EFFECTS OF COMPETITION FROM COMPANION CROP AND FROM INTER-SPECIES ASSOCIATIONS ON FORAGE STAND ESTABLISHMENT AND YIELD

by

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INTRODUCTION

A major portion of the stands of small-seeded legumes and grasses in the Corn Belt States is established with a spring seeded cereal grain companion crop. This crop is principally oats.

The role of the companion crop and methods of managing it are of major importance in establishing legume seedings. An increased use of the companion oat crop for pasture, silage or hay directs even greater attention to the relationship between that crop and the establishment of forage crop stands.

Repeated failures in attempts to establish stands of birdsfoot trefoil indicate a more critical relationship between seedling establishment and plant competition than for other forage species. Competition may arise from companion crops, weeds or from other forage species in the mixture.

This investigation was designed to study responses in seedling development, botanical composition, stand, and hay yields of alfalfa-bromegrass and red clover-timothy mixtures as influenced by management of the companion oat crop. In a greenhouse study, the seedling growth and development of alfalfa, birdsfoot trefoil and orchardgrass were measured under competition from various seeding combinations of these three species.

REVIEW OF PERTINENT LITERATURE

Results from previous investigations are in general agreement that management practices which reduce the competition for light and moisture tend to favor the establishment of legume seedings. A majority of the research on forage crop stand establishment has been reported in terms of seedling stand in the fall of the seeding year.

Investigators are not in general agreement as to whether the legume seeding is favored by sowing oats at reduced rates. Dungan et al. (9) in Illinois found that as the seeding rate of Gopher oats was increased, the stands and growth of red clover were poorer. Thatcher et al. (19) reported that a thin seeding rate of oats may result in a better stand of legumes in Ohio in dry seasons but in most years no significant difference was observed in stands of legumes at different rates of seeding oats, unless lodging resulted from heavier rates.

Bula et al. (7) have reported greater light penetration under Clinton oats seeded at thin rates as compared to heavier rates during the early stages of growth. At later stages of growth the increased height of oats and greater amount of weeds in plots seeded at thin rates eliminated nearly all initial differences due to light seeding rates. Significant differences were not obtained among the rates of and varieties of oats used. Godel (11) and Pavlychenko and

Harrington (14) have reported that thick stands of small grains are effective in reducing weed growth. Pritchett and Nelson (16) concluded from their investigations that light is the principal competitive factor of companion crops when soil moisture and fertility are not limiting.

Collister and Kramer (8) in a year study in Indiana reported a reduction in the stands and development of red clover plants under some spring oat varieties. Smith et al. (18) reported no significant differences in the establishment of legume stands under the four oat varieties used. Weeds were dominant in the thinly sown oats on the heavy soils and on these soils the stands of legumes were not greatly reduced as the oat sowing rate was increased. Differences in the effects of the rates of sowing the oats on the legume stands were leveled out in part by favorable spring moisture conditions and by the higher weed populations which occurred in the oats sown at lighter rates. Weeds tended to equalize the total amount of growth on the plots. Competition for moisture appeared to be the major factor influencing the establishment of the legumes on sandy soils where, in general, poor stands of legumes occurred under the heavy rates of sowing oats.

From a study on the effect of the companion crop upon alfalfa establishment, Moore and Graber (13) concluded that removal of the companion crop at heading stage was beneficial to forage seedings. They reported a requirement of 600 to 900 tons of water per acre to mature a good crop of oats.

Much of that moisture was utilized after heading and during maturity of the companion crop. Removal of the companion crop at heading stage of growth would conserve moisture and eliminate the crowding effect of the companion crop at maturity.

In a study to determine the competitive effect of several companion crops on forage seedings, Woodward (21) suggested that companion crops cut before maturity exerted little injurious effect upon the subsequent yield of alfalfa. A study by Briggs and Harrison (5) on the effects of various companion crops on the establishment of alfalfa indicated that removal of the companion crop at hay stage of growth gave a slightly thinner forage stand and subsequently smaller forage yields than removal at maturity. This study showed that the heavy infestation of weeds following the removal of the companion crop as hay was more competitive to forage seedlings than any of the companion crops remaining until maturity.

Hulbert (12) pointed out in earlier investigations of factors affecting the stand and production of sweetclover that removal of the companion crop at the mature stage resulted in a higher plant mortality than when it was cut at hay stage. He reported that yields of sweetclover hay were nearly equal when the companion crop had been cut for hay or for grain, however, yields from plots in which the companion was cut for grain were slightly higher.

Thatcher *et al*. (19) reported that cereal grains used as a companion crop increased the risk in establishing forage stands. They concluded that vigorous competition between forage and cereals does not begin until the grain crop has jointed. Cereal crops accentuate adverse effects of either dry or wet weather on forage stands. Forage seedlings with a cereal companion crop were smaller and weaker and did not survive as well as those without competition. They also suggested that yield in the first production year was not correlated with stand.

Seedling competition between forage species is at times a factor in establishing forage mixtures. Blaser *et al*. (4) reported that red clover seriously suppressed alfalfa when seedings were made in the spring, but alfalfa was not suppressed in summer seedings. Red clover seedlings made faster growth than alfalfa with lower temperatures in the spring. Subsequent erect growth and tillering of red clover tended to shade alfalfa seedlings in a mixture. It also was suggested that the dense early spring growth of red clover seedlings had an effect on ground level humidity, thus alfalfa leaf disease may tend to reduce the stand.

Torrie and Hanson (20), studying the effects of cutting first year red clover on second year stand and yield, reported clipping in late August was sometimes very beneficial and was never harmful. Cutting on September 14 or later was injurious and reduced hay yields three out of four times.

Best results were obtained when the first year's growth was clipped on August 31 and the clippings removed from the field.

Roberts and Olson (17) report a study with six legumes and two grasses grown in the greenhouse in all possible pure stand combinations of one grass with one legume. No case was observed where both legume and grass were either benefited or injured by associated growth when compared to growth in pure stands. When one component of a mixture produced more dry weight in mixture than in pure stand, the other component produced less when in mixture than in pure stand. Greatest gains due to association occurred when a legume with vigorous growth habits was associated with a grass with weak growth habits. Gains in dry weight due to associated growth of a grass and legume are believed to have resulted from spreading the plants with vigorous growth habits over a greater soil area, thus making more efficient use of the total soil area involved.

Data reported by Blaser et al. (4) on stand and growth of perennial grasses and legumes as influenced by species, varieties, and dates of seeding show that forages differ in rates of establishment. Species were classified as very aggressive, aggressive and non-aggressive in seedling development. Aggressiveness during establishment was associated with seedling emergence. Survival was associated with growth rate of seedling plants. Growth rate and survival of seedlings differed in August and March seedings. Species that were aggressive when seeded in the spring were not necessarily aggressive when seeded in the summer. Variations in survival and growth among forage species under spring and summer seeding was attributed to their differential responses to temperature and moisture conditions during the season when seeded.

Aberg et al. (1) evaluated several species grown alone and in combination to determine if their association was antagonistic, compensating or beneficial. Field experiments with a series of grass-legume combinations showed nearly all associations to be compensating rather than antagonistic or beneficial. Results from greenhouse studies with the same crops were in many cases in poor agreement with field results. This lack of agreement emphasizes the importance of environmental control in studies of crop associations.

As pointed out by Brunk (6) many workers have shown that birdsfoot trefoil is a slow starter, therefore successful stands are quite dependent upon special care during seedling establishment. He concluded that poor yields of birdsfoot trefoil may be expected when established with a companion crop. Competition from the companion oat crop reduced birdsfoot trefoil yields, plant population and plant size. Mowing oats frequently to simulate alternate grazing was the only companion crop management that produced satisfactory stands.

The inability to compete with other plants during the seedling stage is perhaps the primary reason for the usual slow start of birdsfoot trefoil. Gist and Mott (10) have shown the growth of birdsfoot trefoil seedlings to be approximately one-third that of alfalfa. Their work showed that anything which reduced the amount of light reaching birdsfoot trefoil seedling plants adversely affected the ability of those plants to compete for moisture and perhaps nutrients.

Ahlgren *et al*. (2), and Pierre and Jacobs (15) have recommended a reduction in rate of seeding the companion crop, and the control of its growth by clipping or grazing to decrease the competition to birdsfoot trefoil seedlings.

METHODS AND MATERIALS

The field experiment in this study was established on a uniform Webster silty clay loam soil on the Agronomy Farm at Ames, Iowa. On April 15, 1953, three varieties of oats, Shelby (late), Cherokee (early), and CI 3867 (midseason), were seeded with a grain drill at 0, 1, 2, and 3 bushels per acre in a split plot design with three replications. The oat varieties made up whole plots and rates of seeding, the sub plots with treatments including management of companion crop and grass-legume seedings. Oat varieties were randomized within each replication and seeding rates were randomized within each variety. Subplots of oat seeding rates were split for randomized seedings of alfalfa-bromegrass and clover-timothy mixtures. Alfalfa was seeded at 8 pounds, smooth bromegrass at 8 pounds, red clover at 6 pounds and commercial timothy at 2 pounds per acre. The grass and legume seed was mixed with moist white sand and broadcast over each plot by hand and the area rolled twice to cover the seed.

Two methods of management, randomized within each variety, were used to remove the companion oat crop. Methods used were removal of hay and at mature stages of growth.

The companion oat crop removed at hay stage was clipped at a height of 4 inches on June 15. On all plots with 0 bushel rate of oat seeding weeds were clipped on June 15.

All clipped material was removed from plots. Considerable weed growth was clipped and removed from plots without an oat seeding.

Following harvest of the companion oat crop at maturity heavy infestations of foxtail (Setaria spp.) occurred on all plots in the experiment. Therefore all plots were again clipped to a 4 inch height and all residue removed on September 1. This was the only attempt made for weed control. The area was clipped to remove over-winter plant residues on March 30, 1954.

Hay yields were taken on June 20, 1954, the first harvest year. A strip 38 inches wide by 16 feet, 10 inches long was mowed from the center of each plot. Yields of green weight per harvested area were recorded. Samples were removed for moisture determinations and hand separated into grass and legume components of the mixtures. Samples were oven dried at 180° F. for six days and plot yields were recorded on a dry weight basis.

The weather during the seeding year was characterizied by a slightly higher than normal temperature and a rainfall deficiency of approximately 11.6 inches. Table 1 indicates rainfall and temperature conditions between April and November 1953.

The investigation was continued in the greenhouse during the winter of 1956-57 with alfalfa (Vernal), birdsfoot

Table 1. Mean monthly temperature and total monthly precipitation at the Ames Agronomy Farm weather station during the period April to November, 1953[a]

	Temperature °F.		Precipitation inches	
	Average	Departure from normal	Total	Departure from normal
April	43.9	- 5.1	3.04	0.43
May	60.0	- 0.6	1.59	- 2.59
June	72.5	2.5	4.99	0.65
July	74.5	- 0.4	1.77	- 1.65
August	72.5	0.1	2.11	- 1.59
September	64.6	0.2	0.65	- 3.63
October	57.7	5.1	0.27	- 2.11
November	41.0	3.4	1.40	- 0.11

[a]Taken from the U. S. Weather Bureau Summary.

trefoil (Empire strain) and orchardgrass (commercial strain). These three crops were planted in one gallon glazed pots, six inches in diameter and eight inches deep. Plantings were made as pure stands and in four combinations each with alfalfa and birdsfoot trefoil in combination with orchardgrass for a total of 16 treatments. Each treatment was replicated 6 times and sufficient pots established to provide material for four dates of harvest. The greenhouse experiment included 240 pots of plant material.

The soil used in greenhouse studies consisted of two-thirds Webster clay loam, one-sixth fine sand, and one-sixth peat. The soil, sand, and peat were thoroughly mixed after the soil had been screened by sifting over a 1/4 inch mesh screen. A uniform spacing was made for 12 plants in each pot. In the pure stands and mixtures, two or three seeds were planted in each of the 12 marked locations. After emergence the seedlings were thinned to a single plant basis (or transplanted when seed failed to germinate) to obtain a perfect stand of 12 plants in each pot. These three crops were established alone at the rate of 12 plants per pot and in mixtures including alfalfa and birdsfoot trefoil each at 3, 6, and 9 plants per pot in combination with orchardgrass at 9, 6, and 3 plants for a total of 12 plants per pot. The appropriate species of Rhizobium was added to insure inoculation of the legumes. The experiment was arranged in a randomized complete block with six replications for each of four dates of harvest.

The greenhouse was maintained at a temperature of 65° to 70° F. during the day and 60° to 65° F. at night. Lights were used to supplement daylight both morning and evening to provide a day length of 15 hours. Plants were watered with distilled water, the amount used determined by visual observation of the condition of the soil.

The first harvest was made on January 12-13, or 30 days after seeding. The second, third and fourth harvest dates were made on February 13-14, March 13-14, and April 14-15, or 60, 90, and 120 days after seeding. The top growth at each harvest date was cut about 1/2 inch above the soil, mixtures separated into the two crops in the association, and dried at 180° F. for six days prior to making dry weights.

Fertilizer was added at seeding date and as a top dressing just after the second harvest date. Plant food applied at each date was the equivalent of 20 pounds of nitrogen, 60 pounds of phosphorus and 30 pounds of potash per acre.

EXPERIMENTAL RESULTS

Field Studies

Plant populations

The number of alfalfa and red clover plants per square foot from stands established with three oat varieties each seeded at four rates and managed by removal at hay stange and at maturity are shown in Table 2. Stand counts were made in mid-May, 1954. The values shown are the average number of plants per square foot from six quadrates per plot for one replication.

The data from stand counts within each variety show a general but not uniform upward trend in legume plant population as the seeding rates for the companion oat crop were increased from one to two bushels per acre. This trend appears to be more pronounced for alfalfa than for red clover.

Because there was no trend for varietal affects upon legume stands, average values of all three varieties were computed to obtain a larger number of quadrate samples for each comparison of rates, species and management of the companion oat crop. These mean values show a consistently lower plant population when no oats was seeded in the establishment of either alfalfa or red clover. These results suggest that competition from weed growth in the absence of a companion oat crop was more severe than from oats. Legume

Table 2. Average number of legume plants per square foot with each of three companion oat varieties seeded at four rates with two methods of management of the companion crop, removed at hay stage and at maturity

Companion oat crop		Plants per square foot			
		Oats removed at hay stage		Oats removed at maturity	
Variety	Seeding rate bu. per acre	Alfalfa	Red clover	Alfalfa	Red clover
Shelby	0	12.6	8.1	11.6	7.3
	1	13.6	5.6	10.8	4.8
	2	21.8	13.3	13.3	11.5
	3	16.0	9.1	14.0	10.6
Cherokee	0	13.0	6.6	6.8	6.3
	1	16.0	7.6	13.0	8.0
	2	18.6	9.0	16.3	8.3
	3	17.0	8.3	15.0	8.1
CI 3867	0	13.5	6.1	10.8	7.0
	1	15.3	8.1	14.5	6.6
	2	19.8	7.6	18.0	6.0
	3	20.5	8.3	18.1	7.6
Averages for varieties	0	13.0	6.9	9.7	6.9
	1	15.0	7.1	12.8	6.5
	2	20.1	10.0	15.9	8.6
	3	17.8	8.6	15.7	8.8

stands at the one bushel oat seeding rate were consistently lower for both alfalfa and red clover than at the two bushel oat seeding rate. When oats were seeded at the three bushel rate legume stands were slightly lower than at the two bushel rate but only when the companion oat crop was removed at the hay stage. It is difficult to explain why a heavier rate of seeding should slightly depress stand establishment when the competitive effects of oats was removed at the hay stage and not at the mature stage of growth.

Average stands were consistently higher when the oat crop was removed at the hay stage of growth than at maturity, particularly for alfalfa.

Hay yields

Forage yields reported in Tables 3 and 4 are the average of three replications for the alfalfa and bromegrass components and the red clover and timothy components in each seeding rate and each method of management of three companion oat varieties.

Data shown in Table 3 include the total yield of alfalfa and bromegrass as well as the separate yields of each component of the mixture. These data show an increase in total forage yield as seeding rates for the companion oat crop were increased from none to either 1, 2 or 3 bushels per acre. Although there were significant differences in the total yield of forage as well as the legume portion of the mixture (see Table 5) the magnitude of the differences due to 1, 2 or 3 bushels seeding rate was not large. There was a general trend in decreased yields of bromegrass and increased yields of alfalfa as the oat seeding rates were increased. The data in Table 4 indicate a similar yield response for the red clover and timothy association.

The combined analysis of variance for total yield of forage and for the legume portion of the association is given

Table 3. Yield of dry forage in pounds per acre for combined and separate components of alfalfa and smooth bromegrass with three varieties of the companion oat crop seeded at four rates and removed at hay and mature stages

Companion oat crop		Forage yields, pounds per acre					
		Oats removed at hay stage			Oats removed at maturity		
Variety	Seeding rate bu. per acre	Total	Brome-grass	Alfalfa	Total	Brome-grass	Alfalfa
Shelby	0	2763	1262	1501	2624	805	1818
	1	3711	1034	2676	3554	870	2484
	2	3826	848	2977	3314	682	2632
	3	4160	762	3398	3253	697	2555
Cherokee	0	2713	1156	1557	2586	877	1708
	1	3477	1079	2397	3536	1437	2099
	2	3378	800	2578	3241	1063	2177
	3	3451	828	2623	3560	831	2729
CI 3867	0	2790	888	1901	2481	988	1492
	1	3410	749	2661	2904	1206	1698
	2	3625	777	2847	2910	877	2033
	3	3108	749	2314	3228	1217	2011
Averages for varieties	0	2755	1102	1653	2564	890	1674
	1	3533	954	2579	3331	1171	2160
	2	3610	808	2802	3155	874	2281
	3	3573	780	2793	3347	915	2432

in Table 5.

Significant differences also were obtained for methods of management of the companion oat crop. The data in Tables 3 and 4 show that total forage yields were higher when the companion oat crop was removed at the hay stage of growth. As might be expected, a large portion of the variance was due

Table 4. Yields of dry forage in pounds per acre for combined and separate components of red clover and timothy with three varieties of the companion oat crop seeded at four rates and removed at hay and mature stages

Companion oat crop		Forage yields, pounds per acre					
		Oats removed at hay stage			Oats removed at maturity		
Variety	Seeding rate bu. per acre	Total	Timothy	Red clover	Total	Timothy	Red clover
Shelby	0	2408	812	1596	2540	925	1614
	1	2561	683	1878	2705	1052	1652
	2	3101	610	2491	3158	827	2331
	3	3223	580	2643	3111	658	2433
Cherokee	0	3110	1115	1995	2610	939	1671
	1	2615	897	1718	3170	755	2415
	2	3023	636	2387	2593	718	1874
	3	3181	686	2495	2728	648	2086
CI 3867	0	2651	1099	1552	2307	918	1388
	1	3226	708	2517	2719	1359	1359
	2	2905	795	2113	3066	1173	1892
	3	3175	754	2421	2964	1007	1956
Averages for varieties	0	2723	1009	1714	2486	927	1559
	1	2801	762	2039	2865	1055	1810
	2	3010	680	2330	2939	906	2033
	3	3193	673	2520	2934	771	2163

to differences in yield between the alfalfa-bromegrass combinations and red clover-timothy mixture. The yield of alfalfa also was highly significantly greater than red clover.

None of the first order interactions involving varieties, rates, management and forages were significant either in terms of total yield or in terms of the legume component. This suggests that responses in forage yields, primarily due

Table 5. Combined analysis of variance for total yields of dry forage and the legume components from stands established with three companion oat varieties seeded at four rates per acre and removed at hay and mature stages

Source of variation	D.F.	Mean squares: Total yield	Mean squares: Legume component
Total	143		
Varieties	2	.2644	.9667
Replications	2	.7251	.4320
Error (a)	4	1.2477	.7440
Rates of seeding oats	3	2.8854[a]	4.8024[a]
Rates 1, 2, 3 bu.	2	.7073[b]	1.6402[a]
Rates 0 vs. 1, 2, 3	1	7.2414[a]	11.1268[a]
Error (b)	6	.0818	.0513
Management of oats	1	1.0299[b]	3.1599[a]
Forage species or mixture	1	4.5717[a]	2.5347[a]
Oat varieties x rates	6	.1763	.2440
Oat varieties x management	2	.0905	.6565
Oat varieties x forage species	2	.3565	.2370
Rates x management	3	.0462	.2141
Rates x forage species	3	.4141	.2622
Management x forage species	1	.7150	.0481
Remainder[c]	21	.2003	.2197
Pooled error	86	.2654	.4131

[a]Significant at the 1 per cent level.

[b]Significant at the 5 per cent level.

[c]Remainder consists of 3 second order and 1 third order interactions, none of which approached significance at the 5 per cent level.

to rates of seeding and methods of management of the companion oat crop, were relatively the same irrespective of variety of oats and species of forage. Lack of significance due to oat varieties and interactions with varieties thus justify presenting results on a variety mean basis as given in Tables 3 and 4.

From an examination of data on stands in Table 2 with forage yields in Tables 3 and 4 it is evident that differences in stand in the seeding year were strongly associated with yield of dry matter.

Greenhouse Studies

Data from the study conducted in the greenhouse are summarized in Tables 6 to 9, inclusive. The comparative growth made by each of the three crops grown alone as measured by dry weight of tops at four stages in their development from 30 to 120 days after sowing is shown in Table 6 and Figure 1. These data show that alfalfa made a greater growth than birdsfoot trefoil during the first 90 days but by the end of the period of test the two legumes were not greatly different in dry weight per plant. As measured in terms of accumulation of dry matter in successive 30 day periods, birdsfoot trefoil produced a relatively greater growth from 90 to 120 days than alfalfa while alfalfa increased in dry weight much more rapidly than birdsfoot trefoil during the periods from 30 to 60 days and from 60 to 90 days after sowing. This relatively slow growth rate of birdsfoot trefoil during the early stages of its development is in agreement with many observations under field conditions. Orchardgrass plants increased in

Table 6. Yield of dry forage in grams per plant for alfalfa, birdsfoot trefoil and orchardgrass grown alone at each of four dates of harvest

	Grams per plant		
Days after sowing	Alfalfa	Birdsfoot trefoil	Orchard-grass[a]
30	.0245	.0091	.0281
60	.1002	.0240	.2662
90	.7290	.4440	.9731
120	1.3848	1.2609	1.4965

[a]Mean for orchardgrass grown alone in the alfalfa and birdsfoot trefoil series.

dry weight more rapidly than alfalfa and birdsfoot trefoil during the periods from 30 to 60 days and from 60 to 90 days after establishment. The rapid growth rate of orchardgrass during early stages of seedling plant growth also is in agreement with field observations. From the data in Table 6 and Figures 1, 2 and 3, it is apparent that the three forage species differed markedly in their growth patterns, particularly during the first 90 days after sowing. These differences in growth patterns may thus form a logical basis for expectation of differences in their competition when grown in association.

Average yields of forage per plant at each of the four harvest dates for each crop grown alone and in combinations

Figure 1. Increase in dry weight per plant for orchardgrass, alfalfa and birdsfoot trefoil seedlings at 30, 60, 90 and 120 days after sowing when grown alone

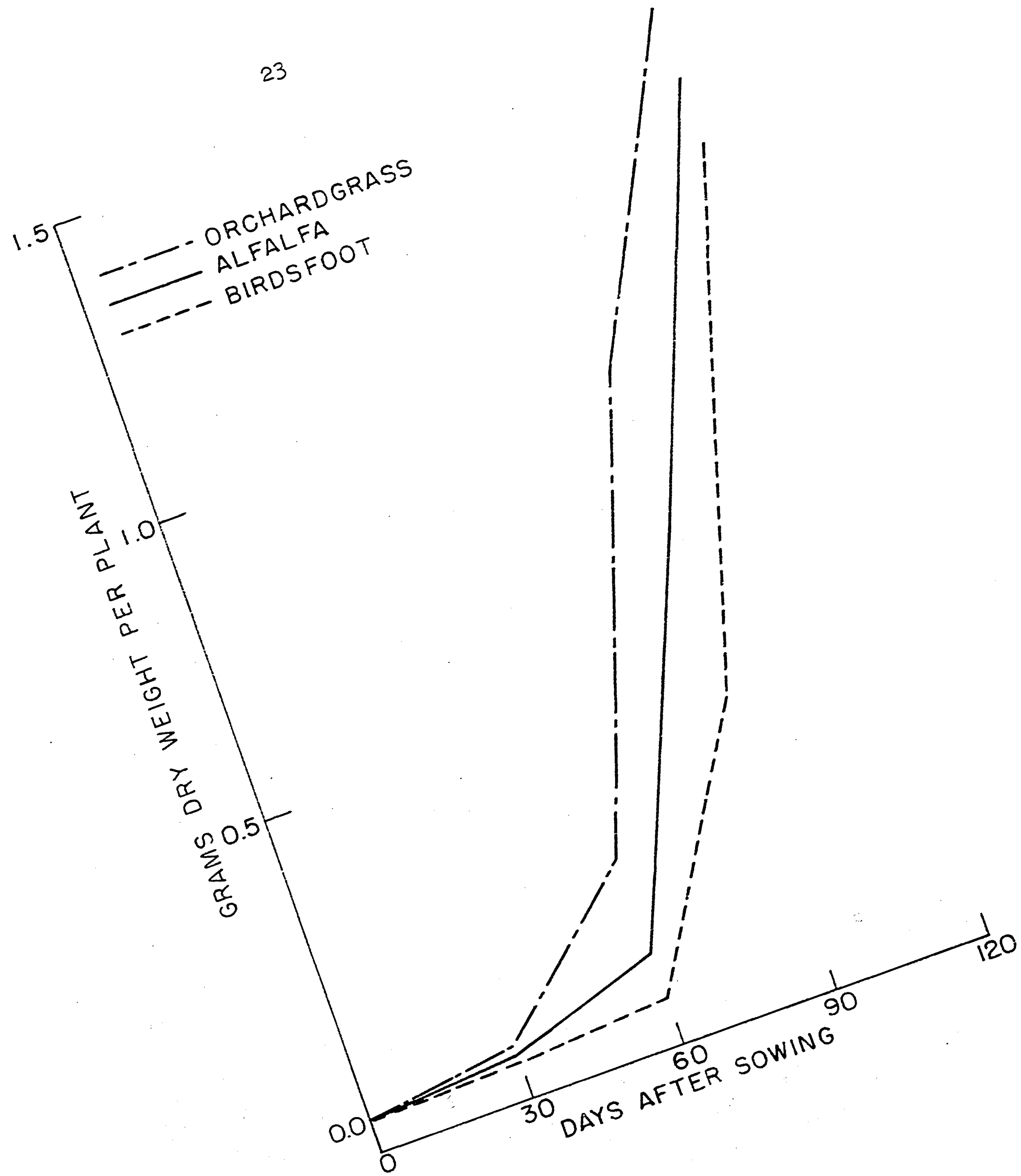
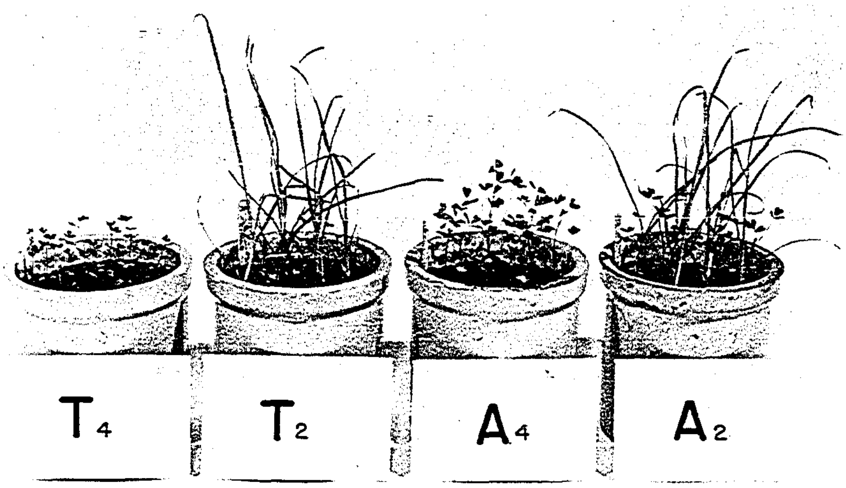
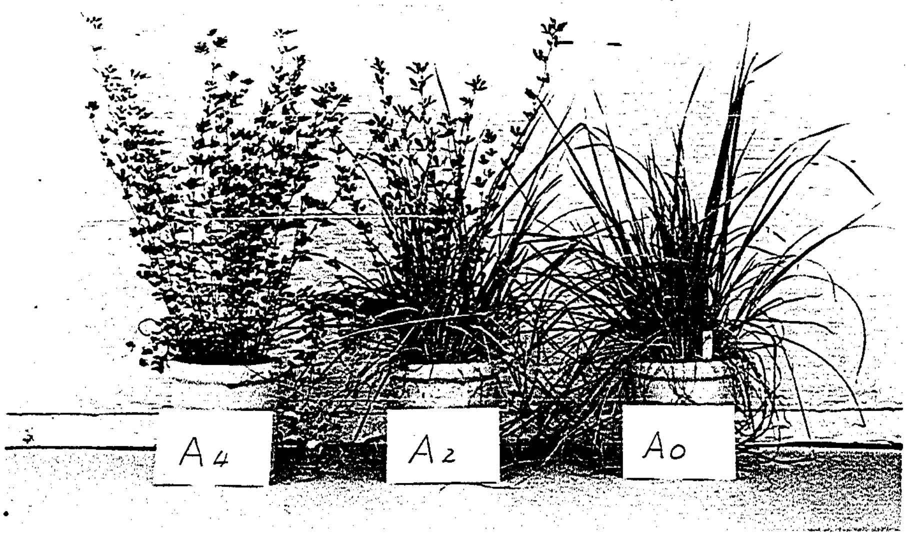

ORCHARDGRASS
ALFALFA
BIRDSFOOT
GRAMS DRY WEIGHT PER PLANT
1.5
1.0
0.5
0.0
0
30
60
90
120
DAYS AFTER SOWING

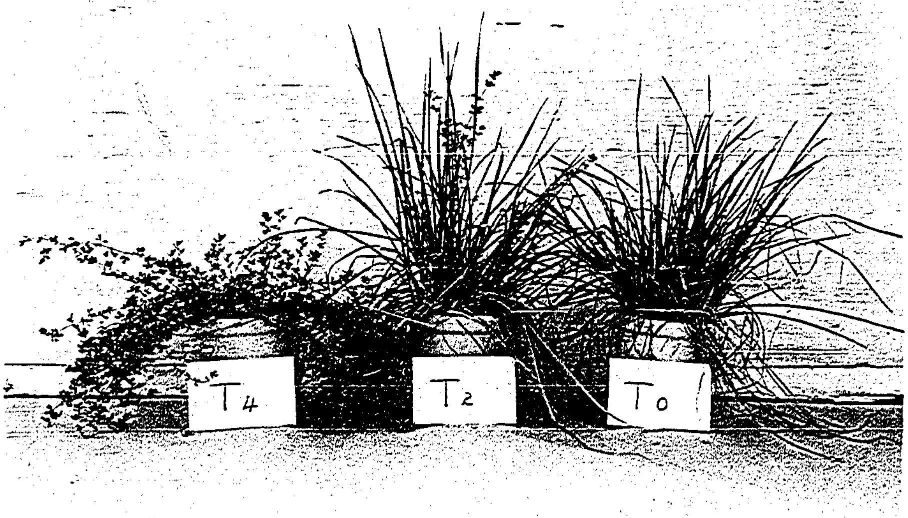
Figure 2. These photographs, taken 30 days after seeding, show alfalfa and birdsfoot trefoil grown alone and in combinations with orchardgrass. T_4 represents 12 trefoil plants per pot, T_2 is 6 plants of trefoil and 6 plants of orchardgrass per pot. Similar rotations for A apply to alfalfa


T4
T2
A4
A2


T4 T2 A4 A2 A0

Figure 3. These photographs, taken 120 days after seeding, show alfalfa and birdsfoot trefoil growing alone and in combinations with orchardgrass. A_4 and T_4 are pure stands of alfalfa and trefoil, respectively. A_2 and T_2 are 6 plants of alfalfa and 6 plants of orchardgrass and 6 plants of trefoil and 6 plants of orchardgrass, respectively


A4
A2
A0


T4
T2
T0

are summarized in Table 7. Data are reported for orchardgrass associated with both alfalfa and birdsfoot trefoil.

From the combined analysis of variance in Table 8 the mean squares for alfalfa grown in association with orchardgrass vs. alfalfa grown alone were highly significant at the third and fourth harvest dates. Data in Table 7 show that at the first harvest date the dry weight per plant of alfalfa was greater when grown in association with orchardgrass than when grown alone. At the second harvest date the growth of alfalfa was slightly greater when grown alone than when grown in association with orchardgrass, however, the difference was not significant at the 5 per cent level. The yield of alfalfa seedlings at the third and fourth harvests were considerably higher when grown alone than when grown in association with orchardgrass. These differences were highly significant. Differences in alfalfa yields when grown in combinations with orchardgrass, either with 3, 6 or 9 plants, were not significant at any harvest date.

The yield per plant of birdsfoot trefoil at the first harvest date, like that of alfalfa, was slightly but not significantly greater when grown in association with orchardgrass than when grown alone. At the second harvest date the yield was significantly greater at the 5 per cent level for trefoil grown alone. Trefoil yields at the third and fourth harvest dates were much greater when grown alone than when in association with orchardgrass. Mean squares for these

Table 7. Yield of dry forage in grams per plant for alfalfa and birdsfoot trefoil each grown alone and in combination with orchardgrass and for orchardgrass grown alone and in combination with alfalfa and birdsfoot trefoil at four harvest dates

Number of plants in each combination		Dry weights in grams per plant age of plants when harvested							
		30 Days		60 Days		90 Days		120 Days	
Legume	Grass	Legume	Grass	Legume	Grass	Legume	Grass	Legume	Grass
				Alfalfa and orchardgrass					
0	12	--	.0279	--	.2615	--	.947	--	1.412
3	9	.0338	.0311	.0833	.2964	.451	1.141	1.081	1.844
6	6	.0294	.0269	.0989	.3572	.387	1.385	1.059	2.119
9	3	.0270	.0355	.0957	.4655	.439	2.109	.944	3.567
12	0	.0245	--	.1002	--	.729	--	1.385	--
				Birdsfoot trefoil and orchardgrass					
0	12	--	.0283	--	.2709	--	.999	--	1.581
3	9	.0166	.0292	.0168	.2846	.114	1.231	.363	1.988
6	6	.0102	.0316	.0194	.4024	.162	1.747	.439	2.997
9	3	.0088	.0400	.0179	.4305	.224	2.713	.632	4.642
12	0	.0091	--	.0240	--	.444	--	1.261	--

Table 8. Combined analysis of variance for alfalfa and birdsfoot trefoil each grown alone and in combination with orchardgrass and for orchardgrass grown alone and in combinations with alfalfa and birdsfoot trefoil

Source of variation	DF		Mean squares Date 1[a]	Date 2	Date 3	Date 4
Total	95					
Replications in groups	20					
Treatments	15		.000540[b]	.15577[b]	3.34987[b]	8.09666[b]
Alfalfa in orchardgrass		2	.000022	.00041	.00676	.03248
Alfalfa in orchardgrass vs. alfalfa alone		1	.000137	.00026	.41355[b]	.43833[b]
Trefoil in orchardgrass		2	.000103	.00001	.01812	.11529[b]
Trefoil in orchardgrass vs. trefoil alone		1	.000035	.00016[b]	.34561[b]	.75867[b]
Orchardgrass in alfalfa		2	.000110	.04402[b]	1.52223[b]	5.14164[b]
Orchardgrass in alfalfa vs. orchardgrass alone		1	.000048	.05527[b]	1.60919[b]	5.42818[b]
Orchardgrass in trefoil		2	.000190[b]	.03596[b]	3.39530[b]	10.76833[b]
Orchardgrass in trefoil vs. orchardgrass alone		1	.000127	.04644[b]	3.63165[b]	11.92610[b]
Remainder		3	.002268[b]	.69125[b]	11.45440[b]	23.92770[b]
Error	60		.000036	.00126	.020770	.02849
Alfalfa alone and in orchardgrass		15	.000042	.00029	.012392	.03089
Trefoil alone and in orchardgrass		15	.000017	.00003	.002142	.00954
Orchardgrass alone and in alfalfa		15	.000042	.00268	.036862	.03406
Orchardgrass alone and in trefoil		15	.000046	.00203	.031696	.03944

[a]Dates of harvest at 30, 60, 90 and 120 days respectively after sowing.

[b]Significant at the 1 per cent level.

differences were highly significant. Differences in birdsfoot trefoil yields when in three combinations with orchardgrass were highly significant only at the fourth date of harvest.

From data in Tables 7 and 8 the higher yields of orchardgrass when grown in association with alfalfa than when grown alone were highly significant at the second, third and fourth dates of harvest. Yield differences for orchardgrass grown in three associations with alfalfa also were highly significant at the second, third and fourth dates of harvest.

Orchardgrass yields per plant when grown in association with birdsfoot trefoil also were highly significantly greater than when grown alone at the second, third and fourth harvest dates. Yield differences for orchardgrass grown in three associations with birdsfoot trefoil were highly significantly different all dates of harvest.

The data in Table 7 therefore show that orchardgrass grown in combination with either alfalfa or birdsfoot trefoil suppressed yields of legumes, most pronounced at the stage in its development when greatest growth was made.

A more critical analysis of the gains or losses for each crop grown in association in comparison with its yield when grown alone is shown in Table 9. These comparisons were made only for the second, third and fourth harvest dates. For example, in the mixture of 9 legume and 3 grass plants in second harvest the yield of alfalfa in association with

Table 9. Gain or loss in dry weight per plant for each of the components in an association and the accumulated gain and loss in their association as based on dry weight per plant when each member was grown alone

Crops grown in association	Number of plants in association: 9 Legume 3 grass	6 Legume 6 grass	3 Legume 9 grass
	Second harvest date		
Alfalfa	- .0169	- .0013	- .0045
Orchardgrass	+ .0349	+ .0857[a]	+ .2040[a]
Net gain or loss	+ .0180	+ .0844[a]	+ .1995[a]
Birdsfoot trefoil	- .0072	- .0046	- .0061
Orchardgrass	+ .0137	+ .1315[a]	+ .1596[a]
Net gain or loss	+ .0065	+ .1269[a]	+ .1535[a]
	Third harvest date		
Alfalfa	- .2779[a]	- .3420[a]	- .2904[a]
Orchardgrass	+ .1936[a]	+ .4380[a]	+1.1622[a]
Net gain or loss	- .0843	+ .0960	+ .8718[a]
Birdsfoot trefoil	- .3296[a]	- .2818[a]	- .2200[a]
Orchardgrass	+ .2324[a]	+ .7484[a]	+1.7143[a]
Net gain or loss	- .0972	+ .4666[a]	+1.4943[a]
	Fourth harvest date		
Alfalfa	- .3043[a]	- .3254[a]	- .4410[a]
Orchardgrass	+ .4327[a]	+ .7069[a]	+2.1555[a]
Net gain or loss	+ .1284	+ .3815[a]	+1.7145[a]
Birdsfoot trefoil	- .8982[a]	- .8215[a]	- .6291[a]
Orchardgrass	+ .4069[a]	+1.4160[a]	+3.0610[a]
Net gain or loss	- .4913[a]	+ .5945[a]	+2.4319[a]

[a]Significant at the 1 per cent level.

orchardgrass was .0169 gram per plant less than when grown alone, but the yield of orchardgrass in this combination was .0349 gram more than when grown alone, or a net gain of .0180 gram per plant for the association. In the mixture of 6 legume and 6 grass plants, although the reduction in the yield of alfalfa was not significant and the gain for orchardgrass was significant, the net gain was statistically significant. In this association the gain in grass yield was .0180 gram per plant more than the loss in legume yield when each was grown in association.

As the grass component in the associations was increased to 6 and 9 plants respectively with 6 and 3 plants of legume, all associations showed a highly significant net gain in yield per plant. In all cases the legume yield was lower when grown in association with orchardgrass than when grown alone. The yield of orchardgrass was increased in each case when grown in association with a legume. In no case was there a significant increase or a significant decrease for both crops in an association. Evidence is therefore lacking for either antagonistic or mutually beneficial associations among these crops under the conditions of the greenhouse study. In two cases among the 18 combinations the increased grass yield did not more than equal the reduction in legume yield when each was grown in an association. These were the combination of 9 plants of birdsfoot trefoil with 3 plants of orchardgrass at the third and fourth harvest dates.

One of the striking features of these comparisons is the consistently greater increase in yield per plant of orchardgrass grown in association with birdsfoot trefoil than orchardgrass grown in association with alfalfa in the third and fourth harvest dates, indicating that orchardgrass was more competitive to birdsfoot trefoil than to alfalfa.

DISCUSSION

Success or failure to obtain stands from forage seedlings usually can be attributed to the favorable or unfavorable interaction of the species to complex factors of the environment and to competition of the species either with other species seeded with it or volunteering as weeds. Contrary to early views, the cereal crops in which forage stands usually are seeded are not "nurse" crops. They are competitors of the young forage seedlings for water, light and nutrients.

Because experimental work in the field is subject to influence by many uncontrolled environmental conditions prior to and during the growing season, interpretation of results and the development of valid conclusions generally are subject to error. Information obtained from this study, like those previously made, is subject to these limitations in lack of control and hence very few generalizations are justified except those applicable to similar conditions.

Temperatures during the establishment of this experiment in 1953 generally were below normal in April and May; slightly above normal in June and very nearly normal through September.

Precipitation during April was 0.43 inches above normal and at the time seedings were made soil moisture conditions were favorable. Precipitation during May was below normal but in June was 0.65 inches above normal. For the remainder of the year a deficiency of 9.09 inches was reported for the period of July 1 through November. Moisture deficiency during July and subsequent months undoubtedly affected seedling survival as related to plant competition for soil moisture.

In agreement with results reported by previous investigators (12, 13, 19) the rate of seeding and method of managing the companion oat crop in this study had an effect upon legume stand survival.

As measured by plant population of legumes, excluding oats was not beneficial and lower rates of seeding did not produce better stand than heavier rates. Differences in the effects of seeding oats at one and two bushels per acre apparently were leveled out by increased weed growth which tended to equalize the amount of growth under both rates.

When oats were seeded at the three bushels rate forage stands and subsequent hay yields were slightly lower than those from the two bushel rate, but only when the companion crop was removed at the hay stage. This stand reduction is explained as an interaction between micro-climatic changes and competing factors. Legume plants under a heavy growth of oats seeded at three bushels per acre were apparently weakened by competition for moisture and light. Sudden removal of the companion crop exposed the legume seedlings to an environment of more intense sunlight, lower humidity, increased ground radiation and higher temperatures. These conditions establish a greater moisture stress upon the seedling plants. These moisture stresses were greater than soil moisture supply and only the more vigorously growing plants were able to survive. Temperatures at the time of oat hay removal were above normal and the precipitation was below normal.

Legume stands and subsequent forage yields were not depressed with the three bushel rate of seeding removed at the mature stage. Under these conditions the legume seedlings were more slowly adjusted to a changed environment as the oat crop matured and were not subjected to the sudden shock as when the oat crop was removed at hay stage.

Perennial forage crop mixtures as generally compounded for hay and pasture are artificial plant associations. Species included in these associations may not be mutually beneficial to each other. Differential responses of perennial grasses and legumes to natural and imposed environmental factors that affect growth account for many difficulties in establishing and maintaining desired botanical composition.

In this investigation alfalfa, birdsfoot trefoil, and orchardgrass were grown alone and in combinations under greenhouse conditions. In terms of dry matter accumulation, each of these crops developed a distinctive growth pattern when grown alone, as shown in Figure 1. The relatively slow growth for birdsfoot trefoil during the first 60 days after sowing is in agreement with field experiences. Many birdsfoot trefoil seeding failures occur under conditions where satisfactory alfalfa stands could be expected. Field observations also show that birdsfoot trefoil stands often fail following the generally accepted forage stand establishment practices. Aggressive early season competition becomes a serious hazard in establishing successful stands of birdsfoot trefoil.

It is evident that orchardgrass has a rapid growth rate during early stages of seedling development. There are important differences in growth behavior patterns among the three species studied, however these differences were not well established until 60 days after sowing. These data show that the most critical time for birdsfoot trefoil seedling survival is within the first 60 days after sowing. These differences in growth patterns give an indication of expected differences in competition when grown in association.

It is recognized that results obtained in the greenhouse represent responses under a single environmental condition. A more precise evaluation of competitive relationships would require a series of controlled environments covering the ranges normally encountered under field conditions.

SUMMARY AND CONCLUSIONS

A field experiment was established in the spring of 1953 to study the relationship between the variety, seeding rate and management of the companion crop and forage crop stands and yields. Three oat varieties seeded at 0, 1, 2 and 3 bushels per acre were removed at hay and mature stages of growth. Forage crops studied included associations of alfalfa-bromegrass and red clover-timothy.

Results of this portion of the study may be summarized as follows:

1. The oat varieties Shelby (late), Cherokee (early) and CI 3867 (midseason) did not differ in effect upon legume stands or forage yields.

2. Competition from weed growth in the absence of a companion crop was more severe than from oats.

3. Legume plant populations were increased as the oat seeding rate was increased from 1 to 2 bushels per acre. Oats seeded at the three bushel rate and removed at hay stage tended to depress legume plant populations.

4. Legume stands were higher and forage yields were increased when the oat companion crop was removed at hay stage of growth.

5. Differences in forage yields due to oat seeding rates 1, 2 and 3 bushels per acre were not large, but forage

yields were significantly lower when no companion crop was used.

A greenhouse experiment was conducted during the winter of 1956 and 1957 to study growth responses of alfalfa, birdsfoot trefoil and orchardgrass growing alone and each legume in three combinations with orchardgrass. Growth behavior patterns were measured in terms of accumulation of dry matter in successive 30 day periods.

Results of this study may be summarized as follows:

1. Alfalfa plants made a greater growth than birdsfoot trefoil during the first 90 days after sowing, however the dry weights per plant for these two legumes were not greatly different after 120 days of growth. Alfalfa increased in dry weight much more rapidly than birdsfoot trefoil during the periods from 30 to 60 days and from 60 to 90 days after sowing while birdsfoot trefoil produced a relatively greater growth from 90 to 120 days than alfalfa.

2. Orchardgrass plants increased in dry weight more rapidly than either alfalfa or birdsfoot trefoil during the periods from 30 to 60 days and from 60 to 90 days after seeding.

3. Orchardgrass grown in association with either alfalfa or birdsfoot trefoil suppressed yields of these legumes. As the proportion of the orchardgrass component was increased in the associations, the greater yields of orchardgrass more than offset reduced yields of the legumes.

4. Orchardgrass was more competitive to birdsfoot trefoil than to alfalfa.

5. There was no evidence for either antagonistic or mutually beneficial effects from associations among the three species included in this study.

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