plants by Species (Average of 3 cultures on March 1)											
		Ladino Clover			Alfalfa			Bromegrass			Total		
		5X*	2X*	Diff.	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
1/8	2	1.7	1.3	-0.4	15.7	16.3	+0.6	4.7	3.7	-1.0	22.0	21.3	-0.7
1/4	3	3.0	2.0	-1.0	19.3	14.7	-4.6	5.7	4.7	-1.0	28.0	21.4	-6.6
1/2	5	4.3	4.3	--	18.7	16.3	-2.4	5.0	4.0	-1.0	28.0	24.6	-3.4
3/4	7	5.7	4.7	-1.0	18.7	19.3	+0.6	4.0	5.3	+1.3	28.4	29.3	+0.9
1	9	8.0	5.7	-2.3	17.7	19.0	+1.3	5.3	4.7	-0.6	31.0	29.4	-1.7
2	19	15.0	12.3	-2.7	20.0	18.0	-2.0	5.0	4.3	-0.7	40.0	34.6	-5.4
3	30	24.7	23.7	-1.0	19.0	18.0	-1.0	4.7	4.3	-0.4	48.4	46.0	-2.4
4	39	28.3	30.0	+1.7	17.0	15.7	-1.3	5.3	3.7	-1.6	50.6	49.4	-1.2
5	46	38.0	33.7	-4.3	18.3	14.3	-4.0	4.7	4.0	-0.7	61.0	52.0	-9.0
RE_9=5%		3.1	2.9		no sig. diff.			no sig. diff.			5.0	no sig.	
1%		4.4	4.0								7.0	diff.	
LSD=5%		2.8	2.5	2.6			3.8				4.4		
1%		3.8	3.5	3.4			5.2				6.1		

*Seedings set up in groups to be cut 5 and 2 times respectively

Table 5. Influence of Seeding Rate on Establishment

Red clover varied - alfalfa constant at 22, Ladino clover at 9 and bromegrass at 6 seeds per culture

Red Clover in lbs. per acre	Red Clover seeds per culture	Number of Plants by Species (Average of 3 cultures on March 1) Red Clover 5X*	Red Clover 2X*	Red Clover Diff.	Alfalfa 5X	Alfalfa 2X	Alfalfa Diff.
1	3	2.3	2.7	+0.4	13.0	10.7	-2.3
2	7	4.7	5.0	+0.3	15.3	12.7	-2.6
4	11	8.7	6.7	-2.0	11.7	13.3	+1.6
6	18	10.0	11.0	+1.0	13.0	14.7	+1.7
8	22	14.3	12.7	-1.6	15.0	12.0	-3.0
10	28	11.7	18.3	+6.6	12.3	13.7	+1.4
RE_6=5%		6.5	3.5		no sig. diff.		
1%		9.6	5.1				
LSD=5%		6.0	3.2	4.2			
1%		8.5	4.5	5.8			

*Seedings set up in groups to be cut 5 and 2 times respectively

Table 5.

Ladino Clover			Bromegrass			Total		
5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
7.3	8.0	+0.7	3.7	4.7	+1.0	26.3	26.0	+0.3
7.7	4.7	-3.0	5.0	4.0	-1.0	32.7	26.4	-6.3
4.7	4.0	-0.7	5.0	5.0	--	29.7	29.0	+0.7
5.7	6.3	+0.6	5.0	3.7	-1.3	33.7	35.7	+2.0
4.7	5.0	+0.3	4.0	4.0	--	38.0	33.7	-4.3
8.0	4.7	-3.3	3.7	4.7	+1.0	35.7	41.4	+5.7

no significant difference

2. Influence of Seeding Rates and Cutting Treatments on the Yield of Forage

Single species

Single species were established to determine the performance of each species under conditions free of interspecies competition and to relate these yields to performance with controlled rates of seeding in mixtures. Dry weight yields are shown in Appendix Table I.

Alfalfa made the greatest initial growth in the group to be cut five times but needed a longer recovery period after cutting than the other species as indicated by the yield in the second and fifth cuttings. A period of fourteen days and ten days respectively elapsed between the first and second and fourth and fifth cuttings, which appears to be too short for good alfalfa recovery.

Although red clover was slow to start, it did produce a slightly higher total yield than alfalfa. Ladino clover and bromegrass showed fast recovery after clipping. Yields between species were not significantly different. Figure 3 shows the regrowth ten days after the first of five cuttings.

Alfalfa produced a significantly greater yield than bromegrass and Ladino clover when cut twice. Red clover was significantly higher yielding than Ladino clover.

The data in Table 6 shows that the total yields of alfalfa and red clover harvested as hay were more than double the pasture yield. The yield of bromegrass as hay

Figure 3. Regrowth of single species 10 days after first cutting, L to R - bromegrass, red clover, alfalfa and Ladino clover.
(Top of stakes were 10 inches above the top of the pot.)

was not significantly greater than that from the pasture treatment. Ladino clover showed slightly less yield when harvested for hay than when harvested as pasture.

Table 6. Comparison of Forage Yield Between Cutting Treatments

Single Species
Dry Weight Yield in Grams - average of 3 cultures

Species	Pasture	Hay	Difference
Alfalfa	19.81	55.44	35.65
Bromegrass	17.88	29.83	11.95
Ladino Clover	16.28	15.87	-1.41
Red Clover	20.58	41.80	21.22
LSD = 5%			12.01
1%			16.85

Alfalfa-Bromegrass Mixtures

In this series the rate of alfalfa varied from one to twenty pounds per acre, while bromegrass remained constant at three pounds. Highest yield as shown in Appendix Tables IIa and IIb was not always significantly different from lower yields.

The nineteen pound (16 lbs. of alfalfa and 3 lbs. of bromegrass (16-3)) rate gave the greatest total yield when cut five times as shown in Table IIa. At the eleven pound rate, the yield of alfalfa and bromegrass were about equal. Generally as the rate of seeding alfalfa increased

the yield of alfalfa increased, and the yield of bromegrass decreased. The rate of increase in alfalfa yields was greater than that of total yield of the mixtures.

The nine pound (6-3) rate gave the greatest total yield when cut twice as shown in Table IIb. The highest yield of alfalfa came from the fifteen pound (12-3) rate. Generally as the rate of seeding alfalfa increased the yield of alfalfa increased, and the yield of bromegrass decreased. The rate of increase in total yield was greater than in alfalfa yield.

The data in Table 7 and Figure 5 shows that the production of forage differs greatly within the component parts of the same mixture clipped two or five times. The highest yield from two cuttings was nearly three times the highest yield from the five cuttings. The increasing rate of alfalfa had an earlier depressing effect on bromegrass under a two cutting system than in the five cutting treatment. Figure 6 shows the regrowth ten days after the first of five cuttings.

Bromegrass-Alfalfa Mixtures

In this series the rate of bromegrass varied from one to ten pounds, with alfalfa constant at eight pounds per acre. Yields shown in Appendix Tables IIIa and IIIb.

The highest total yield from five cuttings came from the seventeen pound (9 lbs. of bromegrass and 8 lbs. of alfalfa (9-8)) rate which also produced the highest yield of

Table 7. Comparison of Forage Yield Between Cutting Treatments

Alfalfa - Bromegrass Mixtures
(alfalfa varied, bromegrass constant at 3 lbs.)

Dry weight yield in grams - average of 3 cultures

Rate of Alfalfa lbs.	Pasture 5X	Hay 2X	Total Differences (2X-5X) Mixture	Alfalfa	Bromegrass
1	16.64	23.37	6.73	5.80	0.94
2	21.18	41.63	20.45	8.93	11.52
4	23.71	41.25	17.54	14.64	2.90
6	19.93	61.40	41.47	27.04	14.33
8	23.57	39.91	16.34	13.96	2.38
10	20.74	47.31	26.57	23.06	3.52
12	22.26	60.23	37.97	28.30	9.67
16	27.67	54.20	26.53	15.59	10.93
20	24.62	52.14	27.52	23.44	4.08
LSD = 5%			13.61	11.01	9.34
1%			18.29	14.79	12.54

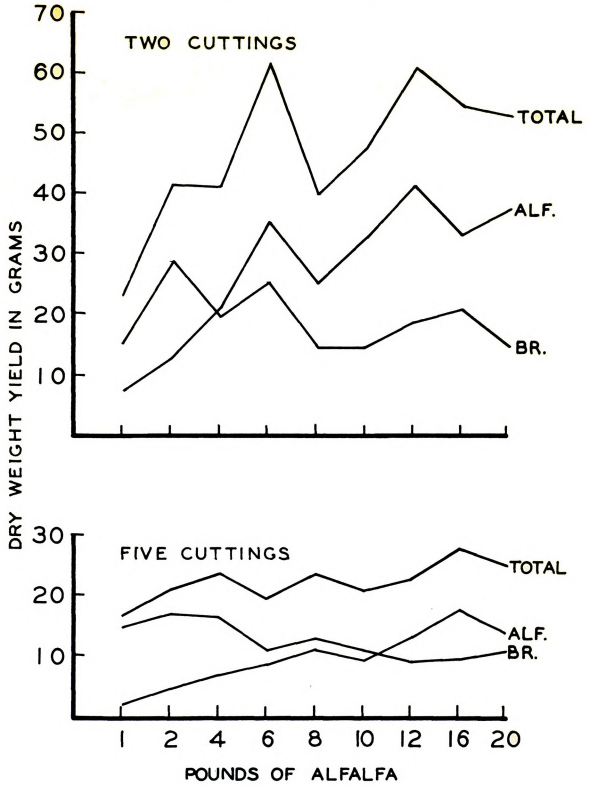


Figure 5. Forage yield as influenced by variation in the seeding rate and two different cutting treatments. Alfalfa-bromegrass mixtures.

Figure 6. Regrowth of alfalfa - bromegrass mixtures 10 days after first cutting
Left to right: Alfalfa 20 lbs; 8 lbs; and 1 lb. Bromegrass at 3 lbs. in all treatments.
(Top of stakes 10 inches above the top of the pot)

bromegrass. Generally as the rate of bromegrass increased the yield of alfalfa decreased, but the rate of decrease was only slightly affected. Total yield followed the yield of bromegrass closely, indicating faster recovery than alfalfa, especially during regrowth periods of short duration.

Under the two cutting system, the highest total yield came from the sixteen pound (8-8) rate, and the highest bromegrass yield from the fifteen pound (7-8) rate. Alfalfa yields decreased generally as the rate of bromegrass increased.

Yields between cutting treatments were highly significant at six of the nine rates of bromegrass, while bromegrass yield differences between cutting treatments were significant only at the seven and eight pound rates. Alfalfa yield differences between cutting treatments were much greater than in bromegrass. (Table 8)

Figure 7, shows that the increasing rate of bromegrass influenced alfalfa yields very early in the five cutting treatment, but did not influence alfalfa yields under two cuttings until the medium rates of seeding were reached. There was more fluctuation in total bromegrass, and alfalfa yields in the two cutting treatments than in the five cutting treatments.

Ladino Clover, Alfalfa and Bromegrass Mixtures

The rates of Ladino clover varied from one-eighth to five pounds in this series with alfalfa constant at eight

Table 8. Comparison of Forage Yield Between Cutting Treatments

Bromegrass - Alfalfa Mixtures
(Bromegrass varied, alfalfa constant at 8 lbs.)

Dry weight in grams - average of 3 cultures

Rate of Bromegrass lbs.	Pasture 5X	Hay 2X	Total Differences (2X-5X)		
			Mixtures	Bromegrass	Alfalfa
1	20.96	35.86	14.90	1.63	13.27
2	21.12	47.20	26.08	1.94	24.14
4	24.24	52.50	28.26	4.12	23.14
5	22.75	51.50	28.75	9.42	19.33
6	27.40	55.40	28.00	8.48	19.52
7	25.24	49.90	23.76	12.97	10.79
8	22.77	56.10	33.23	12.51	20.82
9	32.02	42.40	10.38	5.27	3.21
10	27.55	47.10	19.55	9.28	10.27
LSD = 5%			15.67	9.69	10.56
1%			21.04	13.01	14.19

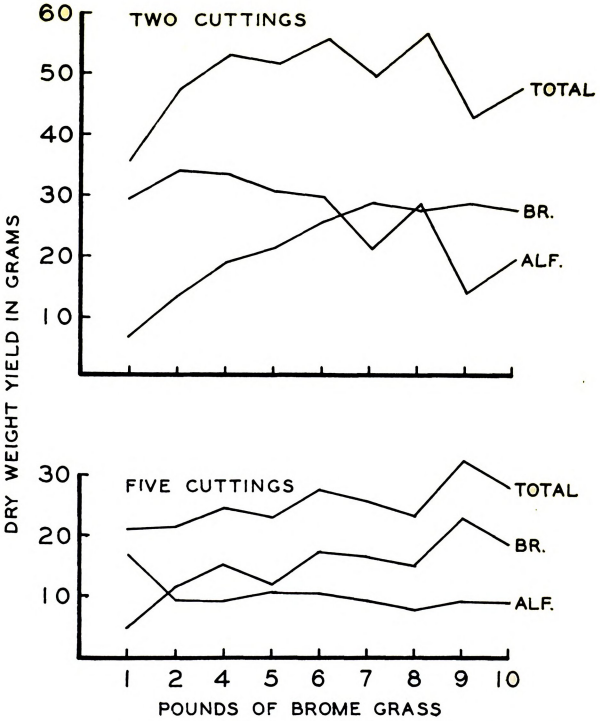


Figure 7. Forage yield as influenced by variation in the seeding rate and two different cutting treatments. Bromegrass-alfalfa mixtures.

and bromegrass at three pounds per acre. Yields are shown in Appendix Tables IVa and IVb.

The maximum rate of seeding produced the highest yield when cut five times. (Table IVa) A steady increase in Ladino clover yield was obtained as the rate increased. As the rate and yield of Ladino clover increased, the yield of alfalfa and bromegrass showed a general decrease. The yield of Ladino clover surpassed the yield from alfalfa and bromegrass after the one pound rate of Ladino. Total yield fluctuations were similar to those of alfalfa and bromegrass until reaching the four and five pound rates of Ladino clover. (Figure 8)

Ladino clover recovered faster after cutting than alfalfa or bromegrass. The yield of Ladino clover increased with each successive harvest.

When these mixtures were cut twice the highest yield came from the eleven and three-quarter pound (3/4 lb. of Ladino clover, 8 lbs. of alfalfa and 3 lbs. of bromegrass) rate. (Table IVb) Increasing the rate of seeding Ladino clover had little effect on alfalfa and bromegrass yields. Yields from these two species showed large fluctuations, with a very different yield pattern than Ladino clover, as shown in Figure 8.

The highest yield under the two cuttings system was double that for the five cutting system at the same rate. (Table 9) To produce the highest pasture yield five additional pounds of Ladino clover were used.

Table 9. Comparison of Forage Yield Between Cutting Treatments

Ladino Clover, Alfalfa and Bromegrass Mixtures
(Ladino clover varied, alfalfa constant at 8 lbs. and bromegrass at 3 lbs.)

Dry weight yield in grams - average of 3 cultures

Rate of Ladino Clover lbs.	Pasture 5X	Hay 2X	Total Difference (2X-5X) Mixture	Ladino cl.	Alfalfa	Bromegrass
1/8	26.35	35.35	9.00	-1.59	10.74	-0.15
1/4	24.24	36.81	12.57	-1.83	5.22	9.18
1/2	32.84	39.58	6.74	-2.39	9.32	-0.19
3/4	27.07	56.03	28.96	-4.28	16.91	16.33
1	33.48	53.93	20.45	-6.49	15.21	11.73
2	29.60	36.26	6.66	-8.19	7.62	7.24
3	26.23	44.40	18.17	-6.70	14.28	10.60
4	32.55	52.73	20.18	-9.01	15.99	13.20
5	34.42	50.96	16.54	-5.61	16.69	5.46
LSD = 5%			15.68	3.87	10.97	9.29
1%			21.05	5.20	14.73	12.48

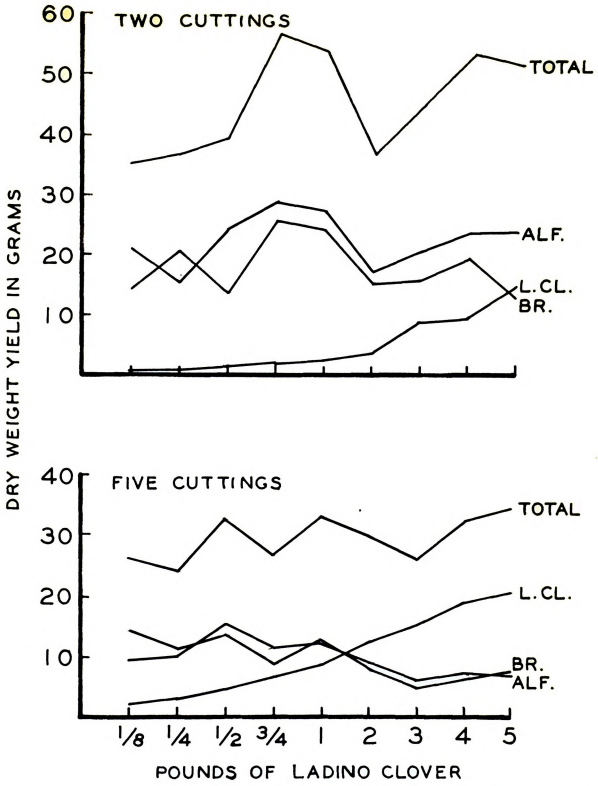


Figure 8. Forage yield as influenced by variation in the seeding rate and two different cutting treatments. Ladino clover, alfalfa and bromegrass mixtures.

Red Clover, Alfalfa, Ladino Clover, and Bromegrass Mixtures

In this series the rate of red clover was varied from one to ten pounds with alfalfa constant at eight, Ladino clover at one, and bromegrass at three pounds per acre. Yields are shown in Appendix Tables Va and Vb.

There were no significant differences in total yield from the five cutting treatments. The highest total yield and highest yield of red clover were obtained at the twenty pound (8 lbs. of red clover, 8 lbs. of alfalfa, 1 lb. of Ladino clover and 3 lbs. of bromegrass (8-8-1-3) rate.

As the rate of red clover increased the yield of red clover increased. Increasing the rate of red clover above two pounds had a depressing effect on the yield from the other three species when cut five times. Ladino clover yield was affected most by the increasing rates of red clover. Total yield was more affected by the yield of species other than red clover until the higher seeding rates.

Ladino clover recovered faster after clipping especially where the period of regrowth was short. Red clover was the next most favorable in regrowth, while alfalfa showed the slowest recovery during short periods of regrowth. Figure 9 shows the regrowth ten days after the first of five clippings.

When these mixtures were cut twice the highest total yield and highest yield of red clover also came from the twenty pound (8-8-1-3) rate. There were no significant

differences in total yields between rates of red clover. (Table Vb)

Red clover yields increased with an increased seeding rate. Alfalfa yields were affected very little by this increase of red clover, but Ladino clover and bromegrass generally decreased. The pattern of total yield of the mixtures followed the yield pattern of alfalfa. When cut five times all species showed a uniform decline in yield as the rate and yield of red clover increased.

The pattern of total yield shown in Figure 10 was more irregular in the two cutting treatment than in the five. This variation occurred with all species but Ladino clover. Total yields are compared in Table 10.

Table 10. Comparison of Forage Yield Between Cutting Treatments Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixtures
(Red clover varied, alfalfa constant at 8 lbs., Ladino clover at 1 lb., and bromegrass at 3 lbs.)
Dry weight yield in grams - average of 3 cultures

Rate of Red Clover lbs.	Pasture 5X	Hay 2X	Total Differences (2X-5X)				
			Mixture	Red Cl.	Alfalfa	L. Cl.	Brome.
1	25.53	42.80	17.27	-0.99	9.54	-4.41	13.13
2	26.11	38.45	12.34	0.87	6.93	-1.70	6.24
4	24.69	38.15	13.46	0.47	10.93	-2.37	4.43
6	24.31	43.54	19.23	0.83	12.97	-1.04	6.47
8	27.66	50.59	22.93	2.89	13.23	-1.06	7.87
10	26.28	39.85	13.57	2.41	6.03	-0.99	6.12
LSD=5%			15.90	no sig. diff.		2.40	6.88
1%			21.61			3.26	9.35

Figure 9. Regrowth of red clover, alfalfa, Ladino clover, and bromegrass mixtures 10 days after first cutting.
Left to right: Red clover 1 lb.; 4 lbs.; and 10 lbs. Alfalfa at 8 lbs.; Ladino clover at 1 lb.; and bromegrass at 3 lbs.
(Top of stake 10 inches above the top of the pot)

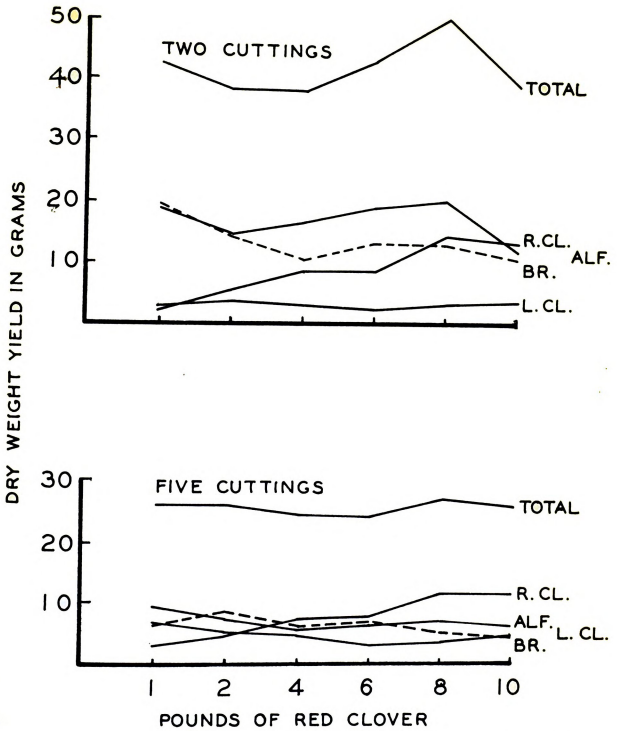


Figure 10. Forage yield as influenced by variation in the seeding rate and two different cutting treatments. Red clover, alfalfa, Ladino clover and bromegrass mixtures.

3. Influence of Seeding Rate and Cutting Treatments on the Botanical Composition of a Mixture

Within the four combinations of species, the proportion of the varied species increased with increasing seeding rates. Under the five cutting treatment the proportion of alfalfa decreased after the first, third and fourth cuttings. At the rates of alfalfa below four pounds seeded with bromegrass, this decrease took place from one cutting to the next.

Under this treatment bromegrass increased markedly in the first two cuttings, but dropped sharply in the third cutting. Between the third, fourth and fifth cuttings there was a marked increase in the proportion of bromegrass in the mixtures.

In those mixtures with Ladino clover the proportion of the mixture that was Ladino clover increased with each successive cutting. By the third cutting in the series where Ladino rates were varied, Ladino clover was the dominant species at rates above two pounds.

The proportion of red clover increased at all rates with each successive cutting through the fourth cuttings but decreased at the higher rates in the fifth cutting.

When these mixtures were cut twice the alfalfa increased as the seeding rate increased, and increased from the first to second cutting. Bromegrass decreased from the

first to the second cutting but it, too, increased in proportion with increased seeding rates.

Ladino clover never comprised more than one third of the mixtures when cut twice but increased in proportion from the first to the second cutting. Red clover also showed an increase from the first to second cutting.

The botanical composition of mixtures is given in Tables 11 through 14.

Table 11a. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Alfalfa - Bromegrass Mixture

Pasture Treatment - 5 cuttings - average of 3 cultures

Species*	Alfalfa (percent of total)					Bromegrass (percent of total)				
Date of Cutting	3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1
lbs. of Alfalfa										
1	30.6	14.5	18.2	12.3	3.1	69.3	85.5	81.8	87.7	96.9
2	43.9	26.6	26.8	20.5	4.0	56.1	73.4	73.2	79.5	96.0
4	61.5	34.9	34.0	28.2	6.6	38.5	65.1	66.0	71.8	93.4
6	61.6	42.6	52.9	44.6	17.0	38.4	57.4	47.1	55.4	83.0
8	69.4	44.9	62.7	46.7	22.6	30.6	55.1	37.3	53.3	77.4
10	71.0	35.4	67.5	43.6	18.8	29.0	64.6	32.5	56.4	81.2
12	79.9	58.8	69.9	54.8	34.3	20.0	41.2	30.1	45.2	65.7
16	79.6	62.6	74.1	62.6	34.0	20.4	37.4	25.9	37.4	66.0
20	81.0	63.7	69.7	47.9	29.4	19.0	36.3	30.3	52.1	70.6

*Alfalfa varied, bromegrass constant at 3 lbs.

Table 11b. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Alfalfa - Bromegrass Mixture

Hay Treatment - 2 cuttings - average of 3 cultures

Species*	Alfalfa (percent of total)		Bromegrass (percent of total)	
Date of Cutting	5-8	6-1	5-8	6-1
lbs. of Alfalfa				
1	36.1	29.6	63.9	70.4
2	29.7	34.0	70.3	66.0
4	49.9	55.5	50.1	44.5
6	54.6	64.0	45.4	36.0
8	57.9	70.2	42.1	29.8
10	64.1	76.2	35.9	23.8
12	66.6	73.6	33.4	26.4
16	58.6	67.3	41.4	32.7
20	68.3	76.0	31.7	24.0

*Alfalfa varied, bromegrass constant at 3 lbs.

Table 12a. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Bromegrass - Alfalfa Mixture
Pasture Treatment - 5 cuttings - average of 3 cultures

Species*	Bromegrass (percent of Total)					Alfalfa (percent of total)				
Date of Cutting	3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1
lbs. of Bromegrass										
1	10.5	24.7	14.3	21.4	49.3	89.5	75.3	85.7	78.6	50.7
2	25.9	49.9	33.8	56.5	83.9	74.1	50.1	66.2	43.5	16.1
4	47.2	65.8	45.7	60.9	86.7	52.8	34.2	54.3	39.1	13.3
5	37.7	50.0	40.3	59.2	76.7	62.3	50.0	59.7	40.8	23.3
6	41.3	72.0	51.1	65.5	82.7	58.7	28.0	48.9	34.5	17.3
7	48.8	65.1	52.0	67.6	82.7	53.2	34.9	48.0	32.4	17.3
8	50.7	82.6	57.0	65.3	86.5	49.3	17.4	43.0	34.7	13.5
9	57.7	74.5	58.8	76.9	88.7	42.3	25.5	41.2	23.1	11.3
10	52.4	65.2	54.9	70.5	85.4	47.6	34.8	45.1	29.5	14.6

*Bromegrass varied, alfalfa constant at 8 lbs.

Table 12b. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Bromegrass - Alfalfa Mixture
Hay Treatment - 2 cuttings - average of 3 cultures

Species*	Bromegrass (percent of total)		Alfalfa (percent of total)	
Date of Cutting	5-8	6-1	5-8	6-1
Lbs. of Bromegrass				
1	16.7	17.8	83.3	82.2
2	28.2	27.6	71.8	72.4
4	36.8	34.7	63.2	65.3
5	43.8	36.7	56.2	63.3
6	51.9	36.7	48.1	63.3
7	62.4	51.1	37.6	48.9
8	50.3	47.2	49.7	52.8
9	70.4	64.0	29.6	36.0
10	59.3	57.1	40.7	42.9

*Bromegrass varied, alfalfa constant at 8 lbs.

Table 13a. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Ladino Clover, Alfalfa, and Bromegrass Mixture
Pasture Treatment - 5 cuttings - average of 3 cultures

Species*	Ladino Clover (percent of total)					Alfalfa (percent of total)					Bromegrass (percent of total)				
Date of Cutting	3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1
lbs. of Ladino Clover															
1/8	1.1	4.0	5.8	11.0	10.2	64.64	42.0	50.7	30.8	13.9	34.3	54.0	43.5	58.2	75.9
1/4	6.9	4.6	8.4	13.8	12.8	64.1	37.4	57.1	37.4	21.1	29.0	58.0	34.5	48.8	66.1
1/2	1.5	5.3	11.5	15.8	23.6	66.2	53.6	53.7	38.6	15.6	32.3	41.1	34.8	45.6	60.8
3/4	2.1	9.5	19.7	32.2	33.9	69.0	50.2	50.8	37.1	19.0	28.9	40.3	29.5	30.7	47.1
1	3.5	16.0	27.7	32.8	38.8	60.7	42.8	41.0	29.3	16.3	35.8	41.2	31.3	37.9	44.9
2	5.0	30.0	40.4	47.6	54.4	63.0	36.0	34.6	27.5	15.4	32.0	34.0	25.0	24.9	30.2
3	10.9	37.3	55.5	69.0	65.7	65.5	25.6	30.7	14.7	10.2	23.6	37.1	14.4	16.3	24.1
4	8.7	39.0	54.8	70.7	66.2	63.3	31.3	26.2	13.8	11.1	28.0	29.7	19.0	15.5	22.7
5	12.5	45.4	62.3	65.2	70.3	52.3	21.2	24.2	13.0	10.3	35.2	33.4	13.5	21.8	19.4

*Ladino clover varied, alfalfa constant at 8 lbs., bromegrass at 3 lbs.

Table 13b. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Ladino Clover, Alfalfa, and Bromegrass Mixture
Hay Treatment - 2 cuttings - average of 3 cultures

Species*	Ladino Clover (percent of total)		Alfalfa (percent of total)		Bromegrass (pct.of tot.)	
Date of Cutting	5-8	6-1	5-8	6-1	5-8	6-1
lbs. of Ladino Clover						
1/8	0.8	2.2	61.1	55.5	38.1	42.3
1/4	1.6	2.4	44.1	40.2	54.3	57.4
1/2	4.1	6.3	58.1	65.9	37.8	27.8
3/4	3.2	4.6	49.4	55.2	47.4	40.2
1	4.3	4.0	48.1	56.1	47.6	39.9
2	9.6	12.3	42.4	53.3	48.0	34.4
3	17.8	21.2	43.3	50.8	38.9	28.0
4	18.2	17.9	41.5	49.4	40.3	32.7
5	26.2	31.9	47.9	43.9	25.9	24.2

*Ladino clover varied, alfalfa constant at 8 lbs., bromegrass at 3 lbs.

Table 14a. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixture

Pasture Treatment - 5 cuttings - average of 3 cultures

Species	Red Clover (percent of total)					Alfalfa (percent of total)				
Date of Cutting	3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1
lbs. of Red Clover										
1	3.3	9.0	6.9	10.8	30.4	69.8	43.4	43.9	30.0	14.4
2	9.6	12.7	11.9	17.5	29.5	62.4	26.8	40.0	26.5	13.6
4	19.7	29.8	28.2	33.6	35.7	45.1	26.2	28.0	21.0	10.8
6	13.4	27.9	31.5	37.3	34.7	60.7	28.0	30.9	21.5	8.5
8	19.9	38.0	43.0	49.3	35.4	60.6	30.3	26.2	19.2	12.5
10	23.5	47.3	44.4	47.9	31.4	58.0	23.5	27.2	16.0	15.2

Table 14a.

Ladino Clover (percent of total)					Bromegrass (percent of total)				
3-28	4-11	5-2	5-22	6-1	3-28	4-11	5-2	5-22	6-1
4.0	15.2	26.0	33.8	30.4	22.9	32.4	23.2	25.4	24.8
1.4	9.5	21.3	25.1	25.1	26.6	51.0	26.8	30.9	31.8
2.6	12.2	19.3	23.5	25.3	32.6	31.8	24.5	21.9	28.2
1.6	9.0	14.1	13.9	15.8	24.3	35.1	23.5	27.3	41.0
.7	9.7	14.9	14.1	18.5	18.8	22.0	15.9	17.4	33.6
1.3	10.3	15.3	19.4	28.4	17.2	18.9	13.1	16.7	25.0

Table 14b. The Influence of a Varied Rate of Seeding and Two Different Cutting Treatments on the Botanical Composition of a Mixture

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixture

Hay Treatment

Species	Red Clover (% of total)		Alfalfa (% of total)		Ladino Clover (% of total)		Bromegrass (% of total)	
Date of Cutting	5-8	6-1	5-8	6-1	5-8	6-1	5-8	6-1
lbs. of Red Clover								
1	4.1	5.5	45.3	43.3	5.9	4.9	44.7	46.1
2	14.4	13.6	40.4	36.5	7.8	12.5	37.4	37.4
4	19.2	24.6	44.8	42.5	5.2	9.2	30.6	23.7
6	18.9	22.5	45.1	41.9	4.7	5.2	31.3	30.4
8	27.8	29.0	39.0	42.0	4.7	5.5	28.5	23.5
10	29.3	39.9	28.7	32.5	11.6	5.8	30.4	21.8

4. Influence of Cutting Treatments on the Number of Plants at Final Harvest

Counts were made in all mixtures and treatments before cuttings were made. At the last harvest the plants were separated by species and counted to determine the influence of the two levels of cutting. In some mixtures there was an increase in plant numbers as a result of late germinating seed. Where plant numbers decreased this was assumed to be the effect of the cutting treatments. Data on plant numbers at final harvest are presented in Tables 15 to 19.

There were no significant decreases in plant numbers of the individual species in mixtures following the two cutting treatments. The delayed germination of seed had a greater influence than did cutting treatments, but these increases were not significant.

There were no significant differences in the number of total plants between cutting treatments. Within individual species there were significant differences in the number of plants at final harvest and this was most evident in Ladino clover and bromegrass in the Ladino clover mixture.

Table 15. Influence of Cutting Treatments on Number of Plants at Final Harvest

Single Species

Species	Number of Plants (average of 3 cultures on June 1) 5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
Alfalfa	19.3	+0.3	21.0	+1.0	+1.7
Bromegrass	5.3	+0.3	6.0	--	+0.7
Ladino Clover	8.0	--	8.3	+0.3	+0.3
Red Clover	17.3	+3.0	17.3	+2.3	--

No sig. diff.

Table 16. Influence of Cutting Treatments on Number of Plants at Final Harvest

Alfalfa varied - bromegrass constant at 3 lbs.

Alfalfa in lbs. per acre	Number of Plants by Species (Average of 3 cultures on June 1)													
	Alfalfa					Bromegrass					Total			
	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
1	2.0	--	2.7	+0.4	+0.7	5.3	--	4.3	--	-1.0	7.3	--	7.0	+0.4	-0.3
2	5.7	+0.4	6.3	+1.0	+0.6	5.3	+0.3	5.7	+0.4	+0.4	11.0	+0.7	12.0	+1.4	+1.0
4	9.7	-0.3	10.7	+0.4	+1.0	3.7	-1.3	4.7	+0.7	+1.0	13.4	-1.6	15.4	+1.1	+2.0
6	16.0	+0.7	17.0	--	+1.0	5.0	+0.7	4.7	--	-0.3	21.0	+1.4	21.7	--	+0.7
8	21.3	+2.3	17.7	+2.4	-3.6	3.7	-1.3	4.3	+0.3	+0.6	25.0	+1.0	22.0	+2.7	-3.0
10	19.0	-1.3	23.7	-1.6	+4.7	5.0	-1.0	5.0	--	--	24.0	-2.3	28.7	-1.6	+4.7
12	28.7	+1.4	31.0	--	+2.3	6.0	-0.3	4.3	+0.3	-1.7	34.7	+1.7	35.3	+0.3	+0.6
16	39.3	+1.0	37.0	+2.0	-2.3	5.7	--	5.0	-0.3	-0.7	45.0	+1.0	42.0	+1.7	-3.0
20	46.0	+2.0	44.3	+0.3	-1.7	5.7	+0.4	5.0	--	-0.7	51.7	+2.4	49.3	+0.3	-2.4
RE_9=5%	4.3	no	2.6	no		no sig. diff.					3.9	no	2.6	no	
1%	6.0	sig.	3.7	sig.							5.4	sig.	3.6	sig.	
LSD=5%	3.8	diff.	2.3	diff.	2.8						3.4	diff.	2.3	diff.	2.8
1%	5.2		3.2		3.6						4.7		3.1		3.7

Table 17. Influence of Cutting Treatments on Number of Plants at Final Harvest

Bromegrass varied - alfalfa constant at 8 lbs.

Brome-grass in lbs. per acre	Number of Plants by Species (Average of 3 cultures on June 1)													
	Bromegrass					Alfalfa					Total			
	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X=5X
1	2.0	+0.7	2.3	+0.3	+0.3	17.3	--	18.7	-0.3	+1.4	19.3	+0.6	21.0	--	+1.7
2	3.7	+0.4	4.0	+1.3	+0.3	18.0	+1.3	19.3	-1.0	+1.3	21.7	+1.7	23.3	+0.3	+1.6
4	6.3	+0.6	6.7	+0.4	+0.4	18.3	+1.3	19.3	-2.1	+1.0	24.6	+1.0	26.0	+0.3	+1.4
5	6.0	+0.3	6.0	+0.7	--	18.0	+1.4	17.0	-1.4	+1.0	24.0	+1.7	23.0	-0.7	-1.0
6	8.7	--	7.7	--	-1.0	21.0	-0.6	19.3	+2.0	-1.7	29.7	-0.6	27.0	+2.0	-2.7
7	8.3	-0.4	9.0	-1.3	+0.7	19.0	+1.0	18.0	-1.0	-1.0	27.3	+0.6	27.0	-2.3	-0.3
8	10.7	+0.4	9.3	+0.6	-1.4	19.0	--	18.0	+1.4	-1.0	29.7	+0.4	27.3	+2.0	-2.4
9	12.0	-0.7	11.7	-0.3	-0.3	19.3	+0.7	16.7	-0.3	-2.6	31.3	--	28.4	-0.6	-2.9
10	11.7	+2.0	12.7	--	+1.0	18.0	+1.4	17.3	+0.7	-0.7	20.7	+3.4	30.0	+0.7	+0.3
RE_9=5%	1.8	no	3.6	no significant difference							2.9	no sig. diff.			
1%	2.6	sig.	5.1								4.0				
LSD=5%	1.6	diff.	3.2								2.5				
1%	2.2		4.5								3.5				

Table 18. Influence of Cutting Treatments on Number of Plants at Final Harvest

Ladino Clover varied - alfalfa constant at 8 lbs., bromegrass at 3 lbs.

Ladino Clover in lbs. per acre	Number of Plants by Species (Average of 3 cultures on June 1)												
	Ladino Clover				Alfalfa				Bromegrass				
	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
1/8	2.0	+0.3	1.7	+0.4	-0.3	16.3	+0.6	16.3	--	--	5.7	+1.0	5.0	+1.3	-0.7
1/4	3.7	+0.7	2.0	--	-1.7	18.3	-1.0	15.0	+0.3	-3.3	6.0	+0.3	5.0	+0.3	-1.0
1/2	4.5	--	4.3	--	--	18.7	--	18.3	+2.0	-0.4	5.7	+0.7	3.7	-0.3	-2.0
3/4	5.7	--	5.3	+0.6	-0.4	18.3	-0.4	19.0	--	+1.0	5.3	+1.3	4.7	-0.6	-0.6
1	9.0	+1.0	5.3	-0.4	-3.7	19.3	+1.6	19.7	+0.7	+0.4	6.0	+0.7	8.7	+4.0	+2.7
2	16.3	+1.3	12.7	+0.4	-3.6	20.7	+0.7	18.0	--	-2.7	5.3	+0.3	4.3	--	-1.0
3	23.3	-1.4	20.0	-3.7	-3.3	20.7	+1.7	19.7	+1.7	-1.0	6.0	+1.3	4.3	--	-1.7
4	23.0	-5.3	32.7	+2.7	+9.7	18.7	+1.7	17.3	+1.6	-1.4	5.0	-0.3	4.3	+0.6	-0.7
5	37.3	-0.7	30.0	-3.7	-7.3	19.3	+1.0	17.3	+3.0	-2.0	5.3	+0.6	5.0	+1.0	-0.3
RE_9=5%	5.0	no	3.3	no		no significant difference					no sig. diff.				
1%	7.0	sig.	4.6	sig.											
LSD=5%	4.4	diff.	2.9	diff.	2.6										
1%	6.1		4.0		3.5								2.2		no sig.
													3.0		diff.

Table 18.

Total				
5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
24.0	+2.0	23.0	+1.7	-1.0
28.0	--	22.0	+0.6	-6.0
28.7	+0.7	26.3	+1.7	-2.4
29.3	+0.9	29.3	--	--
34.3	+3.3	33.7	+4.3	-0.6
42.3	+2.3	35.0	+0.4	-7.3
50.0	+1.6	44.0	-2.0	-6.0
46.7	-3.9	54.3	+4.9	+7.6
62.0	+1.0	52.3	+0.3	-9.7
6.8	no	6.9	no sig. diff.	
9.5	sig.	9.6		
6.0	diff.	6.0		
8.2		8.3		

Table 19. Influence of Cutting Treatments on Number of Plants at Final Harvest

Red clover varied, alfalfa constant at 8 lbs., Ladino at 1 lb., bromegrass at 3 lbs.

Red Clover in lbs. per acre	Number of Plants by Species (3 pot average on 6-1)													
	Red Clover					Alfalfa					Ladino Clover			
	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
1	2.0	-0.3	3.0	+0.3	+1.0	17.0	+4.0	13.3	+2.6	-3.7	8.0	+0.7	7.7	-0.3	-0.3
2	3.0	-1.3	5.7	+0.7	+2.7	18.3	+3.0	15.3	+2.6	-3.0	8.3	+0.6	8.7	+4.0	+0.4
4	9.7	+1.0	7.0	+0.3	-2.7	14.3	+2.6	16.0	+2.7	+1.7	6.3	+1.6	7.0	+3.0	+0.7
6	12.3	+2.3	12.0	+1.0	-0.3	18.0	+5.0	16.0	+1.3	-2.0	7.3	+1.6	8.3	+2.0	+1.0
8	16.7	+2.4	14.7	+2.0	-2.0	16.7	+1.7	16.3	+4.3	-0.4	6.7	+2.0	7.0	+2.0	+0.3
10	14.3	+2.6	20.3	+2.0	+6.0	17.7	+5.4	15.7	+2.0	-2.0	7.0	-1.0	6.0	+1.3	-1.0
RE_6=5%	3.2	no	6.4	no	--	no	--	no sig. diff.			no significant difference				
1%	4.7	sig.	9.3	sig.	--	sig.	--								
LSD=5%	2.9	diff.	5.8	diff.	4.3	diff.	4.0								
	4.2		8.2		5.9		5.5								

Table 19.

Bromegrass					Total				
5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X	5X	Diff. from 3-1	2X	Diff. from 3-1	2X-5X
5.0	+1.3	7.3	+2.6	+2.3	32.0	+5.7	31.3	+5.3	-0.7
5.7	+0.7	6.0	+2.0	-0.3	35.8	+2.6	35.7	+9.3	+0.4
4.7	-0.3	4.7	-0.3	--	35.0	+5.3	34.7	+5.7	-0.3
4.3	-0.7	4.3	+0.6	--	42.0	+8.3	40.7	+5.0	-1.3
4.3	+0.3	6.7	+2.7	+2.4	44.3	+6.3	44.7	+11.0	+0.4
5.3	+1.6	6.0	+1.3	+0.7	44.3	+8.6	48.0	+6.6	+3.7
no significant diff.					no sig. diff.	-- 6.5 8.9	--	no sig. diff.	

5. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Single Species

The yield of roots from the individual species are given in Table 20. Under five cuttings the yield of bromegrass roots was significantly greater than the yield from other species. Alfalfa root yields were greater than red and Ladino clover and Ladino clover was slightly higher than red clover.

Two cuttings produced significantly higher root yields between species than five cuttings. Ladino clover produced a higher yield under five cuttings while the other species had higher yields from two cuttings. Frequent cutting was more severe on the development of alfalfa and red clover roots as shown in Figure 11.

Table 20. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Single Species
Dry weight yield in grams - average of 3 cultures

Species	5X	2X	Difference
Alfalfa	27.10	56.00	+28.90
Bromegrass	34.40	43.65	+9.25
Ladino clover	18.50	14.55	-3.95
Red clover	17.50	30.42	+12.92
RE_4=5%	2.94	9.43	
1%	4.56	14.63	
LSD=5%	2.79	8.96	5.92
1%	4.23	13.57	8.31

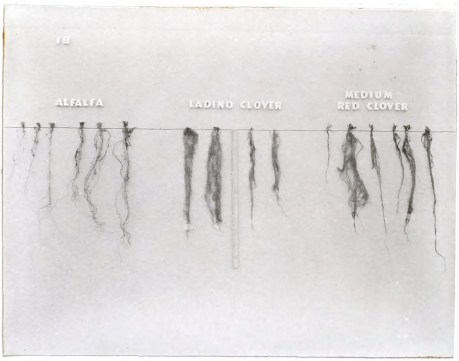


Figure 11. Influence of cutting treatments on the root development of legume species

Left: Alfalfa 8 lbs. Cut 5 times (3 roots), cut twice (3 roots)
Center: Ladino Clover 1 lb. Cut 5 times (2 roots), cut twice (2 roots)
Right: Red Clover 8 lbs. Cut 5 times (3 roots), cut twice (3 roots)

Alfalfa-Bromegrass Mixtures

The alfalfa seeding rate was varied in this series. The yield of roots from the two species are given in Table 21. The ten pound (10 lbs. of alfalfa, 3 lbs. of bromegrass (10-3)) rate of alfalfa gave the highest total yield of roots under five cuttings. The highest yield of alfalfa roots in the two cutting group was at the twenty pound (20-3) rate of alfalfa. Total root yields were significantly greater from two cuttings at all rates of alfalfa.

The left side of Figure 12 illustrates that five cuttings retarded alfalfa root development at all rates of seeding. The difference in yield of alfalfa roots between cutting treatments was highly significant at all but the one pound rate.

Bromegrass root yields were highest in the two cutting group at the two pound rate, but were not significantly different when cut five times. With an increase in the seeding rate of alfalfa, the total yield of roots tended to increase under five cuttings and increased generally under two cuttings. Alfalfa yields increased markedly up to the six pound rate (6-3) of alfalfa, and then leveled off, but showed a general increase under two cuttings. Due to the competitive effects of alfalfa under two cuttings bromegrass yields decreased as the rate of alfalfa increased. These relationships are shown in Figure 13.

Table 21. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Alfalfa-Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Alfalfa in lbs. per acre*	Alfalfa			Bromegrass			Total		
	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
1	3.73	7.30	3.63	19.15	26.50	7.35	22.88	33.80	10.92
2	5.00	9.40	4.40	23.72	39.70	15.98	28.72	49.10	20.38
4	6.55	21.40	14.85	23.05	31.80	8.75	29.60	53.20	23.60
6	10.65	28.55	19.90	20.20	35.50	15.30	30.85	64.05	33.20
8	16.50	21.90	5.40	22.28	21.25	-1.03	38.78	43.15	5.37
10	16.93	29.62	12.69	23.00	20.20	-2.80	39.93	49.82	9.89
12	16.10	31.03	14.93	15.60	25.40	9.80	31.70	56.43	24.73
16	16.50	29.00	12.50	17.00	26.15	9.15	33.50	55.15	21.65
20	16.90	42.30	25.40	18.35	24.10	5.75	35.25	66.40	31.15
RE_g=5%	1.93	4.67		no	4.30		3.23	7.13	
1%	2.69	6.52		sig.	6.00		4.51	9.95	
LSD=5%	1.70	4.11	3.02	diff.	3.78	2.96	2.84	6.27	4.68
1%	2.34	5.66	4.06		5.20	3.97	3.91	8.63	6.28

*Alfalfa varied, bromegrass constant at 3 lbs.

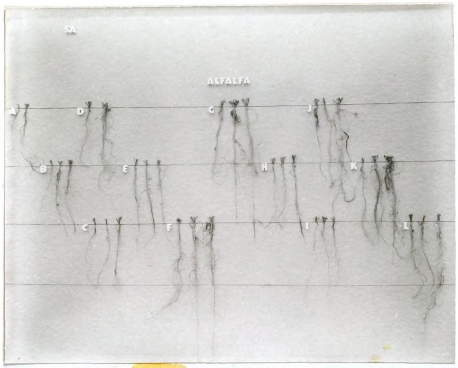


Figure 12. Influence of varied rates of alfalfa and bromegrass and two cutting treatments on alfalfa root development

Left: Alfalfa rate varied, bromegrass at 3 lbs.
A-C cut five times, D-F cut twice
A & D 1 lb., B & E 8 lbs., C & F 20 lbs.

Right: Bromegrass rate varied, alfalfa at 8 lbs.
G-I cut five times, J-L cut twice
G & J 1 lb., H & K 6 lbs., I & L 10 lbs.

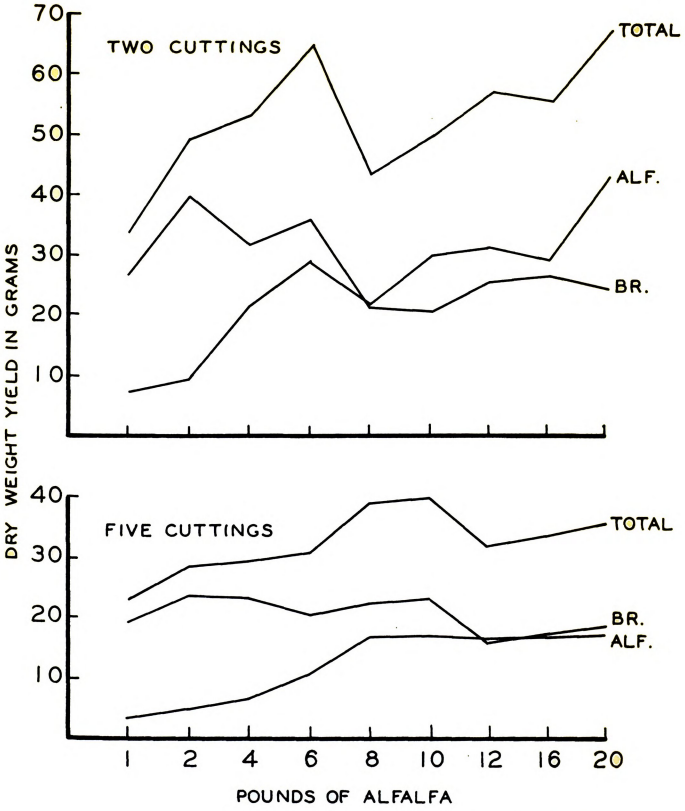


Figure 13. Root yield as influenced by variation in the seeding rate and two different cutting treatments. Alfalfa-bromegrass mixtures.

Bromegrass-Alfalfa Mixtures

The yield of roots from these two species are in Table 22. The nine pound (9 lbs. of bromegrass and 8 lbs. of alfalfa (9-8)) rate of bromegrass gave the highest total yield of roots under five cuttings, with the highest yield under two cuttings at the six pound (6-8) rate. Total root yields from two cuttings in comparison to five were greater at all rates of seeding.

The difference in root yield between cutting treatments was significantly greater from two when compared with five cuttings at rates above four pounds of bromegrass. Alfalfa root yields were not significant between rates but root yields from two cuttings were significantly greater than from five cuttings at all rates of seeding. The right half of Figure 12 shows that the more vigorous alfalfa roots developed at the lower rates of bromegrass. Bromegrass was very competitive to alfalfa under five cuttings.

As the rate of seeding bromegrass increased the total yield of roots increased generally under both cutting systems. Bromegrass root production followed a similar trend and alfalfa root yield decreased generally as the rate of bromegrass increased. (Figure 14)

Ladino Clover, Alfalfa and Bromegrass Mixtures

The yield of roots from mixtures with varied rates of Ladino clover are shown in Table 23. Total yields from both cutting systems were highly significant between rates

Table 22. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Bromegrass-Alfalfa Mixtures
Dry weight yield in grams - average of 3 cultures

Bromegrass in lbs. per acre*	Bromegrass			Alfalfa			Total		
	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
1	8.20	11.15	2.95	15.40	25.45	10.05	23.60	36.60	13.00
2	17.50	16.00	-1.50	12.25	28.85	16.60	29.75	44.85	15.10
4	20.60	19.40	-1.20	11.05	26.40	15.35	31.65	45.80	14.15
5	16.80	20.70	+3.90	13.10	21.80	8.70	29.90	42.50	12.60
6	20.00	36.60	16.60	10.85	23.10	12.25	30.85	59.70	28.85
7	22.90	34.10	11.20	11.60	22.50	10.90	34.50	56.60	22.10
8	28.40	34.10	5.70	10.50	21.80	11.30	38.90	55.90	17.00
9	34.40	32.30	-2.10	9.60	13.30	3.10	44.00	45.60	1.60
10	20.50	35.55	15.05	11.90	20.00	8.10	32.40	56.55	24.15
RE_9=5%	2.34	5.70		no sig. diff.			2.51	8.68	
1%	3.27	7.95					3.49	12.10	
LSD=5%	2.06	5.01	3.70			3.02	2.21	7.62	5.39
1%	2.83	6.80	4.96			4.06	3.04	10.49	7.24

*Bromegrass varied, alfalfa constant at 8 lbs.

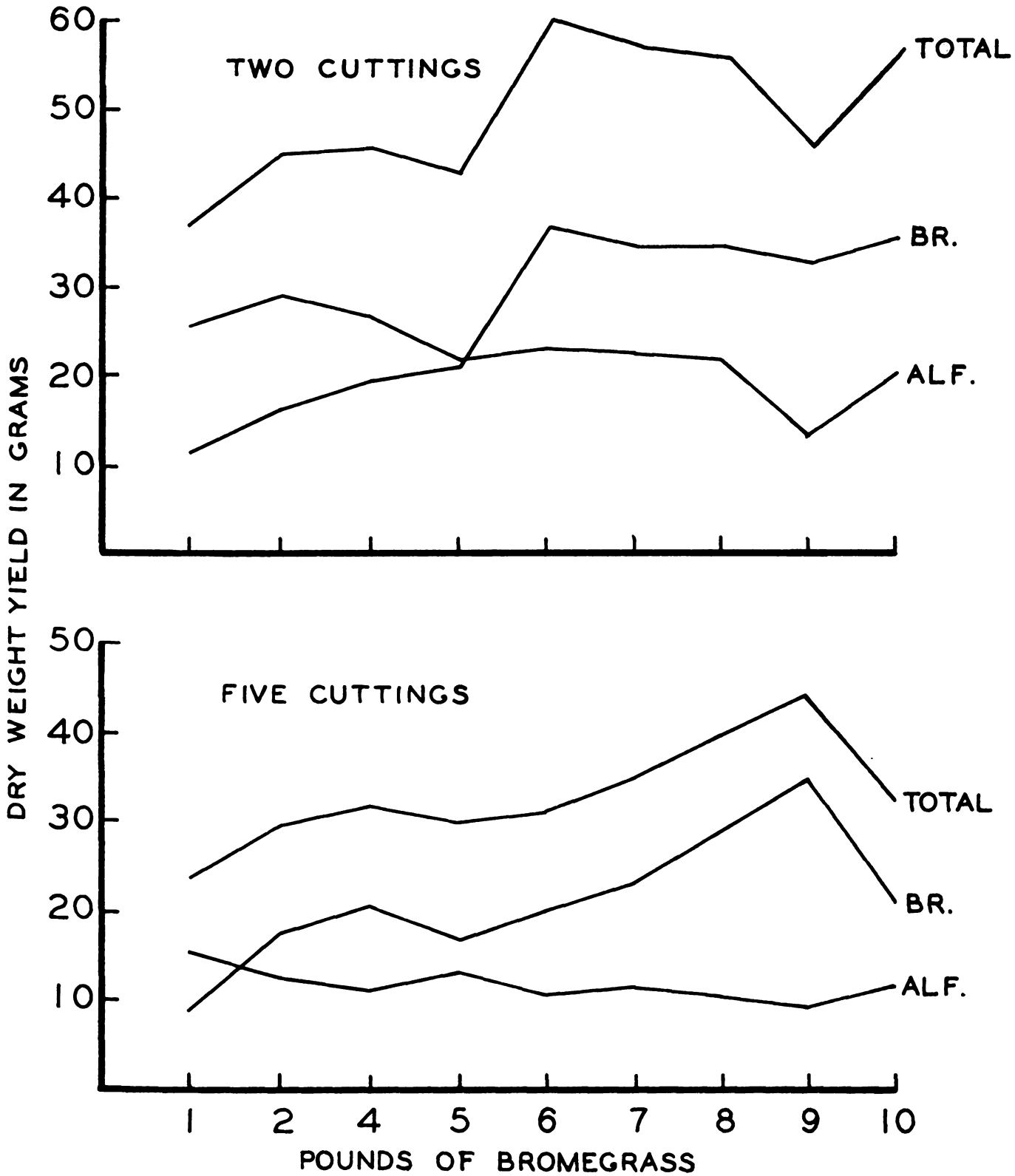


Figure 14. Root yield as influenced by variation in the seeding rate and two different cutting treatments. Alfalfa-bromegrass mixtures.

of Ladino clover. The highest total yield of roots under five cuttings was at the lowest rate of Ladino clover, while the maximum rate of Ladino had the next highest yield. Ladino roots were a minor portion of the highest total yield, but a major portion of the next highest total yield. The highest total yield from two cuttings was at the lowest rate of Ladino clover.

Differences in yields of Ladino roots from both cuttings were highly significant between rates of Ladino, and significantly higher yields came from the group cut five times rather than from the group cut twice. Ladino clover root development was not encouraged under two cuttings. (Figure 15) The root systems from the plants cut five times were more vigorous at all rates.

Alfalfa root yields were not significantly different in either of the cutting groups between rates of seeding, but greater yields were obtained from the two cutting system. Figure 15 shows that the roots from plants cut frequently were less vigorous. As the rate of Ladino clover increased the vigor of individual alfalfa roots was reduced under both cutting treatments.

Bromegrass roots from mixtures cut five times were significantly different between rates of seeding, with the highest yield at the lowest rate of Ladino. The yield from two cuttings was greater at all rates of Ladino clover.

The variation in total root yields between seeding

Table 33. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Table 23. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Ladino clover, alfalfa and bromegrass mixtures
Dry weight yield in grams - average of 3 cultures

Ladino Clover in lbs. per acre*	Ladino Clover			Alfalfa			Bromegrass			Total		
	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
1/8	0.83	1.43	+0.60	9.30	24.50	15.20	26.33	52.00	25.67	36.46	77.93	41.47
1/4	1.21	1.07	-0.14	8.70	17.92	9.22	17.30	29.50	12.20	27.21	48.49	21.28
1/2	2.55	1.85	-1.70	8.41	17.65	9.24	16.29	18.60	1.31	27.25	38.10	10.85
3/4	3.20	1.71	-1.49	11.33	20.40	9.07	15.03	26.27	11.24	29.56	48.38	18.82
1	4.65	2.15	-2.50	8.64	24.70	16.06	14.70	36.60	21.90	27.99	63.45	55.46
2	3.76	2.85	-0.91	6.47	15.80	9.33	9.75	20.82	10.07	19.98	39.47	19.49
3	7.15	3.26	-3.89	5.66	19.50	13.84	8.95	20.20	11.25	21.76	42.96	21.20
4	6.95	3.40	-3.55	6.33	19.60	13.27	11.65	14.95	3.30	24.93	37.95	13.02
5	15.29	6.45	-8.84	7.95	15.93	7.98	10.70	29.10	18.40	33.94	51.48	17.54
RE_9=5%	1.28	0.68		no	no		1.90	no		2.07	8.90	
1%	1.79	0.95		sig.	sig.		2.65	sig.		2.89	12.42	
LSD=5%	1.13	0.60	0.87	diff.	diff.	2.57	1.67	diff.	5.28	1.82	7.83	5.47
1%	1.55	0.83	1.17			3.45	2.30		7.10	2.51	10.78	7.34

*Ladino clover varied, alfalfa constant at 8 lbs., bromegrass at 3 lbs.

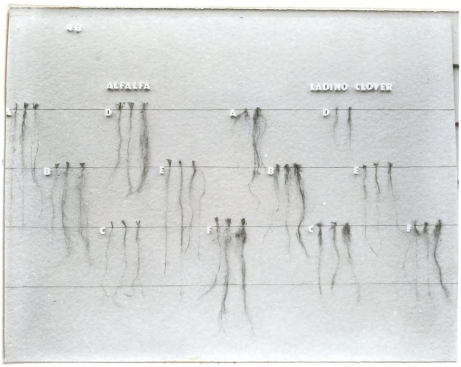


Figure 15. Influence of varying the rate of Ladino clover and cutting treatments on the development of legume roots

Ladino clover varied, alfalfa at 8 lbs., bromegrass at 3 lbs.
A-C cut five times, D-F cut twice
Ladino clover rates A-D 1/8 lb., B & E 1 lb., C & F 5 lbs.

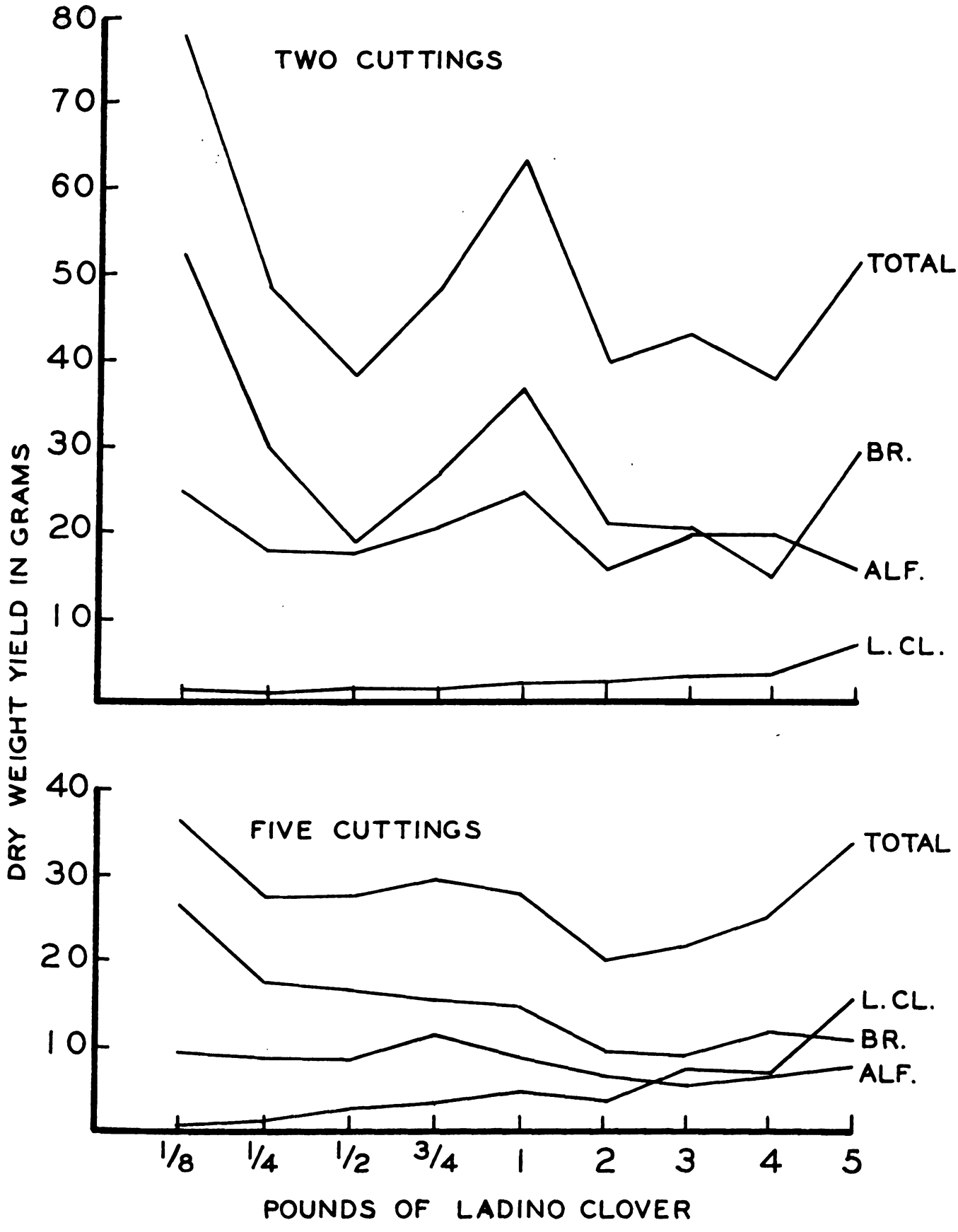


Figure 16. Root yield as influenced by variation in the seeding rate and two different cutting treatments. Ladino clover, alfalfa and bromegrass mixtures.

rates and cutting treatment were greater from these mixtures than in the alfalfa and bromegrass series. At rates above one pound, Ladino clover had a marked effect on total yield and yield from the other two species. (Figure 16)

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixtures

Root yields from this series are shown in Table 24. Total yield from the five cutting system were not significant between rates of seeding, and the highest yield from two cuttings was at the lowest rate of seeding. As the rate of red clover increased total yield of the mixture tended to decrease, with higher yields obtained from the mixtures cut twice.

Root development of the three legume species are shown in Figures 17 and 18. Increased red clover rates and frequent cutting reduced the vigor of alfalfa roots but neither variable affected the Ladino clover. Red clover roots gained in vigor as the rate of seeding increased. (Figure 17)

In Figure 18 the competitive effects of other species on Ladino clover root development are shown when the mixtures were cut twice. The development of red clover and alfalfa roots were about equal at all rates of seeding.

Red clover was never a major portion of the mixtures. Total yield of roots was more affected by the decrease in root yield of the other mixture components than

Table 24. The Influence of Seeding Rate and Two Different Cutting Treatments on the Yield of Roots

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixtures
Dry weight in grams - average of 3 cultures

Red Clover in lbs. per acre*	Red Clover			Alfalfa			Ladino Clover			Bromegrass			Total		
	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.	5X	2X	Diff.
1	1.70	3.40	1.70	9.35	20.85	11.50	9.70	2.97	-6.73	14.40	60.70	46.30	35.15	87.92	52.77
2	2.50	5.20	2.70	8.30	13.55	5.25	4.00	5.58	+1.58	18.15	48.45	30.30	32.95	72.78	39.83
4	6.30	6.50	0.20	7.60	13.85	6.25	5.05	2.90	-2.15	14.25	22.73	8.48	33.20	45.98	12.68
6	6.45	7.20	0.75	7.10	14.65	7.55	2.68	2.55	-0.13	14.17	26.42	12.25	30.40	50.82	20.42
8	8.95	14.80	5.85	7.62	20.45	12.83	2.45	4.45	+2.00	13.20	27.05	13.85	32.22	66.75	34.53
10	9.27	14.60	5.33	8.12	12.20	4.08	3.98	2.45	-1.53	11.10	27.55	16.45	32.47	56.80	24.33
RE_6=5%	no	1.04		no sig. diff.			no sig. diff.			no sig. diff.			no	15.05	
1%	sig.	1.52											sig.	22.01	
LSD=5%	diff.	0.95	3.20			4.10			1.86			8.00	diff.	13.70	9.48
1%		1.34	4.40			5.70			2.50			11.00		19.49	12.89

*Red clover varied, alfalfa constant at 8 lbs., Ladino clover at 1 lb., bromegrass at 3 lbs.

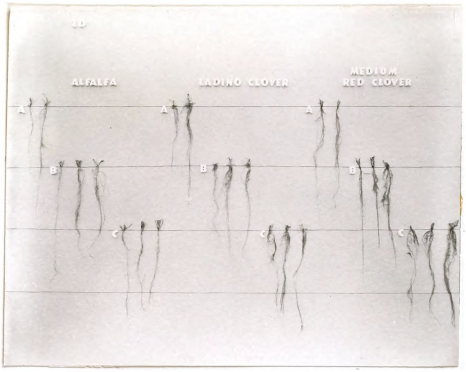


Figure 17. Influence of varying the rate of red clover and five cuttings on the development of legume roots

Alfalfa A-C 8 lbs., Red Clover A 1 lb.
Ladino Clover A-C 1 lb., B 6 lbs.
C 10 lbs.

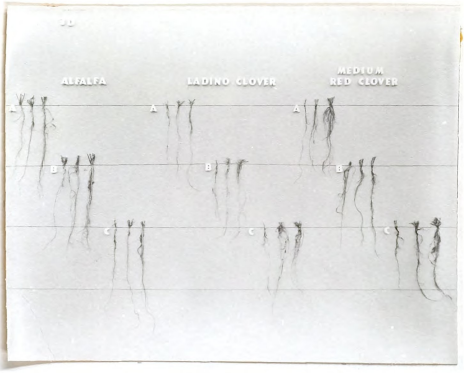


Figure 18. Influence of varying the rate of red clover and two cuttings on the development of legume roots

Alfalfa A-C 8 lbs., Red Clover A 1 lb.
Ladino Clover A-C 1 lb., B 6 lbs.
C 10 lbs.

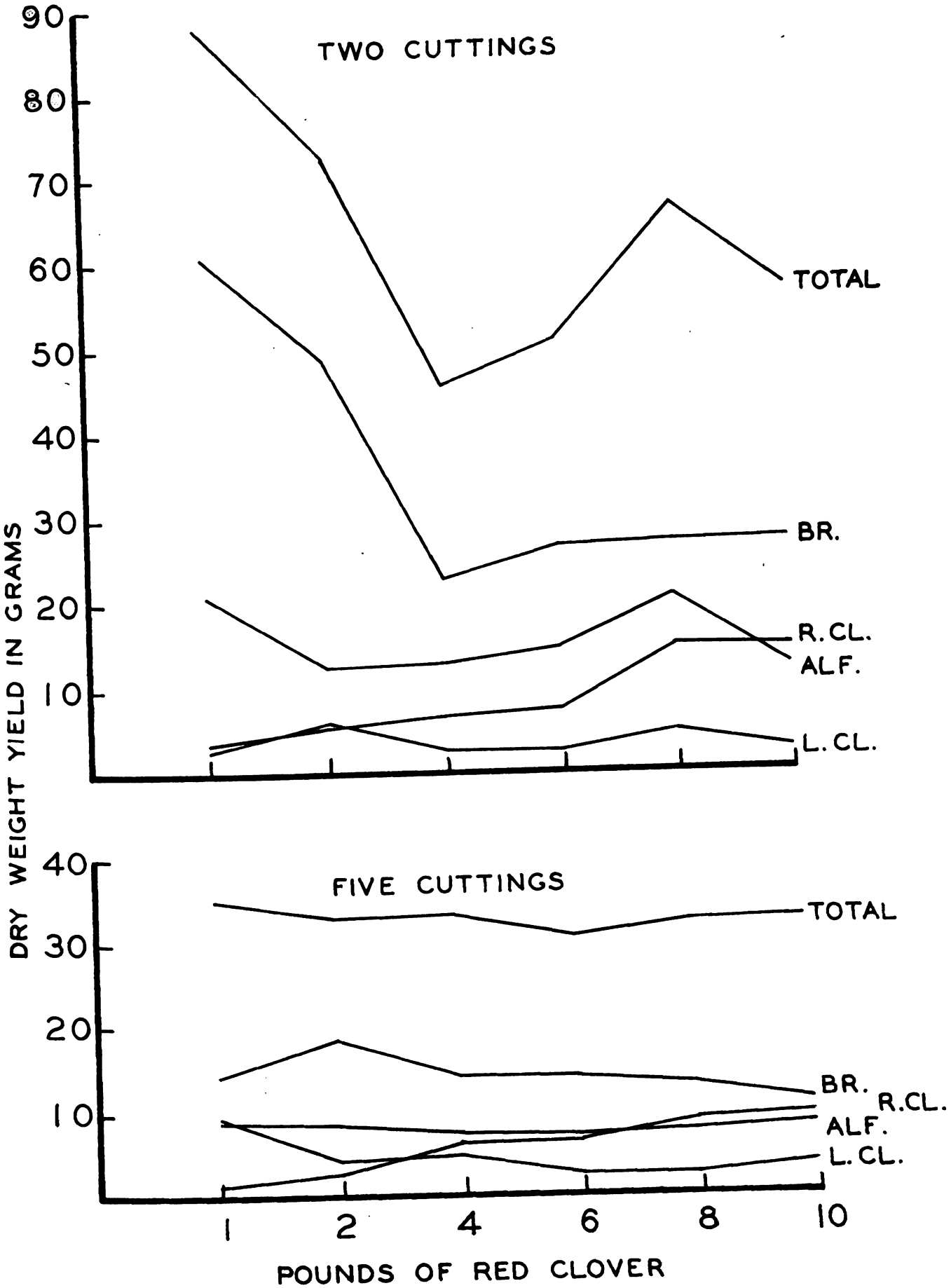


Figure 19. Root yield as influenced by variation in the seeding rate and two different cutting treatments. Red clover, alfalfa, Ladino clover and bromegrass mixtures.

by the increase of red clover root yields as rates of red clover increased. (Figure 19)

Plate I shows representative root cross-sections taken from the selected legume roots at the end of the growing period. A wide variation in diameter size can be seen between roots from the different rates of seeding and between cutting treatments.

Table 35 presents the range of diameters of the various cross sections, some of which are not shown on Plate I. At all rates of alfalfa, alone and in mixture, the frequent cutting reduced the diameter of the cross sections of roots when compared to two cuttings. As the rate of alfalfa or bromegrass increased the diameter of the roots tended to decrease under both cutting treatments. Where alfalfa was seeded alone it reached a larger diameter than when in mixture at the same rate.

Ladino clover had a slightly larger root cross section at the one pound rate seeded alone and in mixture when cut twice. At the minimum and maximum rates, the larger cross sections were from the five cutting treatment. The diameters tended to decrease under both cutting treatments until the maximum rate of seeding and were then only slightly larger than the lower rates.

Red clover roots were largest in both cutting treatments when seeded alone. Frequency of cutting did not have as marked effect on these roots as on alfalfa. The

Table 25. Diameter of Legume Root Cross Sections from Representative Samples

Species	Mixture	Seeding Rate lbs.	Diameter Range m.m. 5 times	2 times
Alfalfa	alone	8	1.01-3.13	1.98-3.89
	with 3 lbs. bromegrass	1	1.01-2.59	0.76-4.14
	" " " "	8	1.01-2.45	1.24-4.02
	" " " "	20	1.15-2.05	1.62-4.02
	bromegrass 1 lb.	8	1.01-2.75	1.94-3.12
	" 6 lbs.	8	0.84-1.78	1.67-4.03
	" 10 lbs.	8	0.78-1.97	0.93-4.07
Ladino Clover	alone	1	0.72-1.22	1.08-1.30
	with 8 lbs. alfalfa, 3 lbs. brome-grass	1/8	0.97-1.08	0.54-0.68
		1	0.68-0.97	0.61-1.06
		5	1.08-1.41	0.72-1.12
Red Clover	alone	8	1.01-2.20	1.12-2.95
	with 8 lbs. alfalfa, 3 lbs. brome-grass, 1 lb. Ladino clover	1	1.01-1.44	0.68-1.26
		6	0.93-1.51	0.72-1.30
		10	0.74-1.38	0.65-2.24

Plate I. Influence of Two Different Cutting Treatments on the Diameter of Legume Roots

The roots shown in this plate are representative of the diameter range as presented in Table 25. Enlargement 35X. Roots on the left side were from cultures cut five times; right side from cultures cut twice.

1 & 2 Alfalfa seeded at 1 lb, bromegrass at 3 lbs.

3 & 4 Alfalfa seeded alone at 8 lbs.

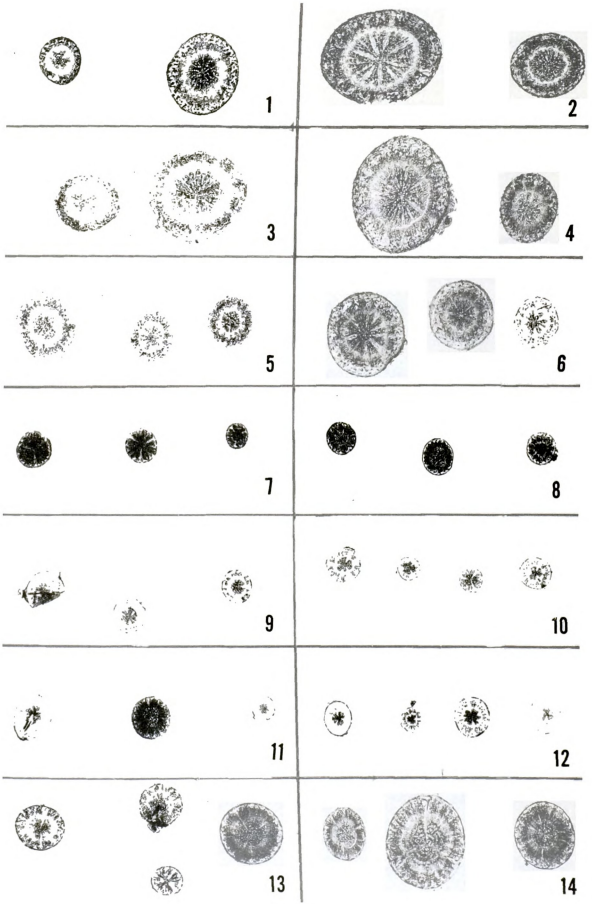
5 & 6 Alfalfa seeded at 20 lbs, bromegrass at 3 lbs.

7 & 8 Ladino clover seeded alone at 1 lb.

9 & 10 Red Clover seeded at 1 lb, alfalfa at 8 lbs, Ladino clover at 1 lb, and bromegrass at 3 lbs.

11 & 12 Red clover seeded at 6 lbs, other species as in #9 & 10 above.

13 & 14 Red clover seeded alone at 8 lbs.


1
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highest rate of red clover produced larger cross sections in the two cutting treatments.

Discussion

This experiment was conducted under controlled conditions in the greenhouse where the supply of moisture and nutrients were plentiful, and temperatures were favorable for rapid development of forage species. The major limitation was the relatively short duration of the growth period. However, results of this experiment illustrate the principles of competition between species in mixtures and how they perform under two systems of cutting.

The beginning premise of the experiment was that seeding rates used on farms were too high within the limits of recognized cultural practices, but that higher rates of seeding may be necessary for those seedings to be pastured. It was also considered that more species are used in forage mixtures than may be ideal in terms of providing management practices that will meet optimum conditions for the individual mixture components.

The work of Blaser, et al (2) has indicated the competitive effects of species seedlings on one another when in mixtures. Their results give valid reason to limit mixtures to only two or three species, and these should have similar management requirements.

In this experiment the total yield of forage under

either cutting treatment was affected very little by having more than two species in the mixture, but root yields did increase under two cuttings as the number of species in the mixture increased. The increased rate of individual mixture components had less influence on total yields than the two different cutting treatments, with higher total yield of forage and roots produced by the mixtures that were cut twice.

The dependence of new growth on stored carbohydrates was seen in the results of this experiment. Other workers have reported decreasing yields of tops and roots and reduced carbohydrate levels from those plants cut frequently, often before storage reserves can be replenished. In this experiment the yield from alfalfa diminished following recovery periods of short duration, but gained when this period was lengthened to 22 days. However, Ladino clover, bromegrass and red clover continued to produce higher yields of forage with each successive cutting, until the final cutting which had only a ten day recovery period.

These results are contrary to the findings of Moran (11) in which the top yield of Ladino clover decreased sharply when cut to one and three inch levels at 14 day intervals for 42 days, with the sharpest decrease at the 1-inch height. He also found that carbohydrate levels were affected by height and frequency of cutting which act as a major factor in the regrowth of Ladino following cutting.

At the levels of cutting used in this experiment it is likely that Ladino clover was defoliated less than alfalfa or red clover. New leaves had already developed at nodes along the stolons, but leaflets had not expanded and the petioles had not elongated so that they were not removed at harvest. When alfalfa and red clover were cut, complete defoliation occurred. New growth had to come from crown buds, requiring a longer period for recovery, and was made at the expense of carbohydrate reserves. This was also true of Ladino clover and bromegrass, but because defoliation was not complete at harvest, photosynthesis was probably not interrupted, at least to the degree as in alfalfa and red clover.

Ladino clover was the only species in this experiment to have more total root yield under frequent cutting. This may be explained by the work of Stewart and Bear (15) who found that starch replenishment commenced 11 days after cutting and the original level was reached in about 17 days. This may also be related to the shading and other competitive effects of the component species which reduced top and root yields of Ladino in the two cutting treatment.

Under field conditions, when mixtures including alfalfa are used for pasture it would be best to use a management system which provides for rapid grazing of the forage, followed by a recovery period sufficiently long to replenish carbohydrates as well as top growth. The inclusion of

Ladino clover will not contribute greatly to total yield. It would appear that the use of Ladino clover in those seedings primarily for hay production may be of limited value because of the competitive effects of the more aggressive alfalfa and bromegrass under these conditions. Red clover contributes very little to increasing total yield, and if used at equal rates with alfalfa, may retard the development of alfalfa plants in the mixture.

Summary and Conclusions

Alfalfa, red clover, Ladino clover and bromegrass were seeded alone and at varying seeding rates in mixtures in the greenhouse, and subjected to two and five cutting treatments.

1. The number of plants of the varied species and total plant numbers increased in all mixtures with increasing rates of the individual species.
2. Total yield from all mixtures were greater from two cuttings than from five. Under five cuttings, mixtures produced higher total yields than species seeded alone. Only four mixtures when cut twice produced more than alfalfa seeded alone, and one-third of the mixtures produced less than red clover seeded alone.
3. Highest total yields under five cuttings

generally came from the higher rates of seeding. The medium rates of seeding produced the higher yield under two cuttings. Cutting treatment had more effect on the yield of forage than did the rate of seeding.

4. Ladino clover was least affected by frequent cutting, followed by bromegrass, red clover and alfalfa. Alfalfa forage yield and its proportion of the yield were markedly reduced when the recovery period was short. This pattern was also shown in the production of roots.
5. The number of plants at final harvest had not been affected by cutting treatments.
6. Cutting treatments had a greater effect on the vigor and yield of root systems than the varying seeding rate of individual species.
7. The results of this study indicate performance trends when the rate of individual species are varied in mixtures and two levels of cutting are used under the controlled conditions of the greenhouse. The performance pattern would be varied by field environment, but the same general trends should be expected.

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APPENDIX

Table I. The Influence of Seeding Rates on Yield of Forage Under Two Different Cutting Treatments

Single Species
Dry weight yield in grams, average of 3 cultures

Pasture Treatment - 5 cuttings

Species	March 28	April 11	May 2	May 22	June 1	Total
Alfalfa	1.57	1.18	4.99	10.17	1.90	19.81
Bromegrass	0.90	1.50	3.28	7.50	4.70	17.88
Ladino Clover	0.03	0.43	3.18	8.47	4.17	16.28
Red Clover	0.52	1.50	4.55	10.23	3.78	20.58
						no sig. dif.

Hay Treatment - 2 cuttings

Species	May 8	June 1	Total
Alfalfa	30.97	24.47	55.44
Bromegrass	19.50	10.33	29.83
Ladino Clover	6.57	9.30	15.87
Red Clover	22.50	19.30	41.80
RE_4 = 5%			15.50
1%			24.10
LSD = 5%			14.70
1%			22.30

Table IIa. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Alfalfa - Bromegrass Mixture
Dry weight yield in grams - average of 3 cultures

Pasture Treatment - 5 cuttings

Species*	Alfalfa					Species Total	Bromegrass					Species Total	Mixture Total	Total seeding rate
Date of Harvest	3-28	4-11	5-2	5-22	6-1		3-28	4-11	5-2	5-22	6-1			
lbs. of Alfalfa														lbs.
1	0.25	0.18	0.59	0.85	0.13	2.00	0.57	1.06	2.66	6.10	4.25	14.63	16.64	4
2	0.48	0.37	1.15	1.90	0.20	4.10	0.62	1.01	3.13	7.52	4.80	17.08	21.18	5
4	1.33	0.72	1.59	2.90	0.30	6.84	0.83	1.33	3.09	7.40	4.22	16.87	23.71	7
6	1.50	0.63	2.53	3.40	0.62	8.68	0.93	0.85	2.25	4.22	3.00	11.25	19.93	9
8	1.28	0.68	3.60	4.70	0.98	11.24	0.57	0.82	2.14	5.40	3.40	12.33	23.57	11
10	0.90	0.37	3.40	4.12	0.75	9.54	0.37	0.67	1.63	5.32	3.20	11.19	20.74	13
12	2.23	0.83	4.11	4.80	1.18	13.15	0.55	0.58	1.76	3.92	2.30	9.11	22.26	15
16	3.53	1.40	5.19	6.67	1.15	17.94	0.90	0.83	1.82	3.96	2.23	9.74	27.67	19
20	2.56	0.97	5.10	4.13	1.20	13.96	0.60	0.55	2.19	4.52	2.80	10.66	24.62	23
RE_9=5%						5.75						5.42	6.8	
1%						8.03						7.56	9.5	
LSD=5%						5.06						4.76	6.0	
1%						6.96						6.56	8.2	

*Alfalfa varied, bromegrass constant at 3 lbs.

Table IIb. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Alfalfa - Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Hay Treatment - 2 cuttings

Species*	Alfalfa		Species Total	Bromegrass		Species Total	Mixture Total	Total Seeding Rate per acre
Date of Harvest	5-8	6-1		5-8	6-1			
lbs. of Alfalfa								lbs.
1	4.90	2.90	7.80	8.67	6.90	15.57	23.37	4
2	7.83	5.20	13.03	18.50	10.10	28.60	41.63	5
4	12.61	8.87	21.48	12.67	7.10	19.77	41.25	7
6	20.62	15.10	35.72	17.18	8.50	25.68	61.40	9
8	13.20	12.00	25.20	9.61	5.10	14.71	39.91	11
10	18.20	14.40	32.60	10.21	4.50	14.71	47.31	13
12	27.25	14.20	41.45	13.68	5.10	18.78	60.23	15
16	19.93	13.60	33.53	14.07	6.60	20.67	54.20	19
20	19.70	17.70	37.40	9.14	5.60	14.74	52.14	23
RE_9=5%			17.49			no	21.70	
1%			24.42			sig.	30.30	
LSD=5%			15.39			dif.	19.10	
1%			21.19				26.30	

*Alfalfa varied, bromegrass constant at 3 lbs.

Table IIIa. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Bromegrass - Alfalfa Mixture
Dry weight yield in grams - average of 3 cultures

Pasture Treatment - 5 cuttings

Species*	Bromegrass					Species Total	Alfalfa					Species Total	Mixture Total	Total Rate of Seeding
Date of Harvest	3-28	4-11	5-2	5-22	6-1		3-28	4-11	5-2	5-22	6-1			per acre
lbs. of Bromegrass														lbs.
1	0.21	0.38	0.89	1.88	1.17	4.53	1.80	1.15	5.35	6.93	1.20	16.43	20.96	9
2	0.41	0.69	1.71	5.23	3.22	11.26	1.18	0.69	3.34	4.03	0.62	9.86	21.12	10
4	1.10	1.03	2.66	6.17	3.82	14.78	1.23	0.53	3.15	3.97	0.58	9.46	24.24	12
5	1.07	1.07	2.76	4.73	2.25	11.88	1.77	1.07	4.08	3.27	0.68	10.87	22.75	13
6	1.27	1.57	3.80	6.80	3.58	17.02	1.80	0.61	3.64	3.58	0.75	10.38	27.40	14
7	0.97	1.33	3.83	6.63	3.27	16.03	1.10	0.71	3.54	3.18	0.68	9.21	25.24	15
8	1.20	1.37	3.50	5.82	3.20	15.09	1.17	0.29	2.64	3.08	0.50	7.68	22.77	16
9	2.73	1.69	5.21	8.70	4.30	22.63	2.00	0.58	3.65	2.61	0.55	9.39	32.02	17
10	1.73	1.27	4.07	7.35	3.80	18.22	1.57	0.68	3.35	3.08	0.65	9.33	27.55	18
RE_9=5%						7.06						no	7.50	
1%						9.85						sig.	10.40	
5%						6.21						dif.	6.60	
1%						8.55							9.10	

*Bromegrass varied, alfalfa constant at 3 lbs.

Table IIIb. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Bromegrass - Alfalfa Mixture
Dry weight yield in grams - average of 3 cultures

Hay Treatment - 2 cuttings

Species*	Bromegrass		Species Total	Alfalfa		Species Total	Mixture Total	Total Seeding Rate
Date of Harvest	5-8	6-1		5-8	6-1			per acre
lbs. of Bromegrass								lbs.
1	3.16	3.00	6.16	15.80	13.90	29.70	35.86	9
2	7.70	5.50	13.20	19.60	14.40	34.00	47.20	10
4	11.90	7.00	18.90	20.40	13.20	33.60	52.50	12
5	14.80	6.50	21.30	19.00	11.20	30.20	51.50	13
6	17.60	7.90	25.50	16.30	13.60	29.90	55.40	14
7	19.40	9.60	29.00	11.70	9.20	20.90	49.90	15
8	18.30	9.30	27.60	18.10	10.40	28.50	56.10	16
9	18.30	10.50	28.80	7.70	5.90	13.60	42.40	17
10	15.90	11.60	27.50	10.90	8.70	19.60	47.10	18
RE_9=5%			14.56			no sig. diff.		
1%			20.33					
LSD=5%			12.81					
1%			17.64					

*Bromegrass varied, alfalfa constant at 3 lbs.

Table IVa. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Ladino Clover, Alfalfa and Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Pasture Treatment - 5 cuttings

Species*	Ladino Clover					Species Total	Alfalfa					Species Total
Date of Harvest	3-28	4-11	5-2	5-22	6-1		3-28	4-11	5-2	5-22	6-1	
Lbs. of Ladino Clover												
1/8	0.03	0.11	0.37	1.23	0.37	2.11	1.60	1.13	3.27	3.42	0.50	9.92
1/4	0.02	0.08	0.54	1.42	0.48	2.54	1.40	0.65	3.66	3.84	0.80	10.35
1/2	0.06	0.13	1.12	2.03	0.93	4.27	2.70	1.28	5.10	4.98	0.62	14.68
3/4	0.08	0.22	1.40	3.36	1.25	6.31	2.47	1.16	3.59	3.87	0.70	11.79
1	0.18	0.51	2.31	4.06	1.70	8.76	3.17	1.37	3.41	3.64	0.70	12.29
2	0.15	0.86	3.08	5.50	2.50	12.09	1.90	1.00	2.64	3.18	0.70	9.41
3	0.24	0.69	4.03	7.24	2.90	15.10	1.43	0.48	2.19	1.54	0.45	6.08
4	0.28	1.10	4.53	9.50	3.20	18.61	2.00	0.88	2.20	1.86	0.53	7.47
5	0.41	1.46	6.33	8.24	3.60	20.04	1.70	0.68	2.46	1.64	0.53	7.01
RE_9=5%						5.49						5.42
1%						7.66						7.57
LSD=5%						4.83						4.77
1%						6.65						6.57

*Ladino clover varied, alfalfa constant at 8 lbs. and bromegrass at 3 lbs.

Table IVa.

Bromegrass					Specie Total	Mixture Total	Total Seeding Rate
3-28	4-11	5-2	5-22	6-1			
							lbs.
0.87	1.45	2.80	6.47	2.73	14.32	26.35	11 1/8
0.63	1.01	2.21	5.00	2.50	11.35	24.24	11 1/4
1.33	0.98	3.30	5.88	2.40	13.89	32.84	11 1/2
1.00	0.96	2.08	3.20	1.73	8.97	27.07	11 3/4
1.87	1.32	2.61	4.70	1.93	12.43	33.48	12
0.97	0.98	1.90	2.87	1.37	8.09	29.60	13
0.52	0.69	1.05	1.71	1.07	5.04	26.23	14
0.90	0.84	1.57	2.08	1.08	6.47	32.55	15
1.17	1.07	1.38	2.75	1.00	7.37	34.42	16
					5.29	8.80	
					7.38	12.30	
					4.65	7.70	
					6.40	10.70	

Table IVb. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Ladino Clover, Alfalfa and Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Hay Treatment - 2 cuttings

Species*	Ladino Clover		Species Total	Alfalfa		Species Total	Bromegrass		Species Total	Mixture Total	Total Seeding Rate
Date of Harvest	5-8	6-1		5-8	6-1		5-8	6-1			
lbs. of Ladino Clover											lbs.
1/8	0.17	0.35	0.52	11.83	8.83	20.66	7.40	6.77	14.17	35.35	11 1/8
1/4	0.33	0.38	0.71	8.90	6.67	15.57	11.00	9.53	20.53	36.81	11 1/4
1/2	1.08	0.80	1.88	15.57	8.43	24.00	10.13	3.57	13.70	39.58	11 1/2
3/4	1.21	0.82	2.03	18.83	9.87	28.70	18.10	7.20	25.30	56.03	11 3/4
1	1.48	0.79	2.27	16.37	11.13	27.50	16.23	7.93	24.16	53.93	12
2	2.03	1.87	3.90	8.93	8.10	17.03	10.10	5.23	15.33	36.26	13
3	5.17	3.23	8.40	12.63	7.73	20.36	11.37	4.27	15.64	44.40	14
4	5.93	3.67	9.60	13.53	9.93	23.46	13.10	6.57	19.67	52.73	15
5	8.53	5.90	14.43	15.57	8.13	23.70	8.40	4.43	12.83	50.96	16
RE_9=5%			3.44			no			no sig. diff.		
1%			4.81			sig.					
LSD=5%			3.03			diff.					
1%			4.17								

*Ladino clover varied, alfalfa constant at 8 lbs. and bromegrass at 3 lbs.

Table Va. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Pasture Treatment - 5 cuttings

Species*	Red Clover					Species Total	Alfalfa					Species Total
Date of Harvest	3-28	4-11	5-2	5-22	6-1		3-28	4-11	5-2	5-22	6-1	
lbs. of Red Clover												
1	0.10	0.17	0.51	1.03	1.20	3.01	2.00	0.80	3.21	2.90	0.55	9.46
2	0.17	0.24	0.85	1.81	1.45	4.52	1.10	0.50	2.86	2.74	0.70	7.90
4	0.42	0.62	2.05	3.11	1.40	7.60	0.97	0.55	2.04	1.94	0.40	5.90
6	0.22	0.49	2.23	3.53	1.50	7.97	1.00	0.50	2.19	2.04	0.40	6.13
8	0.60	0.90	3.29	4.99	1.60	11.38	1.30	0.72	2.01	1.94	0.60	7.07
10	0.50	1.10	3.50	4.82	1.20	11.12	1.20	0.55	2.14	1.61	0.60	6.10
RE_6=5%						2.45						no
1%						3.58						sig.
LSD=5%						2.23						diff.
1%						3.17						

*Red clover varied, alfalfa constant at 8 lbs., Ladino clover at 1 lb., and bromegrass at 3 lbs.

Table Va.

Ladino Clover					Species Total	Bromegrass					Species Total	Mixture Total	Total Seeding Rate per acre
3-28	4-11	5-2	5-22	6-1		3-28	4-11	5-2	5-22	6-1			lbs.
0.12	0.28	1.90	3.22	1.20	6.72	0.67	0.60	1.70	2.42	0.95	6.34	25.53	13
0.03	0.18	1.52	2.60	1.20	5.53	0.48	0.97	1.91	3.20	1.60	8.16	26.11	14
0.06	0.26	1.41	2.17	1.02	4.92	0.70	0.67	1.78	2.02	1.10	6.27	24.69	16
0.03	0.16	1.00	1.31	0.68	3.18	0.40	0.62	1.67	2.58	1.76	7.03	24.31	18
0.02	0.23	1.14	1.42	0.80	3.61	0.57	0.52	1.22	1.77	1.52	5.60	27.66	20
0.03	0.24	1.20	1.95	1.12	4.54	0.37	0.44	1.04	1.69	0.98	4.52	26.28	22
					no sig. diff.							no sig. diff.	

Table Vb. The Influence of Seeding Rates on Yield of Forage under Two Different Cutting Treatments

Red Clover, Alfalfa, Ladino Clover and Bromegrass Mixtures
Dry weight yield in grams - average of 3 cultures

Hay Treatment - 2 cuttings

Species*	Red Clover		Species Total	Alfalfa		Species Total	Ladino Clover		Species Total	Brome-grass		Spe-cies Total	Mix-ture Total	Total Seeding per acre
Date of Harvest	5-8	6-1		5-8	6-1		5-8	6-1		5-8	6-1			lbs.
Rate of Red Clover in lbs.														
1	0.92	1.10	2.02	10.33	8.67	19.00	1.31	1.00	2.31	10.20	9.27	19.47	42.83	13
2	2.99	2.40	5.39	8.40	6.43	14.83	1.63	2.20	3.83	7.77	6.63	14.40	38.45	14
4	4.67	3.40	8.07	10.90	5.93	16.83	1.27	1.28	2.55	7.40	3.30	10.70	38.15	16
6	5.20	3.60	8.80	12.40	6.70	19.10	1.31	0.83	2.14	8.63	4.87	13.50	43.54	18
8	8.67	5.60	14.27	12.20	8.10	20.30	1.45	1.10	2.55	8.90	4.57	13.47	50.59	20
10	6.63	6.90	13.53	6.50	5.63	12.13	2.60	0.95	3.55	6.87	3.77	10.64	39.85	22
RE_6=5%			6.40											no sig. diff. for species or mixture totals
1%			9.36											
LSD=5%			5.83											
1%			8.29											

*Red clover varied, alfalfa constant at 8 lbs., Ladino clover at 1 lb., and bromegrass at 3 lbs.