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THE EFFECT OF SEEDING RATE
ON THE YIELD OF ALFALFA
IN ASSOCIATION WITH GRASS

Thesis for the Degree of M. S.

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THE EFFECT OF SEEDING RATE ON THE
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ASSOCIATION WITH GRASS

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THE EFFECT OF SEEDING RATE ON THE YIELD OF ALFALFA IN ASSOCIATION WITH GRASS

I. INTRODUCTION

The development of the livestock and dairy industries in the United States has brought about the extensive growing of forage crops for hay and pasture in the last few decades.

Because of the wide range of climatic and soil conditions in the United States, a great variety of forage crops is required. In many situations a single species is grown. On the other hand, certain mixtures have been found to be of great value. It has been clearly shown that a legume in association with grass possesses numerous advantages over straight seeding. However, the rate of seeding of the legume in relation to the seeding rate of the grass must frequently be worked out for different species and for different regions. Likewise, the competitive relationships between the species in the mixture in comparison to either grown alone should be studied and seeding rates selected which will give the desired amount of grass and legume in the mixture.

This experiment was designed with the purpose of studying the effects on the yield of alfalfa when in association with four different grasses at various

rates of seeding. The four grasses used were bromegrass, timothy, orchard grass and tall fescue.

II. REVIEW OF LITERATURE

Wagner and Wilkins (18) reported that legumes in mixture with orchard grass and smooth bromegrass improve the quality of pasture through an increase in the protein content of the mixed herbage.

Fulleman (9) reported that the chemical composition of a forage crop as expressed in terms of protein, calcium, phosphorus and magnesium is generally considered to be closely related to its palatability. The protein content of alfalfa and alfalfa-grass mixtures was much higher than that of the grass alone, the calcium content of the alfalfa and the alfalfa-grass mixtures was very high, and bromegrass showed a higher protein content than orchard grass.

Evans (7) discovered in 30 of 31 comparisons that the percentage of protein contained in the green leaf of timothy grown in mixture with clover was higher than in the leaves of the same grass grown alone. Lawn clippings from plots where the grass was grown in mixture with a legume were found to be composed of a large proportion of green leaves and a correspondingly small proportion of dry and brown leaves when compared with a plot where no legume was grown. When timothy was cut at

an early stage of growth and ensiled, it produced a silage higher in protein than corn silage.

Churchill (5) reported that the association of the bromegrass with the alfalfa increased slightly the percentage protein of the bromegrass regardless of strain. He reported that the decrease in the protein content of alfalfa when grown alone in comparison to that of alfalfa grown with bromegrass was probably due to greater loss of leaves.

Harrison and Rather (15) reported that bromegrass is substantially higher in protein content than timothy and many other grasses, especially at the advanced stage of maturity. Pure stands on upland soils are limited in vigor because of lack of sufficient nitrogen. When grown in the presence of well nourished alfalfa, the bromegrass remains vigorous, productive, palatable and rich in nutrients.

Evans (8) reported that the yield of timothy was highest of the grasses followed by tall fescue, orchard and brome grass with 5309, 4307, 3938 and 3532 pounds of hay per acre, respectively. Alfalfa sown alone in comparison to an alfalfa timothy mixture yielded 7540 and 8180 pounds per acre, respectively.

Churchill (5) found that growing bromegrass and alfalfa in mixture reduced the acre yield of each individually when compared with yields of each grown alone.

Aberg and associates (1) found that the yield of brome grass was lower when grown in association with orchard grass and timothy than when grown alone, whereas there was an increase in yield when its partner was alfalfa. Both orchard grass and timothy proved to be better producers when grown in mixtures with alfalfa.

Wiggan (19) found that any seed in excess of 20 pounds per acre used in seeding meadow and pasture was wasted. In a large proportion of cases 15 pounds is probably adequate when conditions are favorable.

Evans (7) found in his timothy seeding test that with each increment of timothy seed, there was a gradual increase in the percentage of timothy and a corresponding decrease in the percentage of clover in the hay. The effect of different rates of seeding tends to diminish as the stand becomes older, but may persist for at least three years. In 16 rates of seeding tests in which timothy was sown in the fall, the rates varied from 1.25 pounds to 20 pounds per acre. The results indicated that three or four pounds per acre may be regarded as satisfactory rate of seeding.

Fuelleman (9) observed that the best seeding rate depends on the way the crop is to be used. When wanted mainly for seed, brome grass planted alone should be seeded at the rate of about 12 to 18 pounds per acre.

When it is to be used for hay and pasture 15 to 20 pounds is the best rate. Alfalfa and brome grass should be seeded in a ratio of two parts alfalfa to three parts of brome grass, for example six pounds of alfalfa and nine pounds of brome grass.

Rather and Harrison (15) recommended seedings of alfalfa-brome at eight pounds of alfalfa and seven pounds of smooth brome. In many of the more recent seedings, only five pounds to the acre of smooth brome seed have been used. Michigan farmers using the mixture have suggested that an even lower rate of brome seed, if evenly distributed, is desirable to prevent the brome grass from dominating the mixture too rapidly.

Hutcheson (12) showed that the seeding rate had little influence on the yield of alfalfa or of alfalfa-orchard grass mixtures.

Effect of Seeding Rate on Total Yield of
Hay in Virginia

Pounds of seed sown per acre		Yield of field Cured
Alfalfa	Orchard grass	hay per acre, lbs. av.
10	--	6,340
20	--	6,890
30	14	6,660
20	14	7,300
10	14	6,490
5	10	6,500

Schotch (16) reported that no significant yield differences with various seeding rate whether drilled

or broadcasted.

Methods of Seeding	Rate of seeding per acre, lbs.	3 yrs. av. acre yield, tons.
Broadcasting	10	5.58
	15	5.31
	20	5.57
Drilled	8	5.30
	12	5.17
	16	5.51

May (13) found that each plant in hay meadow or pasture mixture is influenced in some way by the presence of other plants, the relative abundance of any one species in the mixture may not remain the same seasonally or annually. The change, often described, may in time result in a community very unlike the original one. His experiments indicate that alfalfa will be replaced by Johnson grass if grown in an alfalfa Johnson grass mixture.

Ahlgren and Ammodt (2) showed that the development and activity of roots of certain species of plants may be affected by the plant metabolism of adjoining roots and that some species of plants may have a specific effect on other species which follow on rotation. Toxic secretion, deficient oxygen, excessive carbon dioxide and moisture, harmful pH and nitrogen starvation are among the more important factors listed as being involved in specific root interactions.

III. EXPERIMENTAL PROCEDURE

The experiment was conducted in the greenhouse at Michigan State College, East Lansing, Michigan during the fall of 1949. Four grasses were used in various combinations with alfalfa at different rates of seeding. They were brome grass (*Bromus inermis*), timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*) and tall fescue (*Festuca elatior*). Each of the grasses and the alfalfa were seeded alone as pure species at four, eight and sixteen pounds per acre to serve as checks. Then each grass was seeded at four, eight and sixteen pounds per acre with alfalfa at the same three rates. Thus there were nine possible combinations for the rate of seeding treatments within each species of grass in mixture with alfalfa. Each mixture, and the pure species, was replicated three times, making a total of 153 pots.

The seed was sown in 10-inch clay pot on September 12, 1949, using quartz sand instead of soil. With proportion to the acreage area, it was found that .0228 gram, .0456 gram and .0912 gram of seeds should be planted in a 10-inch pot to equal four, eight and sixteen pounds to the acre, respectively. Since the forage crop seeds are so variable in size and weight, a seed count determination was made for each grass and alfalfa at different rates of seeding. The result is given as follows:

Crops	Rate of Seeding Per acre	Wt. of seed to be planted in 10" pot in grams	No. of seeds to be sown in 10" pot
Alfalfa	4 $\frac{1}{2}$ #	.0228	11
	8 $\frac{1}{2}$ #	.0456	22
	16 $\frac{1}{2}$ #	.0912	44
Brome	4 $\frac{1}{2}$ #	.0228	11
	8 $\frac{1}{2}$ #	.0456	22
	16 $\frac{1}{2}$ #	.0912	44
Timothy	4 $\frac{1}{2}$ #	.0228	69
	8 $\frac{1}{2}$ #	.0456	138
	16 $\frac{1}{2}$ #	.0912	276
Orchard	4 $\frac{1}{2}$ #	.0228	30
	8 $\frac{1}{2}$ #	.0456	60
	16 $\frac{1}{2}$ #	.0912	120
Fescue	4 $\frac{1}{2}$ #	.0228	9
	8 $\frac{1}{2}$ #	.0456	18
	16 $\frac{1}{2}$ #	.0912	36

After sowing, the cultures were watered regularly and supplied with a nutrient solution to secure the best growth under fall greenhouse conditions. The nutrient solution contained the following concentrations and was applied once or twice per week.

Nutrient	Partial volume molecular Conc.
KH_2PO_4	0.0045
$\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$	0.0090
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	0.0045

The greenhouse temperature ranged between 70 to 80 degrees F. and no artificial light was used. The plants were left to grow until December 18th, 1949. At that time the first replication of the experiment was harvested. The sand was washed from the roots and the species in each mixture were separated. Roots and tops were weighed separately, both green weight and oven dried weight being recorded. This harvest extended over a period of ten days because of the time required to separate the species within a mixture.

IV. EXPERIMENTAL RESULTS

Yield Comparison Between Mixtures

Despite the different rates of seeding, all cultures of the same mixture were grouped together to determine the yield differences between mixtures. The green weight of root and top for both components in the mixture was used for this study. Table 1 indicates that the orchard grass-alfalfa mixture had the highest yield of the mixtures studied. The differences in yield between orchard grass-alfalfa and the other three mixtures was very significant, a difference of 357 grams being required for significance at the 5 per cent level. There are no significant yield difference between alfalfa-brome, alfalfa-timothy, and alfalfa-tall fescue.

Table 1. Total Green Wt. of Grasses and Alfalfa
in Different Mixture (Grams)

Mixtures	Alfalfa & Brome	Alfalfa & Timothy	Alfalfa & Orchard	Alfalfa & Fescue
Replication I	1463	1605	2565	1965
Replication II	1618	1688	2320	2110
Replication III	1987	1695	2305	1915
Total	5068	4988	7190	5990
Average	1689	1662	2396	1996

The mixtures under this experiment were grown for a period of three months, but this data proves that orchard grass begins growth earlier and continues more vigorously especially under greenhouse conditions.

A Split Plot Design Analysis on The Yield
Of Mixtures at Different Rates of Seeding

Since this experiment was originally designed as a split plot, the analysis of yield differences, here presented, between rates of seeding and mixtures was based on this design, using the rates of seeding and different mixtures as the main treatment and sub treatment. Total oven dried weight of top and root growth for both components in the mixture was used for this study.

Table 2. Dry Weight of Both Top and Root Growth of Mixtures at Different Rates of Seeding (Yield in Grams From the Average of Three Pots)

Alfalfa Seeding Rate	Grass Seeding Rate	<u>Grass in Mixture</u>				Aver.
		Brome	Timothy	Orchard	Fescue	
4#/A	4#/A	19.5	33.6	48.0	30.8	33.0
	8#/A	31.6	35.6	58.3	47.5	43.3
	16#/A	37.8	41.8	73.5	53.0	51.5
8#/A	4#/A	17.3	23.0	28.8	15.3	21.1
	8#/A	31.0	28.8	31.8	23.3	28.7
	16#/A	31.5	26.3	53.1	43.5	38.6
16#/A	4#/A	20.1	23.3	37.1	19.0	24.9
	8#/A	30.1	19.0	28.0	25.6	25.7
	16#/A	42.0	42.3	50.6	42.5	44.5
Total		785.5	822.0	1228.5	903.0	
Average		29.0	30.4	45.5	33.4	

It was found that yield required for significant difference at 5% level between rates of seeding and mixtures were 7 grams and 4.6 grams, respectively. Comparing the average yield between different rates of seeding regardless of its mixture, it is clearly shown in Table 2 that with each increment in seeding rates of grasses there is a notable increase in yield. Though the seeding rate of grass is doubled the yield does not respond proportionately. It is worthy to note that there is no slight indication of increase in yield when the seeding rate of alfalfa is increased. This can be explained by further analysis on the proportion of alfalfa in each mixture at

different rates of seeding. Since alfalfa is not so aggressive in growth as the grasses, each increment in seeding rate does not influence the yield greatly. So far as the yield as a whole is concerned, it seems that four pounds of alfalfa sown with sixteen pounds of grass has the highest average yield.

It is noted in Table 2 that the average yield differences between the mixtures are substantially the same as we found in Table 1. This further proves that there is a close and positive correlation existing between green weight and oven dried weight of the yield of alfalfa and grasses.

With each increment in seeding rate of brome grass in the alfalfa brome mixture, there was a significant response in the differences of yield. This statement also holds true in the alfalfa-orchard and alfalfa-fescue mixtures when the rate of seeding of orchard grass and fescue were increased. However, there are a few exceptions in these comparisons, as no difference in yield was observed between alfalfa and brome, each seeded at eight pounds to the acre and eight pounds of alfalfa seeded with sixteen pounds of brome grass. There was a significant decrease in yield when eight pounds of orchard grass were sown with sixteen pounds of alfalfa when compared to four pounds per acre of orchard grass. These variations may be due to experimental error or other causes. In the alfalfa

timothy mixture, there was no significant difference in yield when the rate of timothy seeding was doubled. In each individual mixture, no notable yield differences were observed when the rate of alfalfa seeding was increased.

Yield Comparison Between Mixture and
their Components seeded alone
at Various Rates of Seeding

The total green weight in grams of top and root of individual mixtures and their components seeded alone were used for this analysis. In the alfalfa brome mixture, as shown in Table 3, when alfalfa and brome-grass were each seeded alone it seems that there was significant increase in yield with each increase in rate of seeding. By comparing the straight seedings with the mixture, the straight alfalfa and straight brome at high rate of seeding yielded more or less the same and a little bit higher than the highest yield of alfalfa brome mixture.

Table 4 indicates that a straight seeding of timothy yielded a little better than the alfalfa-timothy mixture. The highest yield was found by sowing 8 pounds of timothy alone. With regard to the mixture it seems that there was no striking differences among various rates of seeding.

Table 3. Brome Grass in Association with Alfalfa and Brome Grass and Alfalfa Seeded Alone at Various Rates of Seeding.

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa		Straight		
	4#	8#	4#	8#	4#	8#	4#	8#	4#	8#	
Average	122	207	234	103	210	194	139	212	263	97	138

60 grams needed for significant difference at 5% level.

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Table 4. Timothy in Association with Alfalfa and Timothy and Alfalfa Seeded Alone at Different Rates of Seeding.

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa		Straight Timothy						
	4#	8#	4#	8#	4#	8#	4#	8#	4#	8#					
Average	187	217	246	150	191	166	154	127	224	97	138	207	208	298	268

50 grams found to be significant at 5% level.

The orchard grass seeded with four pounds of alfalfa gave the best yield (Table 5). Increasing the rate of alfalfa seeding when sown in mixture with orchard grass, decreased considerably the total weight harvested. Doubling the rate of seeding of orchard grass in mixture did not increase the yield accordingly. This is why orchard grass seeded alone at four pounds per acre showed no differences in yield when compared to its high rate of seeding. It seems that the mixture had a better yield than straight alfalfa seeding but no difference in yield was observed between the mixture and orchard grass seeded alone.

Table 6 indicates that both yields of alfalfa-fescue mixture and straight fescue were increased when a high rate of seeding of fescue was used. It was also found that increasing the rate of alfalfa seeding in the mixture did not increase its yield. On the contrary, it was observed that a significant decrease in yield occurred when four or eight pounds of fescue were seeded with eight or sixteen pounds of alfalfa when compared to four pounds of alfalfa. The mixture in which fescue was seeded at sixteen pounds showed a notable increase in yield over that of straight alfalfa seeding. No significant difference in yield could be seen between the mixture and straight fescue at same rate of seeding.

Table 5. Orchard Grass in Association with Alfalfa and Orchard Grass and Alfalfa Seeded Alone at Various Rates of Seeding.

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa		Straight Orchard Grass						
	4#	8#	4#	8#	4#	8#	4#	8#	4#	8#					
Average	280	340	356	187	216	277	254	187	297	97	138	207	336	352	342

72 grams needed for significant difference at 5% level.

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Table 6. Rescue in Association with Alfalfa and Rescue and Alfalfa Seeded Alone at Various Rates of Seeding.

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa		Straight Rescue						
	4#	8#	4#	8#	4#	8#	4#	8#	4#	8#					
Average	206	241	299	120	172	293	144	201	318	97	138	207	159	229	324

76 grams needed for significant yield difference at 5% level.

Determination of Alfalfa Yield in Various Mixtures
at Different Rates of Seeding

Table 7 indicates that total alfalfa yield in the alfalfa-brome mixture was decreased even when compared with the lowest rate of seeding of straight alfalfa. In straight alfalfa, as mentioned before, by increasing the rate of seeding the total yield was significantly increased. In the mixture it seems that alfalfa yield was but slightly affected by varying the rate of seeding of brome grass. In other words, regardless of the rate of brome grass seed being used, the alfalfa showed an increase in yield with each increment in alfalfa seeding rate although the difference was not so promising.

In the alfalfa-timothy mixture the same statement can be made that straight alfalfa seeding had a much better yield than the alfalfa yield in the mixture. No clear indication was observed that the alfalfa yield was increased with each increment of alfalfa seeding in this mixture. It is clearly shown that with each increment of timothy seeding there was a marked decrease in the alfalfa yield. So, four pounds of timothy seeded with eight or sixteen pounds of alfalfa seems to give the best yield of alfalfa (Table 8).

A considerable reduction in alfalfa yield was observed with each increment of orchard grass seeding, while alfalfa yield in the mixture was increased by increasing the rate of alfalfa seeding. It seems that sixteen pounds of alfalfa seeded with four pounds of

Table 7. Alfalfa Yield in Combination with Bromo Grass at Different Rates of Seeding. (av. Green Wt. in grams of 3 Pots)

Rate of Seeding	Alfalfa 4 $\frac{1}{2}$		Alfalfa 8 $\frac{1}{2}$		Alfalfa 16 $\frac{1}{2}$		Straight Alfalfa	Total Alfalfa Yield					
	Brome Grass 4 $\frac{1}{2}$	Brome Grass 16 $\frac{1}{2}$	Brome Grass 4 $\frac{1}{2}$	Brome Grass 16 $\frac{1}{2}$	Brome Grass 4 $\frac{1}{2}$	Brome Grass 16 $\frac{1}{2}$							
Average	36.3	32	20	59.6	56	50	71.3	84	97.6	97	138	207	939

Table 8. Alfalfa Yields in Combination with Timothy at Different Rates of Seeding. (Av. Green Wt. in Grams of 3 Pots)

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa	Total Alfalfa Yield					
	4 $\frac{1}{2}$ Timothy	8 $\frac{1}{2}$ Timothy	8 $\frac{1}{2}$ Timothy	16 $\frac{1}{2}$ Timothy	4 $\frac{1}{2}$ Timothy	16 $\frac{1}{2}$ Timothy							
Average	27	20	5.6	37.6	26.6	21.3	54.3	36.6	32	97	138	207	703

orchard grass gave the best yield of alfalfa. None of the mixtures in Table 9 shows an alfalfa yield as high as obtained in straight alfalfa seeding.

Alfalfa yield in association with fescue showed the same responses as in the timothy and orchard alfalfa mixtures. But the decrease in alfalfa yield was not so distinct as the rate of fescue seeding was increased. The best alfalfa yield was observed by sowing sixteen pounds of alfalfa in the mixture. No difference in alfalfa yield could be seen when alfalfa was seeded with four pounds to the acre as compared to that seeded at eight pounds in the mixture.

By comparing the total alfalfa yield in these four mixtures, it is clearly shown that the alfalfa-brome mixture ranks first in terms of total alfalfa yield followed by alfalfa-fescue, alfalfa-orchard and alfalfa-timothy in the order of production.

Determination of Grass Yield in Association
with ALFALFA at Different Rates of Seeding

A similar analysis was made of the grass yield in association with alfalfa at different rates of seeding. A composite table was made with G denoting the grass seeding rate in the mixture.

In general, all the grass yields in mixtures were lower than their respective rate of seeding in straight seeding. But, a few exceptions such as orchard grass, and fescue seeded with four pounds of alfalfa to the acre

Table 9. Alfalfa Yields in Combination with Orchard Grass at Different Rates of Seeding. (Av. Green Wt. in Grams of 3 Pots)

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight Alfalfa	Total Alfalfa Yield					
	4 <i>if</i>		8 <i>if</i>		16 <i>if</i>								
	Orchard Grass	16 <i>if</i>	Orchard Grass	16 <i>if</i>	Orchard Grass	16 <i>if</i>							
	4 <i>if</i> 8 <i>if</i>	16 <i>if</i>	4 <i>if</i> 8 <i>if</i>	16 <i>if</i>	4 <i>if</i> 8 <i>if</i>	16 <i>if</i>	4 <i>if</i> 8 <i>if</i> 16 <i>if</i>						
Average	27	16.3	9.3	29.6	25	20.6	81	34	37.3	97	138	207	723

Table 10. Alfalfa Yield in Association with Fescue at Different Rates of Seeding. (Av. Green Wt. in Grams of 3 Pots)

Rate of Seeding	Alfalfa		Alfalfa		Alfalfa		Straight		Total				
	4 <i>f</i>		8 <i>f</i>		16 <i>f</i>		Alfalfa						
	Fescue	16 <i>f</i>	Fescue	16 <i>f</i>	Fescue	16 <i>f</i>	Fescue	16 <i>f</i>					
	4 <i>f</i>	8 <i>f</i>	16 <i>f</i>	4 <i>f</i>	8 <i>f</i>	16 <i>f</i>	4 <i>f</i>	8 <i>f</i>	16 <i>f</i>				
Average	55.6	31	20	40.3	32	31.9	79.3	59.6	63.6	97	138	207	855



Table 11. Grass Yield in Association with Alfalfa at Different Rates of Seeding
(Green Wt. in Grams)

Rate of Seeding	Alfalfa 4#			Alfalfa 8#			Alfalfa 16#			Straight Grass	Total Grass Yield
	G 4#	G 8#	G 16#	G 4#	G 8#	G 16#	G 4#	G 8#	G 16#		
Brome	86.3	175	214	44	154	144	68	126	176	148 212 298	1848
Timothy	160	196	240	112	164	145	99	90	192	208 298 268	2176
Orchard	253	324	346	157	191	256	173	152	259	336 352 342	3145
Fescue	150	210	279	79	140	261	64	141	254	159 229 324	2295

had almost the same grass yield as their straight seeding.

In the brome-alfalfa mixture it seems that the brome yield was increased with each increase of brome seeding rate. No increase in brome yield was observed by increasing the rate of alfalfa seeding in the mixture. However, a slight decline in brome yield could be noted when eight or sixteen pounds of alfalfa was used in the mixture instead of four pounds. The best combination for producing more brome was found to be sixteen pounds of brome seeded with four pounds of alfalfa.

In the timothy-alfalfa mixture, the timothy yield was consistently decreased with each increment of alfalfa seeding. No consistent increase in timothy yield was shown, however, by increasing the timothy seeding in the mixture. Sixteen pounds of timothy seeded with four pounds of alfalfa gave the best timothy yield in the mixture.

Orchard grass seeded with four pounds of alfalfa gave the best yield of orchard grass. Increasing the rate of orchard in the mixture did not increase its yield much. Eight pounds of orchard grass seeded with four pounds of alfalfa was found to be a good combination as far as the yield of orchard grass in the mixture was concerned.

Fescue yield was markedly increased in the mixture with each increase in rate seeding. But the fescue yield

was not affected by increasing the rate of alfalfa seeding. Sixteen pounds of fescue seeded with four pounds of alfalfa was the best combination.

So far as the total grass yield is concerned orchard grass showed a significantly higher yield than other grasses in the mixture.

Root Growth of Grasses & Alfalfa as Influenced
by Their Mixtures at Different Rates of Seeding

The green weight of roots in each culture and the average per culture for the various treatments are given in Table 12.

The average green weight of brome roots in the alfalfa-brome mixture was increased with each increment of brome seeding rate. A slight decrease in weight of brome was observed by increasing the rate of alfalfa seeding in the mixture. In the same mixture, the weight of alfalfa root was not affected by the various rates of brome seeding. However, it indicates a considerable increase in the weight of alfalfa root when high rates of alfalfa seeding were applied. The weight of brome roots in the mixture was slightly decreased by the presence of alfalfa when compared with the straight seeding.

By varying the rate of timothy seeding, the root weight of timothy in the mixture showed a very inconsistent response. Still a general tendency of increase in timothy root weight could be observed with each increment of

Table 12. Root and Top Growth of Grasses and Alfalfa and their Mixtures at Different Rates of Seeding (In Grams)

Treatment	Root			Top		
	Grass	Alfalfa	Total	Grass	Alfalfa	Total
	Av. of 3 Pots	Av. of 3 Pots		Av. of 3 Pots	Av. of 3 Pots	
A	34.5	8.5	43	52	27.8	79.8
B	69.5	9	78.5	105.6	23.5	129.1
4#	100.6	7.1	107.8	114	13.16	127.1
8#	16.8	14.3	31.1	27.5	45.3	72.8
16#	67.8	9.6	77.5	86.6	46.5	133.1
4#	71.3	12.3	83.6	73.3	37.8	111.1
8#	26.1	17.6	43.8	42	53.8	95.8
16#	47.1	16	63.1	79.3	68.5	147.8
4#	77	22.8	99.8	99	65	164
B	63.3	-	63.3	85.1	-	85.1
4#	94.6	-	94.6	118	-	118
8#	137	-	137	161.6	-	161.6
T	52.6	6.5	59.1	107.5	20.8	128.3
A	75	5.8	80.8	121.8	14.5	136.3
4#	93.8	2.3	96.1	147	3.3	150.3
8#	30.5	9.3	39.8	82.5	28.5	111
16#	53.6	6.6	60.3	110.6	20	130.6
4#	48.5	4.3	52.8	97.1	16.1	113.3
8#	30.5	12	42.5	69.5	42.5	112
16#	27.3	8	35.3	63	28.8	91.8
T	70.3	9.1	79.5	121.6	26.1	147.8
A	78.1	-	78.1	130	-	130
4#	123.1	-	123.1	175	-	175
8#	110.6	-	110.6	157.8	-	157.8

Table 12. (con't)

Treatment	Root			Top		
	Grass	Alfalfa	Total	Grass	Alfalfa	Total
	Av. of 3 Pots	Av. of 3 Pots		Av. of 3 Pots	Av. of 3 Pots	
O						
A 4#	82.1	7.3	89.5	171.6	19.8	191.5
4#	100.1	5.1	105.3	224.1	11.3	235.5
4#	113.1	3	116.1	233.3	6.5	239.8
8#	49.3	6.8	56.1	108.3	22.8	131.1
8#	50	5.3	55.3	141	20	161
8#	71.3	4.6	76	185.6	16.3	202
16#	62	17.6	79.6	111.6	63.6	175
16#	48.1	9.3	57.5	104.6	25.1	129.8
16#	82.5	8.5	91	177.3	29.1	206.5
O						
4#	131.6	-	131.6	205	-	205
8#	119.3	-	119.3	233	-	233
16#	129.1	-	129.1	213	-	213
F						
A 4#	42.3	14.1	56.5	108.3	41.5	149.8
4#	60.6	9.16	69.8	150.1	21.8	172
4#	82.6	7.5	90.1	196.5	12.8	209.3
8#	19.3	9.16	28.5	60.3	31.5	91.8
8#	31.3	8	39.3	109.1	24.1	133.3
8#	69.8	10	79.8	191.3	21.8	213.16
16#	17.8	18.3	36.1	46.6	61.5	108.1
16#	44.3	19.1	63.5	97.6	40.5	131.1
16#	83.3	18	101.3	171.3	46	217.3
F						
4#	37.8	-	37.8	121.3	-	121.3
8#	61.8	-	61.8	167.5	-	167.5
16#	113.6	-	113.6	211.1	-	211.1

Table 12. (con't)

Treatment	Root			Top		
	Grass Av. of 3 Pots	Alfalfa Av. of 3 Pots	Total	Grass Av. of 3 Pots	Alfalfa Av. of 3 Pots	Total
A - Alfalfa	-	32.8	32.8	-	64.5	64.5
B - Brome Grass	-	49.3	49.3	-	88	88
F - Fescue	-	73.3	73.3	-	134	134

timothy seeding in the mixture. Sixteen pounds of timothy seeded with eight pounds of alfalfa and eight pounds of timothy seeded with sixteen pounds of alfalfa were the exceptions to this statement. When the alfalfa seeding rate was increased from four pounds to eight pounds to the acre, a marked decrease of the weight of timothy was observed, but no difference in timothy root weight was shown when alfalfa seed was increased from eight pounds to sixteen pounds. It is also true that timothy seeded alone had a greater weight of roots than that in the mixture at the same rate of seeding. The alfalfa root weight in the mixture showed a distinct decrease as the rate of timothy seeding was increased. Positive response on the weight of alfalfa roots was obtained with each increment of alfalfa seeding in the mixture.

In the orchard-alfalfa mixture, the orchard grass showed an increase and alfalfa roots a decrease in weight when the rate of orchard seeding was increased. As the rate of an alfalfa seeding was increased from four pounds to eight pounds, it was odd to note that the weight of orchard roots in the mixture was markedly decreased. At the same time there was not the least indication that alfalfa root weight was affected by this change. With each increment of the seeding rate of orchard grass seeded alone, there was no difference in root weight. It also outyielded considerably the orchard roots in the mixture.

With each increment of fescue seed in the mixture and in the straight seeding, the fescue root weight was also increased. Although there was some variation, a general tendency could be observed that fescue roots showed a decrease in weight when the alfalfa seed was increased in the mixture.

Alfalfa seeded alone showed an increase in root weight with each increment of seeding rate and also out-yielded several times that of the alfalfa roots in the mixtures under the same rate of seeding.

So far as the weight of alfalfa roots in the various mixtures is concerned, it seems that alfalfa had its best root growth when seeded with brome grass. The alfalfa-fescue mixture also furnished very favorable conditions for alfalfa root growth. The weight of alfalfa roots was decreased to one half when seeded with orchard or timothy.

Alfalfa-orchard mixture had a better total root growth than the rest of the mixtures.

Top Growth of Alfalfa and Grasses and Their
Mixtures at Various Rates of Seeding

Table 12 also indicates that a close relationship existed between root growth and top growth of the grass and the legumes in the mixtures when their rates of seeding were changed. However, a striking difference can be observed in that the alfalfa brome mixture gave the best top growth of alfalfa among the mixtures.

V. DISCUSSION

In discussing the results of this experiment, it should be noted that the plants were grown under greenhouse conditions. Sand culture with nutrient solution was applied to all plants in this experiment and no artificial inoculation was made. So, the findings in this experiment were solely based on the botanical interactions of different grasses with alfalfa as affected by varying the rates of seeding. When the sand was washed from the roots during the harvest, the nodules on the alfalfa roots were very seldom seen. So, the yield of grass in this experiment was not benefited by the presence or absence of a legume for furnishing the nitrogen to the mixture as each pot received the same amount of nutrient.

This experiment was only grown for a period of three months. The total yield of the different mixtures at various rates of seeding found in this experiment might not be the same as under field conditions. However, many differences have been observed between different mixtures at various rates of seeding in this experiment under greenhouse conditions.

The experimental error in this type of experiment is always quite a problem and is hard to control. The

location of steam pipes with regard to the position of pots, differential lighting and improper handling in washing sand from the roots and many others were sources of error in this experiment. The analysis of variance was applied in this experiment with the purpose of presenting the result with the least amount of error. It was found that more replications should be used for this sort of experiment.

From all the data presented in the preceeding paragraphs, the alfalfa-orchard mixture had the highest yield among the mixtures. This can be best explained by orchard grass having a quick growth characteristic and by growing more vigorously, especially under greenhouse conditions. It further proves the above statement as orchard grass seeded at four pounds to the acre had the same yield as at high rate of seeding. This is why four pounds of orchard seeded with sixteen pounds of alfalfa gave the best result.

It was clearly shown in this experiment that with each increment of grass seed used in mixture that it increased the proportion of grass yield accordingly and at the same time the proportion of alfalfa decreased. This statement did not hold true in the alfalfa-timothy mixture. This is due to the fact that timothy seed are so small in size and at four pounds to the acre, a total

of 69 seeds were planted in each 10-inch pot. So, the size of the seed should be considered as one of the factors in determining the proper rate of seeding. Using timothy as an example, the increase in the seeding rate simply caused increased competition for nutrients and light, thus resulting in a very small proportion of alfalfa in the mixture.

By increasing the rate of alfalfa seeding in the mixture, it did not affect the total yield of the mixture. A distinct difference in alfalfa yield in mixture was observed when compared with a straight alfalfa seeding. It is especially true when the mixture is grown with a culture solution. However, if one examines the proportion of alfalfa in the mixture, the presence of alfalfa was increased with each increment of alfalfa seeding.

With regard to the root growth in the mixture, the same statement can be drawn as with the total yield. The grass root growth was increased with each increment of grass seeding, while at the same time the alfalfa root growth in the mixture was decreased. By increasing the seeding rate of alfalfa the grass roots were not influenced very much but the alfalfa root was undoubtedly increased.

It is an observed tendency that the yield of a mixture is increased by increasing the rate of seeding

of both components. But due to the different specific plant growing characteristics, the limited space of light and moisture and the limited supply of available nutrients, the increase in yield did not respond proportionately as the rate of seeding was increased. In many cases the yield was decreased by using an excessive amount of seed. However, this might well be explained on the basis of increased growth per plant at the reduced seeding rates.

Dominance of any given species of the mixture in any particular environment has usually been attributed to different moisture, temperature, light and fertility requirement.

Apparently, the grass mixture relationship is complicated by many environmental factors. This makes it most important to study mixtures in order to determine their adaptations to local condition.

VI. SUMMARY

Alfalfa was combined separately in mixture with brome grass, timothy, orchard grass and tall fescue. These mixtures were grown in quartz sand in the greenhouse in 10-inch clay pots using nutrient solutions, and seeded at various rates. Three levels of seeding rates, four, eight and sixteen pounds to the acre, were used for each grass and for the legume in the mixture, thus forming nine possible combinations of rates of seeding for each mixture.

There were differences between the yields of the mixtures. Orchard grass in association with alfalfa had the highest yield in this experiment, while the rest of the three mixtures were about equal in yield.

With each increment of seeding rate there was, in nearly every case, an increase in total yield, but such responses in yield were not in proportion to the amount of seed applied.

The differences obtained in the various mixtures at different rates of seeding indicates that plant competition was present between various grasses with alfalfa. These competitions or interactions are no doubt profoundly influenced by environmental conditions such as light, nutrient, moisture and temperature.

Seeding two species together, a legume and a grass tended to restrict the top and root growth of both species when compared to either grown alone.

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