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Albert Fischer for the degree of Master of Science

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Title: Interference of Annual Weeds in Seedling Alfalfa

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The interference of barnyardgrass (*Echinochloa crus-galli*), pigweed (*Amaranthus retroflexus*), downy brome (*Bromus tectorum*), and tumble mustard (*Sisymbrium altissimum*) with alfalfa was studied. Alfalfa was seeded with each of the four weeds on August 14 and September 15, 1981, and on April 13, 1982. Alfalfa also was seeded on August 27, 1981, with a mixture of the four weed species, and the weeds were allowed to grow with the crop during several intervals.

The presence of weeds emerging with the crop in the fall reduced alfalfa yields in the first two cuttings in the spring. When alfalfa and each of the weeds were planted on August 14 (early seeding), barnyardgrass and downy brome were the most interfering weeds. In a later seeding (Sept. 15), the summer annual weeds (barnyardgrass and pigweed) were killed by frost in the fall and did not compete with the crop; downy brome and tumble mustard (winter annuals), however, became more aggressive than if allowed to emerge with the crop a month earlier.

When alfalfa seeded on August 27 was kept weed free for approximately 65 days after emergence, no further weed control was needed for maximum forage yields in the spring. Conversely, the crop tolerated weeds that emerged with it if they were eliminated before the onset of winter.

In the spring seedings, the four weeds interfered equally with the crop. Alfalfa needed to grow free of weeds from approximately the 17th to the 39th day after emergence to avoid forage yield and quality reductions.

Weeds that emerged early with the crop reduced forage yields more than later-germinating weeds. Once the alfalfa developed a canopy capable of covering the soil, weeds emerging thereafter were suppressed by shading.

The initial tolerance to the presence of weeds allows the farmer flexibility in the timing of the first weed control measure. This initial tolerance seems to indicate that interference is not significant until competition for light begins.

INTERFERENCE OF ANNUAL WEEDS IN SEEDLING ALFALFA

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DEDICATION

This thesis is dedicated to Mr. Carlos Perea, head of the Plant Protection Project at "La Estanzuela"-Uruguay, who introduced me to the world of weed research.

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INTRODUCTION

Problem

Alfalfa (*Medicago sativa* L.) is grown in several areas of the U.S. covering some 12 million hectares of production (39). In 1978, the state of Washington used 2,993,760 ha as cropland, of which 249,885 ha were grown as pastures. In 1980, 204,525 ha of alfalfa were harvested for hay, yielding 8,288 kg/ha of forage. This represents a total production of 1,695,103 thousand kg of alfalfa hay for this state (52).

Alfalfa has small and slow-growing seedlings that suffer early competition from weeds emerging with the crop (16). Some of the most important weeds infesting new seedings of alfalfa in the Yakima valley are: barnyardgrass (*Echinochloa crus-galli* L. Beauv.), downy brome (*Bromus tectorum* L.), tumble mustard (*Sisymbrium altissimum* L.), hairy nightshade (*Solanum sarrachoides* Sendt.), pigweeds (*Amaranthus retroflexus* L., *A. powellii* S. Wats., and *A. hybridus* L.), and lambsquarters (*Chenopodium album* L.) (12,13,17). Thus we find summer and winter annual broadleaves and grasses.

The interference exerted by each species on the growth of the alfalfa may differ (36,48,49) and may also vary according to the seeding date of the crop (21,41,37). Weeds in new seedings of alfalfa can be more troublesome if the crop is planted in spring rather than in late summer or early fall (21). This fact, and the lower forage production of spring seedings, make late summer and early fall seeding preferable (41,21).

The rather cool temperatures in spring cause slow initial growth of the alfalfa seedlings, but conditions are favorable for many weeds to emerge and develop fast. Those weeds emerging with the crop would be the most damaging.

In late summer or fall seedings, frost will kill the summer annuals, leaving the winter annual weeds as a problem for alfalfa regrowth in the spring (16). Prefrost interference (if any) by weeds should be different if alfalfa is planted in late summer or a month later, because of lower temperatures (Appendix). Seeding in the middle of August would allow the summer annuals to develop more than if seeded on September 15. Later seedings, however, might suffer more severe initial competition from the winter annuals emerging with the crop (16). These emerge and grow in a cooler time of the year, when alfalfa grows slowly; the summer annuals, in turn, may be eliminated by early frosts shortly after emergence.

Alfalfa seeded September 15 will be less developed at first frost than that seeded August 15, thus being more susceptible to frost damage; its spring regrowth will be from a rather small plant, more vulnerable to the interference of weeds emerging in spring.

Thus, the following questions arise:

-What is the effect of weeds in fall upon a new seeding of alfalfa?

-What benefit can be expected by varying planting dates within a late summer-early fall seeding season?

-Is the first clipping in spring effective enough to eliminate the weed problem, or must weeds be controlled earlier? If so, how early and for how long?

-If there is a harmful effect of the weeds in fall, how long will this effect last? Will it be eliminated after the first clipping or will it show in all the cuttings of the season?

In the Yakima valley, State of Washington, alfalfa for hay is irrigated and planted in late summer and occasionally in spring. Spring seedings occur when late summer harvest operations of the preceding crop are delayed and the land cannot be timely prepared for alfalfa.

With spring seedings we should know if the first clipping will eliminate the weed problem, or if there is a depressive effect (and of what magnitude) that requires earlier attention. Will a weedy and a weed-free plot equal their yields after the first or second cutting, or for how long do their yields remain different?

Background

Interference, as defined by Muller (33), is the detrimental effect of one plant upon another, the concepts of competition and allelopathy are included here.

Two or more plants interact competitively when each one tries to satisfy its requirements for a given factor, and the capacity of the environment to supply that factor lies below the level of the combined requirements of those interacting plants. Competition occurs when the growth of two or more organisms, interacting with each other, is reduced or modified in comparison to the growth pattern exhibited when interaction between individuals is not possible (2).

If crop and weeds are physiologically similar (14), both will require the same environmental factors for their growth and development, thus competitive interactions may occur for soil nutrients, water, light, and perhaps air in very particular circumstances.

The duration of competition, i.e., the time this competitive interaction between crop and weeds is allowed to proceed, will be one of the factors determining how severely the weeds will depress the crop's yields.

Several authors (4,6,14,26,35,38,54) have looked into this aspect while working with various crops. Their conclusion is that the longer the weeds are allowed to compete with the crop, the higher the yield losses are. At the same time, they found that the crops are not equally sensitive to competition from weeds throughout their growth cycle. Working with alternating weedy and weed-free periods, they were able to establish the so-called "critical periods" during which the weeds had to be removed to ensure maximum yields from the crop they were growing. In general, crops were most sensitive to the presence of weeds in the early stages of the growth cycle. It thus seems that the weeds emerging with the crop are the most harmful, but they only have to be removed until a certain stage of the crop's development is reached, namely when its canopy is sufficiently developed to shade and suppress further growth of late emerging weeds (14,26,56).

Many authors also found that there is a relatively short initial period during which the crop tolerates the presence of the weeds that emerge with it. Competition begins only when the environmental resources are no longer in excess of the needs of plants growing together; therefore it cannot be assumed that weed presence is always damaging. Even if there is an environmental factor in short supply, competition will not begin until the plants somehow interact with each other (56).

Dawson (14), demonstrated that if beans and sugarbeets had ample water through irrigation and were grown on soils of adequate fertility, the factor that determined the onset of competition was light. This agrees with Donald (20). The presence of the weeds that emerged with the crop was tolerated until the weeds grew taller than the crop and began to shade it. Other authors (32) also saw this effect working with corn intercropped with beans under good rain-fed conditions. If the level of fertilization was high, corn tolerated the weeds during the first 15 days after emergence, but if no fertilizer was added, this initial tolerance disappeared. This means that factors other than light - presumably soil nutrients - were limiting and determined the onset of competition. Under favorable growing conditions such an initial intolerance to weeds could also suggest an allelopathic effect. Since our was work not intended to separate both effects, we prefer to speak of interference rather than competition. According to Donald (19), once an aggressor species gains advantage over another species for a certain growth factor, it rapidly becomes superior in utilizing the other growth factors of the habitat as well. Even if these other factors are not in short supply, the capacity of the suppressed species to utilize them is reduced.

Modifying the planting date may affect the degree of competition a crop suffers from weeds (21,25,37,41). We have already speculated on how this could affect a new seeding of alfalfa. In many cases a change in the time of emergence interacts with the photoperiodic response. Oliver (37) showed that velvetleaf (Abutilon theophrasti emerging with soybeans in mid May was twice as competitive as if it emerged with the crop planted in late June. This was due to the short-day photoperiodic response of velvetleaf which induced an early cessation of the vegetative growth following a late planting; thus the weed was not able to reach its competitive size which would have enabled it to make a significant demand of the environmental growth factors.

Schreiber and Oliver (48,49) related the different competitive ability of pigweed and giant foxtail (*Setaria faberii* Herrm.) to the height and composition of the canopy each species developed.When such weeds competed during the establishment of birdsfoot trefoil (*Lotus corniculatus* L.) or alfalfa, pigweed developed a canopy that allowed earlier and greater attenuation of the light reaching the crop and thus caused the lowest legume production. Schreiber (47),working on the establishment of alfalfa and birdsfoot trefoil, found lambsquarters to be more competitive than giant fox-tail.Several authors expressed the different competitiveness of the weeds by calculating competition indexes or coefficients of weed noxiousness (5, 11, 18, 29, 45, 53). Such calculations generally involve a regression analysis between the obtained crop yield (dependent variable) and different degrees of weediness (independent variable), expressed as number of weeds per unit area or as weed biomass. Some authors consider this last parameter a better estimator of the level of weediness (5, 11, 29, 53). Pulli (45), using relative crowding coefficients to show the competitiveness of alfalfa and weeds, concluded that alfalfa has a good competitive ability against certain weeds. Hollingsworth (24) found a greater benefit from the release of weed competition in birdsfoot trefoil than in red clover (Trifolium pratense) or alfalfa, which indicates a higher competitiveness of the last two species.

Density, or the number of plants per unit area, is another factor affecting the outcome of a competitive interaction. Some farmers will sow their alfalfa using relatively high seeding rates to counteract the flush of weeds usually emerging with the crop. The percentage of alfalfa with respect to weeds present in a first cut of hay can be increased by raising the seeding density of alfalfa (44, 45). However, Norris (36) reports that increasing the seeding density of alfalfa from 16.5 to 33 kg/ha of seed did not compensate for either yield or stand loss caused by several weeds.

Increasing densities of weed infestations are responsible for decreasing crop yields. This relationship appears to follow a sigmoidal (56) or a curvilinear pattern (31, 34). At low densities, each increment in weed population causes a large increment in crop yield loss. The increments in crop yield loss become progressively smaller as we approach the higher densities. There will be a weed density at which maximum crop yield reduction will occur. Further increments in density will be possible due to the plasticity (10) of the weeds; in this case reducing their size to allow more individuals to fit in the habitat. Thus there is a compensatory effect: more plants, but smaller. In any case, maximum crop loss occurs at less than maximum weed density (56). Thus there seems to be a saturating competitive effect at the higher weed populations (14) and such high weed infestations are common amongst commercial crops (14, 36). Therefore, if one does not want density to be a factor while assessing the interference of a weed upon a crop, one should use high, saturating populations of the weed. Working with low densities would be useful to assess the effect of those weeds that remain after incomplete weed control. The soil seed reservoir is such that the emerging populations are usually so high that they provide dense populations with a saturating effect.

A few papers have referred to the effects of weed competition in fall-seeded alfalfa. Norris (36) found a reduction in fall-seeded alfalfa yield and stand in the weed infested plots, at the first forage harvest. This lower yield, compared to the weed-free plots, persisted through the first growing season, up to the last cutting. The reduction in the alfalfa stand increased the severity of infestations by summer annual weeds.

In 1980, Pike and Stritzke (44) worked with downy brome infesting fall-seeded alfalfa. Four alfalfa seeding rates were used. At the first cutting, the weedy plots produced the highest yields in dry matter. Higher alfalfa seeding rates increased the percentage of alfalfa in the harvested forage mixtures. Alfalfa yields were highest in the weed-free plots and at the higher densities. In the subsequent harvests, there were little differences in yield attributable to seeding rates. Downy brome competition reduced alfalfa yields during the first four harvests. The total forage for the season was 1000 kg/ha less in the weedy plots. The downy brome competition reduced the seasonal alfalfa production by 1,500 to 2,000 kg/ha.

On the other hand, Cary and Stritzke in 1978 (8) used downy brome densities ranging from 19 to 134 plants/m^2. The high densities reduced the stand of alfalfa, but the resulting stand was still adequate and no differences in alfalfa production were recorded among treatments at the second harvest.

<u>General Objectives</u>

The objectives of these studies were:

(a) To work with four of the most important weeds in central Washington (barnyardgrass, pigweed, downy brome, and tumble mustard), assess the interference of weeds in the fall on a new seeding of alfalfa, and examine their relative interfering effect.

(b) By modifying the planting date between late summer and early fall,determine any possible beneficial reduction of interference by weeds.

(c) To establish the periods during which the crop either tolerates or suppresses the weeds,and find the time and the duration of the period where weeds have to be removed in order to avoid yield reductions.

(d) If a negative effect by the weed competition in fall is found, to assess for how long, in the growing season such effect will persist.

(e) Working with spring-seeded alfalfa and the same four weeds,to determine their relative detrimental effect in that season and establish that period in the crop's growth cycle when their presence cannot be tolerated.

(f) Predict crop losses in spring, for an alfalfa crop seeded late summer and early fall, based upon alfalfa or weed growth at the onset of cold weather in fall.

(g) Prescribe logical integrated weed management practices that would prevent yield losses in new seedings of alfalfa, and that would also attack weeds when most vulnerable, and in a schedule that offers the farmer maximum flexibility.

II - INTERFERENCE BETWEEN FOUR WEED SPECIES AND ALFALFA SEEDED AT TWO DATES IN LATE SUMMER

Objectives

(a) Determine the respective effects of interference from four common weeds (representing a winter annual grass, a winter annual broadleaf weed, a summer annual grass, and a summer broadleaf weed) on alfalfa, when seeded at the beginning of the normal period for late summer seeding (mid August) or near the end of that period (mid September).

(b) Determine when these species emerge in relation to the crop.

(c) Predict spring losses for an alfalfa crop seeded in late summer and early fall, based upon growth of weeds and alfalfa in the fall, as a guide in determining the control measures needed to protect the crop.

Materials and Methods

The trial was conducted on Warden very fine sandy loam (coarse-silty, mixed, mesic, Xerollic Camborthids) at the Irrigated Agriculture Research and Extension Center near Prosser, Washington.

Water was applied as needed by sprinkler irrigation. Treatments were arranged in randomized complete blocks with split-plots and five replications. The plots were 2.1 by 10.1 m; the blocks were separated by alleyways 0.9 m wide.

Seeding dates (main plot treatments) were August 14 and September 15, 1981. Five treatments were assigned to the subplots: alfalfa free of weeds or overseeded with either barnyardgrass (Echinochloa crus-galli (L.) Beauv.), pigweed (Amaranthus retroflexus L. and A. powellii S. Wats), downy brome (Bromus tectorum L.), or tumble mustard (Sisymbrium altissimum L.) (Table II-1). Tumble mustard and downy brome behave as winter annuals, while barnyardgrass and pigweed are summer annuals.

The seedbed was prepared with a power-driven rotary tiller followed by packer rollers. The seed of each weed species was then broadcast by hand over each corresponding plot and incorporated 2.5 cm deep with a double roller or a power-driven tine-tooth harrow . Seeding density was 1 seed/cm^2 for pigweed, barnyardgrass, and tumble mustard; and 1 seed/7 cm^2 for downy brome. The required amount of seed to be sown in each plot was weighed. Immediately after seeding the weeds, 'Vernal' alfalfa seed was treated with the required amount of Rhizobium meliloti inoculant and drilled 2 cm deep into rows 17.8 cm apart, at the rate of 20.2 kg/ha. The experimental area was irrigated following seeding.At weekly intervals, crop and weed development was assessed and their emergence, within a 0.5 x 0.5 m quadrat located near one corner of each plot, was recorded. After

1 Two metal rollers-packers of a "Brillion" forage seeder Brillion Iron Works, Brillion, Wisconsin 54110.

2 Northwest Rotary Weeder manufactured by Northwest Equipment Co., Yakima, WA 98901.

counting, the seedlings were burnt with a propane burner to facilitate the identification of new seedlings the following week.

The weed-free check and the botanical purity in the weedy plots were maintained by regular hand weedings.

On October 18, 1981, alfalfa and weed plants within a (0.53 m^2) quadrat near one end of the plots seeded August 14, were dug out. The species were then separated and dried at 65 C for 64 h. The dry weights of weed shoot, and alfalfa shoot and root, were recorded. The September 15 seeding was similarly sampled on the same date, but in this case the dry weights of whole plants were taken; they were not divided into shoots and roots.

Alfalfa was first harvested at the late bud stage on May 24 and 26, 1982 (early and late seeding dates, respectively). The crop in the weed-free plots was 88 and 67 cm tall for the first and second planting dates, respectively. Forage was harvested from a central area of 8.6 m^2 (1.07 by 8.06 m) in each plot, with a "Gravely" sickle mower.

Total forage fresh weight and that of a representative sample were measured from each plot. Species in each sample were separated, oven dried at 65 C for 72 h, and weighed. Alfalfa and weed dry matter from each plot was thus assessed.

Second and third forage clippings were on July 1 and August 27. After first and second harvest, the alfalfa stems in the stubble were counted in 1 m of row, twice per plot. After the third harvest, alfalfa plants and stems in the stubble were counted in six 1 m rows in each plot.After the first harvest, tumble mustard and downy brome stems were counted in a $(0.25\ m^2)$ quadrat placed twice in each plot. Twelve soil cores 2 cm in diameter from the top 12 cm of soil, were taken and composited for later analysis for major nutrients.

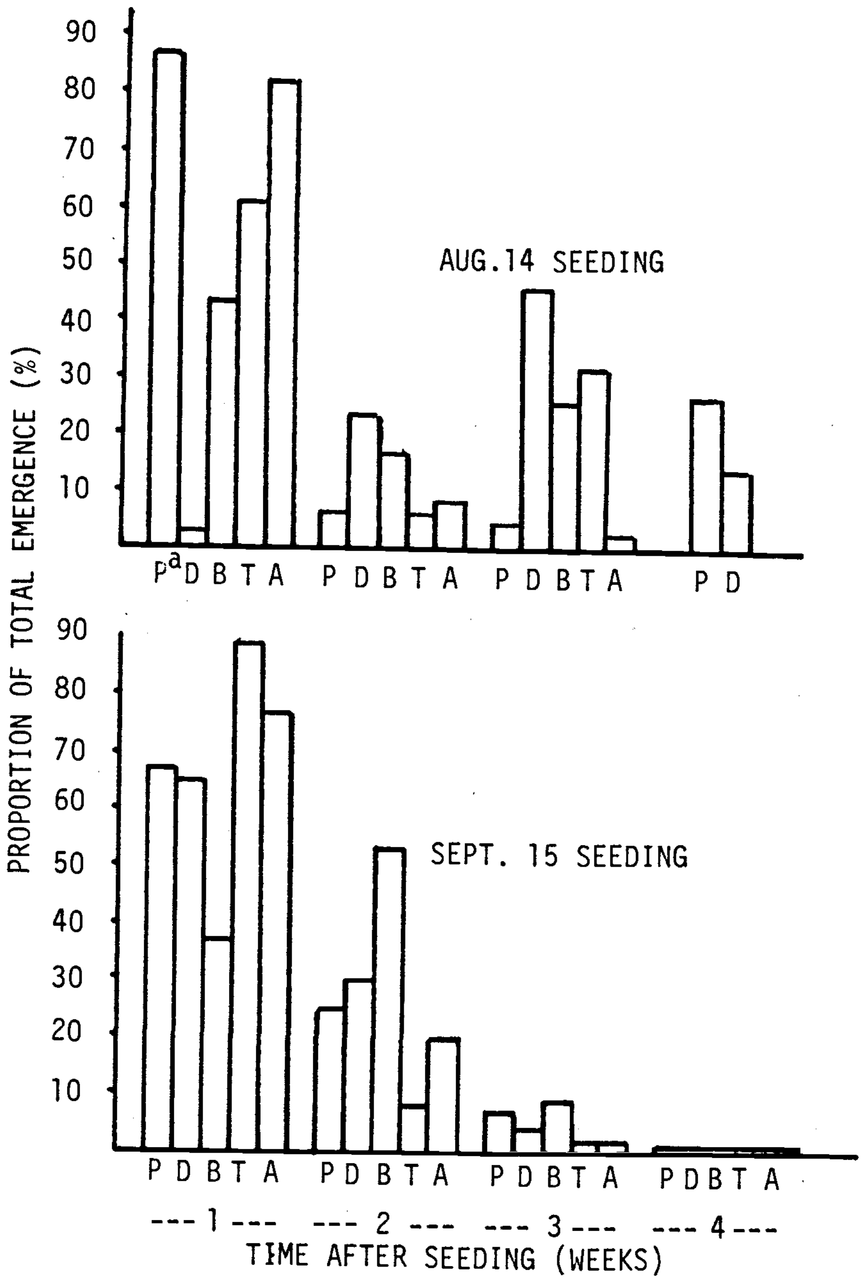
Table II-1. Planting dates and weed species in the interference study between four weed species and alfalfa seeded at two dates in late summer.

Treatments	
Planting date (main plot)	Weed species (sub-plot)
Aug. 14, 1981	pigweed barnyardgrass tumble mustard downy brome weed-free check
Sept. 15, 1981	pigweed barnyardgrass tumble mustard downy brome weed-free check

Results

The peak of alfalfa emergence occurred within the first week after both plantings. The weeds emerged with the crop and in most cases also had their peak of emergence in the first week. There were two exceptions, however. Downy brome, a winter annual, favored by the cooler tempe-

Figure II-1. Emergence of alfalfa and weeds (percentage of total number of plants per species emerged at the end of four weeks) when alfalfa was seeded on two dates in late summer with each of four weed species.



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a P=pigweed; D=downy brome; B=barnyardgrass; T=tumble mustard; A=Alfalfa.

Figure II-2a. Height of alfalfa and weeds on Oct. 18, following the Aug. 14, 1981, seeding of alfalfa with four weed species.

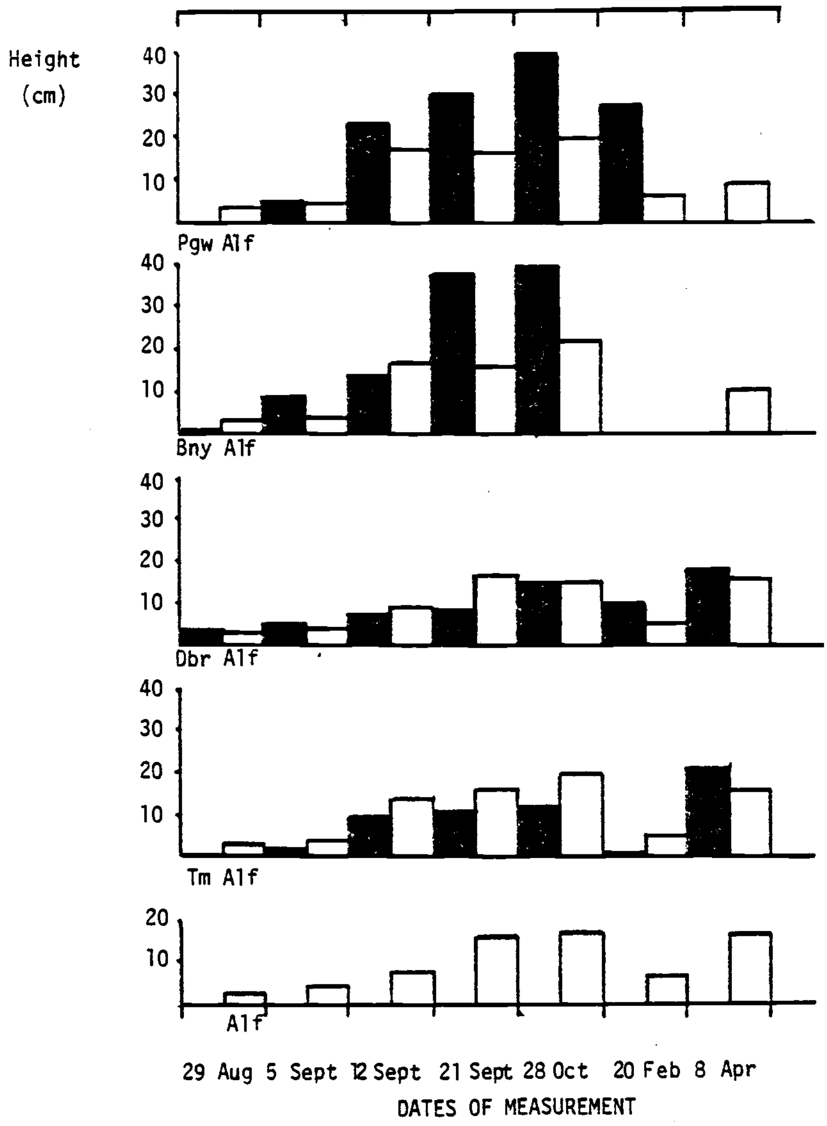
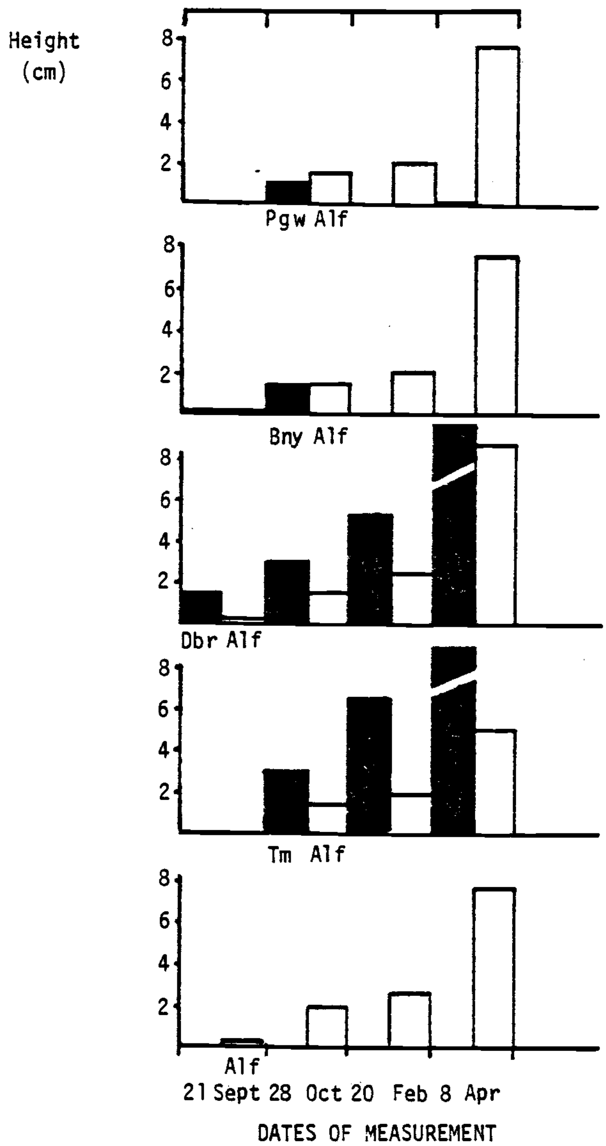


Figure II-2b. Height of alfalfa and weeds on Oct. 18, following the Sept. 15, 1981, seeding of alfalfa with each of four weed species.



ratures following the September 15 seeding, emerged fast reaching its emergence peak during the first week after planting, while after the early seeding its emergence only reached its peak by the third week after planting. On the other hand, barnyardgrass, a summer annual, when seeded late, delayed its peak of emergence until the second week after planting; however, if planted 1 month earlier, warmer temperatures (see Appendix) stimulated its early emergence.

Weeds from the early seeding (August 14) became tall enough to shade the crop before the end of the growing season (Fig. II-2.a). Tumble mustard shaded 80% of the ground and the crop; only the uppermost leaves of alfalfa were visible before the first frosts.

By the end of the growing season in October, interference from weeds following the early seeding had already drastically reduced alfalfa production (Table II-2). This coincides, approximately, with the period in which weeds attain maximum height. After the early seeding, the alfalfa plants elongated in response to shading by weeds, particularly when growing with pigweed, barnyardgrass, and tumble mustard (Fig. II-2.a).

The effects of the weeds on the alfalfa production were the same on either part of the plant, root or shoot; there was a highly significant correlation ($p < 0.001$) between the root dry weight and shoot dry weight ($r = 0.995$). The four weeds did not differ in their effect on the crop shoot; barnyardgrass, however, tended to be the

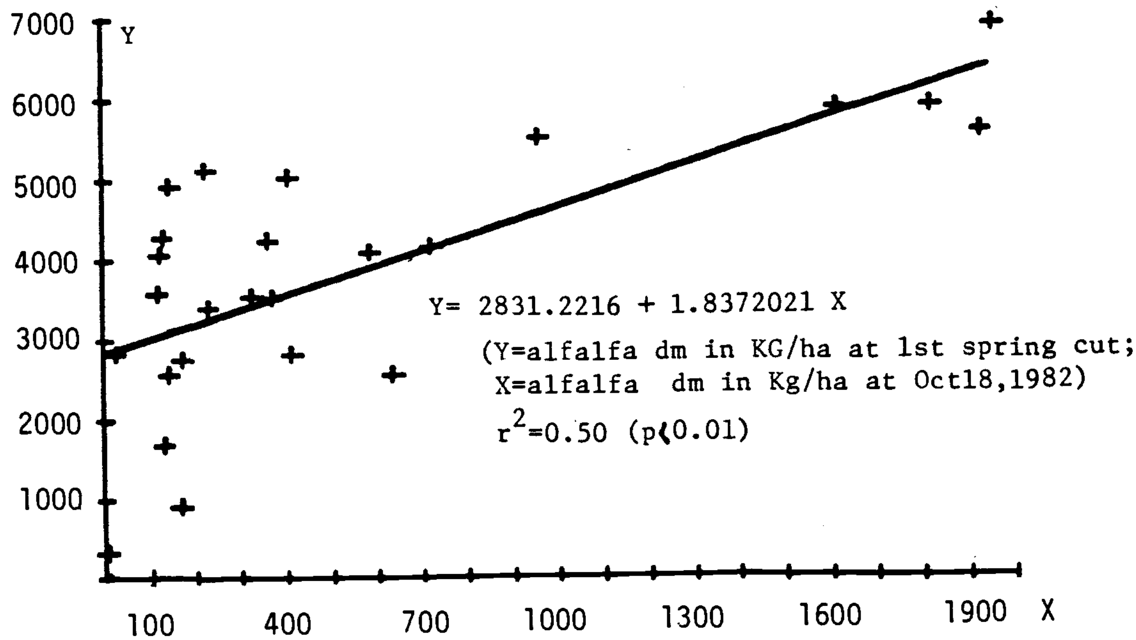
Table II-2. Dry matter production of alfalfa and weeds on October 18, 1981, when alfalfa was seeded August 14, 1981, with each of four weed species.

Treat-ments	Alfalfa Shoot		Alfalfa Root		Weed Shoots	Total Aerial Biomass	
	(kg/ha)	(%) [a]	(kg/ha)	(%)	(kg/ha) [b]	(kg/ha)	(%)
Pgw	213	13p	110	12pq	3665	3878	90op
Bny	132	8p	78	8q	4202	4335	100o
Dbr	467	28p	266	28p	3723	4190	97op
Tm	267	16p	222	23pq	2926	3193	74p
W-F Ck	1650	100o	950	100o	--	1650	38q

a Within columns, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

b The F test in the analysis of variance revealed no significant differences ($p < 0.001$) amongst these means.

Figure II-3. Regression analysis of the alfalfa dry matter (DM) produced in spring 1982 (1st cut) on the alfalfa and weed DM obtained on October 18, 1981, when alfalfa was seeded August 14, 1981, with each of four weed species.



most aggressive species and drastically affected the alfalfa root dry weight (Table II-2).

Mixtures of barnyardgrass, downy brome, and pigweed produced the highest amounts of top growth. By October, the weed-free crop had not fully exploited its habitat, for the dry weight of the top growth in the weed-free plots was lower than that obtained by each weed-alfalfa mixture, or just the weeds in these mixtures (Table II-2).

The plants of the late seeding were still too small to yield meaningful results. Thus the data on Table II-2 resulted from the analysis of one main plot (early seeding), considered as a randomized complete block design.

The best correlation between the parameters assessed in the October 18 sampling and the harvest data of spring, was obtained between the alfalfa dry matter produced in fall and that obtained in the first cutting of spring (Fig. II-3); the variability in the autumn production accounts for 50% of the variability in the alfalfa production at the first cutting in spring.

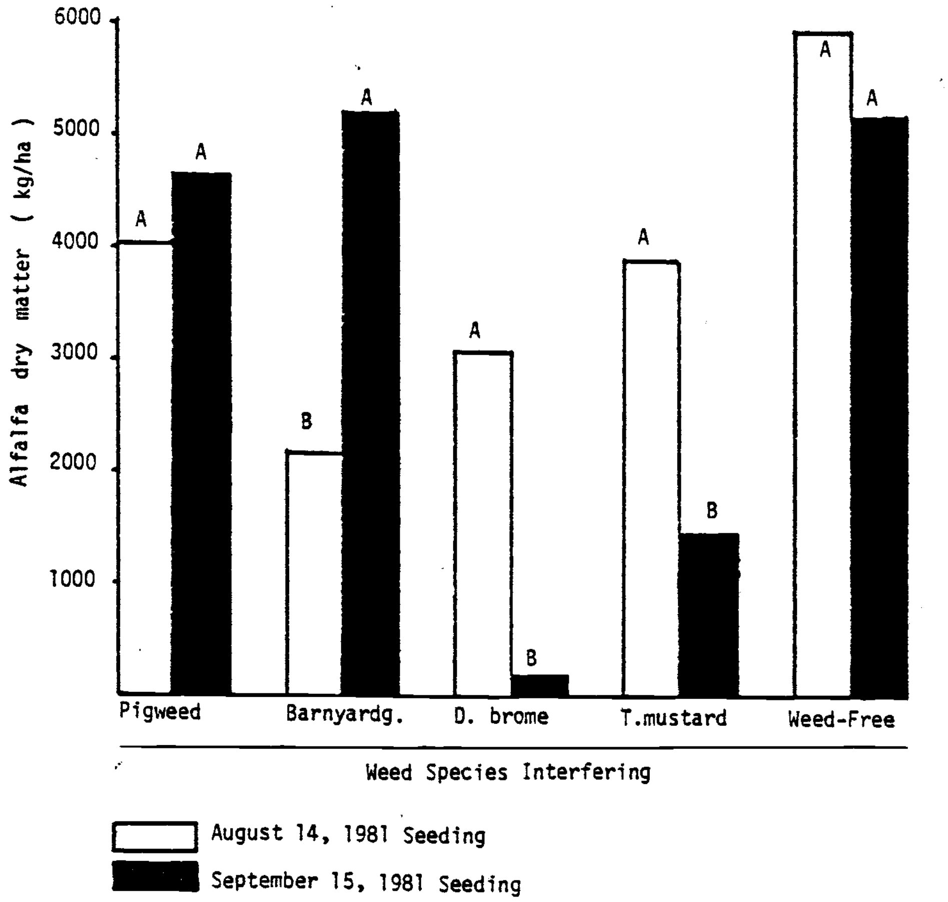
At the first forage harvest, there were no differences between seeding dates (main plot level), Table II-3. At sub-plot level (weed species interfering), the yields of alfalfa varied significantly according to the planting date (interaction between Planting Date x Weed Species) (Fig. II-4). In the early planting, all the weeds grew well and their interference with the crop reduced the alfalfa forage

Table II-3. Dry matter production at first cut of alfalfa seeded on two dates with each of four weed species.

Seeding date	Weed Species	Dry matter[a] (kg/ha)	(%)
Aug. 14, 1981	Pigweed	4058	68p
	Barnyardgrass	2175	37q
	Tumble mustard	3916	66pq
	Downy brome	3084	52pq
	Weed-Free Check	5938	100o
Sept. 15, 1981	Pigweed	4658	90o
	Barnyardgrass	5199	100o
	Tumble mustard	1464	28p
	Downy brome	203	4q
	Weed-Free Check	5160	99o

a Within each seeding date, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Figure II-4. Alfalfa dry matter production at first harvest, when seeded alone or with each of four weeds, at two dates in late summer 1981. Within each pair of bars, those followed by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.



production drastically (Table II-3). However, if the crop was planted 1 month later, the summer annuals emerging with it were killed by frost, and their presence until then did not affect the alfalfa. The winter annuals then severely depressed yields. They benefitted from the cooler season and the concomitant slow initial growth of the crop, becoming even a more serious problem than they were in the early seeding. When seeded September 15, the winter annuals reached higher values of top dry matter than in the early (August 14) seeding (Figs. II-5 and II-7).

Downy brome, independently of the seeding date, was always more productive than tumble mustard, and consequently more depressive on crop production (Fig. II-4 and II-5; Table II-3). For each kg/ha of alfalfa, 42 kg/ha of downy brome and 2.4 kg/ha of tumble mustard were produced in the late seeded plots. In the early seeded plots, where tumble mustard interfered less, for each kg/ha of alfalfa, 0.2 kg/ha of the weed were produced while downy brome yielded 1.3 kg/ha.

It is interesting to note that the weed-free alfalfa planted late yielded more than any of the weedy treatments planted early (Table II-3 and Fig. II-8) and did not differ from the weed-free treatment planted early (Fig. II-4 and Table II-3). However, the crop (weed-free) showed a trend towards higher yields in early plantings (Fig. II-4).

Tumble mustard did not depress the height of the crop; on the contrary, it tended to stimulate its elongation

Figure II-5. Weed dry matter production at the first harvest of alfalfa seeded on two dates in late summer 1981, with each of four weed species. Within each pair of histograms, different letters indicate significant ($p < 0.05$) differences according to Duncan's multiple range test.

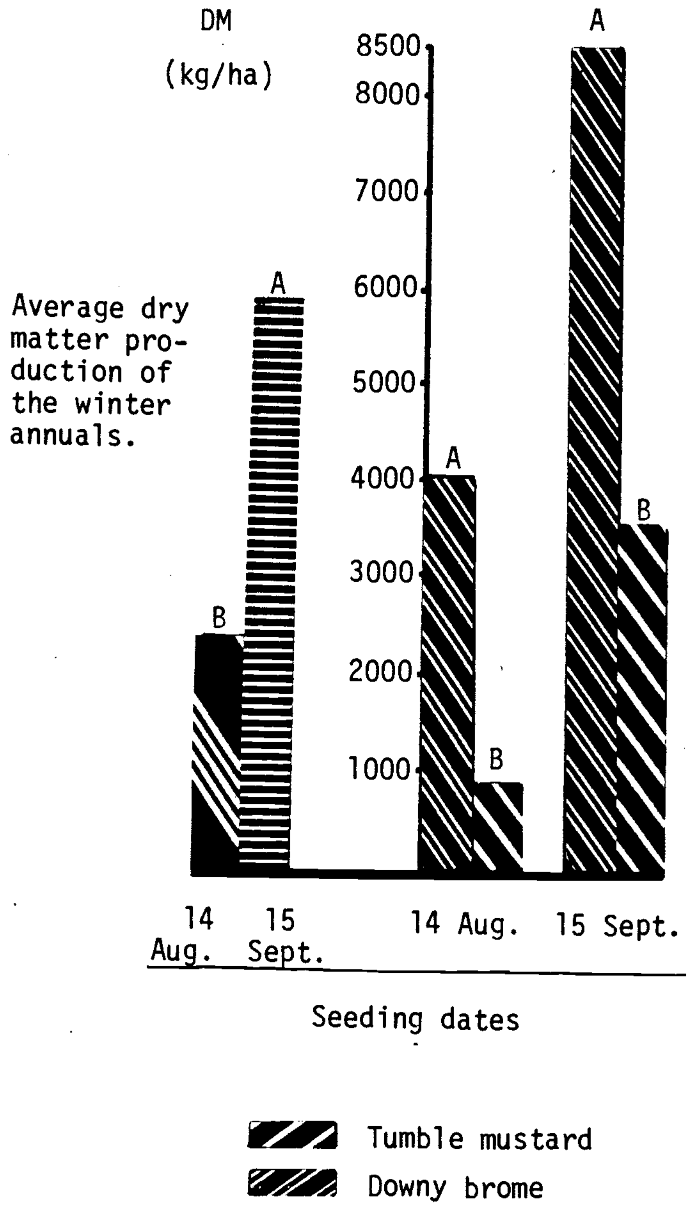


Figure II-6. Height of alfalfa and weeds at the first forage harvest of alfalfa seeded on two dates in late summer with each of four weeds. Within a group of histograms, same letters mean no significant differences at the 5% level according to Duncan's multiple range test.

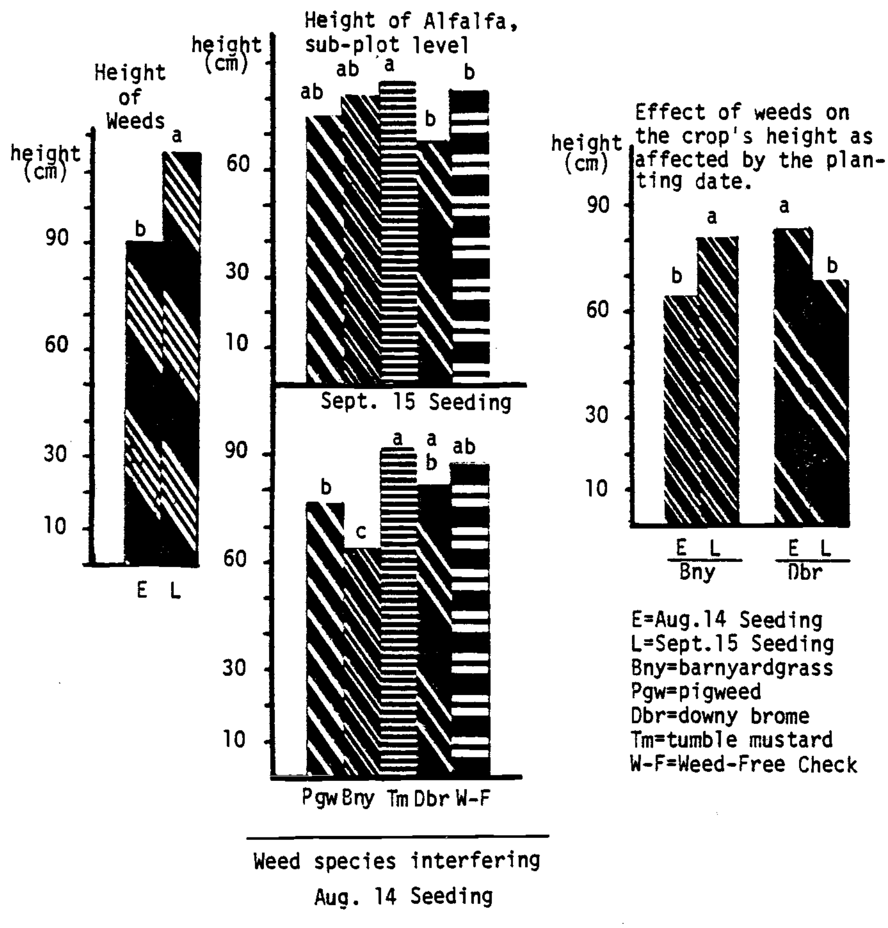
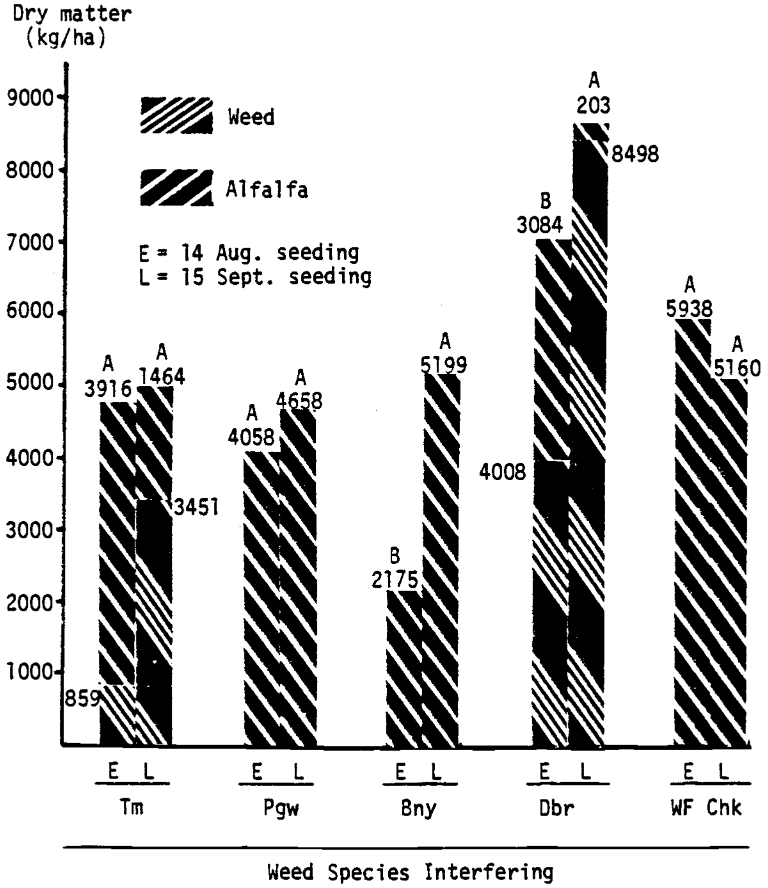


Table II-4. Total top growth of crop + weeds at the first forage harvest of alfalfa seeded on two dates with each of four weeds.

Weed species	Dry matter	
	Early seeding	Late seeding
	---------- (kg/ha) ----------	
Pigweed	4058 q[a]	4658 p
Barnyardgrass	2175 r	5199 p
Tumble mustard	4775 q	4915 p
Downy brome	7074 o	8702 o
Weed-Free Check	5938 p	5160 p

a Within columns, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Figure II-7. Effect of seeding date on total top growth per treatment, at first cut of alfalfa seeded on two dates in late summer 1981, with each of four weed species. Within each species, histrograms accompanied by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.



(Fig. II-6). The other weeds reduced the crop's height.

The effect noted above of planting date on the growth of each species is also reflected by crop height. In this case only downy brome and barnyardgrass reduced height (Fig II-6). Barnyardgrass was prematurely killed by frost when planted late; the crop, which was not affected, therefore behaved like the weed-free check. Downy brome interfered more with crop height if planted late.

The highest forage production (crop + weed) in the first cut was obtained with downy brome seeded September 15. Alfalfa alone was not capable of fully exploiting its available growth environment (Table II-4 and Fig. II-7). On the other hand, plots with tumble mustard yielded either the same or less than the weed-free check (Table II-4).

Pigweed and barnyardgrass, having interfered with the crop in 1981, were then killed by the first frost and were therefore absent at the first cut.

In the second harvest (Fig. II-8) the reductions of alfalfa forage observed in the previous harvest were still present, though the crop was evidently recovering from the early weed interference.

By the third cutting, forage yields in all treatments leveled off and there was no difference between early and late seeding (Fig. II-8).

The numbers of alfalfa stems remaining after the first harvest differed among treatments (Fig. II-9). There was a

Figure II-8. Alfalfa dry matter production in each of 3 cuts during the 1982 season; following the seeding of alfalfa on two dates in late summer 1981, with each of four weeds. Bars within each cutting for a given seeding date, accompanied by the same lower caption letter, are not significantly different ($p > 0.05$) according to Duncan's multiple range test. In comparing response of a given sub-plot treatment in either seeding date and within the same cutting, bars accompanied by the same capital letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.

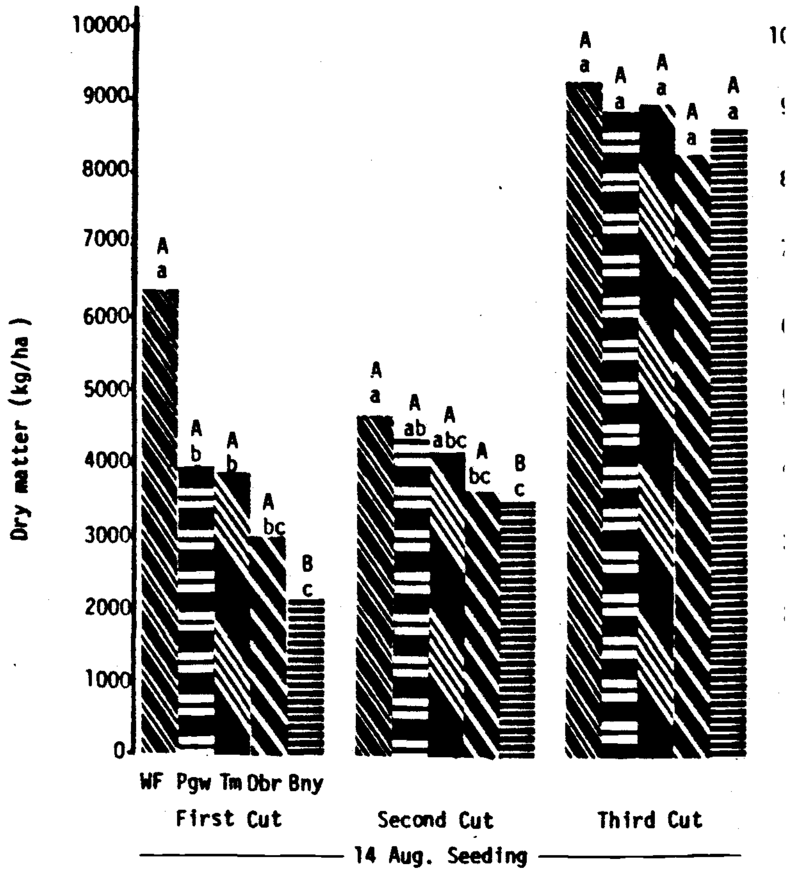


Table II-5. Density of downy brome and tumble mustard stems after first cut of alfalfa seeded on two dates with four weed species.

Planting date	Species	Density
		(stems/10cm^2)
Aug. 14, 1982	Downy brome	2.7
	Tumble mustard	0.7
Sept. 15, 1982	Downy brome	2.8
	Tumble mustard	1.4

close relationship ($r = 0.88$; $p < 0.01$) between the depressive effect of the weeds on total dry matter of alfalfa and the number of resulting alfalfa stems. Downy brome and barnyardgrass, if seeded early, or tumble mustard and downy brome for the late seeding, were the weeds that most interfered with the crop's production and the growth of productive stems.

Pigweed (seeded early) did not seem to affect the yields by lowering the number of productive alfalfa stems (Figs.II-8 and II-9). Downy brome seeded early compared to the late seeding, allowed significantly higher ($p < 0.05$) production of alfalfa stems measured after the first clipping: 64/m of row, if seeded late only 25.

The stubble counts of alfalfa stems after the second cutting were similar to those taken after the first cut. After the third and last cutting, when the crop had recovered from the weed interference, there were no differences ($p > 0.05$) in the number of stems and plants per meter of row, among treatments (Table II-6). The trend, however, suggests that the most severe treatments, barnyardgrass (seeded early) and downy brome (seeded late), could have also lowered the number of plants, which agrees with the fact that at recovery (third cut) alfalfa in these treatments also showed higher number of tillers/plant, but this is still just a trend. An increase in the number of tillers per plant could be responsible for equalizing the yields obtained in the third cutting.

Figure II-9. Number of alfalfa stems per meter of row after the first and second harvest of alfalfa seeded on two dates in late summer 1981, with each of four weed species. Bars followed by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.

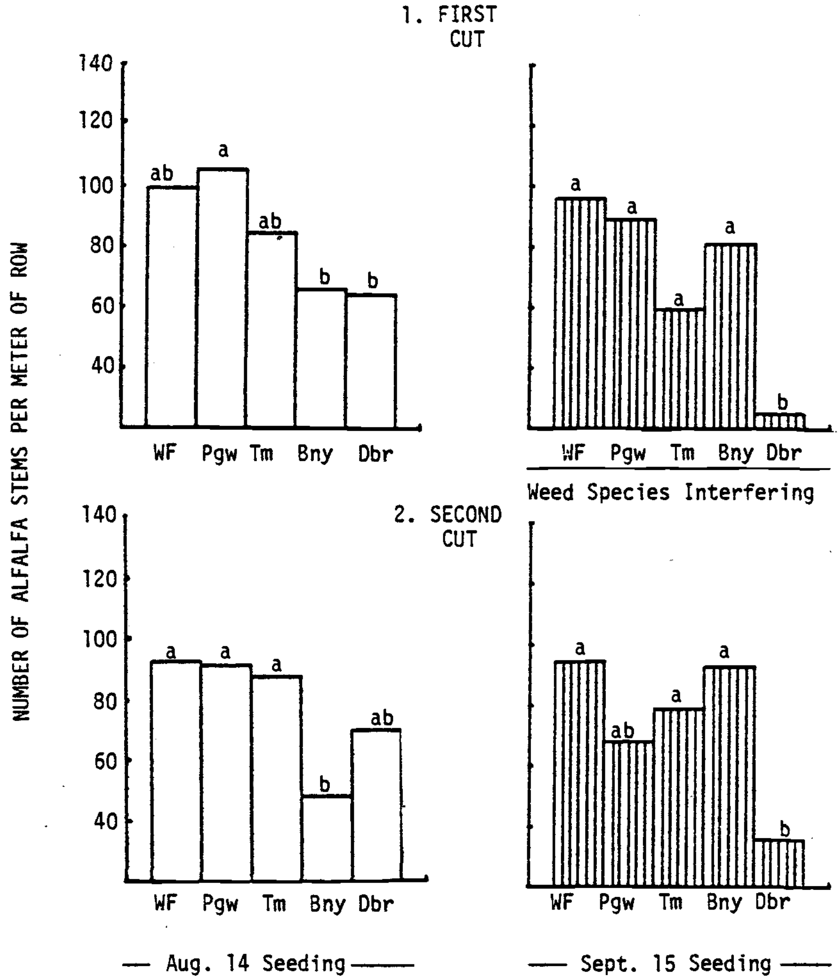


Table II-6. Number of alfalfa stems and plants per meter of row, and number of stems per plant after the third cutting of alfalfa seeded on two dates in late summer, 1981.

Seeding date	Treatment	Stems/ m row	Plants/ row	Stems/ plant
Aug. 14, 1982 (early)	WF	243[a]	44	6
	Tm	138	33	4
	Dbr	136	37	4
	Bny	110	20	7
	Pgw	105	26	5
Sept. 15, 1982 (late)	WF	89	43	2
	Tm	179	45	4
	Dbr	156	30	5
	Bny	142	43	4
	Pgw	132	33	4

a No significant ($p > 0.05$) differences were registered amongst treatments in any of the above three parameters in the analysis of variance (F test) of the data.

Chemical analysis of the soil revealed no differences ($p > 0.05$) among treatments in the levels of nitrogen (average: 7.03 ppm of NO -N) and potassium (average: 224.5 ppm K), after the first cutting of alfalfa. The plots with barnyardgrass used less ($p < 0.05$) phosphorus than the rest (Table II-7), if seeded early. The values (ppm) of K and P would indicate that there were no deficiencies of these elements in the soil (55).

The alfalfa plants were well nodulated; it would thus seem that competition between alfalfa and the weeds for these three main nutrients may not have been relevant.

The differences in alfalfa production at the end of the first growing season (Fig. II-10) corresponded to the alfalfa yield reductions from weed interference observed in the first cutting (Fig. II-8). In spite of the crop's recovery, the early presence of weeds in the fall reduced the amount of alfalfa forage obtained in the first season. The exception was with summer annual weeds in a late seeding which died prematurely from frost.

The mixtures of downy brome and tumble mustard yielded the same amount of total forage as the weed-free check, on either seeding date ($p < 0.05$).

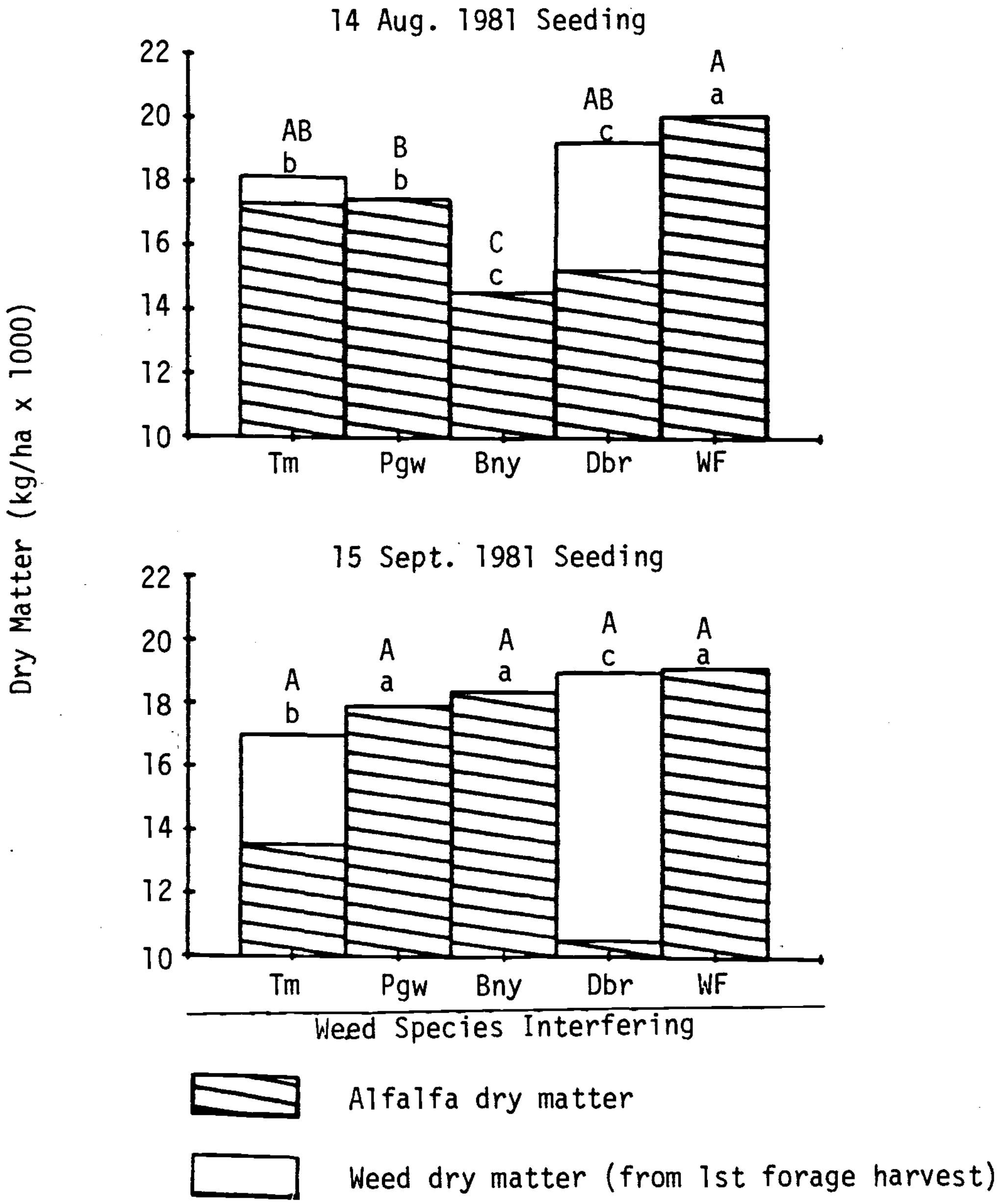
For barnyardgrass and pigweed, of both seeding dates, we only measured alfalfa production because they were killed by frosts and were not part of the harvested forage.

Table II-7. Soil test for phosphorus (ppm) after the first harvest.

Seeding date	Treatment	Phosphorus[a]
		(ppm)
Early	Barnyardgrass	17.2 a
	Downy brome	13.0 b
	Tumble mustard	13.0 b
	Weed-Free Check	12.8 b
	Pigweed	12.0 b
Late	Barnyardgrass	15.4 a
	Downy brome	15.6 a
	Tumble mustard	15.4 a
	Weed-Free Check	15.2 a
	Pigweed	15.2 a

a Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Figure II-10. Total forage (alfalfa + weeds) and total alfalfa dry matter production at the end of the first growing season (3 cuts) in 1982, following the seeding of alfalfa on two dates in late summer 1981, with each of four weed species. Bars with the same capital letter, within each seeding date, indicate treatments with no significant differences (p > 0.05) in total dry matter production according to Duncan's multiple range test; small captions mean the same for alfalfa production.



III - CRITICAL PERIODS OF WEED INTERFERENCE IN LATE SUMMER SEEDINGS OF ALFALFA

Objectives

(a) Establish when, during the seeding year of a late summer-seeded alfalfa crop, interference from weeds reduces forage yields.

(b) Determine how long weeds must be controlled after emergence in late summer in order to obtain optimum forage production in the spring.

Conversely, establish the length of time after emergence the crop can tolerate weed growth without lowering forage yields the next spring.

(c) Observe when the weeds responsible for such yield reductions emerge in relation to the crop.

(d) By knowing when and for how long the presence of weeds is harmful, prescribe a relatively flexible weed control schedule.

Materials and Methods

This trial was placed on the same soil and irrigated in the same way as the previously described experiment. Twenty treatments, involving different weedy and weed-free periods (Table III-1) were arranged in randomized complete blocks and replicated five times. Plots were 2.1 by 10.1 m; blocks were separated by alleyways 0.9 m wide.

On August 27, 1981, those plots where weeds were to emerge with alfalfa and grow with it for various periods after emergence, were sown with a mixture of equal numbers of seeds of barnyardgrass, pigweed, tumble mustard, and downy brome. The required amounts were determined by weight and the mixture was planted at the rate of one seed (of the mixture) per 17 cm^2.

The seedbed was prepared with a power-driven rotary tiller followed by a packer[3]. The weed seed was broadcast by hand and incorporated into the soil with a power-driven tine-tooth harrow set to till 1 to 2 cm deep.

'Vernal' alfalfa seed was treated in the seedbox of the planter with the required amount of <u>Rhizobium</u> <u>meliloti</u> inoculant, and then drilled 2 cm deep into rows 18 cm apart, at the rate of 20 kg/ha. The trial was irrigated 24 h after planting.

At the end of each weedy period, weeds were removed by cutting with a sharp blade at or just below the soil surface, causing a minimum of soil disturbance. Those plots were then kept free of weeds until harvest by periodic hand weedings.Conversely, at the beginning of each weedy period, the corresponding plots were sown with the weed mixture already described and at the same rate. The seeds were then incorporated with a hand rake and the plots were irrigated immediately.

The alfalfa emerged September 6, 1981. At 12 and 26 days after planting, emerging seedlings were counted in

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3 Two metal rollers mounted as packers in a "Brillion" forage seeder.

each plot that had to be weedy since emergence. At 12 days, weeds were counted within one (0.25 m)^2 quadrat per plot, while at the second count this was done three times per plot.

From treatments 14 to 20, weeds were collected at the time of their first weeding; in treatments 14, 15, and 16, all the weeds from the whole plot were collected, while for the rest only a sample was taken.

In the remaining treatments (1-9, 11) the weeds were taken from two 0.5 by 1 m rectangles per plot. In these last treatments, the weediness was considerable and though the plants were removed with great care, a certain degree of injury was noticed in the alfalfa plants. The weeds from the samples were separated by species and oven dried at 65 C for 72 h. Thus, dry matter (kg/ha) of each species at the end of the period of interference was determined for each treatment. The weeds from the weedy check and from all those treatments that remained weedy until the first forage harvest were sampled at harvest time. The height and development of crop and weeds were recorded at irregular intervals.

Alfalfa was harvested for yield on May 24, July 1, and August 26, 1982, when it was at the 10 to 20% bloom stage. In each plot, a central area of 8.6 m^2 (1.07 x 8.06 m) was cut using a 1.07 m wide sickle mounted on a "Gravely" unit. Based on the yields from the second cutting, those treatments likely to yield less than the weed-free check in the

Table III-1. Periods of interference from weeds (treatments) in alfalfa seeded August 27, 1981.

Treatment no.[a]		Description
1	Weed-free until	14 Sept. 1981 (8 d.a.e.)[b]
2		21 Sept. 1981 (15 d.a.e.)
3		28 Sept. 1981 (22 d.a.e.)
4		12 Oct. 1981 (36 d.a.e.)
5		10 Nov. 1981 (65 d.a.e.)
6		23 Feb. 1982 (170 d.a.e.)
7		19 Mar. 1982 (194 d.a.e.)
8		8 Apr. 1982 (214 d.a.e.)
9		29 Apr. 1982 (235 d.a.e.)
10		24 May 1982 (260 d.a.e.= = Weed-Free Check)
11	Weedy until	24 May 1982 (260 d.a.e.= = Weedy Check)
12		14 Sept. 1981
13		21 Sept. 1981
14		28 Sept. 1981
15		12 Oct. 1981
16		10 Nov. 1981
17		23 Feb. 1982
18		19 Mar. 1982
19		8 Apr. 1982
20		29 Apr. 1982

a For statistical analysis, the treatments were separated into two groups (1-11 and 10-20) and each group was considered a randomized complete block design.

b d.a.e. = days after emergence.

next cutting, were harvested for a third time, together with other treatments likely to produce the highest yields and serving as controls.

Total fresh forage weight per plot, and that of a representative sample, were determined in the field. The samples were then botanically separated and oven dried (65 C & 72h) to measure the amount of dry matter produced by the crop and each of the weeds per treatment. For statistical analysis, the data from the first cutting were separated into two groups (1 to 11 and 10 to 20) and each group was considered as a randomized complete block design. The analysis of the 20 treatments and the data from the second cutting allowed us to select the treatments to be harvested for a third time.

Results

Most of the alfalfa seedlings had emerged by the 12th day after planting. The weeds emerged with the crop but their peaks of emergence occurred later. Downy brome had the highest percentage of early emergence among weeds (Table III-2). Twenty-six days after planting, there was 1 weed seedling every 20.5 cm^2. By February 20, 1982, downy brome and tumble mustard covered 80% of the plot area; barnyardgrass and pigweed (the summer annuals) had already been killed by the frost (Fig. III-3).

The weeds that established early caused the highest yield reductions if allowed to grow until the first forage

Table III-2. Stand of crop and weeds in the treatments that were weedy for various periods after emergence of the crop and weeds, when alfalfa was seeded on August 27, 1981.

Species	12 days after seeding	26 days after seeding
	(plants/m2)	(plants/m2)
Alfalfa	362	470
Pigweed[a]	19	47
Barnyardgrass	19	115
Tumble mustard[b]	19	56
Downy brome	141	270

a Includes a few lambsquarters (*Chenopodium album* L.).

b Includes a few flixweeds (*Descurainia sophia* (L.) Webb).

Figure III-1. Yields of alfalfa and weeds at the first forage harvest, as affected by the length of the weed-free period after emergence of alfalfa seeded August 27, 1981. Points followed by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test. Because of proportionality between variances and means, a $\sqrt{(x + 0.5)}$ transformation was used for statistical analysis of the weed DM data. The fitted function is not appropriate for estimation within the 0 - 8 days after emergence period.

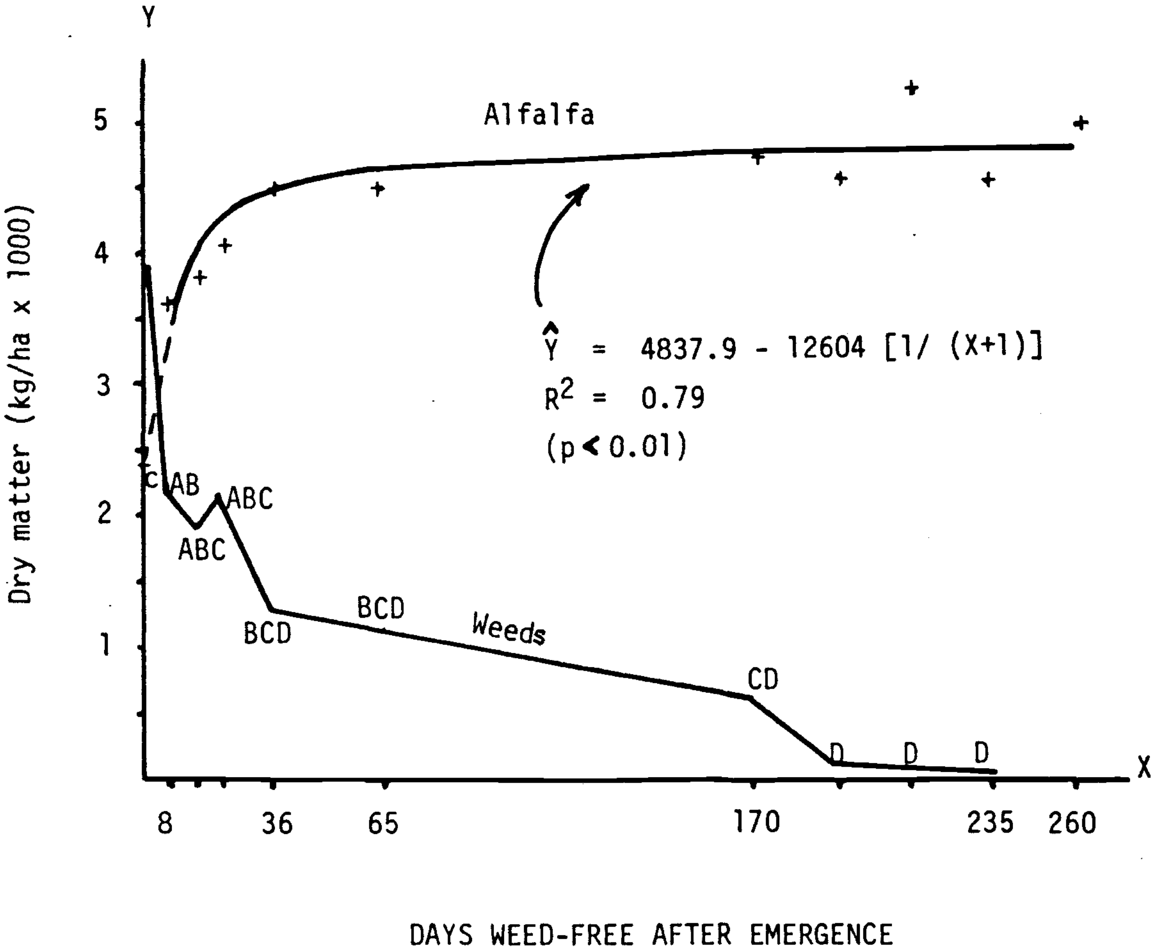
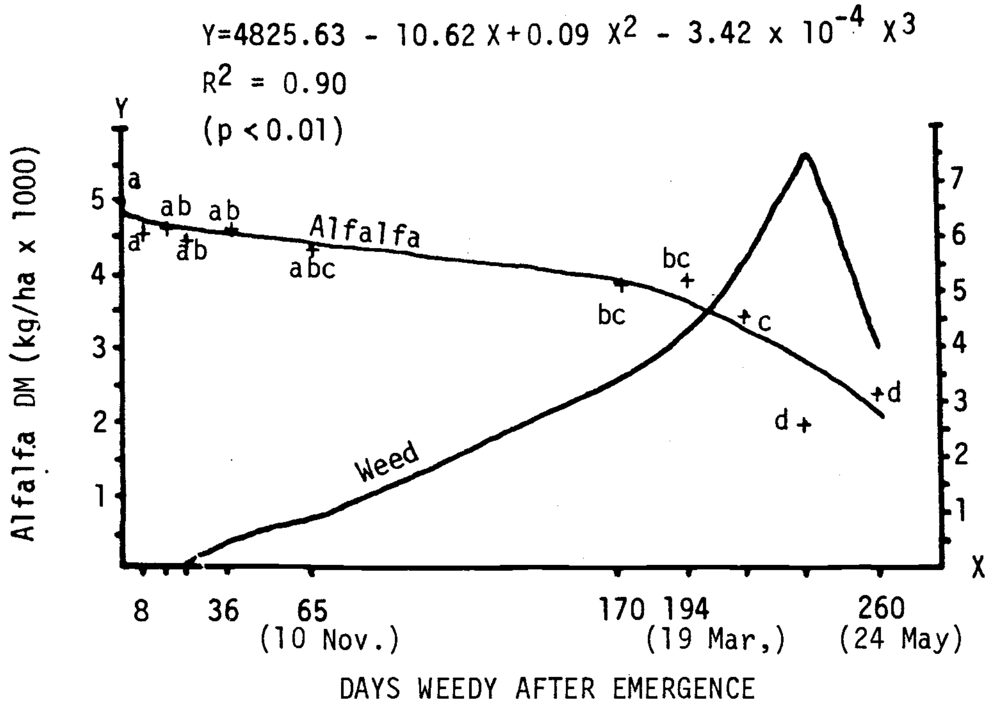


Figure III-2. Alfalfa dry matter at first cutting as affected by the length of the weedy periods after emergence, and weed dry matter production when weeds grew undisturbed together with the alfalfa seeded on August 27, 1981. Points followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.



cutting (Fig. III-1). Weeds allowed to grow during approximately the first 65 days after the crop had emerged caused significant yield loss (Fig. III-1). Further weeding thereafter did not bring significant increments in alfalfa yields. Accordingly, the amount of weed dry matter present at the first forage harvest was sharply reduced when the weeds were not allowed to grow during the first 65 days. Weeds emerging after the first 65 days were not completely suppressed, but the crop seemed to tolerate them. The first harvest yielded up to 1236 kg/ha of weed dry matter, without alfalfa production being significantly reduced (Table III-3).

Complete suppression of weed growth by the crop was observed only if plots were kept free of weeds for at least 194 days after emergence. Thus, this longer period of weed-free maintenance was necessary for maximum forage yield and quality (highest % of alfalfa in the forage mixture; Table III-3).

When the alfalfa grew weedy for several intervals after emergence, a multiple range comparison of the mean yields showed no differences between having the crop weedy during 8 or 194 days after emergence (Fig. III-2). However, a regression line from 8 to 194 days was significantly ($p < 0.01$) downward indicating a gradual cumulative effect from weed interference.

The weedy check yielded only 48% of the weed-free check; and tumble mustard showed a greater capacity than downy brome to become established during the cold season. In all the weed seedings done after September 28, the proportion of downy brome present in the forage mixture at first harvest was much less than that of tumble mustard (Table III-3).

Alfalfa alone could not fully exploit the habitat; higher total forage yields were obtained when weeds were present at harvest (Table III-3). There was a significantly high inverse correlation ($r = 0.93$; $p < 0.01$) between the dry matter of the alfalfa and that of the weeds at first harvest.

By the second forage harvest the only treatments that yielded significantly less than the weed-free check were: weedy until April 29, 1982; weedy check, and weed-free until November 10, 1981 (Table III-4). The effect of the weed interference initiated in fall still persisted in those treatments.

The treatments selected for a third harvest were: weed-free check; weed-free until November 10, 1981; weed-free until September 14, 1981; weedy until April 8, 1982; and the weedy check. No differences ($p < 0.05$) were found in the alfalfa dry matter yielded by these treatments when harvested for a third time on August 26, 1982 (Table III-5). The crop had recovered even from the full-cycle interference from those weeds that grew with it undisturbed until the first cutting.

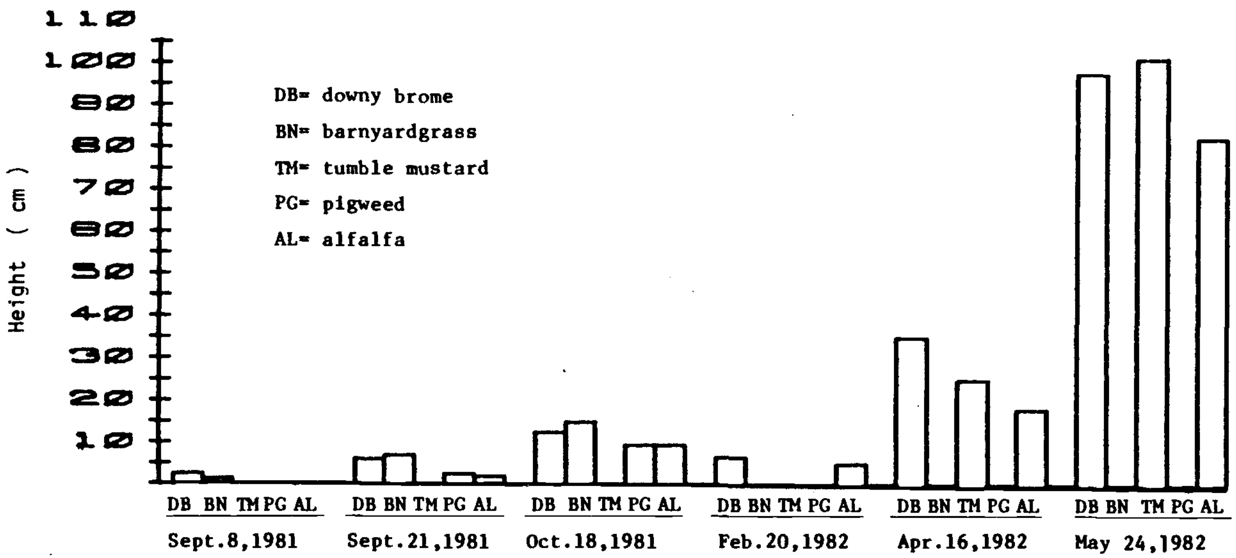
Table III-3. Composition of the forage from the first cutting of treatments with various weed-free periods after emergence, when alfalfa was seeded on August 27, 1981.

Weed-Free period after emergence	Alfalfa		D. Brome		T. mustard		Total
	DM	% of total	DM	% of total	DM	% of total	DM
(days)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)
0	2391q[a]	38	2688	43	1189	19	6268o
8	3628p	61	2040	35	213	4	5882op
15	3852p	67	924	16	968	17	5745opq
22	4095op	65	436	7	1760	28	6275o
36	4513op	78	26	1	1239	21	5778opq
65	4510op	78	-	-	1236	22	5746opq
170	4796op	85	182	3	667	12	5645opq
194	4604po	97	-	-	123	3	4727pq
214	5262o	98	15	-	75	2	5353opq
235	4562op	99	-	-	44	1	4606q
260[b]	4994op	100	-	-	-	-	4994pq

a Within columns, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

b Weed-Free Check.

Figure III-3. Heights of alfalfa and four weeds growing together undisturbed following the Aug. 27, 1981, seeding. [a]



a The Alfalfa emerged September 6, 1981

Table III-4. Alfalfa dry matter production of the Weed-Free Check and the treatments with significantly lower yields at the second cutting, following the August 27, 1981, seeding.

Treatment	Dry matter[a]	Percent of Weed-Free Check
	(kg/ha)	(%)
Weed-Free Check	4061 o	100
Weedy until April 29	3436 pq	85
Weedy Check	3427 pq	84
Weed-Free until Nov. 10	3313 q	82

a Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table III-5. Alfalfa dry matter production of the treatments harvested for a third time, following the August 27, 1981, seeding.

Treatment		Dry matter[a]
		(kg/ha)
11	Weedy Check	11247
1	Weed-Free until Sept. 14	11221
10	Weed-Free Check	11212
9	Weedy until April 29	10489
5	Weed-Free until Nov. 10	10408
8	Weedy until April 8	10298

a No significant differences ($p > 0.05$) were detected among these means in the F test of the analysis of variance.

IV - INTERFERENCE BETWEEN FOUR WEED SPECIES AND SPRING-SEEDED ALFALFA

Objectives

(a) Quantify forage losses due to interference from weeds in a spring seeding of alfalfa, and establish the relative noxiousness of each weed.

(b) Determine when the weeds responsible for the forage losses emerge in relation to the crop.

Materials and Methods

The experiment was installed close to the fall experiments previously described. Water was provided as needed by sprinkler irrigation.

The trial was sown on April 13, 1982, in the same way as the homologous fall experiment. A randomized complete block design with five replications was used, and the treatments were: alfalfa kept weed-free or overseeded with downy brome, tumble mustard, barnyardgrass, or pigweed. Weed, crop seeding rates, and plot size also were the same as described for the fall experiment.

Emergence of the crop and weeds was monitored weekly by counting the seedlings within a $(0.3\ m)^2$ quadrat.

Lambsquarters (native, and also mixed with the pigweed seed) dominated in the pigweed-seeded plots, while pigweed emerged very slowly; it could have been retarded by the cool temperatures of the season (Appendix), to which lambsquarters seemed better adapted.

The weed-free check and the botanical purity of the weedy plots were maintained with herbicide applications. On May 12 and 14, 1982, when the crop was at the one-to-two trifoliolate leaf stage, the weed-free check and the plots with downy brome and barnyardgrass were sprayed with 1 kg acid equivalent/ha of an amine formulation of 2,4-DB. On May 20, the plots with pigweed, tumble mustard, and the weed-free check were sprayed with 0.4 kg active ingredient/ha of sethoxydim to control grass weeds. The weed-free plots and those with grass weeds received an application of 1 kg a.e/ha of 2,4-DB, when the alfalfa was at the seven to eight trifoliolate leaf stage. The herbicides did not injure the crop.

By June 8, barnyardgrass showed nitrogen deficiency signs which prompted the application of 96 kg/ha of nitrogen in the form of ammonium nitrate. The original level of N in the soil was 5.1 ppm NO -N.

On July 5, the crop was harvested (as previously described for the fall experiments) at the 80% bloom stage. Crop and weed dry matter was determined. Second and third harvests were on August 25 and October 13, 1982, respectively.

After the first and third cuttings, alfalfa stems in the stubble were counted in 1 m of row, twice per plot. Weed stems were counted in the same way after the first cutting.

Results

The crop and weeds emerged together between April 23 and May 3, and all the species had their peak of emergence within the first 10 days after emergence (Fig. IV-1).

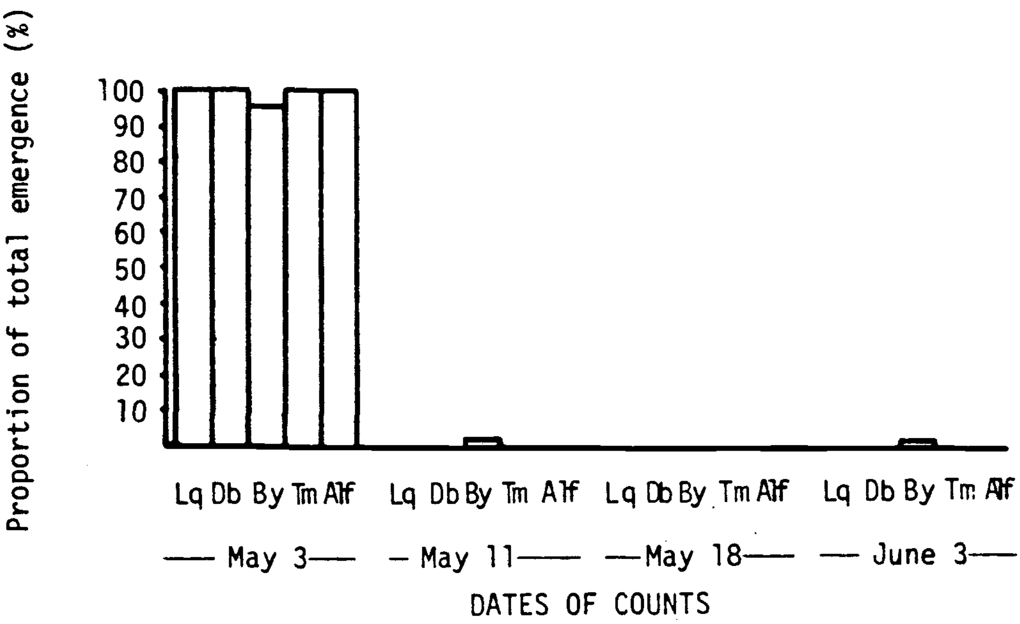
All the weed species reduced ($p < 0.05$) alfalfa yields in the first forage harvest and their individual effects on the crop were similar in spite of their very different growth levels (Table IV-2). At harvest, the tumble mustard seeded plots exhibited only a few flower stalks of the weed; the majority of the plants were small and dry, close to the ground and the alfalfa grew above them. The yield reductions were correlated ($r = 0.65$; $p < 0.01$) with the number of alfalfa stems per meter of row in the stubble (Tables IV-2 and 4, Fig. IV-3).

The nitrogen deficiency gave an initial advantage to the crop which had nodulated well. The weeds would have surely grown more had there been no initial nutrient deficiency.

Under the conditions of the experiment, lambsquarters made the most efficient use of the environmental growth factors. In mixture with alfalfa, it yielded the highest ($p < 0.05$) top growth in the first harvest (Table IV-2) as well as at the end of the season (Fig. IV-5).

The depressive effect of the weeds upon alfalfa yields (Table IV-2), still persisted by the second forage harvest, disappearing at the third and last cutting (Fig. IV-4)

Figure IV-1. Emergence of crop and weeds - percentage of total number of plants emerged, per species, at the end of four counts.



Lq=Lambsquarters; Db=Downy brome; By=Barnyardgrass; Tm=Tumble mustard; Alf=Alfalfa.

Figure IV-2 Comparative heights of crop and weeds, following the seeding of alfalfa on April 13, 1982, with each of four weeds.

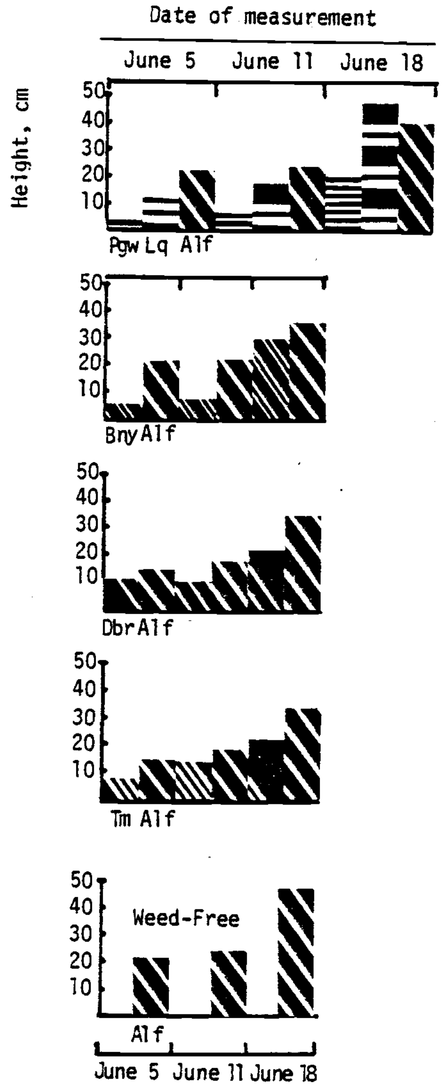


Table IV-1. Weed species that comprised the treatments in the study of the interference between four weeds and alfalfa seeded April 13, 1982.

Treatment no.	Associated species
1	Lambsquarters[a]
2	Barnyardgrass
3	Tumble mustard
4	Downy brome
5	None (Weed-Free Check)

a Though seeded with pigweed, this treatment was completely dominated by lambsquarters.

Table IV-2. Alfalfa and weed dry matter production at the first harvest of alfalfa seeded April 13, 1982, with each of four weeds.

Treatment (associated sp.)	Dry matter[a]			
	Alfalfa		Weeds[b]	Total top growth
	(kg/ha)	(%)	(kg/ha)	(kg/ha)
None (WFChk)	5075 o	100	-	5075 p
Barnyardgrass	3425 p	67	1768 p	5193 p
Tumble mustard	2745 p	54	231 q	2988 q
Downy brome	2390 p	47	2240 p	4631 p
Lambsquarters	2380 p	47	4400 o	6780 o

a Within columns, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

b The weed DM values required a $\sqrt{(x + 0.5)}$ transformation prior analysis of variance due to a proportionality between means and variances.

Table IV-3. Correlation between alfalfa and weed dry matter at first cutting, when alfalfa was seeded April 13, 1982, with each of four weeds.

X[a]	Y	r	F value[b]	p
Lambsquarters DM	Alfalfa DM	-0.45	0.75	>0.10
Barnyardgrass DM	Alfalfa DM	-0.90	13.06	<0.05
Downy brome DM	Alfalfa DM	-0.89	11.03	<0.05
Tumble mustard DM	Alfalfa DM	-0.83	4.53	>0.10

a The weed dry matter values required a $\sqrt{(x + 0.5)}$ transformation due to a proportionality between the means and the corresponding variances.

b With 1 over 3 degrees of freedom.

Table IV-4. Correlation between number of stems/m of row at the stubble counts after the first cut, and the corresponding dry matter yields (kg/ha).

X	Y	r	p
Number of weed stems/m of row	Number of alfalfa stems/m of row	-0.39	>0.05
Number of alfalfa stems/m of row	Alfalfa dry matter at first cutting	0.65	<0.01

Figure IV-3. Number of alfalfa and weed stems per meter of row in the stubble, after the first and third (alfalfa stems only) forage harvest of alfalfa seeded April 13, 1982, with each of four weed species. Within each graph, bars accompanied by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.

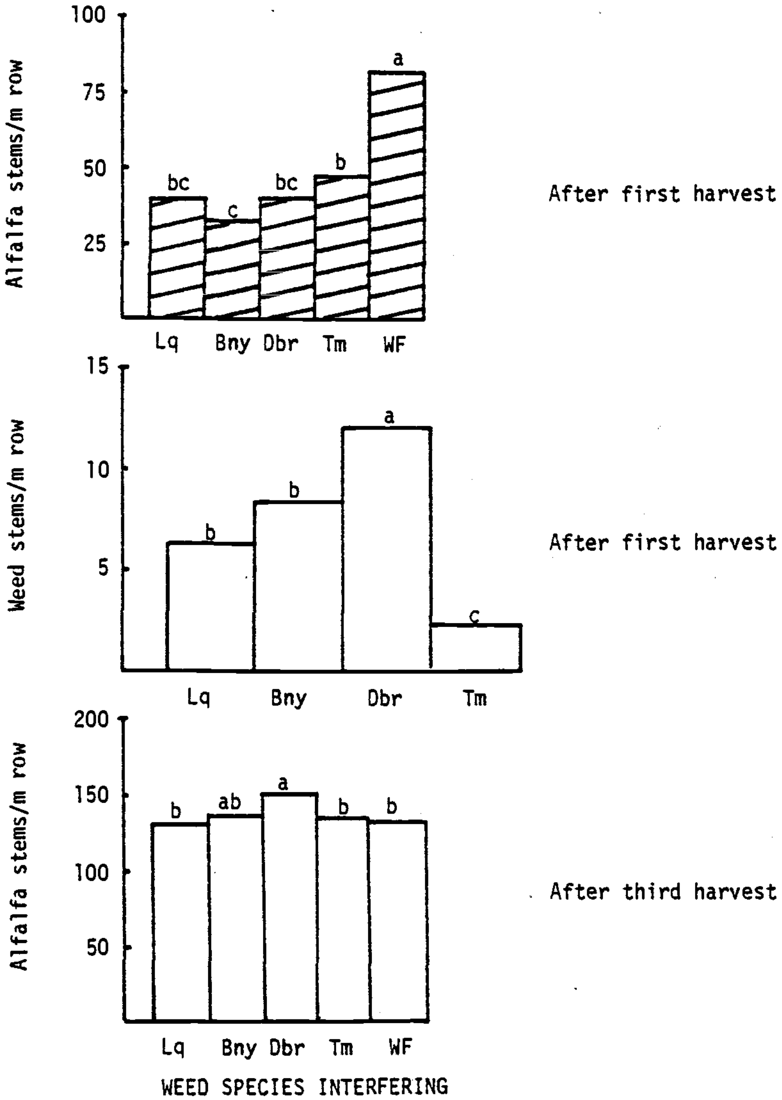


Figure IV-4. Dry matter production from each of three forage harvests during the first growth season of alfalfa seeded April 13, 1982, with each of four weeds. Within each harvest, bars followed by the same letter are not significantly different (p > 0.05) according to Duncan's multiple range test.

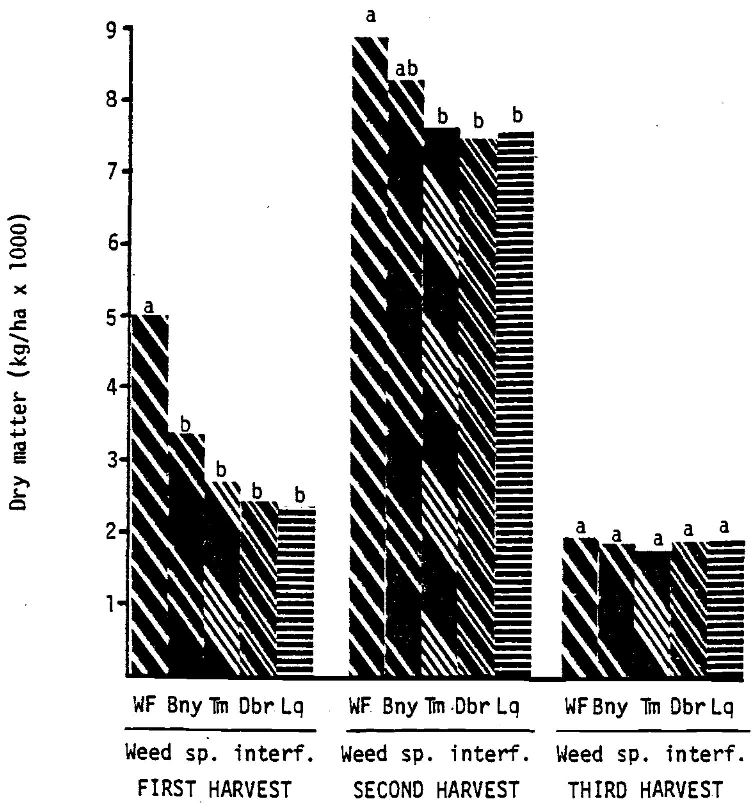
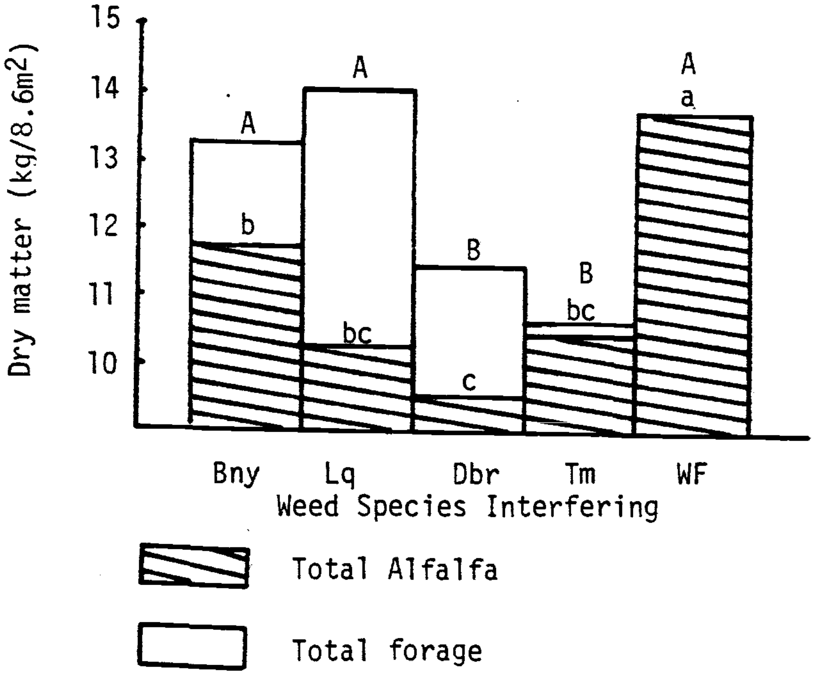


Figure IV-5. Total forage (alfalfa + weeds) and alfalfa dry matter production at the end of the first season following the April 13, 1982, seeding of alfalfa together with each of four weed species. Capital letters compare total forage dry matter; bars accompanied by the same letter do not differ significantly ($p > 0.05$) according to Duncan's multiple range test. Small letters (captions) compare total alfalfa production; bars accompanied by the same letter do not differ significantly ($p > 0.05$) according to Duncan's multiple range test.



because of a remarkable increase in alfalfa tillering (Fig. IV-3).

The differences in the yields of total forage dry matter (alfalfa + weeds) and of total alfalfa dry matter at the end of the first season, basically compare to those of the first harvest (Fig. IV-5).

V - CRITICAL PERIODS OF WEED INTERFERENCE IN SPRING - SEEDED ALFALFA

Objectives

(a) Establish when, during the first growing season of a spring-seeded alfalfa, interference from weeds most reduces forage yields.

(b) Determine when these weeds emerge in relation to the crop.

(c) Determine how long weeds must be controlled after crop emergence in the spring, in order to achieve optimum production in the first growing season of spring-seeded alfalfa.

(d) Establish how long weeds can be allowed to grow with the crop after emergence without reducing the forage yields of a spring-seeded alfalfa.

(e) Prescribe logical management alternatives to prevent losses due to weeds in spring seedings of alfalfa.

Materials and Methods

This trial was planted on the same soil type as the previous experiment, in an adjacent area. A soil analysis of samples taken shortly after emergence revealed the following nutrient levels: 16 ppm of P; 345 ppm of K, and 5.1 ppm of Nitrate. Water was applied by sprinkler irrigation as needed. Eight treatments involving different weedy and weed-free periods were arranged in a randomized complete blocks design with five replications, Table V-1.

Because of the homogeneous condition of the field and the need to work within limits of available land, the plot size in this trial was reduced to 2.1 by 2.3 m (4.9 m^2).

The trial was planted April 14, 1982, with equal numbers of barnyardgrass, pigweed (mixed with lambsquarters), downy brome, and tumble mustard mixed to achieve a final density of 1 seed/17 cm^2. The seed was broadcast by hand over the plots that had to be weedy since the emergence of the alfalfa. The soil had been tilled with a power-driven rotary tiller and, after sowing, the weed seed was incorporated with the two metal rollers-packers of a 'Brillion' forage seeder.

'Vernal' alfalfa seed was seeded at 20 kg/ha, 1 to 2 cm deep, in rows 18 cm apart. The seed had been treated, prior to seeding, with the required amount of *Rhizobium meliloti* inoculant. The crop emerged April 23, 1982.

At the end of its weedy period, treatment number 5 was weeded with an application of 1 kg ae/ha of 2,4-DB (amine formulation), followed 5 days later by 0.4 kg ai/ha of sethoxydim to control emerging grasses. These two herbicides were also applied over all those plots that were to be kept weed-free at that time. Treatments number 6 and 7 were initially weeded by hand, and then sprayed with 0.4 kg ai/ha of sethoxydim for maintenance. No significant harmful effects were noted after the herbicide applications.

Forty-six days after emergence (June 8, 1982), 96 kg/ha of nitrogen, as ammonium nitrate, were applied to correct a notorious deficiency of this element.

At the end of their weed-free period, treatments 1, 2, and 3 were sown by hand with the weed mixture already described, and incorporated with a hand rake.

For treatments 6 and 7, weeds from the whole plots were kept for botanical separation and drying, at 65C during 48h. In the plots where alfalfa was seeded together with the weeds, seedling stand was recorded twice within $(0.25m)^2$ quadrats permanently set in those plots, 29 and 34 days after planting.

On July 7, 1982, the crop was harvested at the 80% bloom stage. In each plot, a central area of 0.8 x 1 m was cut with a sickle mower mounted on a motorized 'Gravely' unit. Total forage fresh weight per plot was determined in the field; the green forage was then dried at 65 C for 48 h, to assess the dry matter production. In treatments with different weed-free periods after emergence, the weeds and alfalfa were separated after harvest, prior to drying, in order to establish the dry matter produced by each component of the mixture. The alfalfa stems remaining in the stubble were counted within one meter of two different rows in each plot.

Second and third harvest dates were August 26 and October 3, 1982. In both cases, a central area of 1.1 by 1.2 m per plot was cut for yield.

The treatments were divided into two groups (1 to 4 and 8, and 4 to 8) for statistical analysis of the yield data. Each group was analysed as randomized complete blocks.

Results

The crop emerged on April 23, 1982; downy brome emerged one day after. By April 28, tumble mustard and lambsquarters had emerged but no barnyardgrass had appeared. Seedling counts showed almost no new emergence beyond 29 days after planting; the weed density at that time was 1 seedling/19 cm^2 (Table V-2). Hairy nightshade (*Solanum sarachoides* (Sendt.)) appeared in the trial and was not removed; those plants suffered a severe attack by the Colorado potato beetle [*Leptinotarsa decimlineata* (Say.)], and were later suppressed by the rest of the vegetation. Hairy nightshade was not present in the weedy plots at first forage harvest.

The alfalfa dry matter yields of treatments 4 to 8 at first harvest (Fig. V-1), showed that the crop was able to grow with weeds for the first 17 days after emergence without a significant ($p < 0.05$) decrease in production, although the trend was downward. By June 1, 39 days after emergence, the total growth of weeds (dry matter) was only 39 kg/ha (Table V-3); however, this was enough to significantly reduce yields at first harvest (Fig. V-1).

The alfalfa yields of treatments 1 to 4 and 8 showed

Table V-1. Periods of interference from weeds (treatments) in alfalfa seeded April 14, 1982.

Treatment no.	Description
1	Weed-free until May 10, 1982 (17 d.a.e.)
2	Weed-free until June 1, 1982 (39 d.a.e.)
3	Weed-free until June 15,1982 (53 d.a.e.)
4	July 7, 1982 (75 d.a.e. = W-F Check)
5	Weedy until May 10, 1982
6	Weedy until June 1, 1982
7	Weedy until June 15, 1982
8	July 7, 1982 (75 d.a.e. = Weedy Check)

Table V-2. Seedling counts of alfalfa and six weeds, following the April 14, 1982, seeding.

	Days after planting	
Species	29	34
	--(plants/m2)--	
Alfalfa	480	0
Downy brome	149	8
Tumble mustard	58	0
Pigweed	29	5
Lambsquarters	69	0
Nightshade	90	5
Barnyardgrass	128	13

Figure V-1. Alfalfa dry matter at first harvest, as affected by the length of the weedy periods after emergence, when seeded April 14, 1982. Points followed by the same letter are not significantly different (p > 0.05) according to Duncan's multiple range test.

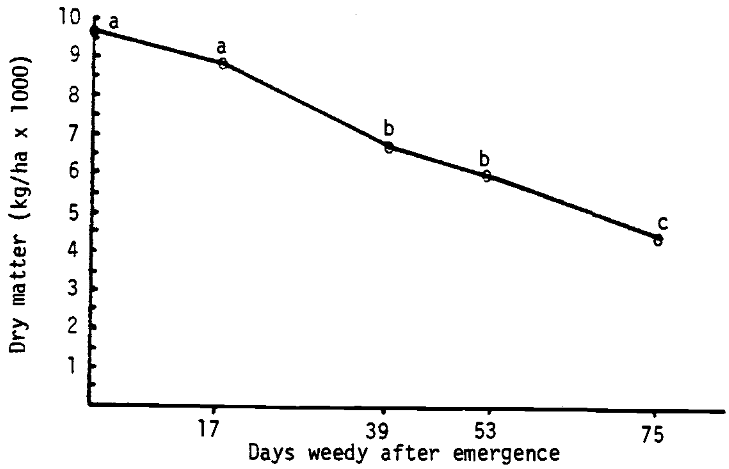
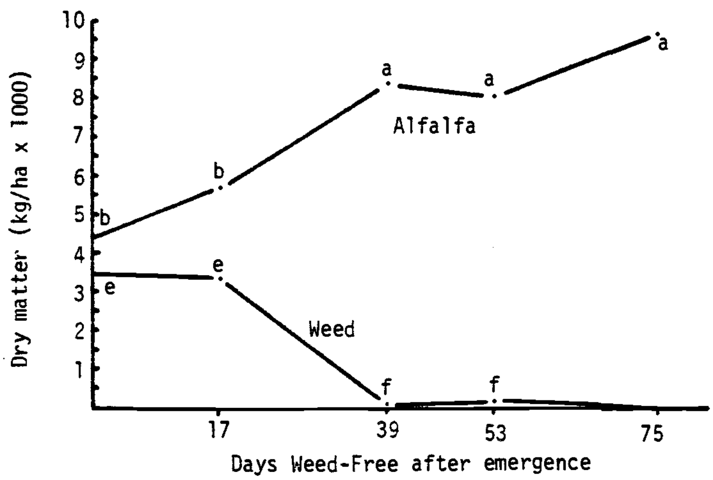


Figure V-2. Alfalfa and weed dry matter at first harvest, as affected by the length of the weed-free periods after emergence, when seeded April 14, 1982. Points followed by the same letter are not significantly different (p > 0.05) according to Duncan's multiple range test.



that the crop should be kept free of weeds at least during the first 39 days after emergence, to avoid significant yield losses ($p < 0.05$). This weed-free period (treatment number 2) also provided excellent purity of the alfalfa forage (Table V-5).

The habitat seemed equally well exploited by the crop, either alone or with weeds, for the treatments did not differ ($p > 0.05$) in their total aerial biomass production (Table V-5). The number of alfalfa stems per meter of row, counted after the first forage cutting, corresponded well with the yield values of the crop [$r = 0.82$ ($p < 0.05$)], thus reflecting the effects of the different treatments on alfalfa yields at the first forage harvest (Fig. V-3).

At the second and third forage harvests, yields were not significantly different ($p > 0.05$), but the weedy check still tended to yield less at the second cut (Table V-6).

Table V-3. Weed dry matter production when weeds were allowed to grow undisturbed with the crop after emergence, following the April 14, 1982, seeding of alfalfa.

Species	Dry matter					
	Days after emergence					
	39		53		75	
	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)
Tumble mustard	7	19	509	20	62	2
Downy brome	27	7	670	26	284	8
Lambsquarters	4	10	1044	41	3041	89
Barnyardgrass	0	0	189	7	37	1
H. Nightshade	1	2	148	6	0	0
Total	39	100	2563	100	3424	100

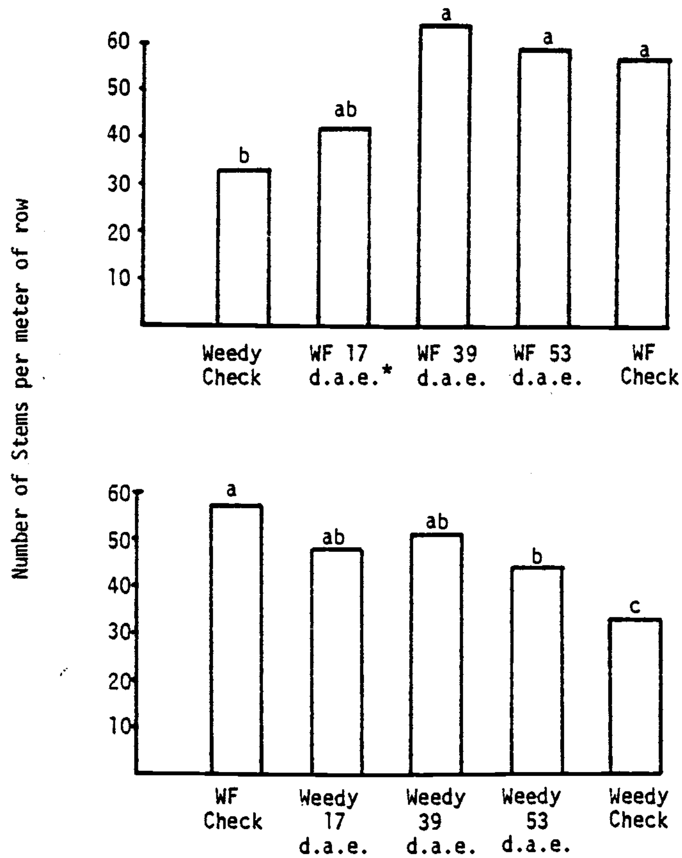
Table V-4. Total aerial weed biomass produced in those treatments with different weed-free periods after emergence, following the April 14, 1982, seeding of alfalfa.

Treatment	kg/ha[a]	% of total biomass (alf. + weeds)
Weed-free 17 d.a.e.[b]	3329 o	37
Weed-free 39 d.a.e.	2 p	0.1
Weed-free 53 d.a.e.	66 p	0.8
Weedy check	3424 o	44

a As the variances of these data were proportional to the corresponding means, a (x + 0.05) transformation was used for the statistical analysis. Values followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

b d.a.e. = days after emergence.

Figure V-3. Number of alfalfa stems per meter of row after the first forage harvest, as affected by the length of the weed-free or weedy period after emergence, following the April 14, 1982, seeding of alfalfa. Within each group, bars accompanied by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.



* d.a.e. = days after emergence.

Table V-5. Composition of the forage at first cutting of the treatments with various weed-free periods after emergence, when Alfalfa was seeded April 14,1982; (Dry Matter in Kg/ha).

W-F period after emergence	Alfalfa		Tumble mustard		Downy brome		Lambs-quarters		Barnyard-grass		Total biomass (aerial)	
	DM	(%)	DM	(%)	DM	(%)	DM	(%)	DM	(%)	DM	(%)
17	5669 b*	63	198	2	4	0	3078	34	49	0	8998 a	100
39	8356 a	99	0	0	0	0	0	0	2	0	8358 a	100
53	8015 a	99	0	0	4	0	62	0	0	0	8081 a	100
75 (WF Chk)	9629 a	100	-	-	-	-	-	-	-	-	9629 a	100
0 (Wdy Chk)	4386 b	56	62	0	284	4	3041	39	37	0	7810 a	100

* Within columns, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table V-6. Alfalfa dry matter yields (kg/ha) at the second and third forage cuttings.

Treatment	2nd cut	3rd cut
	(kg/ha)	(kg/ha)
Weed-free 17 d.a.e.[a]	3402[b]	2665
Weed-free 39 d.a.e.	3359	2909
Weed-free 53 d.a.e.	3230	2650
Weedy 17 d.a.e.	3318	3010
Weedy 39 d.a.e.	3359	3099
Weedy 53 d.a.e	3661	2579
Weed-Free Check	3531	2620
Weedy Check	2756	2710

a d.a.e. = days after emergence.

b Within each column, the values are not significantly different at the 5% level according to the F test.

VI - GENERAL DISCUSSION

Late Summer Plantings

Interference from four weed species

Each weed species differed in ability to interfere with the crop while growing with it undisturbed during the whole of the first season. This species effect has been described by Schreiber (47), Schreiber and Oliver (48, 49), and Norris (36), amongst others, and in our experiment it varied according to the planting date.

When the crop was planted August 14, all the weeds emerging with it reduced the alfalfa yields significantly. Downy brome and barnyardgrass were the most aggressive weeds. When the crop was planted 1 month later, the early frosts killed the summer annuals before they could affect the crop.

A September 15 seeding could therefore be a management alternative in fields where a predominance of summer annuals is expected. There is always the risk, however, that cool temperatures may retard the development of the crop, which would then be too small to survive the winter (21). That did not happen in our 1981 experiment where weed-free alfalfa yielded the same in spring whether planted August 14 or 1 month later. Dawson (15) found that alfalfa seeded from August 14 to early September escaped the effects of dodder (a summer annual weed) and grew large enough to survive the first winter.

The adverse effect of weeds that germinated in the fall persisted during the first two cuttings in the spring but yields from the different treatments did not differ by the third forage harvest of the season. The most aggressive weeds (barnyardgrass and downy brome, for the early and late seeding, respectively) tended to reduce ($p > 0.05$) the stand of the crop. An increase in tillering was responsible for the crop's recovery (by the third cutting) from the early weed interference.

Cary and Stritzke (8) also observed an early recovery (second cutting) from the interference of Bromus secalinus L. and, in this case, in spite of a stand reduction. On the other hand, Pike and Stritzke (44) and Norris (36) observed that early interference from weeds in fall-seeded alfalfa reduced yields for several harvests during the first growing season. In some cases, this occurred along with substantial loss of the alfalfa stand.

In our case, reduced tillering was probably a very important reason for the lowered early yields under weed interference. Chamblee and Lovvorn (1953), cited by Chamblee (9) and Haynes (23), observed that grasses interfere with alfalfa by shading the crown buds as they begin to grow; many buds thus fail to develop.

In terms of total forage production, we have seen in the first cuttings that alfalfa alone was not capable of fully exploiting its habitat. As noted by Pike and Stritzke (44), the total dry matter produced at the first forage harvest was highest when winter weeds were allowed to grow. In our case, the total dry matter produced in the first cutting was larger in the downy brome infested plots than in the weed-free plots from both seeding dates.

This means that the available ecological space could be occupied by an associated species as a companion crop (for forage or grain) only if the value of the associated product compensates for the loss in alfalfa production during the first two cuttings. A companion crop, usually oats, has been used in the establishment of alfalfa. The weeds are thus replaced by a crop that has a direct economic value (16). In some cases this practice has been economically superior to the use of herbicides for alfalfa establishment (28, 46); in others, the interference of the companion crop has been too severe, particularly in dry years. Then the recovery and establishment of the alfalfa has been worse than when weeds were allowed to grow instead of oats (42).

A companion crop such as oats for hay may not improve the quality of the forage as compared to alfalfa alone (51), or even to a mixture of alfalfa and certain weeds such as redroot pigweed (*Amaranthus retroflexus* L.), lambsquarters (*Chenopodium album* L.), and common ragweed (*Ambrosia artemisiifolia* L.). These weeds have a nutrient composition and digestibility essentially equivalent to that of a high quality alfalfa and should not decrease the nutritive value of the forage if grown on fertile soils and the pasture is utilized at early stages of maturity (30).

Perhaps further modifications in the density (44) and distribution of the alfalfa plants may improve its use of the available ecological space at establishment, if weed or companion crops are not present. A relatively higher density than the usual, and lower distributions (narrower rows or an even broadcast seeding), may raise the amount of alfalfa dry matter produced in weedy plots at the first cutting.

Critical Periods of Weed Interference

As noted by Norris (36), a first cleaning cut in spring as the only weed control measure, does not solve the problem of the weeds in fall. Those weeds that get established early in the cycle of the crop cause the highest losses if allowed to grow undisturbed with the crop until the first harvest.

To maximize alfalfa yields, weeds should not be allowed to grow during approximately the first 65 days after emergence. Weeds emerging thereafter are either killed by the frosts (summer annuals) or outcompeted by the crop. Weedings beyond that date seem to bring no statistically significant benefits in crop yield.

For complete weed control (weed-free crop), which allows top quality forage without the harmful effect of downy brome's harsh awns, weeds should not be allowed to grow for the first 194 days after emergence of the crop. Therefore the farmer must decide whether he is interested in maximum purity of his hay, or if he can be satisfied with a safe establishment of the crop with a mild contamination (20%) of weeds in the first cutting. This is a cost versus profit decision.

On the other hand, the crop seems to tolerate for an extended period the weeds that emerge with it. They have to be removed at least at the beginning of spring; weeds that overwinter and continue their growth in spring cause significant ($p < 0.05$) yield reductions (Fig. III-2). Considering that after 36 days from emergence the crop has no height advantage and that interference is mainly competition for light (nutrients and water were in ample supply), one would tend to think that the weed removal should take place before the winter.

This initial tolerance to the presence of weeds was explained by Donald (20) and Dawson (12) as interference being the result of competition for light. When competition is for other exhaustible factors, such as water (in non-irrigated areas) or nutrients, this initial tolerance should not appear (32). Light is either used or lost, there is no storage of light that can be depleted; nutrients or water can be prematurely consumed and affect development later in the growth cycle. So if competition is only for light, then until shading occurs, no other growth factor should have been depleted so as to affect the normal growth of the plants.

Therefore, under the conditions in which we conducted our experiment, when weeds were eliminated in late fall weeds emerging thereafter were outcompeted by the crop (Fig. III-2) and significant yield losses were prevented.

The farmer will thus have flexibility to decide when to apply his weed control treatment. If he uses herbicides, he can apply them early (preemergence or early postemergence), provided the control lasts approximately 65 days after emergence. However, because of the initial tolerance of the crop to weeds, the farmer's other choice would be a later treatment provided the weeds are effectively eliminated until 65 days after emergence.

The situation is particularly suitable for work with postemergence herbicides. Broadleaf weeds in seedling alfalfa are controlled mainly with postemergence applications of 2,4-DB or dinoseb-amine (40). Very efficient postemergence grass killers have been developed recently.

In spite of this flexibility, the farmer should bear in mind that the later one tries to control weeds, the more difficult it becomes. Weeds increase in size, usually becoming more resistant to selective chemical treatments. We do not believe hand or mechanical weeding is a practical alternative in alfalfa for hay; weed control by grazing would compare to a first "cleaning cut" in spring, and we have already seen that it does not work.

Late applications of 2,4-DB will not only be less effective with the larger weeds, but they are also likely to injure the fairly developed alfalfa plants; this crop being more tolerant at the three-to-four trifoliolate leaf stage rather than as older plants (40).

In dealing with the results of this experiment, we must also bear in mind that weeds were sown to initiate a weedy period, instead of allowing for the natural population of weeds from the soil reservoir to emerge. The natural reservoir may not always supply as many seedlings as may be obtained by planting the weeds. We wished to look at the biological response of this crop under conditions of maximum weed infestation.

When we concluded that 65 days after emergence is the period during which the crop should be kept free of weeds, we based our conclusion on the shape of the plotted function fitted to the data (Fig. III-1), and realize that the limit we have assigned to this critical period is not exact. The curve in Fig. III-1 leads us to believe that the limit of that critical period should be set somewhere between 36 and 65 days after emergence.

Similarly, the function describing the tolerance to initial weediness (Fig. III-2) shows a trend towards slight yield reductions in response to very early periods of weediness after emergence. It is difficult to visualize how this can occur in those very early stages of plant development. Eight days after emergence the plants were still very small (Fig. III-4), many still in the cotyledon stage. Unless we could demonstrate very early allelopathic effects acting upon alfalfa germination and early development,it would be difficult for us to explain such very early decreasing yield responses.

Rademacher and Ozolins (1952), cited by Koch (27), demonstrated that if there is competition for nutrients between weeds and cereals, this can start at the germination stage. Bennett (1960), quoted by Donald (20), demonstrated that competition for light in a very dense plant community can begin immediately after emergence.

With further experimentation and more data to fit response functions, we could rely more on the shape of the response curves to establish the limits of our critical periods. Bloomberg et al. (3) establishes the limits of the critical periods he finds, based on the shape of his fitted functions obtained by regression analysis while working with means of three years' data. This regression analysis approach seems to be an appropriate way of interpreting data from these sort of experiments (43).

Spring Plantings

Interference from four weed species

A nitrogen deficiency in this experiment did not allow for the more vigorous growth of weeds expected (21, 41). Consequently, we cannot compare the effects of weeds infesting a spring seeding of alfalfa with those of the weeds emerging in late summer or early fall.

This experiment, however, suggests that a management practice to reduce weed interference in the spring, is to limit as much as possible the supply of mineral nitrogen to a new seeding of alfalfa. The symbiosis with *Rhizobium meliloti* should selectively supply nitrogen to the crop. The weeds should suffer from the lack of this element, and lose much of their competitive ability. Twenty to 88 kg/ha of nitrogen can be enough for a 50 to 83% inhibition of the symbiotic-nitrogen fixation in alfalfa (P. Bottomley, 1981; personal communication)[4] and (7). Thus, with excessive amounts of mineral nitrogen (from a N fixation standpoint), weeds and crop will take this nutrient from the soil and compete for it. Limited amounts of N, however (some 20 kg/ha), may be needed to establish the legume until N fixation by the symbionts begins (7, 21, 23).

All the weeds had a similar effect on the crop's yields. The more severe yield inhibitions registered with certain weeds in the August and September 1981 seedings, did not appear in this spring experiment. Tumble mustard depressed the alfalfa yield in much the same way other

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weeds did, in spite of its own growth being much smaller than that of the other weeds (Table IV-2). However, tumble mustard was overwhelmed by the crop at the first harvest; most of the plants were dead and only a few grew up and flowered. In mid June, before harvest, the alfalfa growing with tumble mustard had appeared slightly chlorotic.

As in the late summer plantings, a weed-crop combination (with lambsquarters in this case) reached the highest top growth values in the first cutting (Table IV-2), showing that alfalfa alone had not been able to fully exploit its growth environment by that time.

Tillering was also depressed in this planting by weed interference. An increase in the number of stems/meter of row allowed the affected plots to recover by the third cutting.

<u>Periods of Interference</u>

Under the conditions in which this experiment was conducted, alfalfa may not have suffered competition for the main nutrients (soil-P level was 12 ppm and K level was 234 ppm;the plants were well nodulated) nor for water. If there was competition for nutrients, it must have been mainly among weeds, and for nitrogen which was deficient. Barnyardgrass emerging later than the crop,lowered the initial weed pressure. Thus the crop had an initial advantage that allowed it to tolerate the presence of weeds during 17 days after emergence. With higher initial levels of soil nitrogen, one would have expected a more severe initial impact of the weeds (21, 41).

Because of the relatively poor weed growth in this experiment (Table V-3), the habitat seemed equally exploited by the crop, either alone or with weeds (Table V-4). In the preceding experiments we saw that the weedy plots tended to yield more total aboveground biomass than those free of weeds.

Again, as in the preceding experiments, the number of productive alfalfa stems was a parameter affected by weed interference.

If we assume that the interference of the weeds could mainly be through shading, it would then be reasonable to say that the crop needs to be weed-free during a critical period between, approximately, the 17th and the 39th day after emergence (22 days). The results in this experiment show no further benefit by weeding beyond the 1st of June (39 days after emergence), for the weeds were thereafter almost totally suppressed by the crop (Fig. V-2). This means that a preemergence herbicide should have a residuality of at least 39 days. A postemergence application should not be delayed beyond the 17th day after emergence and should be able to keep the crop free of weeds until the end of the critical period. The farmer must always bear in mind that the later we try to control weeds, the more difficult and costly it becomes. Good weed control during this 22-day period also should provide alfalfa forage of maximum purity at the first harvest (Fig. V-2 and V-4).

VII - CONCLUSIONS

After working with a crop which was under no apparent nutrient nor water deficiencies, the following conclusions are formulated:

1 The presence of weeds emerging with a new seeding of alfalfa in the fall had a detrimental effect on crop forage yield. This effect not only became evident in the first forage harvest in spring, but also persisted in successive cuttings.

2 In a late summer planting (August 14), barnyardgrass and downy brome were the most interfering of the four weeds present.

3 Planting on September 15 helped avoid the infestation by summer annual weeds (barnyardgrass, pigweed, and lambsquarters). The winter annual weeds (downy brome and tumble mustard), however, became more interfering than if allowed to emerge with the crop a month before. The crop had only three trifoliolate leaves when winter came; its yield (weed-free) in the spring, however, was comparable to that of the August 14 seeding.

4 A late summer seeding on August 27 needed to have all weeds removed until approximately 65 days after emergence for optimum forage yields of alfalfa. When maximum quality was sought, weeding had to be continued until approximately 194 days after emergence of the crop.

5 The crop showed an initial tolerance to the weeds that emerged with it. This tolerance could extend itself until late fall.

From working on a nitrogen deficient soil in spring, the following was concluded:

6 The four weeds tested were equally interfering with alfalfa, in spite of significant differences in their dry matter production. Lambsquarters was most productive, and tumble mustard the least.

7 Alfalfa seemed to require a weed-free period of approximately 22 days: from the 17th to 39th days after emergence for maximum yield and purity of the alfalfa forage.

In general:

8 Weeds emerging early in the crop's growth cycle were most deleterious to the forage yields if allowed to grow undisturbed until harvest.

9 Once the alfalfa developed a canopy large enough to cover the soil completely, weeds emerging thereafter were suppressed by shading and had no detrimental effect upon the forage yields.

10 The crop lacked the capacity to fully exploit the available environment by the time of the first forage harvest. Weedy plots tended to yield more total forage than those weed-free. This leaves the possibility open to use companion crops or modifying seeding rate and

distribution of the alfalfa plants.

11 Because of the initial tolerance the alfalfa exhibited to the early presence of weeds emerging with it, the farmer has flexibility in applying the first weed control measure. He can wait to see which weeds are prevalent, broadleaves or grasses for instance, and decide upon the most appropriate chemical or herbicide mixture to use. The farmer also becomes more independent of weather conditions when he wants to treat his crop with herbicides: he can wait for a suitable day with no risk of losses, before the critical period of interference from weeds begins.

12 In order to have this initial tolerance to the presence of weeds, interference must be mainly competition for light. The alfalfa must therefore be properly inoculated with efficient strains of _Rhizobium meliloti_; high levels of soil nitrogen should be avoided but adequate supplies of other nutrients (P, K, S, etc.) should be provided to cover the requirements of the crop in the presence of an early weed population (unless complete preemergence control is obtained, in which case the amount of nutrients in the soil only needs to cover the crop's requirements). Water should be provided as required.

13 The number of productive alfalfa stems per meter of row, was a parameter affected by the competition from weeds. Increased tillering allowed the crop to recover

from weed interference, usually by the third cutting of the first season.

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A P P E N D I X

Appendix Table 1

Maximum and minimum daily temperatures (degrees F.) from July 1 to Dec. 31, 1981, at I.A.R.E.C.[a]

Day	July		August		September		October		November		December	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	86	44	86	46	80	56	68	40	66	37	48	43
2	77	42	87	47	76	43	78	44	66	34	51	48
3	88	51	87	47	73	47	64	33	60	36	54	24
4	96	56	81	47	78	50	61	31	64	26	42	25
5	102	71	82	51	79	45	60	35	58	24	46	25
6	76	56	88	56	77	47	52	38	53	26	56	42
7	69	42	93	58	82	51	63	45	53	26	52	38
8	69	39	98	60	87	46	63	37	50	27	54	32
9	76	51	98	72	90	58	62	36	54	28	46	32
10	92	43	95	58	91	48	59	43	54	27	45	35
11	74	40	97	60	80	49	55	39	47	27	51	25
12	75	46	96	62	85	50	59	39	49	35	45	21
13	83	50	98	63	86	52	60	40	62	34	38	20
14	72	45	95	49	87	51	60	34	62	37	36	21
15	82	53	97	59	84	49	63	35	55	26	32	20
16	87	58	96	58	89	54	64	36	50	38	40	19
17	90	57	97	53	90	54	68	42	46	36	29	10
18	92	56	91	61	90	59	69	36	51	32	31	15
19	88	51	95	42	94	46	70	41	56	33	32	25
20	88	53	95	53	71	41	74	47	46	29	46	24
21	86	50	81	48	65	56	60	33	47	33	38	32
22	86	51	91	51	63	36	58	29	55	43	33	19
23	85	52	84	51	65	35	59	30	55	37	36	15
24	84	52	92	54	65	39	55	35	55	32	29	22
25	87	62	85	48	65	39	67	38	46	22	34	14
26	86	58	80	45	65	42	62	50	40	25	34	26
27	90	60	83	44	67	45	65	49	41	31	33	19
28	94	60	78	47	62	45	64	48	45	19	34	17
29	89	47	82	49	68	39	61	35	44	27	28	21
30	89	46	77	50	65	37	56	30	46	22	27	11
31	79	50	79	45			50	43			27	10

a Irrigated Agriculture Research and Extension Center, Prosser, Washington.

Appendix Table 1 continued

Maximum and minimum daily temperatures (degrees F.) from January 1 to June 30, 1982, at I.A.R.E.C.

Day	January		February		March		April		May		June	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	26	5	49	35	51	26	53	24	69	43	77	42
2	34	14	37	33	52	31	54	30	72	40	72	37
3	37	29	55	30	56	32	52	34	70	31	73	45
4	38	28	38	11	52	34	55	28	62	29	73	40
5	37	6	31	10	56	27	57	28	62	32	70	42
6	21	-8	32	14	55	26	55	33	68	43	71	39
7	20	-6	31	11	51	27	46	29	76	47	70	40
8	14	2	33	16	57	30	53	25	70	34	71	41
9	17	8	32	16	57	40	60	30	64	39	18	47
10	24	6	33	10	65	62	45	62	30	67	81	50
11	27	14	34	14	65	38	68	48	65	35	86	52
12	22	14	49	25	54	30	69	46	71	40	90	61
13	23	8	48	34	52	43	58	45	73	39	77	55
14	37	11	60	36	53	35	62	38	68	41	88	52
15	49	28	62	50	49	28	53	29	74	44	85	52
16	45	28	65	46	51	23	55	30	77	47	89	53
17	46	30	61	41	52	29	62	33	76	42	90	58
18	45	28	61	30	54	38	62	27	60	34	90	61
19	47	20	51	35	47	32	55	27	67	35	94	54
20	37	20	65	45	55	30	57	28	69	39	95	61
21	35	25	63	48	54	24	62	30	76	53	96	57
22	38	21	46	24	58	27	69	35	84	57	86	53
23	43	28	48	26	61	29	78	45	79	44	89	52
24	55	31	46	24	70	41	79	32	81	42	88	54
25	57	33	47	27	60	26	64	34	82	53	92	54
26	45	30	47	28	61	33	64	34	84	44	89	61
27	50	32	45	29	64	37	69	40	67	42	89	59
28	47	33	52	31	60	30	74	47	60	45	92	54
29	47	27			53	28	60	31	69	42	63	56
30	46	26			53	26	60	39	73	43	74	69
31	51	33			56	32			77	45		

Appendix Table 1 continued

Maximum and minimum daily temperatures (degrees F.) from July 1 to October 14, 1982 at I.A.R.E.C.

	July		August		September		October	
Day	Max	Min	Max	Min	Max	Min	Max	Min
1	80	52	91	48	78	51	65	38
2	82	48	80	45	85	58	73	43
3	83	48	75	51	87	60	69	36
4	72	46	76	50	86	48	71	38
5	73	52	81	51	80	48	62	34
6	76	44	86	52	82	47	64	46
7	77	56	89	59	83	46	57	35
8	81	52	97	67	82	54	58	37
9	78	51	97	62	85	55	56	38
10	84	51	92	52	78	41	63	33
11	88	56	82	46	69	40	65	35
12	91	52	78	48	65	46	67	38
13	89	59	79	48	68	41	70	39
14	85	48	82	49	69	44	69	41
15	72	40	71	52	62	41		
16	70	41	81	49	68	37		
17	76	47	85	49	74	46		
18	85	54	84	53	82	46		
19	89	50	87	57	83	48		
20	91	55	91	65	81	58		
21	92	55	95	61	65	44		
22	82	40	95	52	70	45		
23	77	48	93	53	76	47		
24	85	47	88	60	79	55		
25	89	53	90	56	73	55		
26	96	58	93	55	69	43		
27	97	58	90	50	72	43		
28	98	64	89	44	68	43		
29	98	65	83	56	64	43		
30	97	66	87	44	65	42		
31	91	57	77	46				