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To the Graduate Council:

I am submitting herewith a thesis written by Charles Ray Leslie, entitled "Evaluation of Some Biological and Chemical Measures for Control of Alfalfa Weevil Feeding." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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EVALUATION OF SOME BIOLOGICAL AND CHEMICAL MEASURES FOR
CONTROL OF ALFALFA WEEVIL FEEDING

A Thesis
Presented to
the Graduate Council of
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In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Charles Ray Leslie

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To Mother and Daddy

and

To Carol .

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ABSTRACT

Three alfalfa weevil (Hypera postica Gyllenhal) experiments were conducted at the Plant Science Farm, Knoxville, Tennessee during 1970 and 1971. Treatments applied to the alfalfa (Medicago sativa L.) were different insecticides, varieties, and nitrogen fertilizers. The effects measured were dry matter production, protein-nitrogen, nitrate-nitrogen, and glucose concentration.

Twelve combinations of two factors were incorporated into Experiment A. The alfalfa was sprayed either not at all, once, or twice with Alfatox at 1.15 l/ha. Four alfalfa varieties were included as split-plot treatments. Team, Weevlc hek, Saranac, and Buffalo were the alfalfa varieties. Team produced the highest yield of the four varieties and Buffalo produced the lowest. Yields ranged from 7.09 to 8.73 metric tons/ha. Only one spraying of Alfatox was needed to control feeding under mild weevil infestation (1970) while two sprayings were needed under heavy infestation (1971).

Protein-nitrogen concentrations ranged from 3.14 to 3.28 percent. Saranac had the highest concentration, but Weevlc hek and Team were also significantly higher than Buffalo. Sprays did not affect protein-nitrogen concentration in 1970. Glucose and nitrate-nitrogen were not affected by spraying level or varieties.

Larval feeding damage ranged from severe to slight. Damage was independent of varieties, but Spray 1 and Spray 2 were significantly better than Spray 0. Team had the lowest damage value and Buffalo the highest value.

Experiment B was an evaluation of 8 chemical treatments and a check. Damage values ranged from 9 to 1.5. Twenty-five percent methyl parathion plus commercial 30 percent nitrogen solution gave the best protection followed closely by 25 percent methyl parathion. Commercial 30 percent nitrogen solution increased growth but had a damage value of 6.0. All other treatments offered no protection.

Five nitrogen sources were used as main treatments in Experiment C. Subsidiary plots were solid and liquid application of the nitrogen sources. Nitrogen rate was 56 kg/ha. Forage dry matter yields ranged from 214 to 1533 kg/ha in the spring regrowth. Liquid forms were applied at the same rate except in 1.9 l water. Check plots produced the highest yield, but solid applications produced almost twice the amount of forage that liquid plots produced. Liquid applications at this rate caused severe damage to the plants. Plots receiving urea produced the highest yield while ammonium nitrate plots produced the least.

Nitrate-nitrogen concentrations ranged from .005 to .020. Solid sodium nitrate produced the highest concentration, and check plots produced the lowest. Solid application of nitrogen sources increased nitrate-nitrogen concentrations in plants, but the concentration of nitrates was not enough to deter weevil feeding which was severe. Treatments receiving solid applications averaged .014 percent while check plots averaged .006 percent. Liquid applications caused severe chemical damage to leaves and stems. Glucose concentration ranged from 2.24 to 3.02 percent, but was not affected by nitrogen source or form of application.

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CHAPTER I

INTRODUCTION

The alfalfa weevil (Hyper postica Gyllenhal) is the most destructive pest to alfalfa (Medicago sativa L.) in the state of Tennessee. Economic losses due to yield and quality reduction have also caused a great reduction in acreage. The first harvest and in some instances the second harvest may be completely destroyed.

Damage occurs primarily as the result of larval feeding, but adult weevils cause some feeding and oviposition damage. The larvae feed within the stem tips, on upper leaves as they unfold, and eventually on lower leaves.

Several insecticidal control measures have been eliminated from recommendations due to the presence of chlorinated hydrocarbon residues in milk. Restrictions on the use of these long lasting toxicants have increased interest in other methods to control alfalfa weevil feeding. These methods include resistant varieties, natural predators, flame treatments, sterilization procedures, and effective natural and synthetic chemical substitutes for the restricted chlorinated hydrocarbons.

Since the alfalfa weevil is of economic importance in Tennessee and the Southeast, more information on new control methods is needed. The purpose of this study was to evaluate some of the biological and chemical measures for control of alfalfa weevil feeding.

CHAPTER II

LITERATURE REVIEW

The alfalfa weevil is a native of Europe, but was found in Utah in 1904. In 1952 the weevil was discovered in Maryland. These infestations have spread over almost all of the United States. The weevil was found in Tennessee in 1959. By 1964 it had spread over the entire state (11). Heptachlor was an excellent control as early as 1960, but residues in milk caused it to be withdrawn from use in 1964 (11, 18).

Many other chemicals have since been used to control weevil feeding. Malathion is one of the recommended insecticides (35, 46). The advantage of this insecticide was that no waiting period was needed before the alfalfa could be harvested. Walstrom, Jones, and Gastle (49) found phorate to be an economical control method at 4 lb AI/acre. In years with above average precipitation, they found protein and carotene content to be higher than non-phorate treated alfalfa. Summers and Cothran (44) used GS 13005 and carbofuran in New York to control weevil feeding. Several investigators (20, 44) have found carbofuran to be an effective weevil control. Carbofuran did not maintain control as long as the chlorinated hydrocarbons, but it did protect the first crop and reduced retardation of regrowth (20). Niemczyk and Flessel (33, 34) found methyl parathion to be the most effective spray in Ohio. They determined that two applications were needed for adequate control. Wilson and Armbrust (50) used

methyl parathion as an effective control in Indiana and Illinois. They had some success with aerial applications. Methyl parathion seemed to give the best results under adverse conditions (5, 6). It was effective under wet or dry conditions and temperatures under 55 F. Alfatox (a mixture of 20 percent Methoxychlor and 10 percent Diazinon) was found to be a good control at temperatures above 50 F. The 7-day limitation before harvest or grazing was one-half that of methyl parathion, which was 15 days.

Dimethyl sulfoxide (DMSO) was an effective synergist for an insecticide at concentrations less than 0.1 percent. This low concentration was necessary to avoid adverse effects on plants which were reduction of growth and necrosis (26).

Chemosterilants have also attracted attention (29, 41). Tepa, apholate, and metepa have been found to induce sterility in males and females. Some mortality was also observed in both sexes.

Burgess and Bennett (15) used X-radiation as a method of sterilization. Sterility in male alfalfa weevils was induced at 8000R. X-radiation at lower levels produced only temporary sterility.

Flaming has been used with good results. Bennett and Luttrell (12) in Tennessee reduced weevil numbers by flaming in February. Only one application of malathion was needed after flaming. Flaming was also a good control for chickweed, Stellaria media L. (Cyrillo).

Wilson, Pass, and Bennett (52) studied the possibility of annual spring seeding on weevil populations. They found that alfalfa does escape some injury early in the season. The fields should be rotated or plowed to eliminate the plant host.

In studies to determine what causes weevil feeding, Hsiao (28) has shown adenine and adenosine to be the feeding stimulants in alfalfa leaves. Adenine salts and nucleotides also elicited feeding response. Adenine hyperchloride was the most active form at only one-tenth the concentration of sucrose.

An absence of deterrents is possibly more important than the presence of stimulants in host plant selection by the weevil. Byrne (17) found red clover (Trifolium pratense L.) juice to be a very powerful deterrent. Alfalfa juice must be three times more concentrated to balance the deterrent effect of red clover juice applied to alfalfa. It was postulated that an absence of deterrent might be the basis for host plant selection for oviposition. Bennett (10) found oak leaf tannin to be a deterrent to alfalfa weevil feeding. Increased concentrations caused mortality of the feeding larvae.

Host plant resistance apparently depends upon a balance between feeding stimulants and feeding deterrents. Akesson, Gorz, and Haskins (13) have found glucose to be a stimulant to the feeding of sweetclover weevils (Sitona cylindricollis Fahraeus) upon sweetclover (Melilotus spp.). Nitrates were found to be a deterrent to sweetclover weevils (2). Proper balance of sugars and nitrates was required to achieve resistance.

There has been much interest in breeding resistance to alfalfa weevil feeding. The first step in this process is the screening of present varieties. Plants with favorable characteristics may then be selected and combined to create a resistant variety. The cotyledon test and the surplus food tests have been used to some degree of success (7, 9, 19).

Several investigators (16, 36, 37) have selected physical characteristics in mature plants that correspond to weevil resistance. Plants with decumbent growth, wide crowns, and small stems received fewest eggs and suffered least larval feeding. Small stems would conflict with large plants needed for economical yields.

'Team' appears to be one of the most promising varieties developed after screening and several years of breeding work (8). It is a vigorous variety with moderate resistance to the alfalfa weevil, pea aphid (Macrosiphum pisi Harris), and some pathogens.

'Weevlchek' is also the result of extensive screening and breeding work.

Alfalfa weevils do not necessarily remain on alfalfa throughout the entire year. Knowing which other plants offer protection or food for the weevil would aid in off-season control. DeWitt, Armbrust, Roberts, and White (24) made laboratory studies with alfalfa weevil larvae on soybeans (Glycine max L.). They found that larval feeding did occur on soybean leaf margins and caused a shot-hole appearance. Oviposition was reduced but egg masses were larger. Saad and Bishop (39) found 9 species of weeds used by the alfalfa weevil for oviposition. Common chickweed was reported to be more desirable for oviposition than alfalfa in some instances. They suggest its use as a trap crop. Other investigators (38, 48) have also shown increases in larval damage to alfalfa when henbit (Lamium amplexicaule L.) was present in alfalfa fields.

Biological control of the alfalfa weevil has the advantage of not polluting the environment and being relatively inexpensive when compared with chemical control. Many species of birds, toads, snakes,

frogs, and shrews feed on the alfalfa weevil, but perhaps the most important means of biological control are the parasitic wasps.

Bathyplectes and Microctonus are the two genera containing the most important parasites. Miller (30, 31) stated that neither B. curculionis, B. anurus, nor Tetrastichus incertus can control the weevil alone, but in combination they have offered good protection in the Northeast. Proper timing of a methyl parathion application appeared to be compatible with survival of B. curculionis (51). The parasitized larvae consumed less alfalfa and fed for a shorter period of time than did unparasitized larvae (4).

Microctonus aethiops and M. colesi are important parasites in the eastern United States (42, 25, 22). M. aethiops is ideal for weevil control because its life cycle is well synchronized with weevil activity and disperses with the weevil (42). Parasitization of weevil larvae by Microctonus usually results in complete or partial castration (25).

Several investigators (13, 14, 54) have studied the use of juvenile hormone to control insects. Good results have been obtained, but the cost and availability of these compounds have restricted field experiments.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. EXPERIMENT A

Four varieties of alfalfa, 'Team,' 'Weevlchek,' 'Saranac,' and 'Buffalo,' were hand-seeded at the Plant Science Farm, Knoxville, Tennessee on August 8, 1969. The soil type was a Sequoia silt loam with a pH of 6.0. Lime was applied at the rate of 6,726 kg/ha. A mixed fertilizer containing no nitrogen, 90 kg phosphorus, and 270 kg potassium per ha was applied. Boron was included in the fertilizer at 0.52 kg/ha. The area was divided into plots of 2.13 x 9.14 meters. Forage from these plots was harvested to determine yield and percent protein-nitrogen. Whole plant samples were also taken for analysis of glucose and nitrate-nitrogen concentrations.

The experimental design was a randomized complete block with a factorial arrangement of treatments. Each treatment was replicated four times. All replications were used to make yield calculations, but only replications two, three, and four were sampled for chemical analyses. The main treatments consisted of zero, one, and two applications of Alfatox insecticide, and the split-plot treatments consisted of the four alfalfa varieties.

Alfatox was applied at 1.145 l/ha on April 3 and April 20 in 1970, and on March 31 and April 16 in 1971. One of the main treatments received no spray and was considered a check. The main treatments will hereafter be expressed as Spray 0, Spray 1, and Spray 2 for no spray,

one spraying, and two sprayings respectively. April 3, 1970 and March 31, 1971 were the dates when the Spray 1 treatment was applied.

The split-plot treatments consisted of four alfalfa varieties. Two varieties, Team and Weevlchek, have been characterized as alfalfa weevil-resistant. Saranac showed evidence of being weevil-resistant in screening experiments, and Buffalo, a recommended variety in Tennessee, was used as a check variety for comparison. Table 1 indicates the treatments employed both in 1970 and in 1971.

Yields for both years were determined by cutting a 1.07 x 9.14 m strip from the center of each plot. The green weight of forage was recorded, and subsamples were taken to determine moisture percentage and protein-nitrogen. These subsamples were dried at 70 C, ground in a Wiley Model No. 3 mill equipped with a 20 mm mesh sieve, and stored for laboratory analysis. Yields were reported as weed-free alfalfa on a dry matter basis.

Percent protein-nitrogen of the samples was determined by placing 0.200 g of ground sample in concentrated sulfuric acid and allowing it to digest overnight. The mixture was then heated to over 200 C for 2.5 hours. At the end of this period, 15 ml of 35 percent hydrogen peroxide were added and the mixture reheated until clear and then for 45 minutes after clearing. Following heating, the solution was placed in a 250 ml volumetric flask and brought to volume with distilled water. From this 250 ml, an aliquot was placed in an Auto Analyzer (45) and percent transmission determined after the phenol-hypochlorite color reaction (47). From this transmission value the percent protein-nitrogen was calculated. The samples were analyzed in duplicate.

Table 1. Treatments in Experiment A

No. of sprays	Varieties
0	Team
0	Weevlc hek
0	Saranac
0	Buffalo
1	Team
1	Weevlc hek
1	Saranac
1	Buffalo
2	Team
2	Weevlc hek
2	Saranac
2	Buffalo

Forage samples were obtained from Spray 0 plots in the spring for analysis of glucose and nitrate-nitrogen concentrations. The sampling dates were April 20, April 27, May 4, and June 15, 1970. These samples, about 15 plants each, were dried at 70 C and leaves were separated from stems. Only the leaves were retained, dried, and ground through a 20-mesh screen for laboratory analysis.

Carbohydrate percentages for each treatment were determined by using the procedure outlined by Nelson (32) and Somogyi (43). This procedure involved placing 0.25 gram of ground leaf sample into 25 ml of demineralized water and refluxing for one hour. The contents were then filtered through Whatman's No. 42 filter paper into a 250 ml volumetric flask and brought to volume. A two ml aliquot was transferred into a test tube, and two ml of copper reagent were added. This solution was refluxed for 15 minutes, and after it cooled to room temperature, two ml of arsenomolybdate were added. Twenty ml of water were added to each tube, mixed, and the absorbance read in a Spectronic 20 spectrophotometer at 510 nm. Samples were analyzed in duplicate and reported as percent glucose.

Nitrate-nitrogen concentrations of the samples were determined by the naphthylamine procedure outlined by Woolley, Hicks, and Hageman (53). This procedure involved placing a 0.1 g sample into 20 ml of demineralized water and heating it in a boiling water bath. At the end of a 30-minute period a one-ml aliquot was taken, placed in an acetic acid solution to which a reagent powder consisting of barium sulfate, manganous sulfate, citric acid, sulfanilic acid, naphthylamine, and zinc powder was added. This mixture was then shaken,

centrifuged, and filtered. The absorbance of the filtrate was determined in a Spectronic 20 spectrophotometer at 520 nm. From the absorbance value, the percent nitrate-nitrogen was calculated for each sample. Samples were analyzed in duplicate.

Estimates of weevil damage were made on May 4, 1970, and on May 10, 1971. A rating of 0 indicated no damage, and a rating of 10 denoted complete destruction.

II. EXPERIMENT B

This study was located in a four-year old alfalfa field at the Plant Science Farm, Knoxville, Tennessee. The soil type was an Etowah clay loam, and the alfalfa variety was Buffalo. Plot size was 1.52 x 1.52 meters. Observations were made on these plots at harvest time to determine if various materials that had previously showed promise would control feeding by alfalfa weevil larvae.

A randomized complete block design was used with each spray treatment replicated three times. Table 2 indicates the treatments which were applied on April 12, 1971.

An estimate of weevil damage was made on May 10, 1971 when the alfalfa was rated for visible weevil damage. A rating of 0 indicated no damage, and a rating of 10 denoted complete destruction.

III. EXPERIMENT C

This investigation was performed on a year and a half-old stand of Buffalo alfalfa at the Plant Science Farm, Knoxville, Tennessee. The soil type was an Etowah clay loam. The experimental area received

Table 2. Treatments in Experiment B

Control measures
Concentration in water
10% tannic acid
10% tannic acid + 25% dimethyl sulfoxide
25% dimethyl sulfoxide
10% tannic acid + 2% surfactant
2% surfactant
25% methyl parathion
25% methyl parathion + commercial 30% nitrogen solution
Commercial 30% nitrogen solution
Nothing

a yearly application of a mixed fertilizer containing no nitrogen, 90 kg phosphorus, and 270 kg potassium per hectare. Boron was also included in the fertilizer at 0.52 kg/ha. The area was divided into plots of 1.83 x 6.09 meters. Forage from these plots was harvested to determine yield, percent glucose, and percent nitrate-nitrogen. The objective of this experiment was to determine if various nitrogen sources cause internal changes in alfalfa plants to a degree sufficient to control feeding by alfalfa weevil larvae.

The experimental design was a randomized complete block with a factorial arrangement of treatments. Each treatment was replicated five times. The main treatments consisted of five nitrogen sources and a control receiving no nitrogen. Subsidiary treatments were liquid and solid applications of the nitrogen sources.

The nitrogen sources were ammonium nitrate, sodium nitrate, ammonium sulfate, urea, urea and ammonium nitrate, and no nitrogen. These treatments were applied March 16, 1970 in solid form and April 10, 1970 in liquid form. All applications were made at the rate of 56 kg nitrogen/ha. Liquid applications were sprayed on each plot in 1.9 l of solution. Table 3 indicates the treatments applied.

Samples of forage were collected on April 8, 1970, for analysis of glucose and nitrate-nitrogen concentrations in leaves. No further sampling was feasible because of kill and damage to the plants. The forage was dried at 70 C and leaves were separated from stems. Only the leaves were retained, dried, and ground through a 20-mesh screen for laboratory analysis. Procedures for conducting these laboratory analyses were described in Experiment A. Alfalfa regrowth yields on June 30, 1970 were calculated as described in Experiment A.

Table 3. Treatments in Experiment C

Nitrogen Source	Form
Ammonium nitrate	Solid
Sodium nitrate	Solid
Ammonium sulfate	Solid
Urea	Solid
Urea + ammonium nitrate	Solid
Nothing	Solid
Ammonium nitrate	Liquid
Sodium nitrate	Liquid
Ammonium sulfate	Liquid
Urea	Liquid
Urea + ammonium nitrate	Liquid
Nothing	Liquid

CHAPTER IV

RESULTS

I. EXPERIMENT A

Forage Production

Forage production for 1970 is shown in Table 4 for each harvest throughout the season. Higher yields were harvested on May 4 and again on August 14 as a result of increased precipitation. Yields in 1970 ranged from 7.09 to 8.73 metric tons/ha (Table 5). Team-Spray 1 plots had the highest yields while Buffalo-Spray 2 plots averaged the lowest.

Table 6 shows the average dry matter yield compared across sprayings and across varieties. The Spray 0 and Spray 1 treatments represented the highest main treatment yields at 8.11 and 8.13 metric tons/ha, respectively. Both of these treatments were significantly better than Spray 2. The average yield for this treatment was 7.70 metric tons/ha.

Team and Saranac produced the highest variety yields with Team having the highest average yield at 8.52 metric ton/ha. Saranac and Weevlchek had significantly higher yields than Buffalo, which had an average of 7.37 metric tons/ha (Table 6).

Forage production for the first cutting of 1970 (when most weevil damage occurred) is shown in Table 7. Yields on May 4, 1970 ranged from 2.98 to 4.37 metric tons/ha. Team sprayed once had the highest average yield, and Buffalo unsprayed had the lowest average yield on this date.

Table 4. Forage dry matter yields for individual harvests in 1970

No. of sprays	Variety	May 4	June 17	Aug. 14	Sep. 22	Yearly Totals
				Metric tons/ha		
0	Team	3.79	1.50	1.83	1.55	8.67
0	Weevlc hek	3.49	1.38	1.64	1.40	7.91
0	Saranac	3.41	1.51	1.72	1.55	8.19
0	Buffalo	2.98	1.41	1.78	1.48	7.65
1	Team	4.37	1.43	1.63	1.30	8.73
1	Weevlc hek	3.40	1.37	1.54	1.52	7.83
1	Saranac	4.09	1.46	1.65	1.40	8.60
1	Buffalo	3.16	1.30	1.58	1.32	7.36
2	Team	4.10	1.26	1.52	1.29	8.17
2	Weevlc hek	3.76	1.17	1.52	1.32	7.77
2	Saranac	3.90	1.24	1.44	1.20	7.78
2	Buffalo	3.30	1.10	1.39	1.30	7.09

Table 5. Total forage dry matter yields for 1970

No. of sprays	Variety	Total yield
		Metric tons/ha
1	Team	8.73a*
0	Team	8.67a
1	Saranac	8.60ab
0	Saranac	8.19abc
2	Team	8.17abc
0	Weevlc hek	7.91abc
1	Weevlc hek	7.83abc
2	Saranac	7.78abc
2	Weevlc hek	7.77abc
0	Buffalo	7.65abc
1	Buffalo	7.36bc
2	Buffalo	7.09c

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 7. Forage dry matter yields for May 4, 1970

No. of sprays	Variety	Yield
		Metric tons/ha
1	Team	4.37a*
2	Team	4.10ab
1	Saranac	4.09ab
2	Saranac	3.90abc
0	Team	3.79abc
2	Weevlchek	3.76bcd
0	Weevlchek	3.49cde
0	Saranac	3.41cde
1	Weevlchek	3.40cde
2	Buffalo	3.30cde
1	Buffalo	3.16de
0	Buffalo	2.98e

*Values followed by the same letter are not significantly different at the .05 level of probability.

Sprays were not significantly different on the first cutting in 1970. Average yields ranged from 3.41 to 3.79 metric tons/ha. Spray 1 and Spray 2 did not yield significantly more, but both treatments produced at least 3.76 metric tons/ha while Spray 0 produced 3.41 metric tons/ha (Table 8).

Varieties were significantly different at the 0.5 level of probability. Average yields ranged from 3.15 to 4.09 metric tons/ha. Team had the highest yield followed by Saranac with 3.80 metric tons/ha. The lowest average yield came from plots seeded in Buffalo alfalfa.

Forage production for the first cutting in 1971 is shown in Table 9. Yields on May 10, 1971 ranged from 0.71 to 2.17 metric tons/ha. A Duncan's Multiple Range test revealed that Team sprayed twice with Alfatox yielded higher than any other treatment. Weevlc hek and Buffalo unsprayed produced the lowest yields on this date. No precipitation was recorded during mid-April and probably caused the yields to be lower than in 1970.

The Spray 2 treatment produced significantly higher yields than any other spray treatment. Yields on May 10, 1971, ranged from 1.02 to 1.92 metric tons/ha. Spray 1 was significantly better than Spray 0 with yields of 1.57 and 1.02 metric tons/ha, respectively (Table 10).

Team and Saranac produced the highest variety yields again in the first cut of May 1971. Results of the variety test were identical to 1970. Team represented the highest average yield at 1.86 metric tons/ha, and Buffalo had the lowest average yield at 1.23 metric tons/ha. Saranac and Weevlc hek were again intermediate in yield at 1.59 and 1.32 metric tons/ha, respectively (Table 10).

Table 8. Forage dry matter yields for May 4, 1970 compared across sprayings and across varieties

Varieties	Sprayings			Average
	0	1	2	
	Metric tons/ha			
Team	3.79	4.37	4.10	4.09a*
Weevilchek	3.47	3.70	3.76	3.64b
Saranac	3.41	4.09	3.90	3.80ab
Buffalo	2.98	3.16	3.30	3.15c

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 9. Forage dry matter yields for May 10, 1971

No. of sprays	Variety	Yield
		Metric tons/ha
2	Team	2.17a*
2	Saranac	2.06ab
1	Team	1.76abc
2	Weevlchek	1.75abc
1	Saranac	1.72abcd
2	Buffalo	1.69abcd
0	Team	1.65bcd
1	Weevlchek	1.50cd
1	Buffalo	1.23de
0	Saranac	.99ef
0	Buffalo	.73f
0	Weevlchek	.71f

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 10. Forage dry matter yields for May 10, 1971 compared across sprayings and across varieties

Varieties	Sprayings			Average
	0	1	2	
	Metric tons/ha			
Team	1.65	1.76	2.17	1.86a*
Weevlc hek	.71	1.50	1.75	1.32c
Saranac	.99	1.72	2.06	1.59b
Buffalo	.73	1.28	1.69	1.23c
Average	1.02c	1.57b	1.92a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Protein-Nitrogen Concentration

Protein-nitrogen concentrations in the forage for all harvest dates are shown in Table 11. The September 22 harvest had a lower protein-nitrogen concentration than any other date. Average concentrations throughout the year ranged from 3.07 to 3.33 percent (Table 12). Saranac-Spray 2, Team-Spray 2, and Weevlc hek-Spray 1 produced significantly higher concentrations than other treatments. Buffalo-Spray 2 produced the lowest average concentration.

Analysis of variance of the spray treatments revealed no significant difference, but varietal treatments were highly significant. Concentrations ranged from 3.13 to 3.28 percent (Table 13). Saranac, Weevlc hek, and Team had significantly higher protein-nitrogen concentrations than did Buffalo. Saranac had the highest concentration at 3.28 percent and Buffalo the lowest with 3.13 percent.

Protein-nitrogen concentrations for May 4, 1970, when weevil damage was most severe, are shown in Table 14. Concentrations ranged from 2.91 to 3.17 percent. Buffalo-Spray 1 plots averaged a significantly higher protein-nitrogen concentration than any other treatment. The lowest average concentration came from the Buffalo-Spray 0 plots.

Spray levels were not significantly different on May 4, 1970. Protein-nitrogen concentrations ranged from 3.01 to 3.09 percent (Table 15).

Variety treatments were highly significant on May 4, 1970. Average concentrations ranged from 2.95 to 3.14 percent. Weevlc hek had the highest average protein-nitrogen concentration over all spray

Table 11. Protein-nitrogen concentration in forage for individual harvests during 1970

No. of sprays	Variety	Harvest dates				
		May 4	June 17	Aug. 14	Sep. 22	Ave.
		Percent protein-nitrogen				
0	Team	2.94	3.80	3.49	2.68	3.23
0	Weevlchek	3.16	3.81	3.47	2.62	3.27
0	Saranac	3.03	3.75	3.37	2.88	3.26
0	Buffalo	2.91	3.68	3.26	2.66	3.13
1	Team	2.94	3.64	3.38	2.88	3.21
1	Weevlchek	3.15	3.75	3.33	2.93	3.29
1	Saranac	3.10	4.00	3.33	2.54	3.25
1	Buffalo	3.17	3.77	3.22	2.63	3.20
2	Team	2.97	3.70	3.48	2.99	3.29
2	Weevlchek	3.10	3.82	3.47	2.49	3.22
2	Saranac	3.12	3.84	3.43	2.91	3.33
2	Buffalo	3.01	3.59	3.32	2.33	3.07

Table 12. Average protein-nitrogen concentration in forage in 1970

No. of sprays	Variety	Protein-Nitrogen
2	Saranac	Percent 3.33a*
2	Team	3.29a
1	Weevlchek	3.29a
0	Weevlchek	3.27ab
0	Saranac	3.26ab
1	Saranac	3.25ab
0	Team	3.23ab
2	Saranac	3.22ab
1	Team	3.21abc
1	Buffalo	3.20abc
0	Buffalo	3.13bc
2	Buffalo	3.07c

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 13. Protein-nitrogen concentration in forage in 1970
compared across sprayings and across varieties

Varieties	Sprayings			Average
	0	1	2	
			Percent	
Team	3.23	3.21	3.29	3.24a*
Weevilchek	3.27	3.29	3.22	3.26a
Saranac	3.26	3.25	3.33	3.28a
Buffalo	3.13	3.20	3.07	3.13b
Average	3.22a	3.24a	3.23a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 14. Protein-nitrogen percentages for May 4, 1970

No. of Sprays	Variety	Protein-Nitrogen
		Percent
1	Buffalo	3.17a
0	Weevlchek	3.16ab
1	Weevlchek	3.15ab
2	Saranac	3.12abc
1	Saranac	3.10abc
2	Weevlchek	3.09abc
0	Saranac	3.03abcd
2	Buffalo	3.01bcd
2	Team	2.97cd
1	Team	2.94d
0	Team	2.94d
0	Buffalo	2.91d

*Values followed by the same letter are not significantly different as the .05 level of probability.

Table 15. Protein-nitrogen concentration in forage for the
May 4, 1970 harvest compared across varieties
and across sprays

Varieties	Sprayings			Average
	0	1	2	
	Percent			
Team	2.94	2.94	2.97	2.95c*
Weevilchek	3.16	3.15	3.10	3.14a
Saranac	3.03	3.10	3.12	3.08ab
Buffalo	2.91	3.17	3.01	3.03b
Average	3.01a	3.09a	3.05a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

levels with 3.14 percent. The lowest average protein-nitrogen concentration was 2.95 percent for Team. Saranac was not significantly different from Weevlchek and had an average protein-nitrogen percentage of 3.08 percent (Table 15).

Protein-nitrogen concentrations for May 10, 1971 are shown in Table 16. Concentrations ranged from 3.26 to 3.94 percent. Weevlchek-Spray 0 and Saranac-Spray 0 produced the highest average protein-nitrogen percentages with 3.94 and 3.92 metric tons/ha, respectively. Buffalo-Spray 2 plots averaged the lowest with 3.26 percent,

On May 10, 1971, the Spray 0 treatments represented the highest average concentration of protein-nitrogen (Table 17). Concentrations for the main treatments were 3.81, 3.49, and 3.47 for Spray 0, Spray 2, and Spray 1, respectively. Spray 0 was significantly higher in protein-nitrogen percentage than the other main treatments.

Weevlchek, Saranac, and Team had the highest average protein-nitrogen concentrations on May 10, 1971, of the split-plot treatments (Table 17). These three varieties were significantly higher than Buffalo. Concentrations ranged from 3.41 to 3.67 percent. Weevlchek had the highest concentration at 3.67 percent. The lowest concentration was 3.41 percent for Buffalo.

Glucose Concentration

Since almost all feeding occurs on the leaves, only leaves were analyzed for glucose concentration which is thought to be a feeding stimulant. Only the Spray 0 plots were used to test the natural resistance of the varieties.

Table 16. Protein-nitrogen concentrations in forage on May 10, 1971

No. of sprays	Variety	Protein-Nitrogen
		Percent
0	Weevlc hek	3.94a*
0	Saranac	3.92a
0	Team	3.70ab
0	Buffalo	3.66b
2	Weevlc hek	3.58b
2	Team	3.57bc
1	Team	3.55bc
2	Saranac	3.54bc
1	Saranac	3.53bc
1	Weevlc hek	3.48bcd
1	Buffalo	3.32d
2	Buffalo	3.26d

*Values followed by the same letter are not significantly differently at the .05 level of probability.

Table 17. Protein-nitrogen concentrations in forage for the May 10, 1971 harvest compared across sprays and across varieties

Varieties	Sprayings			Average
	0	1	2	
			Percent	
Team	3.70	3.55	3.57	3.61a*
Weevlchek	3.94	3.48	3.58	3.67a
Saranac	3.92	3.53	3.54	3.66a
Buffalo	3.66	3.32	3.26	3.41b
Average	3.81z	3.47b	3.49b	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Glucose concentrations in alfalfa leaves during 1970 from the Spray 0 plots ranged from 1.22 to 1.48 percent. However, these concentrations were not significantly different. Buffalo had the highest average concentration with 1.48 percent. The lowest average concentration came from the Team plots with 1.22 percent. Saranac and Weevlc hek were intermediate with 1.38 and 1.34 percent, respectively (Table 18).

Sampling dates were not significantly different in early spring of 1970. Concentrations ranged from 0.89 to 2.26 percent. April 27 produced the highest average concentration at 2.26 percent. The lowest average concentration was on May 4, with 0.89 percent. The other sampling dates were relatively even in glucose concentration.

Nitrate-Nitrogen Concentration

Nitrate-nitrogen (a possible feeding deterrent) concentrations for the Spray 0 plots in early spring ranged from .006 to .007 percent within varieties, and were not significantly different (Table 19). Team, Saranac, and Buffalo had the highest concentrations at .007 percent.

The sampling dates were not significantly different (Table 19). Average concentrations for these dates ranged from .004 to .010 percent. June 15 had the highest average concentration at .010 percent, and April 27 showed the lowest average concentration with .004 percent.

Larval Feeding

The forage was evaluated on May 4, 1970 for damage caused by larval feeding. Table 20 shows the average value over four replications.

Table 18. Glucose concentration of alfalfa leaves compared across dates and across varieties

Spray	Variety	Sampling dates				Average
		Apr. 20	Apr. 27	May 4	June 15	
				Percent		
0	Team	1.07	2.03	0.83	0.96	1.22a*
0	Weevlchek	1.17	2.16	0.87	1.17	1.34a
0	Saranac	0.97	2.39	0.99	1.16	1.38a
0	Buffalo	1.17	2.47	0.85	1.43	1.48a
Average		1.10a	2.26a	0.89a	1.18a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 19. Nitrate-nitrogen concentration of alfalfa leaves
compared across dates and across varieties

Spray	Variety	Sampling dates				Average
		Apr. 20	Apr. 27	May 4	June 15	
				Percent		
0	Team	.004	.005	.007	.012	.007a*
0	Weevlchek	.006	.004	.006	.008	.006a
0	Saranac	.006	.006	.009	.009	.007a
0	Buffalo	.007	.003	.008	.009	.007a
Average		.006a	.004a	.008a	.010a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 20. Larval feeding damage values for 1970

No. of sprays	Variety	Damage value
2	Team	3.1a*
2	Buffalo	3.3a
2	Weevlc hek	3.6a
2	Saranac	3.6a
1	Saranac	3.5a
1	Team	4.8a
1	Buffalo	5.0a
1	Weevlc hek	5.1a
0	Team	6.0a
0	Weevlc hek	6.6a
0	Saranac	7.0a
0	Buffalo	7.3a

*Values followed by the same letter are not significantly different at the .05 level of probability.

A value of 0 indicates no damage while a value of 10 indicates complete destruction. Damage values ranged from 7.3 to 3.1. This indicates 70 percent destruction in the control plots and 30 percent in the plots receiving Spray 2.

An analysis of variance revealed that Spray 1 and Spray 2 gave significantly more control than Spray 0 (Table 21). Damage values ranged from 6.7 to 3.4. Spray 2 treatments had best control at 3.4, and Spray 0 treatments were damaged most with a damage value of 6.7.

Varietal treatments were not significantly different in 1970. However, Team received the least damage with a value of 4.6. Damage values ranged from 5.2 to 4.6. Buffalo was least resistant with an average damage value of 5.2 (Table 21).

Only one replication was rated for damage in 1971. These values appear in Table 22. Spray 2 was the only main treatment to control larvae feeding. Spray 1 and Spray 0 both allowed approximately 50 percent damage by larvae. Team received slightly less damage than the other varieties.

II. EXPERIMENT B

Alfalfa weevil feeding damage was evaluated on May 10, 1971. Damage values are presented in Table 23. Methyl parathion plus commercial 30 percent nitrogen solution gave best control. Methyl parathion alone and commercial 30 percent nitrogen solution alone both provided some control. The other treatments did not deter larval feeding by any visible amount.

Table 21. Larval feeding damage values for 1970 compared across sprayings and across varieties

Varieties	Sprayings			Average
	0	1	2	
Team	6.0	4.8	3.1	4.6a*
Weevilcheck	6.6	5.1	3.6	5.1a
Saranac	7.0	4.5	3.6	5.0a
Buffalo	7.3	5.0	3.3	5.2a
Average	6.7b	4.9a	3.4a	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 22. Feeding damage values for 1971

No. of sprays	Variety	Damage value
2	Team	1
2	Weevlc hek	1
2	Saranac	1
2	Buffalo	1
0	Team	4
1	Weevlc hek	4
1	Saranac	4
0	Saranac	5
1	Team	5
0	Weevlc hek	6
0	Buffalo	6
1	Buffalo	6

Table 23. Larval damage values on May 10, 1971

Control measure	Damage value
25% methyl parathion + commercial 30% nitrogen solution	1.5
25% methyl parathion	2.0
Commercial 30% nitrogen solution	6.0
10% tannic acid	9.0
10% tannic acid + 25% dimethyl sulfoxide	9.0
25% dimethyl sulfoxide	9.0
10% tannic acid + 2% surfactant	9.0
Nothing	9.0

III. EXPERIMENT C

Forage Production

Alfalfa weevil damage or chemical damage was severe in the early spring growth on all treatments. The early spring growth was clipped off and very little regrowth (as shown in Table 24) occurred following the first clipping due to weevil and chemical damage. An application of liquid nitrogen fertilizer, a possible deterrent to weevil feeding, was fatal to many alfalfa plants.

Yield of forage dry matter is presented in Table 24 for the regrowth cutting of June 30, 1970. Yields ranged from 214 to 1533 kg/ha. The check treatment (no nitrogen) produced the most dry matter, and generally the treatments receiving applications of solid nitrogen sources produced higher yields than liquid applications. The lowest yield was harvested from the liquid sodium nitrate treatment.

Nitrogen sources were calculated to be highly significant. Average dry matter yields ranged from 686 to 1375 kg/ha (Table 25). Treatments containing urea and the check (no nitrogen) produced more dry matter than those containing ammonium nitrate, sodium nitrate, and ammonium sulfate. These latter treatments severely damaged the plants when in liquid form. Solid applications were significantly higher when compared to liquid treatments.

Nitrate-Nitrogen Concentrations in Alfalfa Leaves

Nitrate-nitrogen concentrations in alfalfa leaves on April 8, 1970 are presented in Table 26. Plots receiving nitrogen sources in solid form were higher in nitrate-nitrogen than the liquid treatment

Table 24. Forage dry matter production on June 30, 1970

Nitrogen Sources	Form	Yield
		kg/ha
Nothing	Solid	1533a*
Urea	Liquid	1323ab
Ammonium sulfate	Solid	1276ab
Urea	Solid	1274ab
Nothing	Liquid	1217ab
Sodium nitrate	Solid	1187b
Urea + ammonium nitrate	Solid	1114b
Urea + ammonium nitrate	Liquid	1094b
Ammonium nitrate	Solid	1050b
Ammonium sulfate	Liquid	394c
Ammonium nitrate	Liquid	322c
Sodium nitrate	Liquid	214c

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 25. Forage dry matter yields for June 30, 1970 compared across form of application and across nitrogen sources

Nitrogen Sources	Form		Average
	Solid	Liquid	
Ammonium nitrate	1050	322	kg/ha 686c*
Sodium nitrate	1187	214	700c
Ammonium sulfate	1276	394	835bc
Urea	1274	1323	1298a
Urea + Ammonium nitrate	1114	1094	1104ab
Nothing	1533	1217	1375a
Average	1239a	761b	

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 26. Nitrate-nitrogen concentration in alfalfa leaves on
April 8, 1970

Nitrogen Sources	Form ⁺	Nitrate-nitrogen
Sodium nitrate	Solid	Percent .020a*
Ammonium nitrate	Solid	.019a
Urea + Ammonium nitrate	Solid	.017ab
Urea	Solid	.014b
Ammonium sulfate	Solid	.006c
Nothing	Solid	.006c
Ammonium nitrate	Liquid	.006c
Ammonium sulfate	Liquid	.006c
Nothing	Liquid	.006c
Sodium nitrate	Liquid	.005c
Urea	Liquid	.005c
Urea + Ammonium nitrate	Liquid	.005c

⁺ Solid form of nitrogen sources applied on March 16, 1970 and liquid form of nitrogen sources applied on April 14, 1970.

*Values followed by the same letter are not significantly different as the .05 level of probability.

plots, but applications of the liquid sources were not made until April 14 while solid sources were applied on March 16. Concentrations ranged from .005 to .020 percent. Sodium nitrate applied in solid form produced the highest nitrate-nitrogen percentage. Sodium nitrate, ammonium nitrate, urea plus ammonium nitrate, and urea increased the concentration in leaves, but not enough to deter weevil feeding.

Form of application was highly significant. Application of nitrogen sources in solid form more than doubled the amount obtained compared with plots receiving no nitrogen application. The average concentration for solid sources was .014 percent while only .006 for the check plots. Neither solid nor liquid sources deterred alfalfa weevil larvae feeding.

Glucose Concentrations in Alfalfa Leaves

Glucose concentrations in alfalfa leaves were not significantly different among treatments. Concentrations of glucose ranged from 2.24 to 3.02 percent. The glucose concentrations are presented in Table 27 for all treatments on April 8, 1970.

Analysis of variance indicated that none of the nitrogen sources applied in solid form were significantly different. Ammonium sulfate applied in solid form produced the highest glucose concentration where nitrogen was applied, but this value is lower than one of the checks which contained 3.02 percent glucose.

Table 27. Glucose concentration in alfalfa leaves on
April 8, 1970

Nitrogen Source	Form ⁺	Glucose
		Percent
Nothing	Solid	3.02a*
Ammonium sulfate	Liquid	2.89a
Sodium nitrate	Liquid	2.85
Ammonium sulfate	Solid	2.83a
Ammonium nitrate	Solid	2.83a
Urea + ammonium nitrate	Solid	2.79a
Sodium nitrate	Solid	2.70a
Nothing	Liquid	2.65a
Urea + ammonium nitrate	Liquid	2.64a
Urea	Liquid	2.45a
Ammonium nitrate	Liquid	2.34a
Urea	Solid	2.24a

⁺ Solid form of nitrogen sources applied on March 16, 1970 and liquid form of nitrogen sources applied on April 14, 1970.

*Values followed by the same number are not significantly different at the .05 level of probability.

CHAPTER V

DISCUSSION

Alfalfa yield was significantly increased in 1970 by spraying once with Alfatox insecticide when compared with Spray 2. Team-Spray 1 and Team-Spray 0 treatments produced significantly highest yields of all treatments. Yields in 1970 ranged from 7.09 to 8.73 metric tons/ha. Alfalfa weevil infestation in 1970 was relatively mild. Treatments receiving Spray 1 produced the highest average yield of 8.13 metric tons/ha. Spray 2 produced the lowest average yield at 7.70 metric tons/ha.

Average yields for varieties in 1970 ranged from 7.37 to 8.52 metric tons/ha. An analysis of variance indicated variety effects were highly significant in 1970. Team had the highest average yield under all spraying treatments at 8.52 metric tons/ha, but it was not significantly greater than Saranac. Buffalo had the lowest average yield with 7.37 metric tons/ha.

Forage yields for the first cutting in 1970 ranged from 2.98 to 4.37 metric tons/ha. Team-Spray 1 produced the highest average yield on this date and Buffalo-Spray 0 produced the lowest yield.

Spraying levels effects on first cutting 1970 were not significantly different. Average forage yields ranged from 3.41 metric tons/ha for the Spray 0 level to 3.79 metric tons/ha for the Spray 2 level.

Varieties were significantly different on May 4, 1970. Team had the highest average yield and Buffalo had the lowest with 4.09

and 3.15 metric tons/ha, respectively. Saranac yielded 3.80 metric tons/ha and was not significantly different from Team.

In 1971, forage yields ranged from 0.71 to 2.17 metric tons/ha for the first cutting. Analysis of variance revealed spray treatments to be highly significant. Spray 2 had the highest average yield with 1.92 metric tons/ha. Lowest yields came from check plots which averaged only 1.02 metric tons/ha, or only one-half that of two spray applications. Alfalfa weevil infestation was heavy in 1971 and increased the importance of using an insecticide.

Alfalfa varieties were highly significant in 1971. Team and Saranac were significantly better than the other varieties. Yields ranged from 1.23 to 1.86 metric tons/ha. Team had the highest average yield again in 1971 with 1.86 metric tons/ha. Buffalo was the lowest yielding variety with 1.23 metric tons/ha. Saranac and Weevlchek were intermediate in yield both years, but Saranac had the higher average. In a year of heavy infestation, none of the varieties tested was resistant to feeding by the alfalfa weevil by visual rating, but Team produced much more with Spray 0. In a mild infestation year, Team appeared to produce slightly more forage.

Protein-nitrogen concentrations in 1970 ranged from 3.07 to 3.33 percent. Saranac-Spray 2 produced the highest concentration while Buffalo-Spray 2 produced the lowest concentration. Average concentrations for all sprays was almost identical in 1970.

Analysis of variance indicated that the varieties were highly significant. Average concentrations ranged from 3.13 to 3.28 percent. Saranac, Weevlchek, and Team had almost identical protein-nitrogen

concentrations, and they were significantly higher than Buffalo with only 3.13 percent.

Protein-nitrogen concentration on May 4, 1970 was highest in the Buffalo-Spray 1 and lowest in the Buffalo-Spray 0 plots. Concentrations ranged from 2.91 to 3.17 percent. Average protein-nitrogen concentrations for spraying levels were not significantly different. Concentrations ranged from 3.01 to 3.09 percent.

Varieties were highly significant on May 4, 1970 when weevil damage was present. Concentrations of protein-nitrogen ranged from 2.95 to 3.14 percent. Weevilchek had the highest average protein-nitrogen concentration on this date with 3.14 percent. Team had the lowest with 2.95 percent.

Protein-nitrogen concentrations in forage on May 10, 1971 ranged from 3.26 to 3.94 percent. Weevilchek-Spray 0 had the highest concentration, and Buffalo-Spray 2 had the lowest concentration. Saranac-Spray 0 was also significantly higher in protein-nitrogen concentration than other treatments with 3.92 percent.

Sprays were significantly different in 1971 at the .05 level of probability. The check treatments or Spray 0 had a higher average protein-nitrogen percentage than treatments receiving sprays. This did not agree with results of Walstrom et al. (49) who found a higher percentage with spray. Concentrations ranged from 3.47 to 3.81 percent as compared with a range of 2.91 to 3.17 percent on the first cutting 1970. Varieties were highly significant in the first cutting of 1971. Concentrations ranged from 3.41 to 3.67 percent. Weevilchek had the highest average percentage, but was

followed very closely by Saranac and then Team. These three varieties were all significantly higher in protein-nitrogen content than Buffalo.

Glucose concentrations in the leaves in early spring of 1970 were not significantly different. Concentrations ranged from 0.83 to 2.47 percent from April 7 to June 15. However, no variety was significantly different from any other variety so no difference in resistance could be attributed to differences in glucose as an attractant. Buffalo contained the highest average glucose concentration at 1.48 percent in 1970. Team had the lowest with 1.22 percent. Dates of sampling were not significantly different. Average glucose concentrations ranged from 0.89 on May 4, 1970 to 2.26 on April 27, 1970.

Nitrate-nitrogen analysis of variance for the early spring leaf samples revealed no significant differences. Concentrations ranged from .003 to .12 percent. Average nitrate-nitrogen concentrations for varieties ranged from .006 to .007 percent. Team, Saranac, and Buffalo had an average of .007 percent in the Spray 0 plots. Weevilchek had the lowest average nitrate-nitrogen concentration at .006 percent. Sampling dates for early spring 1970 were not significantly different. Nitrate-nitrogen concentrations ranged from .004 percent on April 27, 1970 to .010 percent for June 15, 1970. Since none of the varieties contained a significantly different amount of nitrate-nitrogen, no resistance can be attributed to nitrate-nitrogen deterrence.

Analysis of the larval feeding damage values in 1970 revealed sprays to significantly affect feeding. Spray 2 and Spray 1 had

significantly lower damage values than Spray 0. Values ranged from 6.7 to 3.4. Spray 2 had the lowest value with 3.4 and Spray 0 had the highest value at 6.7. Varieties were not significantly different at the .05 level of probability. However, Team had the lowest average damage value of 4.6 and Buffalo had the highest at 5.2. Team, Saranac, and Weevilchek also produced more forage than Buffalo in 1970 and were higher in protein-nitrogen percentage.

Methyl parathion gave better protection in 1971 than nitrogen solutions, dimethyl sulfoxide, tannic acid, surfactants or any combinations used. Methyl parathion plus a commercial 30 percent nitrogen solution gave best results by protecting alfalfa almost completely from weevil damage. Failure of the other treatments resulted in a loss of all forage production.

Nitrogen sources were highly significant in yield production of the first regrowth cutting in 1970. Yields ranged from 686 to 1375 kg/ha. Check plots had the highest yield but were followed closely by urea. The form of nitrogen applied was also highly significant. Solid forms averaged almost twice as much yield as liquid forms because the liquid forms killed the plants. Yields were 1240 kg/ha for solid applications and 761 for liquid forms. Nitrogen source x form was also significant. The highest yield came from a check treatment with 1533 kg/ha. Lowest yield was harvested from a liquid application of sodium nitrate with 214 kg/ha. Alfalfa weevil damage was severe on the first growth of all treatments.

Nitrate-nitrogen concentrations in early April ranged from .005 to .020 in this experiment. Plots receiving solid forms of

ammonium nitrate and sodium nitrate were significantly higher in nitrate-nitrogen than any other treatment. Control plots were lowest in concentration with .005 percent.

Glucose content was not significantly affected by nitrogen sources. Concentrations ranged from 2.24 to 3.02 percent. The highest value came from a check plot, and liquid urea produced the lowest glucose content. Average concentrations for the nitrogen sources ranged from 2.35 to 2.86 percent. No treatment effects were significant, but ammonium sulfate plots averaged the highest glucose content while urea plots averaged the lowest.

Results of these investigations indicate that two sprayings of Alfatox are needed to control alfalfa weevil larval feeding in years of heavy infestation. Team had the highest average yield within each spray level. Sprays did not affect protein-nitrogen content. Saranac, Weevilchek, and Team were all higher in protein-nitrogen percentage than Buffalo. Alfalfa weevil damage was decreased with increasing applications of insecticide. Glucose and nitrate-nitrogen were not affected significantly by spraying levels or varieties. Team had the lowest average larval feeding damage value. Methyl parathion plus commercial 30 percent nitrogen solution gave good control as did methyl parathion alone. Applications of urea and mixtures containing urea applied in solid form produced good yields of regrowth, but offered little weevil resistance. Plant damage occurred from this rate of nitrogen in a liquid application. All nitrogen sources increased nitrate-nitrogen percentages. Glucose percentage was not affected by nitrogen source.

None of the varieties were weevil resistant as measured by visual score. Team did produce the highest yields in both years. Spraying with Alfatox or methyl parathion will provide adequate protection from weevil feeding. Concentrations of glucose and nitrate-nitrogen did not appear to affect weevil feeding. The reason for lack of resistance could be that nitrate-nitrogen concentrations were much lower in alfalfa than reported by Akeson et al. (2) in a sweetclover strain's resistance to the sweetclover weevil. Also nitrate-nitrogen in alfalfa leaves may not repel alfalfa weevil larvae.

CHAPTER VI

SUMMARY

Three alfalfa weevil (Hyper postica Gyllenhal) experiments were conducted at the Plant Science Farm, Knoxville, Tennessee during 1970 and 1971. Treatments applied to the alfalfa (Medicago sativa L.) were different insecticides, varieties, and nitrogen fertilizers. The effects measured were dry matter production, protein-nitrogen, nitrate-nitrogen, and glucose concentration.

Twelve combinations of two factors were incorporated into Experiment A. The alfalfa was sprayed either not at all, once, or twice with Alfatox at 1.15 l/ha. Four alfalfa varieties were included as split-plot treatments. Team, Weevlchek, Saranac, and Buffalo were the alfalfa varieties. Team produced the highest yield of the four varieties and Buffalo produced the lowest. Yields ranged from 7.09 to 8.73 metric tons/ha. Only one spraying of Alfatox was needed to control feeding under mild weevil infestation (1970) while two sprayings were needed under heavy infestation (1971).

Protein-nitrogen concentrations ranged from 3.14 to 3.28 percent. Saranac had the highest concentration, but Weevlchek and Team were also significantly higher than Buffalo. Sprays did not affect protein-nitrogen concentration in 1970. Glucose and nitrate-nitrogen were not affected by spraying level or varieties.

Larval feeding damage ranged from severe to slight. Damage was independent of varieties, but Spray 1 and Spray 2 were significantly

better than Spray 0. Team had the lowest damage value and Buffalo the highest value.

Experiment B was an evaluation of 8 chemical treatments and a check. Damage values ranged from 9 to 1.5. Twenty-five percent methyl parathion plus commercial 30 percent nitrogen solution gave the best protection followed closely by 25 percent methyl parathion. Commercial 30 percent nitrogen solution increased growth but had a damage value of 6.0. All other treatments offered no protection.

Five nitrogen sources were used as main treatments in Experiment C. Subsidiary plots were solid and liquid application of the nitrogen sources. Nitrogen rate was 56 kg/ha. Forage dry matter yields ranged from 214 to 1533 kg/ha in the spring regrowth. Liquid forms were applied at the same rate except in 1.9 l water. Check plots produced the highest yield, but solid applications produced almost twice the amount of forage that liquid plots produced. Liquid applications at this rate caused severe damage to the plants. Plots receiving urea produced the highest yield while ammonium nitrate plots produced the least.

Nitrate-nitrogen concentrations ranged from .005 to .020. Solid sodium nitrate produced the highest concentration, and check plots produced the lowest. Solid application of nitrogen sources increased nitrate-nitrogen concentrations in plants, but the concentration of nitrates was not enough to deter weevil feeding which was severe. Treatments receiving solid applications averaged 0.14 percent while check plots averaged .006 percent. Liquid applications caused severe chemical damage to leaves and stems. Glucose concentration

ranged from 2.24 to 3.02 percent, but was not affected by nitrogen source or form of application.

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APPENDIX

Table 28. Analyses of variance for Experiment A

Source of Variation	Degrees of Freedom	Mean Squares	F ratios
<u>1970 total forage yield</u>			
Sprays	2	0.1859	5.64*
Varieties	3	0.5616	5.47**
S x V	6	0.0299	0.29
<u>1970 Average protein-nitrogen concentration</u>			
Sprays	2	0.0005	0.12
Varieties	3	0.0397	6.49**
S x V	6	0.0086	1.41
<u>May 4, 1970 forage yield</u>			
Sprays	2	0.1272	2.52
Varieties	3	0.3819	13.86**
S x V	6	0.0294	1.07
<u>May 4, 1970 protein-nitrogen concentration</u>			
Sprays	2	0.0196	0.66
Varieties	3	0.0562	9.48**
S x V	6	0.0142	2.39
<u>May 10, 1971 forage yield</u>			
Sprays	2	0.65	45.09**
Varieties	3	0.20	10.89**
S x V	6	0.02	1.21
<u>May 10, 1971 protein-nitrogen concentration</u>			
Sprays	2	0.41	8.93*
Varieties	3	0.13	7.21**
S x V	6	0.02	1.08
<u>1970 glucose concentration</u>			
Varieties	3	1.52	0.49
Dates	3	9.19	2.97
V x D	0	0.05	0.99

Table 28. Analyses of variance for Experiment A (Continued)

Source of Variation	Degrees of Freedom	Mean Squares	F ratios
<u>1970 average nitrate-nitrogen concentration</u>			
Varieties	3	0.00010	2.36
Dates	3	0.00003	0.48
V x D	9	0.00001	0.65
<u>1970 weevil feeding damage</u>			
Sprays	2	44.15	9.88*
Varieties	3	0.74	1.42
S x V	6	0.51	0.98

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

Table 29. Analyses of variance for Experiment C

Source of Variation	Degrees of Freedom	Mean Squares	F ratios
<u>June 30, 1970 forage yield</u>			
Source of Nitrogen	5	580,770.77	6.99**
Form of Nitrogen	1	2,186,667.18	44.41**
S x F	5	313,494.64	6.37**
<u>April 8, 1970 glucose concentration</u>			
Source of Nitrogen	5	0.3813	1.38
Form of Nitrogen	1	0.1441	0.42
S x F	5	0.2069	0.60
<u>April 8, 1970 nitrate-nitrogen concentration</u>			
Source of Nitrogen	5	0.0000	1.24
Form of Nitrogen	1	0.0010	23.57**
S x F	5	0.0001	2.02

**Significant at the .01 level of probability.

VITA

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