INFLUENCE OF FALL PLANTING DATE OF ALFALFA, *MEDICAGO SATIVA* L., ON POPULATION DENSITIES OF THE ALFALFA WEEVIL, *HYPERA POSTICA* (GYLLENHAL)

By

ALAN KIRK DOWDY

Bachelor of Science

University of Wyoming

Laramie, Wyoming

1982

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1984

INFLUENCE OF FALL PLANTING DATE OF ALFALFA,

MEDICAGO SATIVA L., ON POPULATION

DENSITIES OF THE ALFALFA WEEVIL,

HYPERA POSTICA (GYLLENHAL)

Thesis Approved:

Richard Berberet
Thesis Adviser

W. Scott Fargo

John L. Caddel

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

I sincerely thank my advisor Dr. Richard C. Berberet for his professional guidance and personal interest in me as an individual. Appreciation is extended to Dr. John L. Caddel from the Department of Agronomy for use of equipment and direction in the agronomic aspects of these studies. I also wish to thank Dr. W. Scott Fargo for his assistance in computer analysis and constructive criticism of this thesis. Field assistance, which was greatly appreciated, was from Dr. M. Samual Rupp and Mr. Kevin Shelton. I am also indebted to Ms. Phoebe Courtney and Mr. Scott Myers for the endless hours they helped me in the laboratory. Most importantly I sincerely thank my parents, Mr. and Mrs. Auburn W. Dowdy, for their constant support and encouragement while I am striving toward my goals.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

The alfalfa weevil, <u>Hypera postica</u> (Gyllenhal), is the most important insect pest of alfalfa in Oklahoma. The eastern strain of the alfalfa weevil was first reported in northeastern Oklahoma in 1968. The western strain was reported in the Panhandle in 1969, but is believed to have entered the state 2 or 3 years earlier (Berberet et al. 1980). Since that time, the weevil has become a serious economic pest of alfalfa throughout Oklahoma.

The alfalfa industry in Oklahoma generates over $100 million annually from the sales of hay and seed produced on about 200,000 hectares (Sholar et al. 1982). Economically, alfalfa is ranked as the third most important agricultural commodity in the state and is also an important part of the beef and dairy industries. If left unchecked, the alfalfa weevil could have a disastrous effect upon the agricultural community of this state. Research in Oklahoma has indicated that for each increase in population of one weevil larva/stem, first harvest yields were reduced 188 kg/ha (Berberet et al. 1981). Average losses at first harvest due to weevils in unsprayed alfalfa have been nearly 1050 kg/ha (Berberet et al. 1981). Average losses at first harvest due to weevils in unsprayed alfalfa have been nearly 1050 kg/ha (Berberet et al. 1980). Lower yields of second harvest in damaged stands also occurred due to reduction of stem density and plant growth (Berberet et al. 1980, Wilson et al. 1979). As few as 1.5 larvae/stem can cause losses justifying chemical control costing $20 to $25/ha (Berberet and Pinkston 1978). Not only is yield reduced by larval feeding, the quality components of the forage may be reduced as well (Lui and Fick 1975).

Due to economic considerations and restricted pesticide registration resulting from insecticide residue problems in forage, alternative control procedures have been emphasized to maintain alfalfa weevil populations below economically important levels. Such alternatives include flaming of stubble in winter to reduce egg populations, biological control programs, management of alfalfa stands as an annual crop and better timing of currently labeled insecticide applications. A goal of the Oklahoma integrated control program is to reduce alfalfa production costs with cultural measures and biological control agents such as the parasitic wasp, <u>Bathyplectes curculionis</u> Thomson. These measures have resulted in less reliance on chemical controls.

No studies have been conducted in Oklahoma to determine the probability for serious weevil infestation of new stands. The purpose of this research project was to examine the effects of fall planting dates on the migration of weevil adults into alfalfa stands by estimating the resulting egg and larval populations. The objectives include:

1. To determine the influence of alfalfa seeding dates on alfalfa weevil damage to seedling stands by monitoring egg and larval populations, crop phenology and extent of defoliation.

2. To determine if the value of late fall seeding as a weevil control measure offsets lower plant populations and first year yields which may result from this practice.

CHAPTER II

LITERATURE REVIEW

The origins of the alfalfa weevil include Europe, central Asia, and parts of Asia Minor as well as the Mediterranean coast of Africa (Manglitz and App 1958). In these areas it is not considered to be a serious alfalfa pest, although occasional damage has been recorded. The alfalfa weevil was first discovered in the United States on a farm near Salt Lake City, Utah, in 1904 (Titus 1907). This introduction was later to be called the western strain. In 1951, the weevil was found in Maryland (Bissell 1952). This introduction may have come from Europe or from alfalfa forage transported from western states. This population has been termed the eastern strain. Since the 1950's, one or both strains have migrated into 48 states.

The weevil completes one generation per year which begins as adults enter the fields in October and November following summer aestivation in Oklahoma (Berberet et al. 1980). Pausch et al. (1980) showed that movement into the field is at first gradual as the beetles crawl and do not fly until having been in the field for several days. The preflight period is spent replenishing depleted food reserves. In fall, adults can be found in greater numbers on field edges than in the middle of the field (Fronk 1959). Spatial patterns of adults in winter are relatively consistent throughout fields (Blickenstaff 1967). Some females lay eggs during fall, while others do not begin ovipositing until late winter or spring. Temperatures which prevail during fall and winter greatly influence the extent of oviposition prior to spring.

The alfalfa weevil generally lays eggs in stems of alfalfa. In Oklahoma, egg deposition begins in November or December and continues into May (Berberet et al. 1980). Weevil eggs are oval and about 0.65mm long by 0.35mm wide (Titus 1910). They are bright yellow when deposited and become brown as embryonic development progresses. The black head stage occurs shortly before hatching when the black head capsule of the developing larva can be seen through the chorion. Most eggs are clustered in growing stems, but some have been found in dead stems in the early spring (Manglitz and App 1957). Sweetman (1929) found in alfalfa stems up to 46cm in height that 79% of the egg clusters were located within 7.6cm of the crown and 91% were found within 14.2cm of the crown. However, Busbice et al. (1968) recorded 45% of all egg clusters in the top third of stems of comparable height and only 20% in the bottom third in alfalfa grown in a greenhouse.

VanDenburgh et al. (1966) noted in studies on plant physiology versus weevil oviposition that a positive correlation existed between greater stem diameters and ovipositional preference. The adult has a preference for stems with large diameters in which more and larger egg masses may be deposited (Norwood et al. 1967b). Plants with few eggs characteristically had wide crowns, decumbent growth, and small stem diameters (Norwood et al. 1967a). Due to the fact that early fall plantings will result in larger plants with greater stem diameters and plant heights than later fall seedings, it is theorized that the earlier plantings would be preferred for fall and perhaps spring oviposition in Oklahoma.

It has been shown that as winter progresses the percentage of fall laid eggs which are viable decreases in northern states. The highest percent viability occurs in January and lowest in March in Pennsylvania (Townsend and Yendol 1968), and Illinois (Hsieh and Armbrust 1974). This occurs because extended periods of cold temperatures render increasing numbers of eggs unviable. Dively (1970) discovered that lower viability in eggs oviposited in plants which had reached the bud stage in fall is due to less succulent growth and the fact that these egg clusters are located in stems which are more exposed to lethal weather conditions. Due to the relatively mild winters of Oklahoma, fall laid eggs are less likely to be killed than with cold winters occurring in northern states.

In Michigan, there is little fall oviposition, and early spring feeding by larvae is of minor importance (Casagrande and Stehr 1973). Litsinger and Apple (1973) reported that under average fall and winter conditions in Wisconsin, fall oviposition never exceeded 2% of the yearly total egg production. Hsieh and Armbrust (1974) pointed out that 75% of total egg populations are laid in the spring in central Illinois, but in sothern Illinois about 45% are deposited in fall and winter. In Delaware, fall oviposition is related to greater plant damage per larva at first cutting and less damage in those stands with all or nearly all spring laid eggs (Burbutis et al. 1967). In spring, alfalfa stems contained eggs laid in the fall as well as newly laid eggs; data from Burbutis et al. (1967) show that by removing browned stems in the fall or early spring the number of weevils and the percent damage greatly decreases, from 26.5% down to 7.5% injury. Egg samples taken from alfalfa fields in Oklahoma in March, 1972, revealed that the number of eggs found in brown stems was three times greater than the number found in green stems (Berberet unpublished).

Ovipositional rate of the alfalfa weevil increases in warm, dry, spring weather; whereas, cold, damp weather causes the oviposition rate to decrease and continue over a longer period (Titus 1913). Weevil eggs usually begin hatching in late January or early February and continue into May in Oklahoma (Berberet et al. 1980). As the eggs hatch, the larvae move to the plant terminals and feed for the first two instars, then move on to older leaves during the third and fourth instars (Manglitz and App 1957). The larval stage is the most destructive as the early instars feed in the terminals cause "ragging" of the emerging leaves and the older larvae defoliate plants (Sholar et al. 1982). Adult weevils feed on the leaves in a manner somewhat like large larvae. They also feed on stem epidermis and the conductive tissue beneath, with resulting dessication and perhaps death of the stem (Mathur and Pieńkowski 1967).

Developmental time for the alfalfa weevil is dependent upon temperature and is measured in degree days. The degree day (celsius) requirement to complete larval development is 212 above a threshold of 8.9°C for the eastern strain and 207 (threshold = 10.6°C) for the western strain (Hsieh et al. 1974). The lethal low temperatures for larvae are -16.2, -9.8, and -8.2°C for second through fourth instars, respectively (Armbrust et al. 1969). Sweetman (1932) determined the rate of larval development was not greatly influenced by relative humidity because the host plant supplies all fluid needs and young larvae are protected from dessication for several days while feeding in plant terminals. Sweetman also discovered that freezing temperatures which killed plant terminals (2 hours at -2°C) did not necessarily injure the larvae. The lethal low temperatures for the adult range from -4 to -18°C, and the lethal high temperatures are between 46 and 52°C (Bass 1966).

As temperatures in alfalfa fields rise in summer, adult weevils move to areas surrounding the field to aestivate. They remain protected in the ground litter until temperatures decrease in the fall.

Senst and Berberet (1980) studied the merits of winter grazing as a control for the alfalfa weevil. By removing browned stems from the field, the cattle decreased the number of suitable oviposition sites for the weevils. Less plant material was present for overwintering adults and fewer suitable locations for oviposition. Eggs laid in these stems before grazing were also destroyed. Insecticide applications were still necessary for weevil control in the spring, but at a reduced rates and numbers of applications necessary. Though winter grazing may be beneficial in older stands it is not practical on late summer or fall seedings because little forage is present for animal consumption and plant damage may result.

Campbell et al. (1961) suggested that fall insecticidal applications may be effective in reducing the adult population as they enter fields. The result may be reduced larval infestations in the spring. Others agreed with these results by citing that chlorinated hydrocarbon insecticide residues might be high enough in the spring to control remaining adults and newly hatched larvae (Armbrust et al. 1966, Steinhauer and Blickenstaff 1967). It was considered easier to control adults with a single fall application than to attempt control of larvae hatching over an extended period in the spring (Campbell et al. 1961). This strategy became less effective when the weevil began to resist chlorinated hydrocarbon insecticides and control with these compounds became difficult (Dorsey 1966). Some of these products were also subject to label cancellations. Without chlorinated hydrocarbons, timely spring insecticidal applications were found to offer the best chemical control (Armbrust and Gyrisco 1966).

In Delaware, the alfalfa fields most damaged by weevil larval feeding are 2 or more years old. Few serious infestations and little damage had been recorded in the first year of production following planting in late summer or early fall (Milliron and MacCreary 1955). This may be due to the presence of less plant material in fields to attract overwintering adults, resulting in less damage due to larval feeding as compared to older stands.

Wilson et al. (1969) proposed annual spring planting to avoid weevil infection for as far north as southern Indiana because most weevil oviposition occurs before the new crop emerges, or the seedlings are too small to be attractive to ovipositing females. Forage yields of spring plantings are low as compared to first-year yields of fall plantings (Bennett 1968) and by treating alfalfa as an annual crop the reduction in stand productivity would probably not be offest by the lower cost of weevil control. Oklahoma usually has some growth throughout the winter so weevil oviposition is possible as long as the temperature is above the ovipositional threshold of 1.6^{o}C (Berberet et al. 1980). Greater amounts of plant material for oviposition exist in established stands than in late summer or early fall seedings.

Stand establishment and stem density of alfalfa is affected by the interaction of several environmental factors, but the variability can be explained primarily as a function of planting date (Strand and Fribourg

1973). In Tennessee, best establishment occurred with sowing dates of April to early May and late July to early August (Fribourg and Strand 1973). Oklahoma research has shown fall seedings of alfalfa produce a greater stand density than spring plantings in the first year of production (El-Tomi 1982). In the same study highest forage yields were obtained from early fall and early spring plantings and lower yields came from late fall and late spring plantings. Although agronomically more productive than late fall seedings, spring and early fall plantings would present a better habitat for overwintering adults and encourage greater egg and larval populations.

The yield loss resulting from larval or adult weevil feeding depends on the growth stage of the plant when infested. Fewer weevils can be tolerated on young plants than on more mature plants without extensive defoliation (Koehler and Pimentel 1973). Though greater larval populations could be supported in taller alfalfa, a later planting date would have less fall growth and be less attractive to overwintering adults resulting in lower larval populations.

Due to the fact the alfalfa weevil affects the extent of loss in production of alfalfa is dependent upon the weevil population and the plant's developmental stage, it seems appropriate to consider effects of planting date upon larval population densities. By varying the sowing date for alfalfa, differences in attractiveness of plants at several stages of development may be observed. Fall planted alfalfa should be expected to have less fall growth than an established planting thus reducing the overwintering habitat of the weevil and suitable oviposition locations. One of the objectives of the integrated management program for the alfalfa weevil in Oklahoma is reduced insecticide usage. A fall planting date, which allows minimal plant growth for weevil oviposition during the fall and winter after establishment, may reduce weevil numbers.

CHAPTER III

STUDIES OF 1980 AND 1981

Methods and Materials

These studies were conducted on the Agronomy Research Station at Stillwater in 1980, and the South Central Research Station at Chickasha and Agronomy Research Station at Perkins in 1981. Although the experiments were conducted prior to my arrival, data analysis and interpretation have been included as part of my research project. The purpose of the 1980-1981 studies was to determine if planting data by cultivar interactions occurred which may relate to population increase of the alfalfa weevil in new stands. A determination was to be made whether conclusions derived on one cultivar of alfalfa could be applied to others.

Both planting sites were located within 0.5km of a roadside or wooded area where adequate summer aestivation areas existed for adult weevils. The Stillwater 1980-81 and Perkins 1981-82 studies were arranged in a split plot design with four replications. The main plots consisted of the fall seeding dates August 26, September 22, and October 20 in the Stillwater planting on a Port loam soil. Planting dates for the Perkins study were April 6, August 26, September 29, and October 21 on a Teller loam soil. Sowing dates were selected in fall because this time of year offers the greatest opportunity for successful stand establishment in Oklahoma (El-Tomi 1982). Subplots were alfalfa cultivars, 'Buffalo' (Hollowell 1945) and 'Riley' (Sorensen et al. 1978) in the

Stillwater study and 'Arc' (Devine et al. 1975), 'Buffalo', and 'Riley' in the Perkins study. For comparison purposes and not as part of the Stillwater analyses, samples were taken from a block of established alfalfa adjacent to the experimental area seeded September 21, 1979 to determine population levels with fall regrowth versus that in new seedings. Replicated April seedings in the Perkins study were utilized to provide data on egg and larval populations in established alfalfa as compared to the fall plantings and were included in the statistical analyses.

Following seedbed preparation in the summer months, the soil was tilled lightly with a roto-tiller and Tolban® herbicide was applied at a rate of 0.18kg AI/ha and incorporated at the time of planting. The seed was inoculated immediately before planting with Rhizobium meliloti and sown at 11g/5m (22kg/ha). Each cultivar was sown in 1 x 5m plots with a small plot 5-row planter. Plots were irrigated after planting to insure germination and emergence. Irrigation was continued through the study as necessary to maintain plant growth.

The weevil egg population was sampled on February 20, 1981 in the Stillwater study and on January 5 and February 22, 1982, in the Perkins study. These samples provided estimate of the numbers of fall laid eggs. Egg samples were obtained by removing all plant material at or slightly below ground surface from four 0.3 row-meter samples/plot. The samples were processed by the blender extraction method of Pass and VanMeter (1966).

Larvae were sampled in mid-March as feeding first became evident and in mid-April as numbers neared the economic threshold level of 1.5 to 2 larvae per stem. These samples gave estimates of larval numbers resulting from the hatch of fall versus spring laid eggs. Larvae were sampled by collecting a 25-stem sample from each plot and extracted with Berlese funnels for counting. They were separated into two groups for statistical analysis; small larvae consisting of the first two instars, and large larvae consisting of third and fourth instars. This was done as an additional attempt to determine possible differences in seasonal occurrence of larvae as influenced by planting date. The proportion of large larvae in samples would be greater in early samples particularly from those plots which had more fall laid eggs. A plant damage assessment was made as larval samples were taken using a 9 point rating scale where 1 is no damage and 9 is complete defoliation.

Ten plant stems were measured when the egg samples were taken to record the height of growth available for oviposition in fall and winter. Two types of growth were present in established stands and early fall plantings. Fall growth which was browned by frost and new growth from crowns which was typically present all winter as alfalfa was never completely dormant. Browned stems were measured in the plots and an adjacent established area (Stillwater only) with the egg samples as a measure of overwintering habitat for adults. Shoots growing from the crown in winter continue as spring growth. As egg hatch began, ten plant heights (green stems) per plot were taken with the first larval sample. Plant growth near peak larval density was measured with 10 more heights per plot at the time of the second larval sampling.

While the small plot experiments acted as free-choice tests with several alfalfa plantings in close proximity, it was not known whether similar results would be obtained with fall plantings in large areas. A large-plot study was conducted at Chickasha in 1981-82 to compare overwintering weevil egg and subsequent larval populations in fall planted alfalfa fields versus an established stand. The large plots were located within 0.5km of the Washita River with abundant habitat available for summer aestivation of weevil adults. The plots were ca. 1.5 ha in size. The established planting was a 3-year old stand of Arc alfalfa on a Pocasset silty clay loam soil on the South Central Research Station. Fields of cooperating producers were used for the mid-August planting 9cultivar = Arc) on a Dale-Reinach complex soil and the September (1981) planting (cultivar = 'Cody' (Hanson 1961)) on a Yahola fine sandy loam.

Eggs were sampled in each plot at 1 to 2 week intervals beginning January 19, 1982 and continuing until March 11. For each date, 20 random samples of foliage from $0.02m^2$ areas were taken in each plot. Larval populations were sampled three times at approximately 1 week intervals beginning March 2. On each date, foliage was clipped from five $0.1m^2$ areas randomly selected in each plot. Larvae were extracted in Berlese funnels and counted as previously described. Plant growth in spring was estimated from measurements of 10 stems/plot with each larval sample.

Analysis of variance were calculated for each sampling date and F-tests were conducted. Least Significant Difference Test at the 0.05 level of probability was utilized to separate the means of egg counts, larval counts and plant heights.

Results and Discussion

Stillwater, 1980 Planting

Fall growth measured February 20, 1981 was not statistically different by cultivar (Table I). No frost killed stems occurred in any

TABLE I

FALL AND SPRING GROWTH OF TWO ALFALFA CULTIVARS
AS AFFECTED BY DATE OF PLANTING,
STILLWATER, 1980-81

Planting Date	Cultivar	Plant Height (cm)		
		Fall Growth	Spring Growth	
		February 20	March 18	April 8
September 1979	Riley	25.4	19.8	45.6
August 26	Buffalo	19.6	23.6	47.8
	Riley	16.6	23.6	49.5
September 22	Buffalo	--	16.5	38.9
	Riley	--	15.7	38.6
October 20	Buffalo	--	11.2	23.1
	Riley	--	11.7	22.2
LSD[a]	Buffalo	--	4.8	6.2
	Riley	--	2.1	3.7
Interaction[b]		(P = 0.15)	(P = 0.81)	(P = 0.08)

[a] Least Significant Difference (P = 0.05) within a cultivar.

[b] Observed significance level of cultivar x planting date interaction.

of the September or October seedings because all growth was prostrate. More fall growth was present in the established seeding than in the August planting. However they probably offered similar habitat for overwintering adults.

The August seeding had significantly more spring growth than the other fall seedings as measured March 18 (Table I). The established stand had less spring growth than the August planting but more than the September plots. No cultivar differences in spring growth were observed for any planting date. Spring growth measured April 8 still showed the August seeding to have significantly more growth than the other fall seedings. The plant growth of the established stand was similar to the August plots, and they offered comparable spring growth for larval development. Cultivar x planting date interaction was not significant in measurements of fall or spring growth.

More eggs were collected in the established stand than any of the fall seedings. In the fall seedings, cultivars did not have significant effects on egg populations sampled February 20 (Table II). Greater overwintering habitat for adults was available in the established stand which apparently offered more oviposition locations as well. As in the grazing study of Senst and Berberet (1980), lowest egg populations were recovered from those areas with the least plant material for oviposition and overwintering. Dively (1970) recorded similar results with fall growth measuring 15 to 18cm as compared with stubble of 5 to 7cm. Egg numbers were not significantly influenced by the interaction of cultivar and planting date as a similar trend in egg populations existed in each cultivar across the fall seedings.

On March 18 the established stand had many more larvae than any of

TABLE II

INFLUENCE OF FALL PLANTING DATE AND TWO ALFALFA CULTIVARS ON POPULATION DENSITIES OF ALFALFA WEEVIL EGGS, STILLWATER, 1980-81

Planting Date	Eggs/0.02m^2	
	Buffalo	Riley
September 1979	-	70.3
August 26	43.2	20.2
September 22	9.0	10.5
October 20	0.0	0.0
LSD[a]	NS	18.5
Interaction[b]	(P = 0.19)	

[a] Least Significant Difference (P = 0.05) within a cultivar.

[b] Observed significance level of cultivar x planting date interaction.

the fall seedings (Table III). This was predicted from the higher egg numbers. The August and September plantings contained significantly more larvae than the October seeding in both cultivars.

The established stand contained 97.5 larvae/25 stems on April 8 compared with the August seeding numbers of 35.2 and 20.5 in Buffalo and Riley, respectively (Table IV). The established stand also had a higher damage rating than the fall plantings of either cultivar. The August seeding did not contain significantly more larvae than those of September and October in either cultivar. No significant differences were recorded for damage ratings in the August and September stands but both were higher than the October plots. This was consistent with the findings of Milliron and MacCreary (1955) in that older seedings had higher damage ratings due to larger larval populations. Larval populations continued to increase in the established stand with the number of small larvae still particularly high, whereas the August and September plantings had lower numbers than on March 18. Substantial egg hatch occurred in the established stand as indicated by the numbers of small larvae. However in the August and September plantings had lower numbers than on March 18. Substantial egg hatch occurred in the established stand as indicated by the numbers of small larvae. However in the August and September seedings, oviposition was lower in spring and reduced hatching led to the decrease in populations of small larvae. As in the egg samples, cultivar x planting date interaction was not significant in either larval sample. Within each cultivar larval populations responded similarly across each planting date.

In summary, the planting date of alfalfa had a significant influence on egg deposition and subsequent larval populations particularly in

TABLE III

EFFECT OF FALL PLANTING DATE AND ALFALFA CULTIVAR ON POPULATION DENSITIES OF ALFALFA WEEVIL LARVAE, STILLWATER, MARCH 18, 1981

Planting Date	Cultivar	Larvae/25 stems Small	Large	Total	Damage Rating
September 1979	Riley	39.0	40.0	79.0	3.7
August 26	Buffalo	22.7	23.0	45.7	2.5
	Riley	17.2	19.5	36.7	2.2
September 22	Buffalo	17.5	27.7	45.2	2.2
	Riley	12.0	14.7	26.7	2.2
October 20	Buffalo	7.7	3.0	10.7	1.5
	Riley	9.2	1.2	10.5	1.5
LSD[a]	Buffalo	13.2	15.9	24.8	0.8
	Riley	7.4	7.3	9.1	0.9
Interaction[b]		(P = 0.28)	(P = 0.22)	(P = 0.20)	

[a] Least Significant Difference (P = 0.05) within a cultivar.

[b] Observed significance level of cultivar x planting date interaction.

TABLE IV

EFFECT OF FALL PLANTING DATE AND ALFALFA CULTIVAR ON POPULATION DENSITIES OF ALFALFA WEEVIL LARVAE, STILLWATER, APRIL 8, 1981

Planting Date	Cultivar	Larvae/25 stems			Damage Rating
		Small	Large	Total	
September 1979	Riley	64.5	33.0	97.5	5.5
August 26	Buffalo	13.2	22.0	35.2	4.4
	Riley	11.2	9.2	20.5	3.7
September 22	Buffalo	8.7	10.7	19.5	4.0
	Riley	6.5	9.2	15.7	4.0
October 20	Buffalo	12.0	5.7	17.7	3.0
	Riley	9.2	8.0	17.2	3.0
LSD[a]	Buffalo				0.4
	Riley				0.1
Interaction[b]		(P = 0.99)	(P = 0.40)	(P = 0.65)	(P = 0.47)

[a] Least Significant Difference (P = 0.05) within a cultivar.

[b] Probability of cultivar x planting date interaction.

comparison of the late planting (October 20) with any other date. Large crowns, additional fall growth and plant debris from the previous growing season exhibited by established alfalfa produced the greatest response by the weevil in terms of egg and larval populations. More plant material was present as well in the early fall seedings as compared to the October date. Buffalo had consistently higher larval populations although differences between those populations and the numbers in Riley were usually not statistically significant. No significant effect was evident in larval population densities due to cultivar x planting date interaction.

Perkins, 1981 Planting

The April seeding had significantly more fall growth than the August plantings (Table V). Insufficient growth had occurred in the September and October seedings to have been killed by frost. Comparable overwintering habitat for adult weevils was present among cultivars for each planting date.

The April seeding contained significantly more spring growth than any of the fall plantings as measured March 26 (Table V). Fall plantings were significantly different with August sown plots being tallest and October plantings shortest. Significant cultivar differences were present in all but the August and October seedings with Buffalo being tallest in the April and September seedings and Arc had the most growth in the August plots. The interaction of cultivar x planting date was not significant. These taller cultivars offered more plant material for larval development than the other cultivars planted on the same date.

The spring seeding was significantly taller than the fall seedings

TABLE V

FALL AND SPRING GROWTH OF THREE ALFALFA CULTIVARS
AS AFFECTED BY DATE OF PLANTING,
PERKINS, 1981-82

Planting Date	Cultivar	Plant Height (cm) Fall Growth January 5	Spring Growth March 26	Spring Growth April 14
April 6	Arc	26.9	23.9	30.2
	Buffalo	30.2	25.9 (2.6)[a]	29.2 (3.2)
	Riley	26.7	21.6	26.7
August 26	Arc	14.2	14.2	20.6
	Buffalo	15.0	13.0 NS	17.5 (3.0)
	Riley	15.5	13.5	18.8
September 29	Arc	--	6.8	14.0
	Buffalo	--	8.4 (2.2)	15.7 (2.4)
	Riley	--	5.8	11.4
October 21	Arc	--	2.5	6.9
	Buffalo	--	2.5 NS	6.6
	Riley	--	2.5	5.6
LSD[b]	Arc	8.6	2.5	4.6
	Buffalo	3.4	3.7	2.9
	Riley	4.4	3.5	4.4
Interaction[c]		(P = 0.40)	(P = 0.07)	(P = 0.06)

[a] Numbers within parenthesis indicate Least Significant Difference (P = 0.05) within a planting date.

[b] Least Significant Difference (P = 0.05) within a cultivar.

[c] Observed significance level of cultivar x planting date interaction.

for all cultivars on April 14 (Table V). Contrary to the Stillwater, 1980 experiment, the April and August seedings did not have comparable plant height for larval development, Arc was significantly taller than Riley in the April and September plantings thus offering more plant material for larval development. Cultivar x planting date interaction was not significant in fall growth measurements. The interaction in spring growth was significant at P=0.06 and P=0.07.

The spring seeding contained significantly more eggs than the fall seedings as sampled January 5, 1982 (Table VI). The August seeding also contained significantly mroe eggs than the later seedings. No eggs were recovered from the October planting. No definite pattern appeared in egg numbers due to cultivars although it was noted that more eggs tended to be in Riley, which had no more fall growth than Buffalo or Arc.

As in January, significantly more eggs were collected from the April seeding than the fall seedings on February 22 (Table VI). In the January to February interval, numbers of eggs in Arc and Riley remained virtually unchanged in the April seedings. Those in Buffalo increased greatly but were not significantly higher than in Riley or Arc. Among fall seedings the August plantings of Arc and Riley had significantly more eggs than September or October plantings. Numbers in Buffalo were much lower for September and October dates as well, but were not significantly different from the August planting. Those plots with the greatest egg populations also contained the most fall growth for overwintering adults which agrees with the results of Dively (1970). Interaction of cultivar x planting date was not significant for either sampling date.

Significantly more larvae were present in the April seedings than the fall plantings in samples of March 26 (Table VII). More larvae were

TABLE VI

EFFECT OF FALL PLANTING DATE AND THREE ALFALFA CULTIVARS ON POPULATION DENSITIES OF ALFALFA WEEVIL EGGS, PERKINS, 1981-82

Planting Date	Eggs/0.02m² Arc	Buffalo	Riley	
	January 5			
April 6	71.6	77.4	91.0	
August 26	24.6	27.6	38.3	
September 29	1.1	0.7	0.4	
October 21	0.0	0.0	0.0	
LSD[b]	28.5	41.3	25.2	
Interaction[c]	(P = 0.52)			
	February 22			
April	68.4	107.2	89.3	NS
August	13.1	19.5	28.1	NS
September	0.4	9.1	2.0	(3.7)[a]
October	0.0	0.0	0.0	
LSD	11.3	56.0	18.3	
Interaction	(P = 0.07)			

[a] Least Significant Difference (P = 0.05) within a planting date.

[b] Least Significant Difference (P = 0.05) within a cultivar.

[c] Observed significance level of cultivar x planting date interaction.

TABLE VII

EFFECT OF FALL PLANTING DATE AND ALFALFA CULTIVAR
ON POPULATION DENSITIES OF ALFALFA WEEVIL
LARVAE, PERKINS, MARCH 26, 1982

Planting Date	Cultivar	Larvae/25 stems			Damage Rating
		Small	Large	Total	
April 6	Arc	47.0	8.7	55.7	3.0
	Buffalo	53.7 NS	7.5 NS	61.2 NS	2.7 NS
	Riley	48.7	12.5	61.2	2.7
August 26	Arc	17.0	1.0	18.0	2.0
	Buffalo	32.3 (14.4)[a]	2.3 NS	34.7 (16.1)	2.3 NS
	Riley	34.7	3.0	37.7	2.2
September 29	Arc	6.2	1.0	7.2	1.7
	Buffalo	9.2 NS	0.5 NS	0.7 NS	2.0 (0.5)
	Riley	3.7	0.3	4.0	1.0
October 21	Arc	3.7	0.0	3.7	1.7
	Buffalo	4.7 NS	0.5 NS	5.2 (3.4)	1.7 NS
	Riley	1.7	0.0	1.7	1.5
LSD[b]	Arc	12.1	3.4	15.3	
	Buffalo	17.6	6.7	22.9	0.7
	Riley	19.6	4.6	22.2	0.8
Interaction[c]		(P = 0.32)	(P = 0.14)	(P = 0.38)	(P = 0.22)

[a] Numbers within parenthesis indicate Least Significant Difference (P = 0.05) within a planting date.

[b] Least Significant Difference (P = 0.05) within a cultivar.

[c] Observed significance level of cultivar x planting date interaction.

also recovered from the August plots than either the September or October seedings of Buffalo and Riley. The only significantly lower larval numbers attributable to the cultivars occurred in the Arc plots of the August seeding. Due to the fact that greater egg populations occurred in the older seedings, which had more fall growth, it was expected that the largest larval populations would also occur in these seedings. Although all damage ratings were low, significantly higher values were recorded in April vs. September or October plantings. Particularly in the late fall plantings, larval populations had just begun to appear.

The larval sample taken April 14 showed that the April and August plantings contained significatnly higher totals than the September or October plantings in all cultivars (Table VIII). The April seeding also contained more small larvae than any of the fall plantings. Significantly greater damage ratings occurred in the April and August seedings than in the September and October plantings. Larger numbers of larvae which occurred in the older plantings more quickly defoliated the alfalfa than the smaller populations in the younger seedings. The older seedings had more third and fourth instar larvae in mid-April indicating more fall laid eggs. Burbutis et al. (1967) had also found that most damage was in the older plantings. Significant differences in damage rating did occur due to cultivar but were not consistent between planting dates as the highest damage rating was recorded for Riley in the April planting and for Buffalo in the August date. Cultivar x planting date interaction was not a significant factor influencing larval populations in the March 26 larval sample. However, the April seeding affected interaction in the April 14 samples interaction was not significant when only the fall

TABLE VIII

EFFECT OF FALL PLANTING DATE AND ALFALFA CULTIVAR ON POPULATION DENSITIES OF ALFALFA WEEVIL LARVAE, PERKINS, APRIL 14, 1982

Planting Date	Cultivar	Larvae/25 stems Small	Large	Total	Damage Rating
April 6	Arc	64.2	18.7	83.0	5.5
	Buffalo	88.2 (21.2)[a]	30.5 (9.2)	118.7 (28.4)	6.5 (1.0)
	Riley	89.5	42.5	132.0	7.0
August 26	Arc	7.2	28.7	36.0	4.0
	Buffalo	4.0 (5.4)	27.0 NS	31.0 NS	5.5 (1.0)
	Riley	11.5	39.0	50.5	4.7
September 29	Arc	2.5	6.2	8.7	2.5
	Buffalo	2.7 NS	6.2 NS	9.0 NS	3.0 NS
	Riley	3.0	2.7	5.7	2.5
October 21	Arc	0.3	1.7	2.0	2.0
	Buffalo	0.0 NS	3.0 NS	3.0 NS	2.5 NS
	Riley	0.0	2.0	2.0	2.2
LSD[b]	Arc	17.6	12.9	26.4	1.1
	Buffalo	7.0	10.6	7.2	0.9
	Riley	2.9	10.0	9.6	0.9
Interaction[c]		(P = 0.05)	(P = 0.07)	(P = 0.01)	(P = 0.33)
without April		(P = 0.26)	(P = 0.57)	(P = 0.40)	

[a] Numbers within parenthesis indicate Least Significant Difference (P = 0.05) within a planting date.

[b] Least Significant Difference (P = 0.05) within a cultivar.

[c] Observed significance level of cultivar x planting date interaction.

seedings were considered. Similarity of habitats in April and August plantings apparently resulted in some inconsistency in trends for larval populations among cultivars.

In summary, the older plantings contained the most fall growth for overwintering adults and possessed the greatest egg and subsequent larval populations. No particular pattern of preference existed in weevil populations among cultivars although occassional significant differences did occur. Greater weevil damage ratings were recorded from those plots with the larger larval populations. These results agree with Dively (1970) and Senst and Berberet (1980) who reported the determining factor for weevil populations appeared to be the amount of overwintering habitat available to the adult weevil. Though significant cultivar x planting date interaction did exist in the second larval sample when the April planting was analyzed with the fall seedings, this did not occur when the April planting was not included. The April and August plantings were similar enough to cause this interaction.

Chickasha, 1981 Field Study

In the large plot study at Chickasha in 1981-82, fall growth in the established stand of alfalfa was estimated to be 30 to 40 cm in height while fall stem height of the August planting was 10 to 15 cm. The September planted field had insufficient fall growth to be browned by frost, however, growth in early December was 3 to 5 cm in height.

In the three egg samples taken on January 19, February 7, and February 18, the established stand contained significantly more eggs than the fall seedings (Table IX). Also, the August seeding contained significantly more eggs than the September planting. More plant

TABLE IX

EFFECT OF FALL PLANTING DATE ON POPULATION DENSITIES OF ALFALFA WEEVIL EGGS IN LARGE PLOTS, CHICKASHA, 1981-82

Planting Date	Eggs/0.02m^2					
	1/19	2/7	2/18	2/23	3/2	3/11
August (1978)	210.0	289.8	253.2	106.6	60.1	78.5
August	99.3	146.5	154.2	109.1	17.0	63.0
September	30.6	22.1	19.4	34.2	5.5	7.9
LSD[a]	29.0	34.3	27.6	19.4	7.3	12.4

[a] Means separation was accomplished using Least Significant Difference Test ($P \leq 0.05$).

material was present in the older seedings which offered more over-wintering habitat for adults and more sites for oviposition. On February 23, no significant differences in egg populations appeared between the established stand and the August seeding but both contained significantly more than the September planting. The egg population of $34.2/0.02m^2$ on this date was the peak population for the September planting. Egg counts in the August planting and established plots peaked one and two weeks earlier, respectively. Fall egg lay was much greater in these plots than in the September planting. Counts made on March 2 and 11 indicated extensive hatching in all plots as numbers were much lower than in previous samples. The reason for the low count for the August planting on March 2 is not known. Apparently due to spring oviposition, numbers for this planting and the others were higher on March 11.

In the first larval samples, March 2, no significant differences existed in population levels between the established stand and the August seeding (Table X). The September sown field contained significantly fewer larvae. No large larvae were collected from either fall seeding and the established field had only 1.6 large larvae/$0.1m^2$.

The second larval sample on March 11 showed no significant difference between total larval populations among plots (Table X). Large larvae numbered $25.4/0.1m^2$ in the established stand which was significantly greater than the populations of this category in the August or September plantings. The established stand had significantly more fall laid eggs than the other seedings and, as expected, it contained more large larvae at this early date in the growing season.

TABLE X

EFFECT OF FALL PLANTING DATE ON POPULATION DENSITIES OF ALFALFA WEEVIL LARVAE IN LARGE PLOTS, CHICKASHA, 1981-82

Planting Date	Larvae/0.1m^2		
	Small	Large	Total
		March 2	
August (1978)	91.2	1.6	92.8
August	104.3	0.0	104.3
September	48.9	0.0	48.9
LSD[a]	33.6	1.1	33.6
		March 11	
August (1978)	251.3	25.4	276.7
August	252.4	2.4	254.8
September	145.4	1.5	146.9
LSD	130.2	9.0	132.3
		March 18	
August (1978)	396.0	136.5	532.5
August	375.7	108.8	484.5
September	182.1	38.8	220.9
LSD	91.7	38.6	117.7

[a] Means separation was accomplished using Least Significant Difference Test ($P \leq 0.05$).

The third larval sample was obtained on March 18 and as had been the case of March 2, the September seeding contained significantly fewer larvae than the older stands (Table X). The number of large larvae increased faster than small larvae in the established stand and August planting. Total numbers of larvae were at levels by this date which threatened to cause serious damage to the alfalfa. Even the September stand had a population in excess of $200/0.1m^2$ (Table X). Following this sample, recommendation was made that plots be sprayed.

As compared to the "free choice" studies conducted at Stillwater and Perkins, it appears that alfalfa weevil ovipostion and resulting larval population growth responded similarly in small plots and large acreages. Later fall seeding resulted in lower numbers of eggs and larvae, and larger larval populations occurred in the older seedings because of fall laid eggs in these stands. Lower weevil populations in younger seedings would result in less feeding damage and yield reduction as were also the findings of Milliron and MacCreary (1955).

Summary

Late fall seeding greatly reduced alfalfa weevil egg deposition and resulting larval populations compared to established stands. Established stands contained more larvae than the new seedings and were subjected to greater feeding damage leading to the potential for serious yield reductions.

Though occasional significant differences in weevil populations did result in the cultivars utilized in these studies, no preference for any single cultivar over others was apparent. Cultivar x planting date interaction did occur in one instance when the April planting was compared to the fall dates. When the April planting was excluded from analysis, no interaction was evident even in this instance. Riley was selected as a representative cultivar for additional studies and was utilized in 1982 and 1983 because it possesses resistance to the Spotted Alfalfa Aphid, Therioaphis maculata (Buckton), and the Pea Aphid, Acyrthosiphon pisum (Harris). This resistance has value for these studies because of the prospect of reducing the need for chemical sprays to control aphids should infestations occur (Sorensen et al. 1978).

The small plots did not appear to be a factor which affected the preference of overwintering locations for weevil adults as the same egg and larval population patterns occurred in large acreages as well. The determining factor for weevil populations appeared to be the amount of overwintering habitat for the adult regardless of plot size or alfalfa cultivar.

CHAPTER IV

STUDIES OF 1982 AND 1983

Methods and Materials

These studies were conducted at three Oklahoma locations; the South Central Research Station at Chickasha, the Agronomy Research Station near Perkins, and the Agronomy Research Station at Stillwater in 1982-83 and at the Stillwater location only in 1983-84. At each location, a randomized complete block design was used with six replications of planting dates in April, August, September, and October. At the Stillwater (Port loam soil) and Perkins (Teller loam soil) locations in 1982, plantings were made on April 1, August 20, September 21, and October 14. Planting dates at Chickasha in 1982 were April 5, August 24, September 23, and October 12 on a Dale silt loam soil. Dates for the Stillwater 1983 seedings were August 19, September 9, and October 3. The April plots used for 1983 were the same April plantings used the previous year. Each plot, representing a planting date, measured 2 by 5m. One half of the plot was used for forage yield determinations and stand density measurements, while the other half was for the destructive measurements necessary to count egg and larval populations. The alfalfa cultivar was Riley.

The planting procedure was accomplished as described in Chapter III. To determine stand density, five samples of plants/0.3 row-meter were counted in each plot about 2 weeks after planting and stems/0.3 row-meter at first harvest to measure stand establishment and habitat available for the alfalfa weevil.

Egg counts were taken in January to estimate the extent of fall oviposition and again in late February or early March as larval hatch began to estimate peak egg population density and potential larval numbers from overwintered eggs. The increase in egg numbers from the first to second sample was considered to result from oviposition in winter. Egg viability was tested from samples in February or March to determine the extent of hatching expected and to measure differences in survival related to planting date. Three samples of 100 eggs from each planting date/location were incubated at 22-25°C for 10 days. For the 1983 planting at Stillwater, egg viability was determined for the egg samples in January (1984) as well as in March to determine more fully the effects of an unusually cold December.

Heights of 10 stems/plot were measured when the first egg samples were taken to determine fall growth and the overwintering habitat for weevils. Fall growth consisted of erect stems of alfalfa that had been killed by freezing temperatures in December. Heights of 10 stems/plot were taken with the second egg sample to determine the amount of spring growth. Some green growth was present in alfalfa throughout the winter in Oklahoma which was measured as spring growth with the second egg sample.

Larvae were sampled as damage first became evident in order to detect possible differences in numbers resulting from the hatch of fall laid eggs and again when the population neared the economic threshold to determine if differences existed which would influence treatment decisions and ultimately, the extent of damage to the alfalfa. A 25-stem sample was pulled from each plot on each date for extraction of larvae and a nine point damage rating scale was used for each sample as previously described. Ten stems were measured per plot with each larval sample to determine plant material present for larval development.

Each planting date was harvested throughout the summer at approximately 10% bloom with a Carter® harvester. Green forage was weighed and percent dry matter were determined to calculate dry forage yields. The purpose of measuring forage yield was to determine if the value of forage production which may be lost due to late fall planting would be offset by the savings from reduced weevil feeding and less chemical control cost. All data were analyzed utilizing F-tests and Least Significant Difference Tests at the 0.05 level of probability.

Results

Stillwater, 1982 Planting

Data from the October seeding date of 1982 were not included in statistical analyses because the stand density in winter and early spring was exceedingly poor (Table XI). The data for the October seedings are included in tables so that comparisons with the other planting dates can be made. The stand densities of the fall plantings measured 2 weeks after seeding were not significantly different. However, as indicated at the time of first harvest, the October planting contained far fewer stems/0.3 row-meter than the other dates. Insufficient establishment time was allowed for the October planting prior to the onset of winter weather to allow for adequate plant growth in the spring.

Fall growth of alfalfa which was killed by frost was measured on January 5, 1983 (Table XI). The plant heights of the spring seeded

TABLE XI

STAND DENSITY AND FALL AND SPRING GROWTH OF ALFALFA AS AFFECTED BY DATE OF SOWING, STILLWATER, 1982-83

Planting Date	Stems/0.3 row-meter		Plant Height (cm)		
	After Planting	First Harvest	Fall Growth 1/5	Spring Growth 3/2	Spring Growth 4.27
April	--	45.8	29.2	9.7	45.3
August	18.8	41.7	26.0	10.1	46.5
September	21.3	42.8	--	7.9	39.4
October	19.6	23.6	--	3.0	8.6
LSD	NS	6.2	2.2	0.8	3.7

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

plots, last harvested September 25, were significantly greater than the August seeding. These plots had much more plant material than the September and October plantings and offered a better habitat for overwintering adults. No growth was killed by frost in the September or October seedings.

The August planting had spring growth equivalent to the April stand and both were significantly taller than the September seeding on March 2 (Table XI). Spring growth in the October stand measured less than one half that of the September plots. In measurements taken on April 27 as larval feeding became evident, the spring growth in the April and August seedings did not differ significantly but both were taller than the September seeding (Table XI). The October planting had average spring growth of only 8.6cm.

In the first egg samples (January 5), the April seeding contained significantly more eggs than any of the fall seedings (Table XII). Virtually no eggs were present in the October plantings. Stem growth afforded abundant oviposition sites in the April and August seedings for egg laying.

Significantly more eggs were collected from the April planting than from the fall seedings at the second egg sample taken March 2 (Table XII). By comparison, the numbers of eggs were much higher in March than in January, as well. As little opportunity for spring growth had occurred by this sampling date, these eggs would have been oviposited primarily in the fall growth through the winter. It is likely that the September plots contained significantly fewer eggs than the August seeding at this time because there was limited fall growth in these plots

TABLE XII

POPULATION DENSITIES OF ALFALFA WEEVIL EGGS AS AFFECTED BY THE SOWING DATE OF ALFALFA, STILLWATER, 1982-83

Planting Date	Eggs/0.3 row-meter		% Viability
	January 5	March 2	
April	9.2	62.2	85.1*
August	3.4	41.4	88.7
September	1.4	21.2	88.1
October	0.1	0.0	--
LSD	5.7	19.4	NS

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

* Percent viability of eggs on March 2.

for oviposition. No eggs were recovered from the October plots. Egg viability was similar for all planting dates from which eggs were collected.

About equal proportions of small and large larvae were obtained from the larval sample of April 27 (Table XIII). The larger larvae came from the first viable eggs laid in the fall of 1982 which had survived the winter. Small larvae were likely from those eggs laid after January 1. Significantly more larvae, both small and large, were obtained from the April as compared to fall plantings.

The second larval sample was not taken because of an infestation by the so-called Blue Alfalfa Aphid, Acyrthosiphon kondoi Shinji. All plantings were treated with malathion (0.8kg AI/ha) which, in addition to controlling aphids also greatly reduced the weevil population. The April and August seedings were highly productive in the first and second harvests (Table XIV). The September planting gave significantly lower production at first harvest. Although the production was not significantly less at second harvest, the September planting measured over 2000kg/ha less than either the April or August seedings. Production was lower at second harvest than first for all plantings even though plant heights were greater. This was possibly due to lower stand density in the second harvest as compared to the first. It is not possible to make a definite conclusion because stand density was not counted prior to the second harvest. The first harvest of the October seeding was taken with the second harvest of the other plantings because of insufficient growth for an earlier harvest. The October planting yielded just 3562kg/ha for this harvest.

Based on the larval density prior to spraying, potential losses due

TABLE XIII

EFFECT OF FALL PLANTING DATE OF ALFALFA ON POPULATION DENSITIES OF WEEVIL LARVAE, STILLWATER, 1982-83*

Planting Date	Larvae/25 stems			Damage Rating
	Small	Large	Total	
April	33.2	23.0	56.2	2.0
August	12.2	9.5	21.7	2.0
September	4.2	6.2	10.3	2.0
October	4.0	1.5	5.5	1.7
LSD	9.4	5.5	12.9	NS

Within a column,means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

* Sample date = April 27, 1983.

TABLE XIV

INFLUENCE OF FALL PLANTING DATE AND THE ALFALFA WEEVIL UPON FIRST AND SECOND HARVEST YIELDS OF ALFALFA, STILLWATER, 1982-83

Planting Date	May 6 Yield (kg/ha	May 6 Plant Height (cm)	June 13 Yield (kg/ha)	June 13 Plant Height (cm)
April	8054	57.4	6557	78.3
August	7538	55.5	6664	79.7
September	5990	57.5	4463	73.8
October	--	--	3562	78.1
LSD	1471	NS	2577	4.2

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

to feeding damage in the April seeding would have been about 414kg/ha as compared to 169kg/ha in the August seeding, based on an average loss of 188kg/ha for each increase of 1 larva/stem in infestation level (Berberet et al. 1981). The October seeding was fairly tall when larval infestation occurred so the production losses would be less than that predicted by Berberet et al. (1981). Potential loss without chemical control in the September planting was estimated to be just 75kg/ha. This planting would not be a viable alternative to minimize larval populations due to greater productivity of the April and August plantings which yielded 4158 and 3749kg/ha, respectively. The October planting could not be considered an appropriate seeding time due to poor stand establishment and growth. The April planting produced only 409kg/ha more than the August seeding in the first two harvests.

Perkins, 1982 Planting

No significant differences were detected in stand densities of the fall plantings measured 2 weeks after seeding (Table XV). By first harvest, the April and August seedings contained significantly more stems/0.3 row-meter than the September seeding. The October seeding had just 14.9 stems/0.3 row-meter and as in the Stillwater 1982 study, was not included in statistical analyses. Insufficient time for plant establishment had passed to allow winter survival of many plants or adequate branching in spring. Fall growth measured January 5, 1983 in the April and August seedings was not significantly different. The April planting was last harvested September 25. No growth was killed by frost in the September or October seedings.

No significant differences were observed in the spring growth of the

TABLE XV

STAND DENSITY AND FALL AND SPRING GROWTH OF ALFALFA AS AFFECTED BY DATE OF SOWING, PERKINS, 1982-83

Planting Date	Stems/0.3 row-meter		Plant Height (cm)			
	After Planting	First Harvest	Fall Growth 1/5	Spring Growth 2/25	4/18	5/6
April	--	45.7	25.9	6.7	26.4	40.6
August	16.1	44.6	22.5	6.8	22.1	38.1
September	17.1	36.8	--	4.2	12.9	24.1
October	14.6	14.9	--	1.6	3.6	11.1
LSD	NS	6.9	NS	1.2	2.3	6.6

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

April and August seedings measured February 25 (Table XV). Less plant material was available for oviposition in the September plots because spring growth was significantly less than that of the older seedings. The October planting averaged just 1.6cm of spring growth.

Plant heights taken on April 18 as larval feeding became evident showed the April seeding had significantly more growth than the August seeding and both of these dates had considerably more growth than the September or October plantings (Table XV). This situation remained unchanged when spring growth was measured at peak larval populations in early May.

Significantly more fall laid eggs were recovered from the spring seeded plots than any of the fall plantings as measured on January 5 (Table XVI). The lack of suitable habitat for adult weevils was indicated by the observation that no eggs were collected from either the September or October seedings.

The same trends were shown in egg samples taken February 25, with fall seedings having significantly fewer eggs than the April planting (Table XVI). No eggs were collected from the September and October plantings which had little fall or spring growth for the adult weevil. The eggs recovered from the August seeding were significantly lower in viability than those from the April planting. This may be because a more suitable micro-environment existed about the plant crowns in the April seeding which offered greater protection from lethal temperatures. Dively (1970) reported similar findings in comparing stubble alfalfa to new growth.

As expected from the overwintering egg counts, significantly more larvae were collected on April 18 from the spring planting than from

TABLE XVI

POPULATION DENSITIES OF ALFALFA WEEVIL EGGS AS AFFECTED BY THE SOWING DATE OF ALFALFA, PERKINS, 1982-83

Planting Date	Eggs/0.3 row-meter		%
	January 5	February 25	Viability
April	11.2	37.0	75.7*
August	1.9	9.5	60.4
September	0.0	0.0	--
October	0.0	0.0	--
LSD	3.5	14.7	1.1

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

* Percent viable eggs on February 25, 1983.

those of the fall (Table XVII). As had been the case in previous experiments, the April and August seeded plots were expected to contain the greatest larval populations because they also possessed the most fall growth for overwintering adults. Though eggs were not recovered from September and October plantings, the low numbers of larvae collected in April indicated that a few eggs had been present or that some were laid in spring. Low readings for the damage ratings in all seedings were evidence of the minimal amounts of weevil feeding by this time (Table XVII).

Samples obtained as the larval population approached its peak (May 6) contained proportionately more large larvae than small in all planting dates and defoliation was more serious as indicated in the damage ratings (Table XVII). As in the previous sample, the April planting contained significantly more larvae than the fall seedings and both the April and August dates had several times more larvae than the September or October plantings.

The April seeding had the greatest amount of growth and forage production at first harvest (Table XVIII). Yields were significantly reduced with each delay in fall planting date. As in the Stillwater, 1982 experiment, the October plantings were not cut at the time of the first harvest due to insufficient growth (Table XVIII). Yield of the April seeding at second harvest was highest, also, with decreasing yields through the fall seedings. The lower production at second harvest resulted despite greater plant heights than occurred at first harvest. Even though reduced weevil populations occurred in the September and October seedings, the reduced forage production of these plantings as compared with the August planting did not justify using them to

TABLE XVII

EFFECT OF FALL PLANTING DATE OF ALFALFA ON POPULATION DENSITIES OF WEEVIL LARVAE, PERKINS, 1982-83

Planting Date	Larvae/25 stems			Damage Rating
	Small	Large	Total	
		April 18		
April	25.7	15.3	41.0	2.2
August	7.3	8.5	15.8	2.0
September	2.8	0.8	3.7	1.7
October	1.5	0.5	2.0	1.3
LSD	8.0	6.2	11.1	NS
		May 6		
April	36.8	83.7	120.5	4.5
August	15.2	55.0	70.2	3.7
September	4.5	10.5	15.0	2.2
October	4.0	6.8	10.8	2.3
LSD	12.0	19.1	27.6	0.6

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

TABLE XVIII

INFLUENCE OF FALL PLANTING DATE AND ALFALFA WEEVIL INFESTATION UPON FIRST AND SECOND HARVEST YIELDS OF ALFALFA, PERKINS, 1982-83

Planting Date	May 7 Yield (kg/ha)	May 7 Plant Height (cm)	June 13 Yield (kg/ha)	June 13 Plant Height (cm)
April	6869	40.6	5677	70.5
August	4905	38.1	4256	68.2
September	2404	24.1	2838	53.8
October	--	--	1400	47.5
LSD	1022	6.6	744	5.4

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

manipulate weevil populations. As determined by Berberet et al. (1981), potential loss in production based on the larval populations of the second larval sample was estimated to be 902.4kg/ha in the April planting and 526.4kg/ha in the August planting. September and October plantings had potentially reduced production of 113 and 81kg/ha, respectively. Though greater production loss was estimated to have occurred in the August seeding, 3919kg/ha more forage was produced than in the September planting. This far outweighed any higher loss which would result from weevil feeding.

Chickasha, 1982 Planting

Stand densities measured 2 weeks after seeding were similar in all of the fall seedings (Table XIX). In contrast to the Perkins experiment where stand density was lower in the September seeding, readings taken at first harvest showed no significant differences in stand densities of the April, August, and September plantings. Due to very low plant populations in the October seeding, data for this date were not included in statistical analyses. While the other three plantings averaged between 48.0 and 50.3 stems/0.3 row-meter at first harvest, the October plots averaged only 21.5 stems/0.3 row-meter. As in the previously described studies, stand establishment was poor in the October seeding because the plants had insufficient growth for winter survival and adequate branching from the crown in spring.

The April planting, which was last harvested September 25, had significantly more fall growth than the fall seedings as measured January 8, 1983 (Table XIX). No frost killed stems were present in the September or October seedings. In spring growth measured March 8, no

TABLE XIX

STAND DENSITY AND FALL AND SPRING GROWTH OF ALFALFA AS AFFECTED BY DATE OF SOWING, CHICKASHA, 1982-83

Planting Date	Stems/0.3 row-meter		Plant Height (cm)			
	After Planting	First Harvest	Fall Growth 1/8	Spring Growth 3/8	4/18	5/2
April	--	48.7	30.5	15.0	35.5	55.0
August	20.8	48.0	21.6	14.4	34.6	54.6
September	18.7	50.3	--	10.4	29.4	54.8
October	19.5	21.5	--	3.7	12.8	25.8
LSD	NS	6.9	3.6	1.2	2.9	NS

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

significant difference was detected between the April and August seedings. Much less plant growth was evident in the September and October plantings.

Spring growth measured April 18 as larval feeding became evident still showed no significant differences between the April and August seedings (Table XIX). No significant differences in spring growth were detected between any of the plantings by May 2. Comparable habitat was present in each seeding for larval development.

Significantly more fall laid eggs were collected in the April seeding than any of the fall plantings as sampled January 8 (Table XX). No significant difference in egg numbers was observed between the August and September seedings. No eggs were recovered from the October planting.

Greatly increased egg numbers in April and August plantings on March 8 were indicative that most oviposition occurred in January and February (Table XX). No eggs were found in the October seeded plots. Egg viability was not significantly different between any of the seedings.

As larval feeding became evident, the April planting had significantly more small and large larvae than any of the fall seedings. Significantly more larvae were recovered from the August seeding than the September seeding. The October plots contained only 3.7 larvae/25 stems which must have hatched from eggs laid in March. No significant differences in damage ratings were detected between the April and August seedings but both had significantly more damage than the September seeding (Table XXI).

In larval samples taken on May 2 as the larval population approached

TABLE XX

POPULATION DENSITIES OF WEEVIL EGGS AS AFFECTED BY THE SOWING DATE OF ALFALFA, CHICKASHA, 1982-83

Planting Date	Eggs/0.3 row-meter January 8	Eggs/0.3 row-meter March 8	% Viability
April	12.6	107.2	76.2*
August	5.5	53.1	71.3
September	1.2	4.0	87.7
October	0.0	0.0	--
LSD	4.4	38.9	NS

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

* Percent viability of eggs on March 8, 1983.

TABLE XXI

EFFECT OF FALL PLANTING DATE OF ALFALFA ON POPULATION DENSITIES OF WEEVIL LARVAE, CHICKASHA, 1982-83

Planting Date	Larvae/25 stems			Damage Rating
	Small	Large	Total	
	April 18			
April	43.8	19.7	63.5	3.0
August	25.7	12.0	37.7	2.8
September	5.8	2.0	7.8	2.0
October	2.7	1.0	3.7	1.7
LSD	11.4	5.7	14.7	0.6
	May 2			
April	28.3	56.2	84.5	4.3
August	14.2	45.0	59.2	4.2
September	8.7	18.2	26.8	2.5
October	0.5	3.2	3.7	2.0
LSD	10.0	13.0	19.6	0.8

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

its seasonal peak, proportionately more large larvae than small were recovered in all planting dates (Table XXI). In comparison to plantings with mostly small larvae, more rapid defoliation occurred in seedings with greater numbers of large larvae. As in the first larval sample, the April planting contained significantly more larvae than the fall seedings. No significant difference was recorded between the damage ratings of the April and August seedings but both were significantly higher than the damage rating for the September planting.

No significant differences in yield at first or second harvest were detected between the April and August plantings (Table XXII). In both harvests, the September planting averaged significantly less than the older stands. The October seeding was not harvested until the second cutting when sufficient growth had occurred to make harvesting profitable. When the October planting was first harvested, forage production was about the same as the production from the second harvest of the September seeding. The October 12 planting date was not considered a viable method to manipulate weevil populations because of the poor stand establishment. The lower production of second harvest as compared to first harvest was again accompanied by greater plant heights as occurred in the previous experiments and was probably due to lower stand density at second harvest.

While potential yield loss for the April seeding was 639.2kg/ha, the August planting was potentially reduced 451.2kg/ha based on 188kg/ha reduction for each larva/stem (Berberet et al. 1980). The production from the first 2 harvests of the August planting was 244kg/ha greater than the April seeding. The September seeding yielded 2286kg/ha less than the August seeding in the first 2 harvests which would make it a

TABLE XXII

INFLUENCE OF FALL PLANTING DATE AND THE ALFALFA WEEVIL UPON FIRST AND SECOND HARVEST YIELDS OF ALFALFA, CHICKASHA, 1982-83

Planting Date	May 4		June 16	
	Yield (kg/ha)	Plant Height (cm)	Yield (kg/ha)	Plant Height (cm)
April	5779	55.0	5109	72.7
August	6081	54.6	5051	72.3
September	4579	54.8	4267	65.0
October	--	--	4359	71.9
LSD	640	NS	645	2.3

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

questionable choice to assist in controlling larval numbers as any benefit would be outweighed by the cost of reduced production. The August planting was clearly the best fall planting date because of the greater forage yield even though more weevil larvae occurred in these plantings than the later fall seedings.

Stillwater, 1983 Planting

Stand densities measured 2 weeks after planting showed the August seeding to have significantly more plants/0.3 row-meter than the other fall seedings (Table XXIII). The October seeding also contained significantly more plants/0.3 row-meter than the September plots. Fall weather conditions of 1983 were more conducive to stand establishment than fall, 1982 which allowed the October seeding better development than what had occurred in the 1982 plantings. By first harvest, comparable stand densities occurred in all plantings therefore statistical analyses contained all seedings.

Fall growth which was killed by frost was measured January 4, 1984 (Table XXIII). Fall growth of the April (last harvested September 21) and August plantings was not significantly different as was also the case in the August and September seedings. Greater fall growth occurred in this September seeding than in the previous experiments due to warmer fall weather than 1982. The October seeding had insufficient growth to be killed by frost.

Plant heights of spring growth in the April and August seedings were equivalent when sampled March 16 (Table XXIII). By April 1, when larval feeding first became evident, plant heights in the April and August seedings were still similar. With less plant growth present in the

TABLE XXIII

STAND DENSITY AND FALL AND SPRING GROWTH OF ALFALFA AS AFFECTED BY DATE OF SOWING, STILLWATER, 1983-84

Planting Date	Stems/0.3 row-meter		Plant Height (cm)			
	After Planting	First Harvest	Fall Growth	Spring Growth		
			1/4	3/16	4/1	4/25
April	--	19.3	33.8	7.8	16.1	41.0
August	24.7	20.5	29.6	8.2	16.9	40.8
September	13.2	18.7	21.8	6.2	14.7	37.7
October	19.6	18.1	--	3.0	8.6	27.8
LSD	3.5	NS	10.4	1.1	1.2	4.4

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

younger seedings, these plots would not be as capable of withstanding larger larval populations as would the older seedings. Spring growth measured as peak larval populations were reached was not significantly different in the April, August, and September seedings but was significantly less in the October plots.

The April and August seedings did not significantly differ in egg populations measured on January 4 but contained significantly more than the September and October plantings. Greater egg numbers in the older stands were apparently due to more overwintering habitat and oviposition sites for adults. Due to the unseasonably cold weather of December, egg viability was tested in the April and August seedings and found not significantly different. Both dates contained eggs in which one half or less were viable. December, 1983 and January, 1984 were much colder with temperatures below -22^{o}C occurring that had not been recorded the previous year.

The egg samples taken March 16, 1984 showed that the fall seedings contained significantly fewer eggs than the April planting. The August seeding contained significantly more eggs than the later seedings (Table XXIV). Fall and spring growth were comparable in the older seedings and were somewhat greater than in the younger stands so it was expected that the older stands would contain the greatest number of eggs. Significantly lower viability was recorded in the April seeding than in fall seedings. Among fall seedings, the highest viability occurred in the October planting. This was expected as what few eggs found in the plots seeded in October were probably laid after cold weather ceased. Due to the fact that the greatest fall oviposition had occurred prior to

TABLE XXIV

POPULATION DENSITIES OF ALFALFA WEEVIL EGGS AS AFFECTED BY THE SOWING DATE OF ALFALFA, STILLWATER, 1983-84

Planting Date	January 4 Eggs/0.3 row-meter	January 4 Percent Viable	March 16 Eggs/0.3 row-meter	March 16 Percent Viable
April	19.9	37.0	125.4	70.2
August	14.7	51.1	74.3	83.8
September	6.0	--	33.2	80.1
October	0.1	--	1.6	94.6
LSD	9.2	45.9	37.0	2.5

Alfalfa weevil eggs counted per 0.3 row-meter sample. Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

adverse weather conditions in the April seedings, a greater proportion of eggs were rendered inviable by lethal temperatures in these plots.

The total number of larvae in the April and August seedings did not significantly differ in the larval samples taken April 1 (Table XXV). Both seedings contained significantly more larvae than the September and October plantings. All damage ratings were low, however only the October planting was significantly lower than the April seeding. Due to the fact that the most eggs were collected from the older seedings, it was expected that these stands would also have the greatest larval populations.

In the larval sample taken April 25, significantly more larvae were collected from the April seeding than any of the fall dates (Table XXV). The August plantings also contained significantly more larvae than the October stands. Proportionately more large than small larvae occurred in all seedings indicating egg hatch was similar in each planting date. Significantly more larval feeding was present in the April and August seedings than in the September and October plots. The greater number of large larvae more quickly defoliated the alfalfa than the smaller populations which were present in the younger seedings.

First harvest yields of the April, August, and September seedings were not significantly different but were all significantly greater than the October planting (Table XXVI). The September planting was significantly taller than the August and October seedings and had equivalent growth to the spring stand. The same relationship between yields and plant heights of first and second harvests in the previous experiments was again true for the fall seedings.

The April and August stands did not significantly differ in damage

TABLE XXV

EFFECT OF FALL PLANTING DATE OF ALFALFA ON POPULATION DENSITIES OF WEEVIL LARVAE, STILLWATER, 1983-84

Planting Date	Larvae/25 stems			Damage Rating
	Small	Large	Total	
	April 1			
April	26.7	4.0	30.7	2.3
August	20.0	3.0	23.0	2.0
September	10.0	0.7	10.7	2.0
October	11.3	0.3	11.7	1.5
LSD	9.2	2.1	10.1	0.5
	April 25			
April	27.8	84.7	112.5	3.5
August	15.5	50.3	65.8	3.3
September	12.3	30.8	43.2	2.2
October	3.7	12.5	16.2	2.3
LSD	13.0	29.1	39.8	0.6

Within a column,means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

TABLE XXVI

INFLUENCE OF FALL PLANTING DATE AND THE ALFALFA WEEVIL UPON FIRST AND SECOND HARVEST YIELDS OF ALFALFA, STILLWATER, 1983-84

Planting Date	May 13 Yield (kg/ha)	May 13 Plant Height (cm)	May 13 Damage Rating	June 20 Yield (kg/ha)	June 20 Plant Height (cm)
April	5180	59.2	6.2	5647	75.3
August	5429	58.2	5.7	4416	75.2
September	4907	65.4	4.7	3431	62.5
October	3708	58.5	2.8	2817	64.3
LSD	845	6.2	0.8	1249	4.7

Within a column, means were separated utilizing the Least Significant Difference Test ($P \leq 0.05$).

ratings at first harvest but had more damage than the September and October plantings (Table XXVI). Greater damage had occurred in those seedings which offered the most attractive overwintering and ovipositional habitat for adult weevils. Though potential loss in production due to larval feeding was 488.8 and 324.9kg/ha in the August and September plantings, respectively, the 1507kg/ha difference in yield of the first 2 harvests did not appear to make the September planting a satisfactory alternative to control the weevil population. Potential production losses of 188kg/ha for each larva/stem (Berberet et al. 1981) would account for a first harvest decrease of 121.8kg/ha inthe October planting. Even utilizing chemical control the October planting could not have produced as much forage as the August or September seedings.

Though the October seeding was more productive than in the previous studies, it still did not appear to be a viable alternative for manipulating weevil populations because of significantly less forage production than the other dates. Loss in production due to larval feeding in the October seeding may have been as much as 112.8kg/ha while the 2 harvest total production was 4302kg/ha less than the April planting.

Discussion

The April plantings, which were representative of established stands, possessed a greater amount of overwintering habitat for the adult weevil than any of the fall seedings. The habitat in the April seedings which made it more attractive than the fall seedings was stubble and plant debris about the alfalfa crown as well as greater plant height. The September seedings contained sufficient growth in only one of the four experiments to be browned by frost but still did not have as much overwintering habitat as the August seedings. Due to poor stand establishment and growth, the October seedings offered little overwintering habitat and few oviposition sites for adult weevils.

Typically, egg deposition begins in Oklahoma during November and December and continues in January and February as weather permits (Berberet et al. 1980). In all the experiments, greatest populations of fall laid eggs occurred in the April seedings and lower numbers through the fall plantings with fewest present in the October sown plots. The same pattern occurred when later sampling included eggs laid through the winter. Limited growth of plant stems in September and October plantings was likely less attractive for oviposition by adults at any time in fall or winter. Norwood et al. (1967b) also documented that smaller stems were less attractive for oviposition than larger stems.

The September and October plantings contained fewer larvae than April or August plantings because of the lower egg populations over the winter. This is in agreement with Senst and Berberet (1980) who reported that lower larval populations occurred in those seedings with the least overwintering habitat for adult weevils. Greater plant height in the April and August seedings would have been expected to withstand more larval feeding than the September and October plantings. However, the older seedings were also more attractive to overwintering adults for oviposition, and the resulting larger larval populations caused more feeding damage than what occurred in the later fall plantings. Burbutis et al. (1967) also documented that greatest feeding damage occurred in those seedings with more fall laid eggs.

Based on 188kg/ha loss for each larva/stem (Berberet et al. 1981), greatest potential yield reduction due to larval feeding occurred in the April seedings which had the largest larval populations. August, September, and October plantings had comparably less reduction in yield due to lower larval numbers and feeding damage. The August plantings appeared to be the best new seeding as compared to the April stand and was not expected to yield as much forage in the first year of production as the April seedings. Though the later fall seedings contained fewer weevils, the decreased yield resulting from poorer stand establishment and growth did not allow these seedings to be a viable alternative to August planting.

CHAPTER V

SUMMARY AND CONCLUSIONS

The determining factor for egg population and subsequent larval buildup appeared to be the amount of overwintering habitat available for adult weevils. The established stands (April) and August seedings had the most plant growth at the time adult weevils reentered the fields in the fall. These plantings also offered more oviposition locations which allowed for a greater concentration of larvae in these plots in the spring. Less plant material in the September and October seedings was apparently not as attractive to the adult weevil for overwintering and allowed for smaller weevil populations in the spring.

Lower potential for losses due to weevil feeding in the late fall seedings did not offset the decrease in forage production due to the later planting dates. In no instance was forage yield from the first 2 harvests of the September or October plantings comparable to the productivity of the August planting. Even with larval numbers reducing potential yield up to 996kg/ha, the August seedings produced as much as 3919kg/ha more than the September seeding. Stand establishment in the October seedings of several experiments was not considered acceptable because of insufficient forage production.

Sowing of alfalfa in late fall significantly reduces egg numbers and subsequent larval populations and feeding; however, lower feeding damage and forage loss due to feeding did not compensate for the reduced production of the first 2 harvests.

LITERATURE CITED

Armbrust, E. J., and G. G. Byrisco. 1966. Alfalfa weevil control in New York. J. Econ. Entomol. 59: 801-4.

Armbrust, E. J., R. J. Prokopy, W. R. Cothran, and G. G. Gyrisco. 1966. Fall and spring oviposition of the alfalfa weevil and the proper timing of fall insecticide applications. J. Econ. Entomol. 59: 384-7.

Armbrust, E. J., C. E. White, and J. R. DeWitt. 1969. Lethal limits of low temeprature for the alfalfa weevil in Illinois. J. Econ. Entomol. 62: 464-7.

Bass, M. H. 1966. Temperatures lethal to the alfalfa weevil. J. Econ. Entomol. 59: 1530-1.

Bennett, S. E. 1968. A decade with the alfalfa weevil in Tennesee. Tenn. Agr. Exp. Sta. Bull. 446, 33p.

Berberet, R. C., and K. N. Pinkston. 1978. Control of the alfalfa weevil in Oklahoma. OSU Ext. Facts No. 7166. Okla. State Univ.

Berberet, R. C., R. D. Morrison, and K. M. Senst. 1981. Impact of the alfalfa weevil, Hypera postica (Gyllenhal), on forage production in nonirrigated alfalfa in the southern plains. J. Kansas Entomol. Soc. 54: 312-8.

Berberet, R. C., K. M. Senst, K. E. Nuss, and W. P. Gibson. 1980. Alfalfa weevil in Oklahoma: the first ten years. Okla. State Univ. Agr. Exp. Sta. Bull. B-751, 25p.

Bissell, T. L. 1952. First report of the alfalfa weevil in Maryland. U.S. Bur. Entomol. Plant Quar. Coop. Econ. Insect. Rep. 2: 4.

Blickenstaff, C. C. 1967. Winter distribution of adult alfalfa weevils within alfalfa fields. J. Econ. Entomol. 60: 1185.

Burbutis, P. P., D. F. Bray, and A. H. Mason. 1967. Overwintering eggs of the alfalfa weevil in Delaware. J. Econ. Entomol. 60: 1007-10.

Busbice, T. H., W. V. Campbell, J. O. Rawlings, D. K. Barnes, R. H. Ratcliffe, and C. H. Hanson. 1968. Developing alfalfa resistant to alfalfa weevil oviposition. Crop Sci. 8: 762-7.

Byrne, H. D. 1969. The oviposition response of the alfalfa weevil. Univ. Md. Agr. Exp. Sta. Bull. A-160, 42p.

Campbell, W. V., T. G. Bowery, and K. G. Jester. 1961. Seasonal history and control of the alfalfa weevil in North Carolina. J. Econ. Entomol. 54: 743-7.

Casagrande, R. A., and F. W. Stehr. 1973. Evaluating the effects of harvesting alfalfa on alfalfa weevil parasite populations in Michigan. Can. Entomol. 105: 1119-28.

Devine, T. E., R. H. Ratcliffe, C. M. Rincker, D. K. Barnes, S. A. Ostazeski, T. H. Busbice, C. H. Hanson, J. A. Schillinger, G. R. Buss, and R. W. Clevelenad. 1975. Registration of Arc alfalfa (Reg. No. 76). Crop Sci. 15: 97.

Dively, G. P. 1970. Overwintering alfalfa weevil eggs in three stages of alfalfa growth in New Jersey. Ann. Entomol. Soc. Amer. 63: 1212-6.

Dorsey, C. K. 1966. Spring and fall applications of insecticides for alfalfa weevil control - 1963-64. J. Econ. Entomol. 59: 735-8.

______, and D. O. Quinn, 1962. Alfalfa weevil control studies in West Virginia. J. Econ. Entomol. 55: 365-8.

El-Tomi, O. A. 1982. Influence of sowing date on establishment of alfalfa in Oklahoma. M.S. Thesis. Okla. State. Univ., 50p.

Fribourg, H. A., and R. H. Strand. 1973. Influence of seeding dates and methods on establishment of small seeded legumes. Agron. J. 65: 804-7.

Fronk, W. D. 1959. Observations in Wyoming on the alfalfa weevil and its control. J. Econ. Entomol. 52: 939-42.

Hanson, C. H. 1961. Registration of varieties and strains of alfalfa, VI. Cody (Reg. No. 14). Agron. J. 53: 400.

Hollowell, E. A. 1945. Registration of varieties and strains of alfalfa, I. Buffalo (Reg. No. 2). J. Am. Soc. Agron. 37: 649-52.

Hsieh, F., and E. J. Armbrust. 1974. Temperature limits of alfalfa weevil oviposition and egg density in Illinois. J. Econ. Entomol. 67: 203-6.

Hsieh, F., S. J. Roberts, and E. J. Armbrust. 1974. Developmental rate and population dynamics of alfalfa weevil larvae. Environ. Entomol. 3: 593-7.

Koehler, P. G., and D. Pimentel. 1973. Economic injury levels of the alfalfa weevil. Can. Entomol. 105: 61-74.

Litsinger, J. A., and J. W. Apple. 1973. Oviposition of the alfalfa weevil in Wisconsin. Ann. Entomol. Soc. Amer. 66: 17-20.

Lui, B. W. Y., and G. W. Fick. 1975. Yield and quality losses due to alfalfa weevil. Agron. J. 67: 828-32.

Manglitz, G. R., and B. A. App. 1957. Biology and seasonal development of the alfalfa weevil in Maryland. J. Econ. Entomol. 50: 810-3.

______. 1958. The alfalfa weevil in the eastern United States. Farm Chem. 121: 16-8.

Mathur, R. B., and R. L. Pienkowski. 1967. Effect of alfalfa weevil feeding on alfalfa quality. J. Econ. Entomol. 60: 601-2.

Milliron, H. E., and D. MacCreary. 1955. The alfalfa weevil in Delaware, 1953-54. J. Econ. Entomol. 48: 283-9.

Norwood, B. L., R. S. VanDenburgh, C. H. Hanson,and C. C. Blickenstaff. 1967a. Factors affecting resistance of field planted alfalfa clones to the alfalfa weevil. Crop Sci. 7: 96-9.

Norwood, B. L., D. K. Barnes, R. S. VanDenburgh, C. H. Hanson, and C. C. Blickenstaff. 1967b. Influence of stem diameter on oviposition preference of the alfalfa weevil and its importance in breeding for resistance. Crop Sci. 7: 428-30.

Pass, B. C., and C. L. VanMeter. 1966. A method for extracting eggs of the alfalfa weevil from stems of alfalfa. J. Econ. Entomol. 59: 1294.

Pausch, R. D., S. J. Roberts, R. J. Barney, and E. J. Armbrust. 1980. Localized field migration of the adult alfalfa weevil, clover leaf weevil, and clover root curculio, and its implications for a fall pest management program. Great Lakes Entomol. 13: 195-200.

Peterson, L. K. 1960. Effects of low temperature on the survival of the alfalfa weevil in Alberta and Utah. J. Econ. Entomol. 53: 570-2.

Senst, K. M., and R. C. Berberet. 1980. Effects of winter grazing of dormant alfalfa stands on populations of Hypera postica (Gyllenhal) and its parasite Bathyplectes curculionis (Thomson). J. Econ. Entomol. 64: 437-8.

Shade, R. E., J. D. Axtell, and M. C. Wilson. 1971. A relationship between plant height of alfalfa and the rate of alfalfa weevil larval development. J. Econ. Entomol. 64: 437-8.

Sholar, R., J. Caddel, L. Rommann, J. Stritzke, G. Johnson, D. Schwab, S. Coppock, R. Berberet, E. Williams, W. Bowers, and T. Shaklee, 1982. Alfalfa production and pest managemnt in Oklahoma. Okla. State Univ. Coop. Ext. Circ. E-826.

Sorensen, E. L., D. L. Stuteville, and E. Horber. 1978. Registration of Riley alfalfa (Reg. No. 88). Crop Sci. 18: 911.

Steinhauer, A. L., and C. C. Blickenstaff. 1967. Fall application of parathion for control of the alfalfa weevil. J. Econ. Entomol. 60: 611-2.

Strand, R. H., and H. A. Fribourg. 1973. Relationship between seeding dates and environmental variables, seeding methods, and establishment of small-seeded legumes. Agron. J. 65: 807-10.

Sweetman, H. L. 1929. Field studies on the physical ecology of the alfalfa weevil. Wyo. Agr. Exp. Sta. Bull. No. 167, 31p.

______. 1932. Further studies on the physical ecology of the alfalfa weevil. J. Econ. Entomol. 25: 681-93.

Titus, E. G. 1907. In an interview: A new pest of alfalfa. Desert Farmer 3(51): 7. July 27.

______. 1910. On the life history of the alfalfa-leaf weevil. J. Econ. Entomol. 3: 459-70.

______. 1913. The control of the alfalfa weevil. Utah Agr. Exp. Sta. Circ. 10: 105-20.

Townsend, H. G., and W. G. Yendol. 1968. Survival of overwintering alfalfa weevil eggs in Pennsylvania. J. Econ. Entomol. 61: 916-8.

VanDenburgh, R. S., B. L. Norwood, C. C. Blickenstaff, and C. H. Hanson. 1966. Factors affecting resistance of alfalfa clones to adult feeding and oviposition of the alfalfa weevil in the laboratory. J. Econ. Entomol. 59: 1193-8.

Wilson, M. C., B. C. Pass, and S. E. Bennett. 1969. Influence of annual spring seeding of alfalfa on alfalfa weevil populations. J. Econ. Entomol. 62: 1421-3.

Wilson, M. C., J. K. Stewart, and H. D. Vail. 1979. Full season impact of the alfalfa weevil, meadow spittlebug, and potato leafhopper in an alfalfa field. J. Econ. Entomol. 72: 830-4.

VITA 2

Alan Kirk Dowdy

Candidate for the Degree of

Master of Science

Thesis: INFLUENCE OF FALL PLANTING DATE OF ALFALFA, MEDICAGO SATIVA L., ON POPULATION DENSITIES OF THE ALFALFA WEEVIL, HYPERA POSTICA (GYLLENHAL)

Major Field: Entomology

Biographical:

Personal Data: Born in Cheyenne, Wyoming, September 10, 1960, the son of Mr. and Mrs. Auburn W. Dowdy.

Education: Graduated from East High School, Cheyenne, Wyoming, in May, 1978; received Associate of Arts and Sciences degree in Business Administration from Laramie County Community College in 1980; received Bachelor of Science degree in Entomology from the University of Wyoming in 1982; completed requirements for the Master of Science degree in Entomology at Oklahoma State University in December, 1984.

Professional Experience: Field assistant, U.S.D.A. A.R.S. Honeybee Lab, Laramie, Wyoming, 1981-82; graduate research assistant, Department of Entomology, Oklahoma State University, 1982-84.

Professional Organizations: Entomological Society of America.