EFFECTS OF FALL FORAGE REMOVAL AND PESTICIDE TREATMENTS ON WEEDS IN ALFALFA

By

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IN ALFALFA

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EFFECTS OF FALL FORAGE REMOVAL AND PESTICIDE TREATMENTS ON WEEDS IN ALFALFA

Abstract. The effects of fall harvest management treatments and pesticide treatments in established alfalfa (*Medicago sativa* L. #MEDSA) on weed populations were investigated over a five year period. Three fall harvest treatments, ungrazed-unharvested, grazed by cattle, and fall-cut were subplot treatments, implemented for the control of winter annual weeds and the alfalfa weevil (*Hypera postica*) Gyllenhal. Pesticide treatments were untreated, carbofuran (2,2-(dimethyl)-2,3-(dihydro-7-benzofuranyl)-N-methylcarbamate), terbacil (5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4-(1H,3H) - pyrimidinedione) + oryzalin (4-(di-propylamino)-3,5-dinitrobenzenesulfonamide), alone and in combinations, providing four sub-subplot treatments. Both fall harvest treatments decreased the weed populations at the time of preseason counts, compared to the ungrazed-unharvested treatment. Although weeds were reduced with a fall management treatment alone, the herbicide treatment effectively reduced weed populations better than any management alone. First harvest alfalfa forage yields were greatest with the combination of pesticides, or the insecticide treatment. Alfalfa stand decline over years was

the greatest factor influencing weed populations. When alfalfa stem density decreased below 20 stems/0.1 m^2 weeds became a larger forage component. At low densities of alfalfa, a herbicide + insecticide treatment combination was required to maintain a marginal alfalfa productivity level.
Additional index words. Integrated pest management, alfalfa weevil, BROSE, BROTE, CAPBP, LAMAM.

INTRODUCTION

Weed infestations in established alfalfa can decrease alfalfa production and forage quality (4,11,21). When alfalfa plant populations decline due to winter killing and pest damage, weeds establish and compete for growth resources (14,18). With declining stands and exposed soil surface areas among remaining alfalfa plants becoming larger, Bromus spp. are often the first weeds to invade (9). These weeds can then further reduce productivity of remaining alfalfa plants by altering light, temperature, and moisture conditions.

Competition for water between alfalfa plants and weeds is extremely important in semi-arid regions under non-irrigated conditions (23). However, shading may be more important since alfalfa yields increase with increasing soil moisture only when plants are unshaded (7). Pritchett and Nelson (17) reported from mixed plantings of alfalfa and smooth bromegrass (Bromus inermis Leyss. #[1] BROIN) seedlings that growth of alfalfa was greatly reduced by shading, with

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1. Letters following this symbol are WSSA approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

the reduction being much more serious in root growth than with vegetative growth. Reduced root growth is an important factor that limits the ability of plants to take up moisture and nutrients. They also reported that decreased light intensity decreased the number of nitrogen fixing nodules.

Cheat (Bromus secalinus L. #BROSE), a winter annual grass, is a troublesome weed in winter wheat and is becoming a major problem in alfalfa (16). Like several other cool-season weeds, its limited growth in fall may cause little concern and application of herbicides for control may be delayed until plants are too large. Also, some of these annual bromes can mature before the initial spring alfalfa harvest, assuring a plentiful seed source for future generations (9). Pike and Stritzke (16) reported that cheat infestations in seedling stands can be damaging to alfalfa forage production and forage quality. Not only did cheat competition reduce alfalfa production at first harvest in their studies, but alfalfa plants growing in competition with cheat were less productive throughout much of the season. They found that early harvesting intervals only slightly decreased the effect of the cheat competition.

Alfalfa harvest dates and intervals have been studied from the standpoint of maximizing yield and stand longevity (12,19). The use of harvest management to control cheat and other Bromus spp. in established alfalfa has received limited study.

Annual bromes can be effectively controlled in established alfalfa with herbicides (6,10,11,23). The lack of awareness of the severity of the problem and lack of information on potential economic return from controls may be major reasons for the limited utilization of effective pest management (15). Robinson et al. (18) noted that most of the weeds in alfalfa are more effectively controlled with soil-applied rather than with foliar-applied herbicides, but costs have been a deterrent to acceptance by producers.

The combination of stress from various pests on alfalfa can often cause greater losses than damage from individual pests (1,13). Many workers (2,3,8,20) have documented the reduction in alfalfa yield and quality of forage by the alfalfa weevil (*Hypera postica*) Gyllenhal. Interactions of weeds and insects, primarily the alfalfa weevil, further complicate the strategies for pest management in the alfalfa community. Berberet et al. (1) reported that the combined effects of alfalfa weevil and weeds greatly reduced forage production and stand longevity of alfalfa. They reported average seasonal yield reductions for alfalfa infested by the weevil only (2.0 Mg/ha), by weeds only (0.4 Mg/ha) and by a combination of the weevil and weeds (3.7 Mg/ha). The combined pest stress causes much greater losses than the sum of losses for the pest occurring individually. Waldrep et al. (22) found a high positive correlation between henbit (*Lamium amplexicaule* L. #LAMAM) infestation and alfalfa weevil damage. Alfalfa plots with 50% or more ground cover by henbit showed 75% or more damage by the alfalfa weevil. Fick and Liu (5) noted that damage by alfalfa weevil larvae delayed the development of alfalfa. They suggested the loss of leaf area due to weevil defoliation decreased the photosynthetic capacity of alfalfa, thereby making it less competitive. To date, however, there has been little clarification of the influence of weeds and their removal on pest dynamics in alfalfa management programs.

The objectives of this study were to evaluate the integrated effects of three fall harvest managements and pest management schemes on establishment and growth of cool-season weeds and to determine how this relates to alfalfa growth and production during the life of an alfalfa stand.

MATERIALS AND METHODS

The study was conducted at the South Central Research Station, Chickasha, OK. Alfalfa was planted in September, of 1981, with a Brillion[2] seeder at 13.5 kg/ha, on a Dale silt loam (fine-silty, mixed, thermic, Pachic Haplustolls) soil. Fall harvest management treatments were first imposed in 1982, and pesticide treatments began in February of 1983.

The experimental design was a 2^2 strip-split plot design with 4 replications. Main plots (36 x 40 m) were randomly arranged and consisted of the cultivars "Arc", "OK-08", and "WL-318". After a harvest taken mid-September of each year beginning in 1982, three fall harvest treatments were imposed on 12 x 40 m subplots. These consisted of a fall-cut (mid-November), winter grazing (December and January), and unharvested-ungrazed with no harvest after September. The grazing was conducted within a 2-3 week time period following the first killing freeze (20°C) using 6-10 cattle per hectare. The subplots were randomized in strips. The four sub-subplots (10 x 12 m) consisted of a factorial arrangement of two levels of weed control and two levels of alfalfa weevil control. This arrangement resulted in sub-

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2. Brillion Iron Works, Brillion, WI 54110

subplots which received no pesticides, herbicides only, insecticide only, and those which received both types of pesticide. A tank mixture of the herbicides terbacil (0.55) and oryzalin (1.5 kg ai/ha) was applied as a dormant application in February or early March. Carbofuran was applied at 1.1 kg ai/ha as needed for control of the alfalfa weevil on those sub-subplots designated to receive insecticides. All pesticide treatments were applied with a boom sprayer mounted on a tractor.

Preseason weed densities were determined each February, before any pesticide treatments had been applied, by identifying and counting the weeds of various species in six (15 x 50 cm) quadrats placed randomly in each sub-subplot. Natural stands of downy brome (Bromus tectorum L. #BROTE), rescuegrass (Bromus catharticus Vahl. #BROCA), shepherdspurse (Capsella bursa-pastoris (L.) Medik. #CAPBR), henbit (Lamium amplexicaule L. #LAMAM), and chickweed (Stellaria media (L.) Cyrillo #STEME) developed during this study. The entire test area was overseeded with cheat (19 kg/ha) during the fall of 1985 and 1986 to insure a uniform infestation of cool-season annual grass.

Prior to the initial spring harvest, percentage compositions of broadleaf weeds and weedy grasses in forage were visually estimated after calibrating estimates based on hand separations. These percentages were used to calculate the production of weeds, which was then subtracted from the total forage harvested to obtain an estimate of alfalfa forage yield. Stand density estimations were made by quadrat sampling in each of the sub-subplot areas. Stems that were greater than 8 cm were used to determine average stem densities. Yield estimations were made at the 10-25% bloom stage with a flail type harvester. Wet forage weights were determined from a 1 x 5 m area in each plot and a subsample (300-400 g) of forage was taken for dry matter determinations.

Two (15 x 50 cm) permanent quadrats were established randomly within each sub-subplot in March of 1987 and additional growth and environmental data were taken every 2 weeks in insecticide treated and untreated plots of the cultivars Arc and WL-318. (OK-08 was omitted due to insufficient alfalfa plant density remaining by the spring of 1987.) Within each quadrat, weed and alfalfa densities and heights were determined. Soil moisture and temperature were also determined at 2 week intervals adjacent to the quadrat areas. Soil samples were taken at two areas adjacent to the quadrat with a stainless steel (2 x 30 cm) probe to a depth 15 cm and soil moisture was determined gravimetrically. Soil temperature at a depth of 20 cm was obtained with a soil temperature probe. Sunlight canopy penetration was determined by laying a Li-Cor[3] quantum line sensor (Model LI-191SB) across the quadrat area, with minimal disturbance of vegetation. Light meter readings

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3. Li-Cor, Lincoln, NB 68504

were recorded in mV output and converted to photosynthetic photon flux density (PPFD) expressed as $uE \cdot m^{-2} \cdot s^{-1}$.

Quadrats in all sub-subplots were hand clipped and separated into yield components of alfalfa, Bromus spp., and broadleaf weeds at first harvest. Viability of seed of cheat, rescuegrass and downy brome was determined at first harvest to provide estimates of the amounts of viable seeds produced by each species before cutting. Seeds were collected randomly throughout the test area at the time of first harvest in 1987. Seed from each specie was prechilled for 7 days at 4°C, and then germinated in an alternating 20° C (16 hours dark)/30° C (8 hours light) environment for 24 days.

All data were first subjected to analysis of variance, for a strip-split plot design and LSD values were calculated for those factors with a significant (P = 0.05 level) F-test. Multiple regression techniques were used to establish a response surface relating stand density, alfalfa forage yield, and weed yield, and to describe the predictive model. Data were pooled across all treatments, then sorted by insecticide treatments. For clarity, Bromus spp. consisted of a mixture of cheat, downy brome, and rescuegrass. Broadleaf weeds were a mixture of sheperdspurse, henbit, and chickweed. All yield data presented are expressed on an oven-dry weight basis.

RESULTS

WEED POPULATIONS

When preseason weed counts were first taken in 1983, population density of broadleaf weeds averaged $146/m^2$ and made up the majority of the weed population. Grassy weeds averaged $3.3/m^2$. There were no significant interactions for cool-season weed populations between cultivars and harvest treatments in any year. Alfalfa cultivars did not influence the germination and establishment of cool-season weeds based on preseason weed counts during any year of the study.

Fall harvest treatments imposed during this study resulted in fewer broadleaf weeds in grazed plots than in the other treatments in February of the first 4 years of the study, with significant decreases in 1984 and 1986 (Table 1). There were also fewer weedy grasses in the grazed plots in 1986.

There were two cases of interaction in densities of cool-season, weedy grasses which involved the fall harvest and pesticide treatments, once in 1984 when weed numbers averaged less than $1/m^2$, and in 1985 when weed numbers averaged less than 3 $plants/m^2$. There were also two cases of interaction involving densities of broadleaf weeds and they were both involved with a herbicide treatment.

In 1984, there was a herbicide * insecticide interaction due to the greater number of broadleaf weeds in the sub-subplots that had received no herbicide ($10/m^2$) compared to the six broadleaf weeds/m^2 in the sub-subplots which received both herbicide and insecticide. In 1985, there was also a herbicide * cultivar treatment interaction. Without a herbicide treatment, the number of broadleaf weeds increased from $49/m^2$ in Arc, to $96/m^2$ in OK-08, but when a herbicide treatment was applied, broadleaf weed populations were 30 and 37 plants/m^2, respectively for the two cultivars (Data not shown).

There were no interactions among or between any of the treatments in the preseason weed counts in 1986 and 1987. There were significantly fewer broadleaf weeds in 1985, 1986, and 1987 in plots that had been treated with herbicides (Table 2). There was also a decrease in cool-season weedy grasses in herbicide treated plots in 1985 but, no significant differences in populations of cool-season weedy grasses in 1986 and 1987 (Table 2). The lack of difference in preseason cool-season weedy grass populations among pesticide treatments in 1986 and 1987 is probably due to the overseeding of cheat during the fall of 1985 and 1986, and a high density of downy brome in 1987.

WEED YIELDS

There were no significant interactions in dry matter production of weeds between the cultivar and herbicide treatments in any year. Total weed production in herbicide treated plots was decreased in all years. In addition, yields of grassy weeds were significantly reduced by application of herbicides in 1983 and 1987. In 1983, herbicide treated sub-subplots yielded an average of 15 kg/ha of weedy grasses, compared to 90 kg/ha in the unsprayed plots. Grassy weed yield in 1987 was 2830 kg/ha in the unsprayed plots and 1042 kg/ha in the herbicide treated plots. In 1984 and 1985, weed yield at first harvest consisted primarily of broadleaf weeds, so weed yield was not partitioned into broadleaf weed and grassy weed components.

Treatment effects of insecticide application on weed yields were significant in all years of this study (Table 2). This does not suggest that insecticides control weeds, but as Berberet et al. (1) noted, the increased stress that the alfalfa weevil causes renders the alfalfa plants less competitive for nutrients, moisture, and light. When insect induced stress is eliminated, alfalfa effectively competed with the weeds.

In 1984, 1985, and 1986, the lowest weed yields among harvest treatments were recorded in the grazed plots, but in

1987, the lowest weed yields were in the fall-cut plots. There were herbicide * fall harvest treatment interactions for weed yields in 1984, 1985, and 1986. These interactions were primarily due to larger weed yields within the fall harvest treatments when no herbicide treatment was applied, since the herbicide treatment essentially controlled the weeds in all of these fall harvest treatments. In plots not treated with herbicide, fall grazed plots usually had lower weed yields than fall cut, and unharvested plots. The only exception was in 1987, when cut had less weeds than grazed and unharvested treatments. Decreased weed yield in grazed plots was attributable to some utilization of grasses by livestock and some possible weed seedling damage by the cattle. The failure for grazing to reduce weeds in 1987 could be related to the declining stand of alfalfa and a late freeze in the spring of 1987 that killed the alfalfa topgrowth.

A significant herbicide * insecticide treatment interaction resulted with weed yield in 1983, 1984, and 1986. This resulted because there was essentially no weeds produced in herbicide treated plots, and a decrease in the amount of weeds produced when insects were controlled in the plots not treated with herbicides.

ALFALFA FORAGE YIELD

Fall harvest treatments had little effect on alfalfa production (Table 1). There was a significant reduction in alfalfa production with winter-grazing relative to other harvest treatments in 1983, but in 1986, grazed subplots produced more alfalfa than plots that were fall cut (Table 1). During the first 2 years of production, the unsprayed and the herbicide + insecticide treatments were not significantly different in alfalfa dry matter production. Early in the life of the stand (1983, 1984, and 1985) when weeds were not a major component of the forage production, the best yields resulted with the insecticide treatments (Table 4). As the alfalfa stand began to decline, the unsprayed plots were consistently lower in alfalfa dry matter production than the herbicide + insecticide treatment. This related well with the yield of weeds in sub-subplots treated with insecticide that allowed alfalfa to compete better with weeds. In contrast, by the fourth and fifth year of production, the herbicide + insecticide treatment combination was needed to maintain alfalfa productivity. This effect appeared to be caused primarily by the alfalfa stand decline in all plots.

In 1985, alfalfa forage production in all sub-subplots treated with herbicide averaged 5505 kg/ha and those not treated with herbicide averaged only 5050 kg/ha of alfalfa.

In 1987, alfalfa production from herbicide-treated plots averaged 3045 kg/ha while those on which herbicides were not used averaged 1535 kg/ha.

In 1985, forage yield for all insecticide-treated sub-subplots averaged 5600 kg/ha compared to an average of 4955 kg/ha for those without insecticide. In 1987, insecticide-treated plots averaged 2915 kg/ha, compared to 1665 kg/ha of alfalfa in those not sprayed with insecticide.

QUADRAT STUDY

Soil moisture was adequate throughout the spring of 1987, with no differences in soil moisture attributed to fall harvest or pesticide treatments. There were 14 cm of precipitation received during the first three sampling dates, and 10 cm of precipitation received during the remaining sampling dates. Soil moisture contents averaged 16% water by weight for the first three sampling dates, and dropped to 10% moisture for the last three sampling dates.

No differences in soil temperatures were detected among any of the treatments on any of the sampling dates. Soil temperatures averaged 5, 8, 4, 14, 17, 19 C for the respective sampling dates.

Height of *Bromus* spp. was significantly reduced by grazing and fall cutting at all sampling dates except for May 12 (Table 3). None of the fall harvest treatments had an effect on alfalfa plant height. *Bromus* height was significantly increased in WL-318 plots and this was attributed to the taller WL-318 alfalfa plants. There appeared to be more *Bromus* spp. in WL-318 than in Arc plots early, but by harvest, densities were similar (Table 3).

Insecticide treatments had a significant effect on *Bromus* spp. density. At the time of the first count, there were more *Bromus* spp. in the insecticide treated plots, but by first harvest, there were more stems in the unsprayed plots. This represents a 70% reduction of *Bromus* spp. in insecticide treated plots compared to only a 30% reduction in the unsprayed plots.

Alfalfa stem densities were significantly greater in the insecticide treated plots compared to the unsprayed plots with differences being significant at the last three sampling dates (Table 3). This along with the fact that alfalfa was generally taller in the insecticide treated plots, would account for alfalfa being more competitive in the insecticide treated plots.

The PPFD penetrating the plant canopy and reaching the soil surface was dependent upon the cultivar and the insecticide treatment (Table 4). Stem densities of WL-318 were always higher than Arc with differences being significant at three sampling dates. This resulted in less PPFD penetrating the canopy of WL-318 at all sampling dates, compared to Arc. There was less PPFD penetration into the insecticide treated plots than into the unsprayed plots. Alfalfa weevil had damaged the alfalfa leaf canopy of unsprayed plots and that would allow more light to reach the soil surface (5).

The yield of *Bromus* spp. did not appear to be significantly effected by early differences in height and density of *Bromus* spp. or by differences in PPFD reaching the soil surface. *Bromus* yields were not affected by cultivar or fall harvest treatments. There was however, a difference in alfalfa yield in the insecticide treated plots where 2380 kg/ha was produced, and only 950 kg/ha in the unsprayed plots (Table 5).

VIABILITY TESTS

None of the spikelets of cheat had developed a caryopsis, so no germination estimate was made for cheat. Only 2.5% of the rescuegrass seeds germinated. Downy brome, which is generally an earlier maturing grass, had 10% germination of collected seed. Hulbert (9) noted that the viability of downy brome was excellent after the purple coloration had begun to be noticeable. At the time of collection of these seed samples, the majority of the seeds had not attained this purple coloration. This evaluation of seed viability provides an inference on the soil seed reserve. These results show that harvesting at this date should decrease the weed seed reserves in the soil.

DISCUSSION

The factors contributing to weed establishment and production are complex. Early in the life of the stand, weeds were not a major problem at first harvest. The alfalfa stand density was such during the first 3 years of the study that the competitive nature of alfalfa suppressed the invading weeds, resulting in very little weed production. In the fourth and fifth years, the overall stand density began to decline to a critical point. This allowed weeds to fill the voids and then the weeds were able to compete with the alfalfa. This resulted in substantial weed yields and decreased alfalfa production during the final two years of the study.

Since grazing and fall-cutting treatments imposed during the course of this study did reduce the weed populations, with minimum alfalfa yield reductions, it is possible that these management tools could serve as an alternative method for chemical weed of cool-season annual weeds. The value of the forage utilization and the elimination of over-wintering sites for the alfalfa weevil are also important additional considerations for the reductions of pests with these two management options.

The critical factor for weed invasion in this study appeared to relate directly to alfalfa stand density. The surface planes derived from multiple regression techniques (Figures 1 and 2) illustrates that as alfalfa stand declines the alfalfa yield potential is decreased, and weed yield potential increased. The major difference between the planes is that when the weevil stresses are decreased with the insecticide treatment, there is a greater alfalfa yield potential than without the insecticide treatment.

This data relates well to that of Berberet et al. (1). These researchers proposed that good alfalfa weevil control is a good weed management tool. This means that alfalfa plants free of insect stress are more competitive with weeds.

These results indicate that when alfalfa stand density reaches about 200 stems/m^2, the alfalfa yield potential decreases and the weed yield potential increases. The manner in which the stand reductions come about is irrelevant. Producers can decrease the rate of stand decline by the proper incorporation of pesticides in their management program and by selection of improved cultivars that are resistant to multiple pests.

The removal of fall forages had an effect on weed establishment and production of weeds, but production of weeds was not strictly related to preseason weed counts. High population densities of weeds at the time of the preseason weed counts didn't necessarily lead to high weed yields at first harvest when alfalfa stand densities were greater than 200 stems/m^2. Although weeds germinated at these stand densities, the rapid growth of alfalfa in the spring resulted in alfalfa out-competing the invading weeds.

Although some weed reductions resulted with fall-cutting and grazing, a herbicide treatment became necessary for adequate weed control by 1986. This is again related to alfalfa stand density. The voids created by reducing the stand density increases the likelihood of a greater weed problem.

Early in the life of a stand, insecticide treatments alone provided good alfalfa yields. Late in the life of the stand, herbicide treatments became as important as insecticide treatments and the best alfalfa forage yields were obtained when the combination of pesticides were used. This means that the amount of management inputs became increasingly important as the stand density decreased.

In established stands of alfalfa many factors should be considered for sound pest management. The results presented herein relate well to a producer's field situation. Depending upon weed density, type of weed present, alfalfa stand density and the presence or absence of insects, the use of pesticides plays a major role in maintaining productivity and persistence of a stand.

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Table 1. Broadleaf (BLW) and grassy weed (GRA) populations at preseason counts and first harvest weed and alfalfa yields among fall harvest managements treatments.[a]

FALL HARVEST TREATMENT	PRESEASON WEED COUNTS (plants/m^2) BLW	GRA	DM PRODUCTION (kg/ha) WEEDS	ALFALFA
		1983		
Grazed	127 a	3 a	90 a	4670 b
Cut	152 a	3 a	110 a	5090 a
Unharvested	154 a	4 a	120 a	4910 a
		1984		
Grazed	4 b	§ 1 a	20 b	5590 a
Cut	9 ab	§ 1 a	65 a	5380 a
Unharvested	14 a	§ 1 a	61 a	5640 a
		1985		
Grazed	40 a	2 a	290 b	5480 a
Cut	53 a	5 a	540 a	5090 a
Unharvested	60 a	2 a	420 a	5270 a
		1986		
Grazed	87 b	9 b	650 b	2720 a
Cut	150 a	16 a	870 a	2220 b
Unharvested	120 a	14 a	1050 a	2510 a
		1987		
Grazed	120 a	220 a	2180 a	2560 a
Cut	100 a	190 a	1680 b	2190 a
Unharvested	110 a	180 a	2080 a	2130 a

[a] Observations followed by the same letter are not significantly different at the 5% level according to multiple T-tests of the least square means. Comparisons should only be made within the same year and column.

Table 2. Broadleaf (BLW) and grassy weed (GRA) populations at preseason counts and first harvest weed and alfalfa yields among pesticide treatments.[a]

PESTICIDE TREATMENTS	PRESEASON WEED COUNTS (plants/m²) BLW	GRA	DM PRODUCTION (kg/ha) WEEDS	ALFALFA
		1983		
Unsprayed	150 a	4 a	230 a	4790 bc
Herbicide	140 a	3 a	28 c	4620 c
Insecticide	150 a	3 a	160 b	5200 a
Herb.+ Insect.	140 a	3 a	5 c	4950 bc
		1984		
Unsprayed	9 a	2 a	120 a	5630 a
Herbicide	10 a	§ 1 b	9 c	5450 a
Insecticide	13 a	§ 1 b	54 b	5510 a
Herb.+ Insect.	6 b	§ 1 b	8 c	5550 a
		1985		
Unsprayed	76 a	5 a	740 a	4730 d
Herbicide	31 b	2 b	320 b	5180 c
Insecticide	65 a	4 a	390 b	5370 b
Herb.+ Insect.	31 b	2 b	210 c	5830 a
		1986		
Unsprayed	150 a	12 a	1730 a	1160 d
Herbicide	100 b	14 a	280 c	2200 c
Insecticide	130 a	12 a	1180 b	2990 b
Herb.+ Insect.	90 b	13 a	240 c	3590 a
		1987		
Unsprayed	140 a	210 a	3040 a	860 c
Herbicide	82 b	180 a	1150 c	2470 b
Insecticide	150 a	180 a	2670 b	2210 b
Herb.+ Insect.	75 b	180 a	1060 c	3620 a

[a]Observations followed by the same letter are not significantly different at the 5% level according to multiple T tests of the least square means. Comparisons should only be made within the same year and column.

Table 3. Quadrat study, Bromus and alfalfa heights and relative densities.[a]

COUNT #	1	2	3	4	5	6
DATE	3-3	3-19	3-31	4-16	4-27	5-12
			Bromus height (cm)			
Grazed	3 a	7 a	14 a	20 a	40 a	75 a
Cut	5 b	8 a	15 a	21 a	40 a	78 a
Unharvested	7 c	11 b	18 b	23 b	45 b	81 a
WL-318	5 a	9 a	18 a	23 a	46 a	83 a
ARC	5 a	7 b	13 b	20 b	37 b	73 b
			Bromus plants/m^2			
WL-318	19 a	16 a	14 a	17 a	10 a	8 a
ARC	14 b	14 a	11 a	13 b	10 a	7 a
Insecticide	19 a	16 a	14 a	17 a	8 a	6 a
Unsprayed	15 b	14 a	11 b	13 b	12 b	9 b
			Alfalfa heights (cm)			
WL-318	6 a	10 a	16 a	17 a	30 a	44 a
ARC	4 b	8 b	12 b	15 a	27 a	37 b
Insecticide	5 a	10 a	15 a	20 a	37 a	51 a
Unsprayed	4 a	8 a	12 a	13 b	19 b	30 b
			Alfalfa stem density (0.1/m^2)			
WL-318	21 a	29 a	23 a	24 a	19 a	19 a
ARC	13 b	17 b	17 a	16 b	15 a	15 a
Insecticide	19 a	26 a	22 a	25 a	22 a	21 a
Unsprayed	15 a	21 a	18 a	15 b	13 b	13 b

[a] Observations followed by the same letter are not significantly different at the 5% level according to multiple T-tests of the least square means. Comparisons should only be made within the same sampling date and column.

Table 4. Quadrat study, light canopy penetration at soil surface ($uE \cdot m^{-2} \cdot sec^{-1}$).[a]

COUNT #	4	5	6	7
DATE	3-31	4-16	4-27	5-12
WL-318	771 a	670 a	811 a	326 a
Arc	1010 b	937 b	1040 b	439 b
Insecticide	838 a	671 a	714 a	276 a
Unsprayed	943 a	937 b	1138 b	535 b

[a] Observations followed by the same letter are not significantly different at the 5% level according to multiple T-tests of the least square means. Comparisons should only be made within the same sampling date and column.

Table 5. Yields of hand clipped quadrats, for broadleaf weed (BLW), *Bromus*, and alfalfa by insecticide treatment.[a]

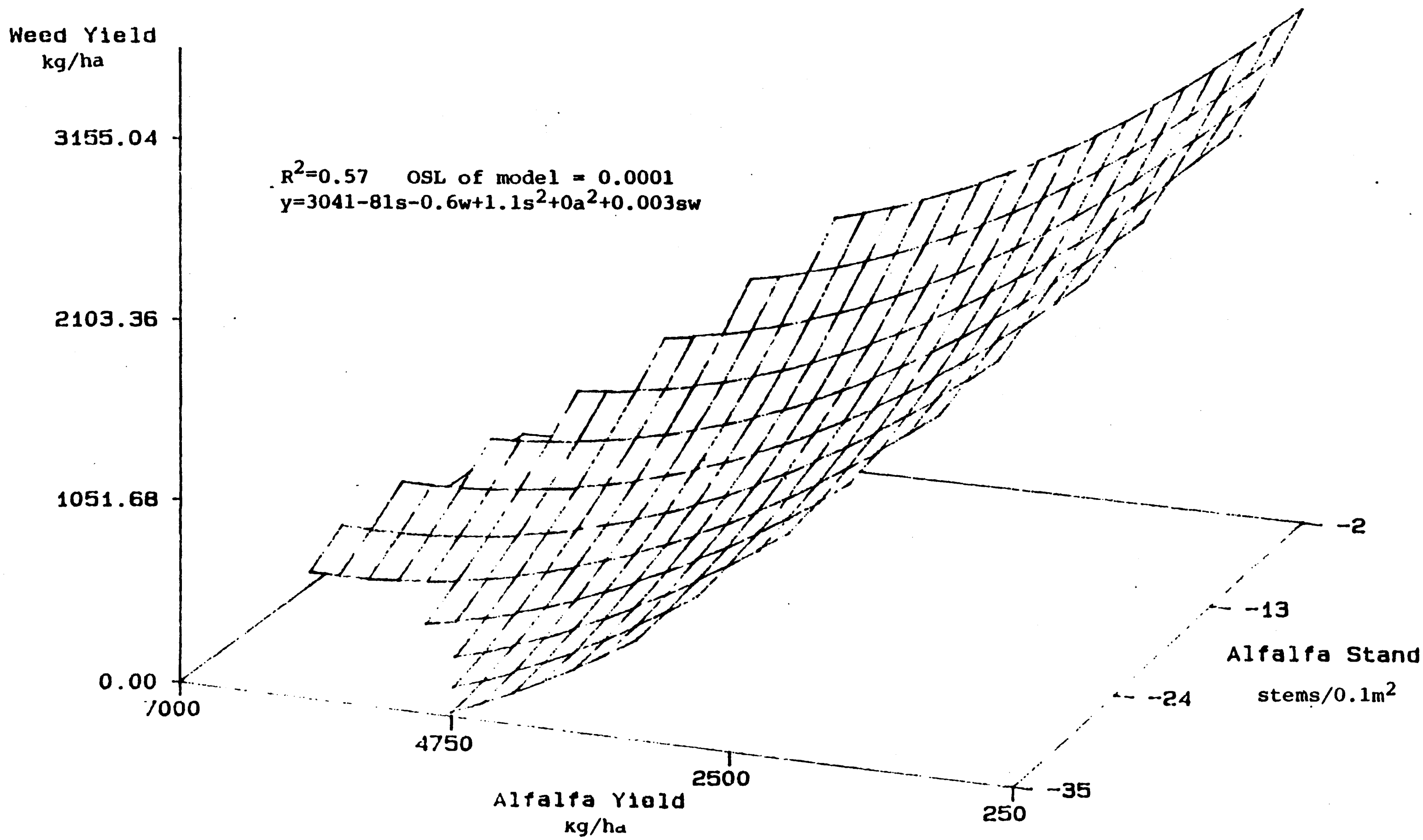
	PRODUCTION (kg/ha)		
	BLW	*Bromus*	ALFALFA
Insecticide	75 a	2834 a	2382 a
Unsprayed	3 a	2812 a	990 b

[a] Observations followed by the same letter are not significantly different at the 5% level according to multiple T-tests of the least square means. Comparisons should only be made within the same column.

2--Degree Response Surface

INS=Insecticide

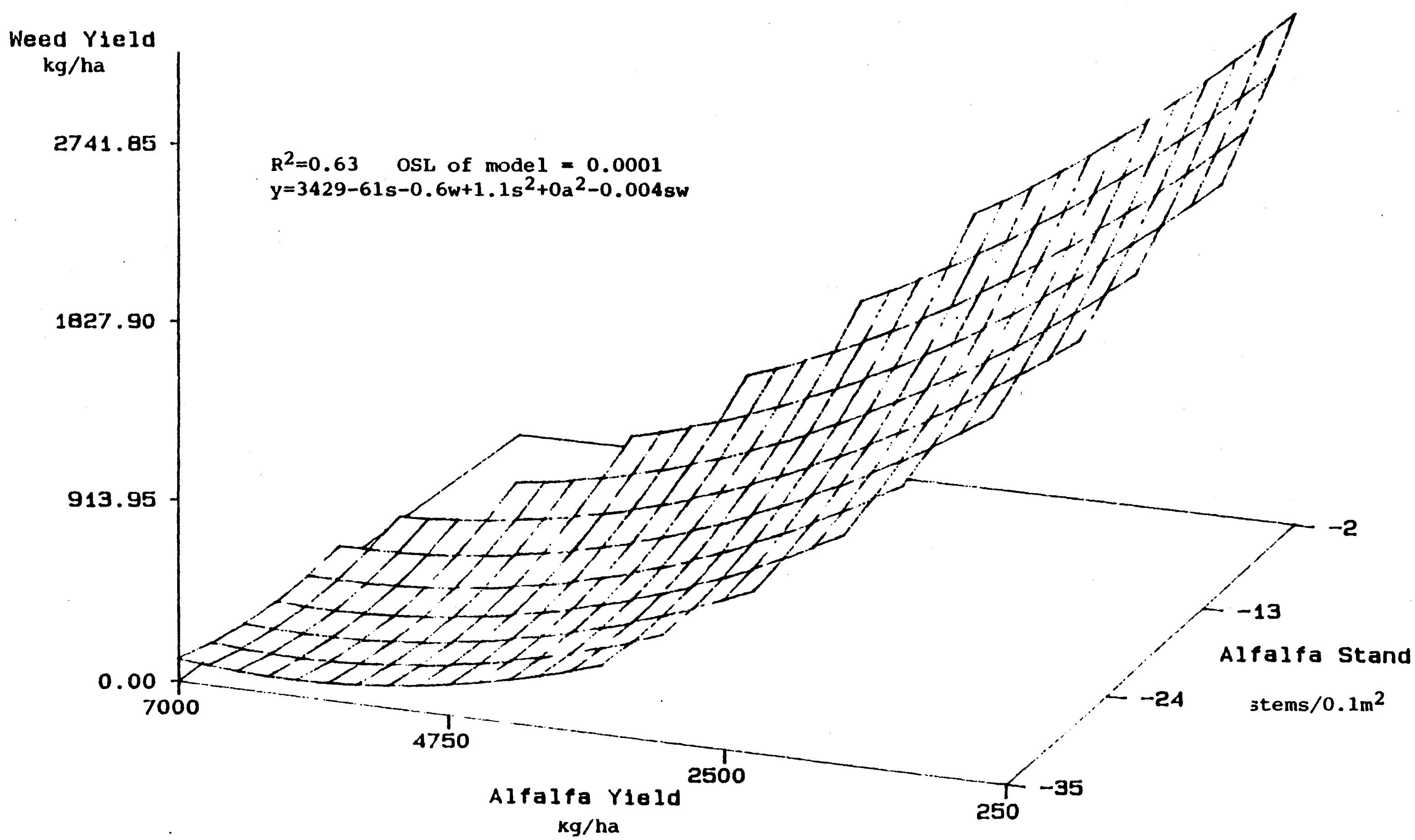
FIGURE 1. Surface plane depicting the weed yield given alfalfa stem density and the alfalfa forage yield, with insecticides.



2–Degree Response Surface

INS=No Insecticide

FIGURE 2. Surface plane depicting the weed yield given alfalfa stem density and the alfalfa forage yield, without insecticides.



VITA

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