IMPROVING FORAGE PRODUCTION AND PROFITABILITY IN THINNING ALFALFA STANDS WITH INTEGRATED MANAGEMENT AND LIVESTOCK GRAZING

By

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Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, OK

1997

Submitted to the Faculty of the
Graduate College of
Oklahoma State University
in partial fulfillment of
the requirements for
the degree of
MASTER OF SCIENCE
May, 2000

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PROFITABILITY IN THINNING ALFALFA

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ACKNOWLEDGEMENTS

The author would like to thank his major adviser, Dr. Jim F. Stritzke, professor of Plant and Soil Sciences, Dr. Richard C. Berberet, professor of Entomology, and Dr. P.L. Claypool, professor of Statistics for their assistance, guidance, helpful criticism, and support during the course of this research. On a personal note, I would especially like to thank Jim Stritzke and Richard Berberet for their help in and out of the fields of labor. The extent of knowledge that I gained from these individuals is indisputably the best education I could receive at Oklahoma State University inside and outside of the classroom.

Appreciation is also extended to the Department of Plant and Soil Science and the Department of Entomology and Plant Pathology for the research funding and personnel to complete this research. I want to thank Ken Nelson, Trey Koger, Kevin Nickell, James Enis, Jake Boyett, Jeff Fassett, Don Hooper and the Chickasha crew, Tommy Pickard and the Haskell crew, and Art Bisges for their dedication and hard work throughout this research. I want to extend a special thanks to Sabrina Hurst, Jeff Fassett, Jamie Donaldson, and James 'Neil' Enis for all the good times, help, and encouragement over the last couple of years.

The author extends his sincere appreciation to his parents, Dan and Cindy, for their love, dedication, and understanding; and to my brother and sister-in-law, Steve and Lisa, for their help and encouragement through the tough times in my life.

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INTRODUCTION

Chapter I of this thesis is a literature review on alfalfa management and stand life. Chapters II and III are to be submitted for publication in Agronomy Journal, published by the American Society of Agronomy.

BACKGROUND

Alfalfa production in Oklahoma and is valued at over $120 million per year and is an important factor in livestock as both hay and standing forage used for grazing. With over 162,000 hectares in alfalfa production in the state of Oklahoma, the crop brings is grown on only 1/10 the hectares of wheat production.

PROBLEM

The cost of establishing a stand of alfalfa is estimated at $320 ha^{-1}, therefore it is economically important to develop and utilize alfalfa management strategies that will maximize the longevity of the stand. Many alfalfa fields in Oklahoma are managed below optimal levels of soil phosphorus, potassium, or pH, leading to decreased alfalfa competitiveness with weeds. Weed interference in thinning alfalfa stands can significantly reduce alfalfa productivity at first harvest. As alfalfa stands thin, alfalfa plant populations decrease and weeds become more competitive with alfalfa for resources like water, light, and nutrients. Alfalfa yield is also reduced at the first harvest by alfalfa weevils, *Hypera postica* (Gyllenhal). Alfalfa weevil females can lay between 400 and 1000 eggs each in old alfalfa stems if not controlled. The weevil eggs can hatch in approximately 350 degree days Farenheit. The alfalfa weevil larvae (the most damaging life stage) begin feeding in late winter and early spring (Berberet et al., 1980).

GOAL OF STUDY

The goal of this research is to evaluate the use of cattle grazing (with and without over-seeded cool-season grasses) as an alternative to mechanical harvesting to increase the profitability of thinning alfalfa stands.

OBJECTIVES

I. **<u>Evaluation of haying and grazing harvest methods on alfalfa weevil incidence, alfalfa forage production, and stand density in an established alfalfa stand</u>**

(Hypothesis: The haying and grazing harvest methods will be similar in production, but the grazing method will provide less risk in harvesting problems for the producer and be more profitable.)

Haying and grazing harvest methods were evaluated in the alfalfa variety grazing trial at the Eastern Oklahoma Agronomy Research Station, Haskell, Oklahoma with the following treatments:

1. 'Alfagraze', 'OK08', 'OK49', 'OK178', and 'Cimarron VR' entries planted in a randomized complete block with 4 replications
2. Main plots (entries) were divided with one half hayed and one-half grazed to make a split plot design in strips
3. Alfalfa weevil populations monitored in all subplots

II. **Evaluation of over-seeded, cool-season forage grasses and spring grazing with cattle to improve forage production and profitability in thinning alfalfa stands**

(Hypotheses: Forage production and profitability will be increased with the addition of cool-season forage grasses. Livestock grazing the alfalfa-grass forage will decrease the alfalfa weevil habitat and disrupt weevil reproduction so that populations can be maintained below economic threshold levels. The over-seeded, cool-season grasses will fill the void left open by thinning alfalfa plants and compete with the less desirable cool-season weeds.)

A. Objective II was evaluated in thinning alfalfa stands at three locations with the following treatments in a randomized complete block design with 3 or 4 replications:

1. Hayed – weeds and insects controlled at economic threshold levels
2. Hayed – with no pesticides used for weeds or insects
3. Grazed – with no over-seeded grasses
4. Grazed – with wheat over-seeded (with a no-till drill) in October
5. Grazed – with ryegrass over-seeded (with a no-till drill) in October
6. Grazed – with oats over-seeded (with a no-till drill) in January

B. The main plots were divided in 1999 so that one half of each plot had 130 kg ha^{-1} applied to test the effects of increased fertility on the over-seeded grasses

CHAPTER I

LITERATURE REVIEW

Literature Review

BACKGROUND AND SIGNIFICANCE

Alfalfa (*Medicago sativa* L.) is a perennial, forage legume introduced into the United States in the late 1800's (Caddel, 1997). Alfalfa production in Oklahoma is valued at over $120 million per year and is a key factor in feeding livestock from both the cut hay produced and the standing forage used for grazing. With over 162,000 hectares in alfalfa production in the state of Oklahoma, the crop brings approximately $1 billion in spending power for the state, grown on only 1/10 the hectares of wheat production. However, alfalfa is also one of the most cost intensive crops to grow.

Establishment costs alone are estimated at $320 ha^{-1}, with annual costs for herbicide and insecticide applications valued at over $100 ha^{-1} per year (Diel, 1991). Costs of alfalfa establishment are usually not completely recovered until the third year of production. In one example, stem densities of alfalfa from the second year to the fifth year of production were above 21.5 stems 0.1m^{-2} and alfalfa production was good. By the fifth and sixth year of production, stem densities were below 21.5 stems 0.1m^{-2} and alfalfa yield significantly decreased (Cummings et al., 1999). When the alfalfa production declines, profitability of the stand also declines. At some point, the producer must decide whether to plow up the old alfalfa stand or continue producing marginally profitable alfalfa from the thinning stand. Profitability of the thinning alfalfa stand might be improved by over-seeding with cool-season forage grasses and grazing in the spring during peak alfalfa weevil Hypera postica (Gyllenhal) hatch. This should result in reduced pesticide costs and increased spring forage production for grazing.

In Oklahoma, alfalfa is grown primarily for dairy, beef, or horse hay; however, alfalfa stands can also be grazed by livestock like sheep, cattle and goats. When used for hay, alfalfa can be harvested from three to six times each year (Sheaffer et al., 1988) and stands can remain productive for 8 years, if well managed. Cutting intervals range from 25-35 days between cuttings, with the first cutting of alfalfa usually taken in late April (or when crown buds start to send up new shoots from the base of the plant). The first cutting of alfalfa is usually the most productive and can provide up to 40 % of the total annual alfalfa production per year in alfalfa (Latheef et al., 1988). When grazed, alfalfa can be as effective as hayed alfalfa if managed properly. Both hayed and grazed alfalfa stands thinned to the same degree after four years of production (Caddel, 1997).

Alfalfa production is decreased by insects and by weeds, especially where natural stand decline promotes an increase weed infestation (Altom, 1990). The most common insect pest is the alfalfa weevil, *Hypera postica* (Gyllenhal). Researchers in Oklahoma reported larval feeding of this pest alone can reduce first harvest yield of established alfalfa by 1000 kg ha^{-1} (Berberet et al., 1987). Buntin (1989) reported alfalfa weevil larval feeding reduced the competitive ability of the alfalfa plants, allowing weeds to grow and occupy open space left by the declining alfalfa stand. These cool-season weeds can also decrease alfalfa production in thinning stands. Kapusta and Streiker (1975) reported that increased alfalfa yields in an established alfalfa stand were directly related to decreased downy brome (*Bromus tectorum* L.) yields.

Weed and Insect Suppression in Thinning Alfalfa Stands

Weed Management. Currently, cool-season weeds are controlled with a dormant season application of broad spectrum, herbicides. Two important herbicides for Oklahoma alfalfa production are terbacil and hexazinone. Both herbicides are applied in the winter or early spring when there is little alfalfa growth (Stritzke, 1989; Swan, 1972). This not only prevents injury to the alfalfa, but also controls cool-season weeds which compete with alfalfa during growth of the first crop. In 1988, terbacil was applied on 53% of the total alfalfa acreage (Stark et al., 1990). Since that time, hexazinone has replaced terbacil in western Oklahoma. It requires less rainfall for activation and still provides good control of a wide spectrum of grass and broadleaf weeds. Hexazinone is not used statewide because it is very water soluble and can leach out of the soil with significant rainfall events. Terbacil is not as water soluble, so its use is more dependable in central and eastern Oklahoma.

The dormant application of herbicides like terbacil and hexazinone control most cool-season grasses and broadleaf weeds resulting in weed-free alfalfa hay at first harvest. Weeds are usually not a problem in second harvest alfalfa because cool-season weeds were harvested with the first cutting growth and warm-season weeds are minimal. By the third harvest, however, warm-season weeds like crabgrass (*Digitaria* spp.) and pigweeds (*Amaranthus* spp.) will be large enough to contribute to forage production.

Summer grasses can be controlled by sethoxydim, clethodim or paraquat applied soon after harvesting (Wilson, 1981; Wolf and Foy, 1984; Smith, 1995; Smith, 1991), or season-long control of summer annual grasses can be obtained with a preemergence application of norflurazon. However, due to problems such as erratic emergence, dry weather, poor application timing, or incorrect identification of the weed species, summer weeds are often not adequately controlled.

Insect Management. The alfalfa weevil is a perennial pest to alfalfa throughout the southern plains. The need for alfalfa weevil control is commonly determined by field scouting and by the accumulation of degree days (DD), calculated daily when the temperature rises above its developmental threshold of 50° F. One hundred fifty DD is sufficient for alfalfa weevil egg hatch. As soon as they hatch, alfalfa weevil larvae can begin feeding and causing damage to the plants. This usually occurs from February to mid-March in Oklahoma. When threshold levels are reached (as determined by the number of larvae in 30 stems at a given alfalfa plant height), control measures must be taken at the thresholds to avoid first-harvest damage. Alfalfa weevil larvae are effectively controlled by applying insecticides like carbofuran, methyl parathion or chlorpyrifos (Doss et al., 1993).

Integrated Management of Pests. Insect suppression and cool-season weed control are critical to the profitability of alfalfa production. In an attempt to control both insects and weeds, herbicides and insecticides are commonly used in concert. In 1987, Berberet et al. reported on the effect of weed and insect control on alfalfa production and stand longevity. Treatments included: 1) no weed or insect control, 2) weed control with herbicides [terbacil (.55 kg a.i./hectare) plus oryzalin (1.5 kg a.i./ha)] but no insect control, 3) insect control with insecticide [carbofuran (1.1 kg a.i./ha)] but no weed control, and 4) weed and insect control. The researchers found that alfalfa yield was reduced by 2.0 Mg/ha by insect damage when herbicides, but no insecticides were used, 0.4 Mg/ha with weed competition but no insect damage, and 3.7 Mg/ha in when both insect damage and weed competition were present. In contrast, stem densities were maintained at significantly higher levels with the use of pesticides. The no herbicide or insecticide treated alfalfa had the lowest stem density with 8.7 stems $0.1m^{-2}$, compared to the herbicide treated alfalfa (17.4 stems $0.1m^{-2}$) and herbicides plus insecticides (15.7 stems $0.1m^{-2}$). The alfalfa yield reductions suggest a synergistic effect between alfalfa weevil damage and weed competition, since the combined effects of both pests on forage yield and stand retention are greater than the sum of the effects occurring separately.

Gdara et al. (1991) reported that it was possible to maintain a productive stand for up to seven years if comprehensive weed and insect control programs are employed on improved cultivars. These results were confirmed in a later study that evaluated the contributions of alfalfa entries, optimal harvest schedules, and pest controls to alfalfa productivity and stand persistence (Latheef et al., 1992). The experiment tested four possible treatments of improved and unimproved alfalfa entries: 1) no pests controlled, 2) weeds controlled withherbicides [terbacil (.55 kg a.i./hectare) plus oryzalin (1.5 kg a.i./ha)], but no insect control, 3) insect control [carbofuran (1.1 kg a.i./ha)] but no weed control and 4) weed and insect control. Application of both insecticide and herbicide were found to be essential for productivity in years 5 through 7 of the experiment. At the termination of the study, only the herbicide + insecticide treatment on the improved alfalfa cultivar had sufficient stem densities remaining for continued alfalfa production.

Comparisons of Grazing and Hayed Alfalfa for Pest Control

In a declining stand of alfalfa, the cost of weed and insect control reduces the profitability from the hay produced. So, alternative management systems for control of insects and weeds in declining alfalfa stands require evaluation. Alfalfa has been used for grazing since the late 1800's, when alfalfa was introduced to the U.S. However, many producers do not graze alfalfa due to the increased profitability of selling the hayed crop (Caddel, 1997; Guerrero and Marble, 1991). In addition, the bloat problems associated with grazing cattle on alfalfa also limits producer acceptance of grazing for forage utilization.

In thinning alfalfa stands, weed composition of the total forage increases. Weeds decrease the quality of the forage produced and lower quality forage sells for a lower price than premium alfalfa hay. When the stand starts to decline (fifth or sixth year of production), the producer must decide between the decreased quality, production and profit of the conventionally hayed alfalfa, and profitability of grazing the weedy forage. Conventional hay harvest uses forage harvesters (swathers, balers, forage choppers, etc.) to take the forage off the field. In contrast, mob grazing uses livestock to harvest the standing forage, eliminating the need for mechanical harvest.

In Virginia, Wolf and Blaser (1981) reported that grazing alfalfa in early spring for insect control and taking the first hay harvest three weeks later than normal is a viable management alternative to conventional pesticide use and haying for alfalfa utilization. In Georgia, research was conducted over several years on grazing alfalfa. Spring grazing decreased alfalfa weevil larval densities by 60% in 1993 and 45% in 1994 (Buntin and

Bouton, 1996); however, larvae caused moderate to severe damage to the first alfalfa crop before grazing could decrease infestation. In the 1996 study, Buntin and Bouton reported that a combination of early application of an insecticide with a short grazing restriction, followed by grazing, allowed effective alfalfa weevil larval control and direct forage use by grazing. Therefore, early spring grazing on alfalfa not only controls the alfalfa weevils, but also provides good quality forage for the livestock (Jung et al., 1996; Temme et al., 1979).

Alfalfa-Grass Mixtures in Production Systems

Pure stands of alfalfa are commonly grazed, but to decrease bloat problems in the livestock, grasses such as ryegrass, orchardgrass, or timothy are seeded with alfalfa (Jung et al., 1982). These alfalfa-grass mixtures provide ample nutrition and fiber for growing livestock, while minimizing the chance of bloat. Bloat occurs when ruminants (cattle, sheep, etc.) consume fresh, or young alfalfa (and other legume) plants. Legumes cause an increase in the production of ammonia gas which leads to swelling in the first three compartments of the ruminant stomach. If uncontrolled the swelling can lead to the death of the animal.

The importance of alfalfa-grass mixtures lies not only in its ability to suppress bloat, but also in its ability to provide a complete nutritional balance for livestock. Jung et al. (1982) compared ryegrass-alfalfa and orchardgrass-alfalfa mixtures for dry matter yields, nutritional value, alfalfa persistence, animal acceptance, and average daily gain of beef cattle. Crude protein values were 22% for alfalfa, 20% for ryegrass, and 16% for orchardgrass. Ryegrass-alfalfa mixtures were higher in herbage protein (400 kg protein per ha per year more) and in vitro dry matter digestibility (7% higher) than orchardgrass-alfalfa mixtures. Jung and others concluded that average daily gain on ryegrass-alfalfa mixtures averaged 21% higher than those on orchardgrass-alfalfa mixtures. The researchers also concluded both orchardgrass- and ryegrass-alfalfa mixtures could be widely used for forage animal production systems.

Future Research Potential in the Area of Grazing and Companion Crops for Weed and Insect Control

These studies clearly show that effective control of weeds and alfalfa weevils is needed to ensure long term productivity of the alfalfa stand. Producer interest in grazing through winter and early spring on alfalfa fields has gained popularity. However, many of the insecticide treatments have grazing restrictions after application and do not allow continued grazing in early spring. Therefore, alternative solutions to chemical control or grazing alone must be obtained.

In thinning alfalfa stands, we propose alfalfa-grass mixtures and grazing with livestock will provide economical means of weed and insect suppression, without the large expense of chemical control. These alfalfa-grass mixtures will provide alfalfa producers an alternative to costly chemical control and allow a regionally specific use of alfalfa for the wheat producing areas of Oklahoma, Texas, and Kansas. In these regions where wheat pasture is grazed during the winter, stocker steer grazing must be terminated on wheat pasture at approximately the same time that alfalfa-grass mixtures would have optimal forage production. For the producer, this system provides the option of transferring stockers directly from wheat pasture grazing onto alfalfa-grass pasture.

Current systems also use perennial cool-season grasses, that do not allow the production of pure alfalfa hay in the later harvests of each year. By over-seeding annual grasses such as wheat or ryegrass, the producer will have the option of producing weed- and grass-free hay after the first or second harvest.

Cool-season grasses will occupy the open spaces left by the thinning stand of alfalfa. The cool-season grasses provide some control of cool-season weedy grasses and broadleaf weeds by competing with them for water, nutrients and space. Cool-season grasses established in thinning alfalfa stands will provide the producer the option of grazing the highly palatable alfalfa-grass mixture or using it as a hay crop for forage livestock (Jung, et al 1996; Moyer 1985).

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CHAPTER II

EVALUATION OF HAYING AND GRAZING HARVEST METHODS ON ALFALFA WEEVIL INCIDENCE, ALFALFA FORAGE PRODUCTION, AND STAND DENSITY IN AN ESTABLISHED ALFALFA STAND

Evaluation of haying and grazing harvest methods on alfalfa weevil incidence, alfalfa forage production, and stand density in an established alfalfa stand

ABSTRACT

Five established alfalfa (*Medicago sativa* L.) entries were evaluated over a two year period to determine the effects of two harvest methods (haying and short duration, high intensity grazing) on alfalfa weevil larvae incidence, forage composition and stand density. Cyfluthrin (0.045 kg a.i. ha-1) was applied in 1998 and 1999 on the hayed alfalfa when alfalfa weevil populations reached economic threshold levels. Grazing initiation occurred when the alfalfa weevil larvae reached economic threshold levels in the grazed plots. Alfalfa weevil larval populations were consistently higher when the alfalfa entries were grazed in 1998 and 1999. In 1998, both alfalfa and season total forage production were higher when the alfalfa was hayed. The entry 'OK08' had the lowest alfalfa yields among entries when either grazed or hayed (7.03 and 10.00 Mg ha^{-1}). In addition, seasonal weed production was higher when the alfalfa was grazed. In 1999, both alfalfa and total seasonal forage production were higher when the alfalfa was hayed. Grazed alfalfa had higher weedy grass production than hayed alfalfa. In 1998, alfalfa stem densities were consistently higher when the alfalfa entries were hayed versus grazed. Alfalfa stem densities in all entries declined substantially from 1998 to 1999. Improved alfalfa cultivar selection is one important key to maintain stand density and forage production. In this study, haying was the best option among all alfalfa entries for forage utilization in a thinning stand of alfalfa.

INTRODUCTION

In Oklahoma, alfalfa (*Medicago sativa* L.) is grown primarily for dairy, beef, or horse hay; however, alfalfa can also be grazed by livestock like sheep, cattle and goats. When used for hay, alfalfa can be harvested from three to six times each year (Shaeffer et al., 1988) and stands can remain productive for 8 years, if well managed. Cutting intervals range from 25-35 days, with the first cutting of alfalfa usually taken in late April or early May. The first cutting is usually the highest yielding and can provide up to 40 % of the total annual alfalfa production per year in alfalfa (Latheef et al., 1992).

Herbicide and insecticide effectiveness are critical to the profitability of alfalfa production. In an attempt to minimize damage from insects and weeds, herbicide and insecticide treatments are often required. Berberet et al. (1987) suggested a synergistic effect between alfalfa weevil damage and weed interference, since the combined effects of infestations on forage yield and stand retention from both types of pests are greater than the sum of effects when occurring separately. One alternative method to pesticides for minimizing alfalfa weevil damage is cattle grazing. Buntin and Bouton (1996) stated that grazing by cattle in early spring on alfalfa provided adequate control of alfalfa weevil larvae.

Senst and Berberet (1980) reported that grazing of alfalfa by cattle was effective as a mechanism for control of the alfalfa weevil larvae. However, there has been little research conducted to compare the production potential and extent of weed and insect suppression with haying and grazing harvest systems. The objective of this research is to compare mechanical harvesting and grazing in terms of seasonal alfalfa production, weed and insect infestation levels, and stand retention.

MATERIALS AND METHODS

An experiment was established at the Eastern Oklahoma Agronomy Research Station in Haskell, Oklahoma.

Five alfalfa entries (cultivars 'Alfagraze', 'OK08', 'OK49', and 'Cimarron VR' and germplasm 'OK178') were sown on September 13, 1994 with a five-row drill with 0.30-m row spacing. The cultivars were planted into 3.34- by 30.4-m plots in a randomized complete block design, with four replications. Alfagraze was released by Georgia in 1991, for use as a continuously grazed alfalfa. The other four entries are hay-types, 'OK08' is a released 'Oklahoma common' entry. 'OK49', 'OK178', and Cimarron VR are all improved multiple-pest resistant entries. The experimental area was grazed five times in 1995 and six times in 1996 by cattle with short duration, high intensity grazing. In the fall of 1997, plots were subdivided to form two subplots (3.4 by 7.6 m) for haying and grazing harvest treatments with a center alleyway (3.4 by 15.2 m) to facilitate fencing and grazing. This division modified the experimental design into a split plot design in strips with the entries comprising the main plots and the subplots composed of haying or grazing harvest methods for each entry. Forage yields were taken in 1998 and 1999. Alfalfa weevil larval populations were monitored in 1998 and 1999.

Alfalfa Weevil Monitoring Techniques

The alfalfa weevil is a perennial pest to alfalfa throughout the southern plains. The need for alfalfa weevil control is commonly determined by field scouting and by the accumulation of degree days (DD), calculated daily when the temperature rises above its developmental threshold of 50° F. It is recommended that field monitoring for weevils begin in Oklahoma with the accumulation of 150 degree days (Fahrenheit) from January 1 (Berberet and Mulder, 1993). At this point there may be sufficient numbers of alfalfa weevil larvae to cause damage to the plants. This usually occurs from February to mid-March in Oklahoma. When economic threshold levels are reached (as determined by the number of larvae in 30 stems at a given alfalfa plant height), control measures must be taken to avoid losses in yield at first harvest.

The experiment was sampled from January to first harvest to determine alfalfa weevil population densities. Ten alfalfa crown samples (0.025 m^2) were taken from each replicate and processed by the blender technique of Pass and VanMeter (1966) to estimate egg numbers in each field in late January to early February. Thirty alfalfa stem samples were taken from each plot periodically from mid-February to first harvest to monitor weevil larval number and size. Stem samples were rated for damage and placed on Berlese funnels for larval extraction (Berberet et al., 1987). If larval populations exceeded the economic threshold in the hayed plots, cyfluthrin [cyano(4-fluoro-3-phenoxyphenyl)-methyl-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate] at 0.045 kg a.i. ha^{-1} was applied. When populations reached the economic threshold in the grazed subplots, the quantity of forage available in each subplot was estimated by clipping quadrats (explained below) and a short duration, high intensity grazing period was initiated for 3 to 4 days at 51 animal units ha^{-1}.

Forage Production and Alfalfa Stem Density Measurements.

Before each harvest by grazing or haying, percentages of forage composed of weeds and alfalfa were visually estimated. Available forage was estimated before grazing initiation by clipping forage from two- 0.42 m^2 quadrats in each sub-plot. These samples were combined and oven dried at 52° C for approximately seven days and then weighed. Weed and alfalfa dry matter yields were calculated based on their respective percentage of the total dry matter production from each plot.

In hayed plots, forage production was estimated by cutting a 1- by 5-m forage sample with a Carter Forage Harvester. Each forage sample was immediately weighed and a sub-sample of approximately 400 grams was taken from each forage sample and oven dried to determine moisture content. Weed and alfalfa dry matter yields were then calculated based on their respective percentages from visual estimates.

Alfalfa stem densities were estimated at second alfalfa harvest by counting stems in four 0.15- by 0.61- m quadrats in each subplot. These four counts were then combined and averaged for each subplot.

Analysis of variance for forage yield data was conducted using the General Linear Models Procedure of SAS (SAS Inst., 1988). Means within each harvest method were separated using Fisher's protected LSD (α=0.05) on first harvest (or cool-season) yield data because hayed treatments and grazed treatments were harvested at separate dates, making the design a randomized complete block design with no split. Significant differences in seasonal forage yield among cultivar by harvest methods were calculated (P<0.05). Analysis of variance for alfalfa weevil larval populations and alfalfa stand density were also conducted with the General Linear Models Procedure. Significant differences in larval numbers per stem and average alfalfa stem densities were calculated (P<0.05).

RESULTS

Insect Populations

1998. Alfalfa weevil larval populations were significantly higher in grazed alfalfa than hayed on all three sampling dates (Table 1). The cyfluthrin (0.045 kg ha^{-1}) application on 9 April 1998 provided more residual control than the grazing period initiated on the same day. Larval populations on 22 April were higher in the grazed alfalfa (0.87 larva $stem^{-1}$) than in the hayed alfalfa (0.15 larvae $stem^{-1}$). There were no significant differences in alfalfa weevil populations among entries at any of the sampling dates.

1999. Alfalfa weevil larval populations were higher at the 19 February sampling date in the grazed alfalfa, but by 25 February there were no differences (Table 3). After a cyfluthrin (0.045 kg ha^{-1}) application on 25 February on the hayed plots, the larval population had dropped to 0.26 larvae $stem^{-1}$ in the hayed plots compared to 2.69 larvae $stem^{-1}$ in the grazed plots.

The only significant difference in alfalfa weevil larvae populations among alfalfa entries occurred with Cimarron VR and Alfagraze at the February sampling dates (Table 4). On the 19 February and 25 February sampling dates, Cimarron VR (4.96 and 5.50

larvae stem^{-1}) had significantly higher alfalfa weevil larvae per stem than Alfagraze (3.58 and 4.38 larvae stem^{-1}).

Forage Production

1998. Total first harvest forage yield for the entries in the grazed plots were not different (Table 5). Alfalfa production at first harvest was significantly lower in 'OK08' compared to 'OK178'. Consequently, weeds dry matter was significantly higher in the 'OK08' (0.90 Mg ha^{-1}) than in the 'OK178' (0.36 Mg ha^{-1}). There were no differences in alfalfa production among entries when hayed on 30 April 1998.

Seasonal production for both alfalfa and total forage production were consistently higher for all five entries when hayed versus grazed. 'OK08' produced the lowest alfalfa yields when either grazed or hayed, 7.03 and 10.00 Mg ha^{-1}. Season total weed production for each entry tended to be higher when grazed, but the increase was statistically significant only with Cimarron VR.

1999. There were no significant differences among entries in first harvest total forage yield with either harvest method (Table 6). Yields ranged from 0.94 to 1.06 tons ac^{-1} (2.10 to 2.37 Mg ha^{-1}) in the grazed cultivars, and 1.57 to 1.69 tons ac^{-1} (3.52 to 3.79 Mg ha^{-1}) when hayed. At the first grazed harvest, 'OK49' had a significantly higher weedy grass yield than Alfagraze, 'OK08' or Cimarron VR. There were no significant differences in alfalfa yield at first harvest between entries within either harvest method.

Seasonal alfalfa production was significantly higher for all entries when hayed than grazed. Also, weedy grass yields were significantly higher when the cultivars were grazed for all entries except Cimarron VR. Weedy grasses included Italian ryegrass

(*Lolium multiflorum* Lam.), annual bromes (*Bromus* spp.), and tall fescue (*Festuca arundinacea* Schreb.) in the cool-season, with the addition of encroaching populations of bermudagrass (*Cynodon dactylon* L.) Pers. in the summer harvests. These data are consistent with conclusions from Kapusta and Streiker (1975) and Degooyer et al. (1999) who stated higher downy brome (*Bromus tectorum* L.) yields resulted in lower alfalfa yields. There were no significant differences in season total forage production among entries when hayed. However, when the entries were grazed, 'OK178' had a higher season total forage yield than Alfagraze, 'OK49' or Cimarron VR. Season total broadleaf weed yields were significantly higher for Alfagraze, 'OK49' and 'OK178' when hayed than when grazed.

Stand Density

1998. Alfalfa stem densities ranged from 16.89 stems to 27.43 stems $0.1m^{-2}$ (Table 7). Alfalfa stem densities at second harvest were higher in four out of the five cultivars when hayed versus grazed. Only 'OK08' had statistically similar alfalfa stem densities under grazed and hayed harvest methods at second harvest. There were no significant differences between entries when the alfalfa was grazed. When the alfalfa was hayed, stand density of 'OK08' was significantly lower than all other entries.

1999. Overall, alfalfa stem densities declined substantially between 1998 and 1999 (Table 7). In 1999, mean alfalfa stem densities ranged from 16.08 stems $0.1m^{-2}$ down to 9.75 stems $0.1m^{-2}$. There were no significant differences between entries at either harvest method in second harvest alfalfa stem densities. In addition there were no significant differences between harvest methods with any entry. Stem densities in the grazed entries tended to be less than hayed entries; however, differences were not significant at 0.05 level.

DISCUSSION

Differences in alfalfa stand density between 1998 and 1999 indicate that by the fifth year of this stand, decline had occurred regardless of entry selection. All alfalfa entries declined in 1999 to levels well below what would be considered a full stand (26.9 stems $0.1m^{-2}$). In fact, the highest alfalfa stand density in 1999 was comparable to the lowest stand density observed in 1998 (16.89 stems $0.1m^{-2}$ in 1998 compared to 16.08 stems $0.1m^{-2}$ in 1999). The fact that alfalfa stand density was so low might account for the difference in performance of the alfalfa entries between 1998 and 1999. Grass establishment and growth causes a competitive disadvantage to the alfalfa at this point. Since the weed yields tended to be higher in 1999 than in 1998, this competition effect was exaggerated in the 1999 data.

However, in 1998 stand density was marginally acceptable (from 16.89 to 27.43 stems $0.1m^{-2}$), and the entries had higher seasonal alfalfa yields and seasonal total yields when hayed versus grazed. The high numbers of alfalfa weevil larvae could have caused increased damage on the grazed alfalfa, but alfalfa production was not significantly different between harvest methods at the first harvest in 1998. So, decreased alfalfa production must be attributed to factors other than alfalfa weevil damage.

One factor that producers should consider is the inevitable risk that accompanies harvesting hay with conventional harvest methods of swathing, raking and baling. In Oklahoma, the complete procedure takes several days from the time the hay is cut to the removal from the field. This process can take up to three weeks or more if weather conditions, like rain, inhibit the producer from making timely harvest procedures. Hay quality begins to decrease rapidly with the increase in time spent on the ground in the wind-row.

However, grazing with cattle provides a very efficient harvesting mechanism. There is no need for moisture testing in the wind-row, raking, baling or hauling. Granted problems can occur if proper steps are not taken to prevent bloat, but grazing with cattle incurs much less risk in the harvesting procedure than haying.

In conclusion, alfalfa entry selection only made a difference in 1998, when stem density was near 26.9 stems $0.1m^{-2}$ in most entries. In 1998, improved entries performed better than the Oklahoma common release when hayed. In 1999, when stem densities were half that of the previous year, alfalfa entry selection was not a key factor in performance. Providing insecticide at economic thresholds and haying produced higher yields than grazing for forage utilization in thinning alfalfa stands.

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Table 1. Alfalfa weevil larvae per stem in grazed and hayed alfalfa– Haskell, OK 1998

Harvest method	3-Apr †	9-Apr *	22-Apr
	Larvae stem $^{-1}$		
Grazed	1.75a	2.59a	0.87a
Hayed	1.30b	1.92b	0.15b

† Means followed by the same letter are not significantly different within sampling date (Fishers Protected LSD, P<0.05).

* Grazing initiated or cyfluthrin (0.045 kg ha^{-1}) applied on 9 April 1998.

Table 2. Alfalfa weevil larvae per stem in five alfalfa entries– Haskell, OK 1998

Alfalfa entry	3-Apr †	9-Apr *	22-Apr ‡
	Larvae stem $^{-1}$		
Alfagraze	1.57a	2.36a	ND
'OK08'	1.48a	2.24a	ND
'OK49'	1.64a	1.89a	ND
'OK178'	1.35a	2.21a	ND
Cimarron VR	1.59a	2.56a	ND

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P<0.05).

* Grazing initiated or cyfluthrin (0.045 kg ha^{-1}) applied on 9 April 1998.

‡ ND = No Data. Individual entries were not sampled at this date.

Table 3. Alfalfa weevil larvae per stem in grazed and hayed alfalfa combined over alfalfa entries– Haskell, OK 1999

Harvest method	19-Feb †	25-Feb ‡	30-Mar	15-Apr •
	Larvae stem $^{-1}$			
Grazed	4.68a	4.72a	2.69a	1.78a
Hayed	3.82b	4.52a	0.26b	0.24b

† Means followed by the same letter are not significantly different within sampling date (Fishers Protected LSD, P<0.05).

‡ Cyfluthrin (0.045 kg ha^{-1}) application made to hayed plots after this sampling date.

• Grazing initiated on 16 April 1999.

Table 4. Alfalfa weevil larvae per stem in five alfalfa entries combined over harvest methods– Haskell, OK 1999

Alfalfa entry	19-Feb †	25-Feb ‡	30-Mar	15-Apr •
	Larvae stem $^{-1}$			
Alfagraze	3.58b	4.38b	1.29a	0.88a
'OK08'	4.32ab	5.06ab	1.60a	1.09a
'OK49'	4.20ab	4.15b	1.67a	0.98a
'OK178'	4.28ab	4.08b	1.48a	1.18a
Cimarron VR	4.96a	5.50a	1.35a	0.92a

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P<0.05).

‡ Cyfluthrin (0.045 kg ha^{-1}) application made to hayed plots after this sampling date.

• Grazing initiated on 16 April 1999.

Table 5. Effect of grazing and haying harvest methods on forage production of alfalfa and weeds in five alfalfa entries – Haskell, OK 1998

Harvest method and alfalfa entry	First harvest forage production †			Season forage production ‡		
	Alfalfa	Weeds	Total	Alfalfa	Weeds	Total
	Mg ha^{-1}			Mg ha^{-1}		
Grazed						
Alfagraze	1.57ab	0.63ab	2.20a	7.80ef	1.21abc	9.01f
'OK08'	1.50b	0.90a	2.40a	7.03f	1.61a	8.64f
'OK49'	1.99ab	0.40ab	2.39a	9.41de	0.69c	10.10def
'OK178'	2.13a	0.36b	2.49a	9.41de	0.53c	9.94def
Cimarron VR	1.52ab	0.90a	2.42a	7.70ef	1.52ab	9.92ef
Hayed						
Alfagraze	4.65a	0.47a	5.12a	12.20ab	0.81c	13.01ab
'OK08'	4.43a	0.34ab	4.77ab	10.00d	1.05abc	11.05cde
'OK49'	4.14a	0.22b	4.36b	11.78abc	0.81c	12.59abc
'OK178'	4.57a	0.25b	4.82ab	12.99a	0.69c	13.68a
Cimarron VR	4.45a	0.25b	6.69ab	10.62bcd	0.76c	11.38bcd

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P< 0.05). Grazed plots were harvested on 9 April 1998. Hayed plots were harvested on 30 April 1998.

‡ Means followed by the same letter are not significantly different (General Linear Models Procedure, P< 0.05).

Table 6. Effect of grazing and haying harvest methods on forage production of alfalfa, weedy grass, and broadleaf weeds in five alfalfa entries – Haskell, OK 1999.

Harvest method	First harvest forage production †				Season forage production ‡			
and alfalfa entry	Alfalfa	Weedy grass	Broadleaf weeds	Total	Alfalfa	Weedy grass	Broadleaf weeds	Total
	Mg ha^{-1}				Mg ha^{-1}			
Grazed								
Alfagraze	1.01a	0.78b	0.47a	2.26a	2.13bc	3.11ab	0.69b	5.93b
'OK08'	1.10a	0.60b	0.67a	2.37a	1.50c	3.92a	0.96ab	6.38ab
'OK49'	0.83a	1.21a	0.25a	2.29a	1.23c	4.03a	0.60b	5.86b
'OK178'	0.78a	0.87ab	0.44a	2.09a	1.66c	4.30a	0.63b	6.59a
Cimarron VR	0.85a	0.67b	0.69a	2.21a	1.39c	3.67ab	1.01ab	6.07b
Hayed								
Alfagraze	1.99a	0.87a	0.72a	3.58a	4.10a	2.08c	1.10a	7.28a
'OK08'	1.63a	1.39a	0.63a	3.65a	3.20ab	2.91b	1.16a	7.27a
'OK49'	1.48a	1.14a	0.90a	3.52a	2.53b	2.58bc	1.30a	6.41ab
'OK178'	1.64a	1.39a	0.78a	3.81a	3.25ab	2.93b	1.39a	7.57a
Cimarron VR	1.30a	1.21a	1.10a	3.61a	2.33bc	2.80bc	1.84a	6.97a

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P< 0.05). Grazed plots were harvested on 15 April 1999. Hayed plots were harvested on 11 May 1999.

‡ Means followed by the same letter are not significantly different (General Linear Models Procedure, P< 0.05).

Table 7. Evaluation of stand decline over a two year period in five alfalfa entries with grazing and haying harvest methods – Haskell, OK

Harvest method and alfalfa entry	Stem density †	Stem density †
	stems $0.1m^{-2}$	stems $0.1m^{-2}$
	1998	1999
Grazed		
Alfagraze	17.22b	9.89b
'OK08'	16.89b	10.02b
'OK49'	17.70b	9.75b
'OK178'	18.36b	14.06ab
Cimarron VR	17.16b	10.42ab
Hayed		
Alfagraze	25.74a	13.32ab
'OK08'	20.39b	12.30ab
'OK49'	26.30a	14.26ab
'OK178'	27.43a	16.08a
Cimarron VR	24.78a	11.24ab

† Means followed by the same letter are not significantly different within year (General Linear Models Procedure, $P< 0.05$).

CHAPTER III

EVALUATION OF OVER-SEEDED, COOL-SEASON FORAGE GRASSES AND SPRING GRAZING WITH CATTLE TO IMPROVE FORAGE PRODUCTION AND PROFITABILITY IN THINNING ALFALFA STANDS

Evaluation of over-seeded, cool-season forage grasses and spring grazing with cattle to improve forage production and profitability in thinning alfalfa stands

ABSTRACT

Alfalfa (*Medicago sativa* L.) production decreases as the alfalfa stand density declines from plant disease and insect damage. At some point the cost of weed and insect control exceeds the profit made from a conventionally hayed alfalfa system. The objectives of this experiment are to evaluate the effects of cattle grazing and over-seeded ryegrass (*Lolium multiflorum* Lam.) or wheat (*Triticum aestivum* L.) on forage production and profitability in thinning alfalfa stands. Three experiments were conducted in 1999 on established stands of alfalfa in south central Oklahoma.

Alfalfa over-seeded with ryegrass or wheat had the highest alfalfa weevil larval numbers at all locations. Cyfluthrin (0.045 kg ha^{-1}) insecticide application in February at the alfalfa weevil economic threshold significantly decreased larval populations from February (1.3 larvae $stem^{-1}$) to April (0.1 larvae $stem^{-1}$). Cattle grazing decreased larval populations by an average of 2.8 larvae $stem^{-1}$ pooled over all three experiments. This decrease was equal to the insect suppression with the insecticide treatment. Over-seeding ryegrass or wheat into the alfalfa increased total spring forage production by an average of 35% or 31%, respectively, compared to the conventionally hayed alfalfa. However, over-seeding ryegrass decreased the alfalfa component by an average of 25% compared to the conventionally hayed alfalfa, whereas wheat had little effect on alfalfa production. Spring weedy grass and broadleaf weed suppression was consistently higher (P<

0.05) in alfalfa over-seeded with ryegrass or wheat than in the conventionally hayed alfalfa with herbicides + insecticides.

Seasonal forage production was higher (P<0.05) in ryegrass over-seeded and wheat over-seeded alfalfa than in the conventionally hayed alfalfa with an average 16% and 15% increase in production, respectively. In 1999, March and May crude protein (CP) content was higher in conventionally hayed alfalfa (30% CP) compared to ryegrass (13% CP) or wheat (15% CP) over-seeded alfalfa. There were no differences between over-seeded treatments in crude protein, however, ryegrass over-seeded alfalfa had higher total dietary nutrients (TDN) than wheat over-seeded alfalfa. Spring profitability was significantly increased by the addition of ryegrass and wheat at two locations; however, all treatments had positive net returns.

Over-seeding wheat or ryegrass into thinning alfalfa stands suppressed weed production and increased forage production. Grazing with cattle effectively controlled the alfalfa weevil. This system in return increased the profitability of thinning alfalfa stands.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) stands decline primarily as a result of plant disease and insect damage. The alfalfa weevil *Hypera postica* (Gyllenhal) causes considerable damage to first harvest alfalfa (Dowdy et al. 1993). Buntin (1989) reported alfalfa weevil larval feeding resulted in defoliation of plants and decreased the competitive ability with cool-season weeds. This allows the weeds to grow and occupy the open space in the plant canopy, decreasing alfalfa forage quality (Cummings et al., 1999). The two types of pests, weeds and alfalfa weevils, act in combination to produce great reductions in alfalfa yields (Berberet et al. 1987). In addition, alfalfa weevil populations vary with the presence or absence of weeds and the combined effects of weed competition and weevil feeding cause the greatest losses in alfalfa yield (Norris et al. 1984). So, some alternative control methods, like winter grazing by livestock, have been explored to reduce populations of the alfalfa weevil by consuming eggs and larvae in foliage while also consuming the cool-season weeds(Buntin and Bouton, 1996).

Many producers do not harvest alfalfa by grazing because of greater profit potential in selling hay (Caddel, 1997; Guerrero and Marble, 1991). However, when stands start to decline (fifth or sixth year of production), the producer must decide between the profitability of grazing, and declining production of the conventionally hayed alfalfa. Expense of conventional hay harvest far out-weighs the minimal expense associated with grazing. In contrast, mob grazing uses livestock to harvest the standing forage, eliminating the need for mechanical harvest.

Wolf and Blaser (1981) reported that grazing alfalfa in early spring for insect control and taking a first hay harvest three weeks later than normal is a management alternative for alfalfa grown in Virginia. In several studies performed in Georgia, spring grazing decreased alfalfa weevil larval densities by 60% in 1993 and 45% in 1994 (Buntin and Bouton, 1996). However, weevils caused moderate to severe damage before grazing could decrease infestation. In 1996, Buntin and Bouton also reported that a combination of an early application of insecticide having a short grazing restriction, followed by grazing, allowed effective alfalfa weevil larval control and direct forage use by grazing. But this essentially defeats the cost advantage of grazing because of the added cost of the insecticide.

Grazing alfalfa not only controls the alfalfa weevils, but also provides good quality forage for the livestock. Jung et al. (1996) reported that when inter-seeded with alfalfa, perennial ryegrass (*Lolium perenne* L.) provided high quality forage contributions for cattle production systems. In fact, average daily gains of the cattle in the experiment were 21% higher with ryegrass-alfalfa mixtures than with orchardgrass (*Dactylis glomerata* L.)-alfalfa mixtures. However, Temme et al. (1979) reported that feeding alfalfa alone had increased forage quality over alfalfa mixtures with oats (*Avena sativa* L.). The objective of this research is to evaluate the profitability of over-seeded, cool-season forage grasses and livestock grazing in thinning alfalfa stands.

MATERIALS AND METHODS

Three experiments were initiated on established alfalfa stands in 1998, at locations near in Grady and Garvin counties in Oklahoma. Of the two experiments in Grady county, one was located on the South Central Agronomy Research Station at Chickasha, OK (Reinach silt loam soil) on a six year old, supplemental irrigated stand of 'Garst 630' alfalfa. The second experiment, located several miles northeast of Chickasha (Port silt loam soil), was a 7 year old, dryland stand of 'Cimarron VR' alfalfa. The third experiment, located in Garvin county south of Paoli, OK (Konsil loamy fine sand soil), was on a five year old, dryland stand of 'Cimarron VR'.

At each of the locations, a split-plot design with six main plot treatments and two subplot treatments was used to evaluate over-seeded cool-season grasses and grazing for their ability to increase profitability in thinning stands of alfalfa. Main plot size at the Chickasha agronomy research station experiment was 4.6- by 15.2-meters with four replications. Subplot size was 4.6- by 7.6-m. At the second and third experiments, main plots were 10.6- by 30.4-m with three replications. Subplots were 10.6- by 15.2-m.

The six main plot treatment combinations were initiated in the fall of 1998 and winter of 1999 in all experiments and included: 1) no pesticides for weed or insect control, no over-seeding and no grazing, 2) herbicides including terbacil [3-*tert*-butyl-5-chloro-6-methyluracil] (0.56 kg a.i. ha^{-1}) dormant, imazethapyr [(±)-5-ethyl-2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)nicotinic acid] (0.07 kg a.i. ha^{-1}), and norflurazon [4-chloro-5-methylamino-2-(α,α,α-trifluoro-*m*-tolyl)pyridazin-3-(2*H*)-one] (1.34 kg a.i. ha^{-1})} and the insecticide cyfluthrin [cyano(4-fluoro-3-phenoxyphenyl)-methyl-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate] (0.045 kg a.i. ha^{-1}) with no over-seeding and no grazing, 3) grazing with no pesticides and no over-seeding, 4) grazing with no pesticides and over-seeded in October 1998, with 'Marshall' ryegrass (*Lolium multiflorum* Lam.) (27 kg ha^{-1}) and the application of 112 kg ha^{-1} 18-46-0 at planting, 5) no pesticides and over-seeded in October 1998, with 'Tonkawa' wheat (*Triticum aestivum* L.) (134 kg ha^{-1}) and 112 kg ha^{-1} 18-46-0 at planting, and 6) no pesticides and over-seeded in January 1999, with 'Okay' oats (*Avena sativa* L.) (72 kg ha^{-1}) and 112 kg ha^{-1} 18-46-0 at planting. Treatments 1, 2, and 3 also had 112 kg ha^{-1} 18-46-0 broadcast applied to negate fertility differential among main plots. Over-seeding was done with a tractor-driven, five-row small seed drill with 0.3-m row spacing. On December 17, 1998, 146 kg ha^{-1} 46-0-0 was applied to one of two subplots within each main plot at all three experiments. Although the subplots were established in all six treatments, the main purpose for this split was to test the effects of increased nitrogen content of the soil on forage production from the over-seeded ryegrass and wheat.

In the early spring of 1999, it was determined by visual identification that no oats had germinated at any of the three sites. The lack of germination was attributed to poor soil moisture from the time of planting to the initiation of the grazing period in March. For this reason, data taken from treatment 6 were not considered in the data analysis .

A bicycle sprayer with CO_2 gas propellant and 51 cm nozzle spacing was used to apply herbicide and insecticide treatments at 187 L ha^{-1}. Terbacil treatment was applied to treatment combination 2, at all three locations on 4 February 1999.

Alfalfa weevil larval populations were monitored using the same sampling procedures as Berberet et al. (1987). Twenty-five alfalfa stems were collected from each main plot. Larval extraction was conducted with standard Berlese funnels. When larval populations reached economic threshold, the insecticide application was made to treatment 2 at each location, and grazing was then initiated on treatment combinations 3, 4, 5, and 6 using cattle.

Grazing periods of varying lengths and stocking rates were initiated in March at all three locations. Only treatments 3, 4, 5, and 6 were grazed at this time. After this grazing period, all other harvests were performed to simulate conventional hay harvesting methods. Deviations from the given methods and additional information follow the general methodology.

Alfalfa weevil monitoring techniques. The alfalfa weevil is a perennial pest to alfalfa throughout the southern plains. The need for alfalfa weevil control is commonly determined by field scouting and by the accumulation of degree days (DD), calculated daily when the temperature rises above its developmental threshold of 50° F. Three hundred DD is sufficient for alfalfa weevil egg hatch. At this point the alfalfa weevil larvae begin feeding and causing damage to the plants. This usually occurs from February to mid-March in Oklahoma. When threshold levels are reached (as determined by the number of larvae in 30 stems at a given alfalfa plant height), control measures must be taken at the thresholds to avoid first-harvest damage by the weevil larvae.

The experiment was sampled periodically from January to first harvest to determine alfalfa weevil population densities. Ten alfalfa crown samples (0.025 m^2) were taken from each replicate and processed by the blender technique of Pass and VanMeter (1966) to estimate egg numbers in each field in late January to early February. Twenty-five alfalfa stem samples were taken from each plot periodically from January to first harvest to monitor weevil larval number and size. Stem samples were rated for damage and placed on Berlese funnels for larval extraction.

Alfalfa weevil larval numbers reached high levels before the alfalfa had sufficient growth to consider grazing at Experiment 2 in Grady county and Experiment 3 in Garvin county. So that sufficient growth could occur for grazing without complete defoliation of the plants by the alfalfa weevil, each area was over-sprayed on 22 February with permethrin [(3-phenoxyphenyl)methyl (±) cis-trans 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate] at 0.11 kg a.i. ha^{-1}. This application was made to reduce, but not eliminate the alfalfa weevil larval populations. On the same date, the cyfluthrin (0.045 kg a.i. ha^{-1}) application was made on treatment 2 at each location.

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Alfalfa stand density estimation. Before the first alfalfa harvest an estimation was made for alfalfa stand density. Stem numbers were estimated by counting stems in four 0.15- by 0.61- m randomly placed quadrats in each plot area.

Forage available at grazing. Before grazing, percentages of forage composed of alfalfa, over-seeded grass, weedy grass and broadleaf weeds were visually estimated. Forage production was determined by taking two- 0.42 m^2 clipped samples from each subplot at grazing initiation. The samples were dried for seven days at 52° C. Total forage production was estimated from the dried samples.

Hay harvest methods. After the March grazing period, forage production at subsequent harvests was conducted with a Carter Forage Harvester. Before each subsequent hay harvest, percentages of forage composed of alfalfa, over-seeded grass, weedy grass and broadleaf weeds were visually estimated. The Carter Forage Harvester was used to take a 1- by 5-m^2 sample from each subplot. This sample was immediately weighed to get an actual field weight. From each harvested sample a 400 g sub-sample was taken to determine dry matter. The sub-sample was then dried for seven days at 52° C. Forage production from each component was estimated from the predetermined component percentages.

Forage analysis. After drying and weighing, the dry matter sub-samples were taken to the Oklahoma State University Soil, Water and Forages Analytical Laboratory for quality analysis. Sample preparation and analysis procedures are discussed in Undersander, et al. (1993). Crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) were determined from the analysis procedures. Total dietary nutrients (TDN) and relative feed value (RFV) were extrapolated using equations found in Caddel and Allen (1994) and Zhang et al. (1998).

Profitability analysis. Economic inputs, profits and net returns were calculated for each main plot at each location. Input factors are listed in Table 1, along with the given assumptions for hay prices, grazing and land costs. Swathing, baling and hauling costs are all yield dependent within main plot. Inputs for over-seeding the wheat and ryegrass into treatments 4 and 5 are also considered.

Gross return values for treatments 1 and 2 reflect seasonal yield values, whereas gross returns for the grazed treatments 3, 4, and 5 include a value placed on the March grazing period (yield dependent) as well as seasonal yield values. All input and return considerations are partial analyses modified from the 1997 budget plans for dryland alfalfa production, calculated and distributed by the Oklahoma State University Department of Agricultural Economics and Oklahoma Cooperative Extension Service.

Other given calculations include: good quality hay sold for \$100 Mg^{-1} and fair quality hay sells for \$88 Mg^{-1}. In addition it was considered that 4.54 kg of forage produced 1 kg of animal gain and current rental rates on land leased for grazing were \$0.66 kg^{-1} of animal gain. These considerations were pooled from Oklahoma Cooperative Extension personnel assumptions, based on current market values.

Statistical Analysis. Means for insect populations, stem densities, cool-season forage production (which included the March grazing period and May harvest for treatments 3, 4, 5, and 6, and only the April or May hay harvest for treatments 1 and 2), seasonal forage production and weed composition and forage analysis (crude protein, acid detergent fiber, neutral detergent fiber, and total dietary nutrients) and profitability were subjected to an analysis of variance using the General Linear Models procedure (SAS Inst., 1988). Means were separated using probability differences (α=0.05) to infer statistical differences.

DEVIATIONS BY LOCATION

Experiment 1 (So. Central Agronomy Res. Station – Grady County). Cattle grazing was initiated 5 March 1999 on treatments 3, 4, 5, and 6. The grazing period lasted for 27 days at 8.4 AU ha^{-1}.

Experiment 2 – Grady County. Cattle grazing was initiated on 29 March 1999. Only treatments 3, 4, 5, and 6 were grazed. The grazing period lasted for 14 days at 3.7 AU ha^{-1}. Forage yields were estimated on March and again in May for all treatments. The study had to be discontinued after the May harvest because the cooperating producer was unable to perform timely harvests of the experimental area after that date.

Experiment 3 – Garvin County. Cattle grazing was initiated on 23 March 1999. Only treatments 3, 4, 5, and 6 were grazed. The grazing period lasted for nine days at 9.4 AU ha^{-1}.

RESULTS AND DISCUSSION

Alfalfa Weevil Larval Populations

Experiment 1 – Grady Co. Peak alfalfa weevil larval populations were observed on 8 April in the no pesticides and no over-seed (3.4 larvae $stem^{-1}$) (Table 2). Cyfluthrin applied 23 February in the herbicide + insecticide treatment decreased larval populations from 1.3 larvae $stem^{-1}$ on 23 February to 0.2 larvae $stem^{-1}$ by 4 March.

Peak larval populations were significantly higher in the ryegrass over-seed (3.5 larvae $stem^{-1}$) and wheat over-seed (2.8 larvae $stem^{-1}$) treatments than in the no over-seed (1.9 larvae $stem^{-1}$). However, the grazing period initiated on 4 March decreased larval populations to a mean of 0.5 larvae $stem^{-1}$ on 8 April in all grazed treatments. The grazing lowered alfalfa weevil populations to levels equivalent to those where insecticide was applied. The data coincide with Buntin and Bouton (1996) who concluded that grazing effectively suppressed alfalfa weevil larval feeding. By the last sampling date, alfalfa weevil larval numbers in all grazed and hayed treatments were below 0.6 larvae $stem^{-1}$.

Experiment 2 – Grady Co. Alfalfa weevil larval populations were higher on average at this location than in Experiment 1. For the first two sampling dates on 18 February and 23 February, there were no differences in larval populations among treatments (Table 3). On the 23 February sampling date, cyfluthrin was applied to the herbicide + insecticide treatment decreasing alfalfa weevil larval populations from 4.2 larvae $stem^{-1}$ on 23 February to 0.1 larvae $stem^{-1}$ on 23 March. On the same date the permethrin (0.11 kg ha^{-1}) application was made to all treatments. This application was made to decrease weevil populations because the alfalfa was too short to graze and further alfalfa weevil damage at that time would cause extensive damage to the crop. For this reason, there was no significant difference ($P<0.05$) between the no pesticide treatment and the herbicide + insecticide treatment on 23 March.

The grazing period for treatments 3, 4, 5, and 6 from 23 March to 6 April decreased the larval populations an average of 0.7 larvae $stem^{-1}$. Population density for 17 April for all treatments was 0.2 larvae $stem^{-1}$. Grazing decreased alfalfa weevil populations to a level equal to that of the cyfluthrin application.

Experiment 3 – Garvin Co. Peak alfalfa weevil larval numbers were recorded on 23 February (Table 4). The highest alfalfa weevil larval numbers were observed in the wheat over-seed (6.5 larvae $stem^{-1}$). This population was significantly higher than the no over-seed treatment with 3.3 larvae $stem^{-1}$. The phenomenon of higher populations in the over-seeded treatments was observed at all locations. The increase in alfalfa weevil larval population in the over-seeded treatments was possibly due to the increased cover for weevil adults provided by the grasses in the fall and early winter on the alfalfa. Increased ground cover may have given a habitat preferred by the weevil adults over that provided by the alfalfa alone.

After the cyfluthrin application was made to the herbicide + insecticide treatment, larval numbers decreased from 4.9 larvae $stem^{-1}$ on 23 February, to 0.3 larvae $stem^{-1}$ on 23 March. On the 23 February date the permethrin (0.11 kg ha^{-1}) application was made to all treatments. This application was made to decrease weevil populations because the alfalfa was too short to graze, and further alfalfa weevil damage at that time would cause extensive damage to the crop. On the 23 March sampling date, the herbicide + insecticide treatment had significantly fewer larvae than all other treatments ($P<0.05$).

However, the grazing period for treatments 3, 4, 5, and 6 decreased larval populations equal to or greater than the insecticide treatment on 17 April. The no pesticide treatment contained the most alfalfa weevil larvae on 17 April with 0.9 larvae $stem^{-1}$.

Alfalfa Stand Density

Experiment 1. Alfalfa stem densities at first harvest in May were highest in the herbicide + insecticide treatment (25.9 stems $0.1m^{-2}$) and lowest in the ryegrass over-seed (11.6 stems $0.1m^{-2}$) (Table 5). The no over-seed treatment (18.0 stems $0.1m^{-2}$), wheat over-seed (15.7 stems $0.1m^{-2}$), and no pesticide treatment (17.1 stems $0.1m^{-2}$) were all intermediate in first harvest stem densities. Ryegrass and wheat may have caused a decrease in the competitive ability of the remaining alfalfa plants because the stem densities were decreased with the addition of the cool-season forage grasses.

Experiment 2. Alfalfa stem densities were also higher in the herbicide + insecticide treatment (14.0 stems $0.1m^{-2}$) than all other treatments (Table 5). However, even these stem densities were too low to sustain adequate alfalfa production. Therefore the addition of the over-seeded, cool-season grasses increased the production and profitability of this declining stand. At this site there were no differences between alfalfa stem densities between the other four treatments, all were under 10.8 stems $0.1m^{-2}$.

Experiment 3. Alfalfa stem densities were highest in the herbicide + insecticide treatment (12.9 stems $0.1m^{-2}$) (Table 5). However, alfalfa stem densities were all too low for profitable alfalfa production. Ryegrass over-seed had the lowest alfalfa stem densities (5.2 stems $0.1m^{-2}$), and as expected, the low stem densities caused a decrease in alfalfa competitiveness allowing the cool-season and later warm season weeds to become a noticeable component of the total forage produced. Full season alfalfa production in the ryegrass over-seeded plots indicated this low alfalfa stem density. This decrease of alfalfa stem density in the ryegrass over-seed plots occurred at Experiment 1 as well, indicating the aggressive nature of the ryegrass depressed alfalfa stand.

Several aspects of the over-seeded, cool-season forage grasses will be addressed in the following sections. However, in addition to forage production and profitability, the producer should consider the potential for production through the summer months. For cool-season forage production, the increase in alfalfa stem density with the herbicide + insecticide treatment indicates this might be the best treatment provide season-long productivity. However, the potential increase in forage production from the over-seeded grasses could compensate for this decrease in alfalfa stand if the producer is only interested in cool-season forage production. This system would optimize the last months of production, particularly if a producer planned on plowing up the alfalfa stand in mid- to late summer for seedbed preparation of the next crop.

Forage Production

Experiment 1. Seasonal forage production was highest ($P<0.05$) in the ryegrass or wheat over-seed treatments (Table 6). In total forage production, there was no significant difference between ryegrass over-seed (15.1 Mg ha^{-1}) and wheat over-seed (14.6 Mg ha^{-1}). The herbicide + insecticide treatment produced significantly more alfalfa over the season than all other treatments. The ryegrass over-seed had the least amount of alfalfa production and was significantly less than the no over-seeding treatment. Weedy grass yield was lowest in the herbicide + insecticide treatment in total production and in cool-season production. There was no significant interaction between treatment and fertility level in the seasonal forage production ($P > 0.05$). Therefore significant increase existed in forage production of ryegrass or wheat with the addition on the 146 kg ha^{-1} of 46-0-0 fertilizer.

When considering only spring production, the ryegrass over-seed (6.8 Mg ha^{-1}) and wheat over-seed (7.34 Mg ha^{-1}) had the highest total production compared to all other treatments. Weedy grass production was lowest when ryegrass (0.04 Mg ha^{-1}) or wheat (0.07 Mg ha^{-1}) was over-seeded or when herbicides and insecticides (0.09 Mg ha^{-1}) were applied. The significant difference in the over-seeded component of season long production for ryegrass and wheat resulted primarily from the greater persistence of the ryegrass until the second harvest in June.

Experiment 2. Only spring forage production was recorded at this location because it was impossible to make timely harvests between researchers and the producer. Ryegrass over-seeded and wheat over-seeded treatments had the highest spring forage production (6.3 and 6.6 Mg ha^{-1}) (Table 7). The lowest spring forage production was observed in the no over-seed treatment (3.4 Mg ha^{-1}) and resulted from alfalfa weevil damage early in the season. The ryegrass over-seed and the herbicide + insecticide treatment had the highest alfalfa production (1.4 and 1.4 Mg ha^{-1}) from February to May. A significant interaction existed between treatment and fertility for the over-seeded wheat or ryegrass production. A significant increase in over-seeded wheat was observed with 146 kg ha^{-1} 46-0-0 fertilizer (5.1 Mg wheat ha^{-1}) compared to wheat with no topdressed fertilizer (3.4 Mg wheat ha^{-1}). The opposite effect was observed in ryegrass over-seeded alfalfa. Ryegrass without topdressed fertilizer produced 0.9 Mg more ryegrass per hectare than with the 146 kg ha^{-1} 46-0-0 fertilizer. Weedy grass and broadleaf weed production were lowest in the ryegrass over-seed and wheat over-seed treatments during the spring.

Experiment 3. Ryegrass over-seed and wheat over-seed treatments had the highest seasonal production of all treatments (11.6 and 10.5 Mg ha^{-1}) in 1999 (Table 8). The herbicide + insecticide treatment had the lowest seasonal production (6.3 Mg ha^{-1}). Ryegrass over-seed and wheat over-seed treatments also had the lowest season long weedy grass (0.3 and 0.6 Mg ha^{-1}) and broadleaf weed (0.3 and 0.3 Mg ha^{-1}) production of all treatments. Ryegrass production (7.4 Mg ha^{-1}) was higher than wheat production (5.9 Mg ha^{-1}), but the ryegrass over-seed plots also decreased mean alfalfa production (2.4 Mg ha^{-1}), compared to wheat over-seed (3.7 Mg alfalfa ha^{-1}) and the herbicide + insecticide treatment (3.62 Mg ha^{-1}).

Spring forage production demonstrated the same trend. Spring total forage production was higher in the ryegrass over-seed and wheat over-seed treatments (9.8 and 9.4 Mg ha^{-1}), but there were no significant differences between over-seeded treatments and the herbicide + insecticide treatment. A significant increase was observed when 146 kg ha^{-1} 46-0-0 fertilizer was topdressed on ryegrass (8.1 Mg ryegrass ha^{-1}) and wheat (6.7 Mg wheat ha^{-1}) compared to no fertilizer topdressed ryegrass (6.7 Mg ryegrass ha^{-1}) and wheat (5.2 Mg wheat ha^{-1}). Spring weedy grass and broadleaf weed production was lowest in the over-seeded ryegrass and wheat plots. There were no differences in spring alfalfa production among the treatments.

Forage Analysis

Experiment 1. High producing diary cows need hay with at least 20 % crude protein (CP), less than 30% acid detergent fiber (ADF) and less than 40% neutral detergent fiber (NDF), equivalent to a relative feed value (RFV) of 150 (Caddel and Allen 1994). Hayed treatments were not harvested on the 4 March harvest date; however, means were included in the analysis to account for all treatments. The CP was highest in the with no over-seeding (26 % CP), when actual forage utilization occurred (Table 9). The over-seeded alfalfa with ryegrass (13% CP) or wheat (15% CP) had the lowest CP values, however all treatments had RFV's above 200 with the exception of wheat (181). Temme et al. (1979) also indicated the crude protein of alfalfa forage decreased with an increase in cool-season grasses.

Total dietary nutrients (a general measure of the nutritive value of a feed) were highest in the ryegrass over-seeded plots (74% TDN) compared to all other treatments (avg. 71.25% TDN).

Profitability

Experiment 1. Spring net returns were highest in the wheat over-seed ($\$757.51\ \text{ha}^{-1}$) and wheat over-seed ($\$655.06\ \text{ha}^{-1}$) treatments compared to all other treatments (Table 10). In fact all grazing treatments, including the no over-seeding ($\$376.10\ \text{ha}^{-1}$) had higher net returns than the herbicide + insecticide treatment ($\$299.70\ \text{ha}^{-1}$) or the no pesticide treatment ($\$123.21\ \text{ha}^{-1}$). The increase in forage production from the over-seeded grass and the decrease in pesticide costs from grazing account for the largest portion of difference in net return between grazed and hayed treatments.

Experiment 2. Over-seeding and grazing were not as profitable at this location compared to Experiment 1 (Table 10). There was no difference in spring net returns among the no pesticide ($\$822.40\ \text{ha}^{-1}$), herbicide + insecticide ($\$785.88\ \text{ha}^{-1}$) or wheat over-seed ($\$613.45\ \text{ha}^{-1}$) treatments. The graze with no over-seed treatment had the lowest net return ($\$360.42\ \text{ha}^{-1}$). The application of permethrin to the entire study area at the beginning of the growing season reduced alfalfa weevil damage that could have severely decreased first harvest production in the no pesticide treatment and no over-seeded treatment. Increased weed competition due to grazing in the no over-seeded treatment decreased alfalfa production in the spring, thus decreasing net returns.

Experiment 3. Increased spring forage production from the over-seeded ryegrass and wheat followed by grazing had a significant effect on the net returns in this study (Table 10). The only significant difference among treatments occurred between ryegrass over-seed (\$925.53 ha^{-1}) and no over-seeded (\$691.23 ha^{-1}) or herbicide + insecticide (\$633.88 ha^{-1}) treatments. The significant decrease with the herbicide +insecticide treatment resulted from the decrease in production when cool-season weeds were suppressed and no over-seeded grass was present. At this location, even with the herbicide + insecticide treatments alfalfa stand density was so low that weeds were still able to grow and compete with the alfalfa, causing a decrease in alfalfa percentage of total forage and thus a decrease in price of the hay produced. Ryegrass and wheat over-seeding followed by grazing, provided ample quality forage production and decreased pesticide costs to increase the profitability of the poor alfalfa stand.

SUMMARY

Alfalfa stem densities, a predictor of alfalfa forage production, were higher in the herbicide + insecticide treatment than in all other treatments at all locations. There are several reasons for this. First, herbicide and insecticide application at critical time periods enabled the alfalfa to grow with little competition from weeds and insects. In addition, the over-seeded cool-season grasses exhibit a very aggressive growth habit in the late winter and early spring, as shown in the spring production data, which will cause a decrease in the competitive ability of the alfalfa.

To improve the forage production potential and profitability in thinning stands of alfalfa, the research indicated that over-seeding cool-season forage grasses like ryegrass and wheat provided increased forage production. The wheat and ryegrass also decreased weedy grass and broadleaf weed production without increased pesticide cost. This increase in forage production translated to increased profitability in two locations. Increasing nitrogen fertilizer increased cool-season grass forage production at two locations. This indicated fertility is important in thinning alfalfa stands for forage production. Over-seeding with ryegrass also increased the nutritive value (74% TDN) of the early spring forage. With increased early season forage production, the thinning alfalfa stand can provide additional forage for use as potential livestock feed for early spring utilization (Jung et al. 1996). Grazing alfalfa in early spring will effectively decrease alfalfa weevil larval populations as well (Buntin and Bouton, 1996). With the increased forage production by ryegrass and wheat for livestock feeding profitability of the stand is also increased in the final months of production.

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Table 1. Economic inputs for haying and grazing treatments in 1999 at all three locations.

Economic input	Cost to producer $\$$ ha^{-1}	Treatments affected
1. 112 kg ha^{-1} 18-46-0 @ $\$0.57$ kg^{-1}	29.12	All
2. Fertilizer spreader	5.55	All
3. Cyfluthrin (0.045 kg ha^{-1})	16.42	2
4. Terbacil (0.55 kg ha^{-1}) + Norflurazon (3.7 kg ha^{-1}) + imazethapyr (30.6 g ha^{-1})	121.36	2
5. Annual operating capital	2.69	All
6. Machinery labor @ $\$6.50$ hr^{-1}	4.52	All
7. Machinery fuel, lube and repairs	4.02	All
8. Fixed costs	6.91	All
9. Ryegrass @ $\$25.25$ bushel^{-1}	29.92	4
10. Wheat @ $\$6.00$ bushel^{-1}	29.63	5
11. Over-seeding machinery labor @ $\$6.50$ hr^{-1}	32.47	4, 5
12. Over-seeding other labor @ $\$6.50$ hr^{-1}	6.42	4, 5
13. Over-seeding machinery fuel, lube and repair	46.17	4, 5
14. Swathe and bale (29.21 Mg^{-1})	Yield dependent	All
15. Custom hauling [$\$0.42$ per small square bale (weighing 33.3 kg)]	Yield dependent	All

Table 2. Effect of grazing (with and without over-seeded wheat or ryegrass) and haying harvest methods on alfalfa weevil larval populations (MEAN ± SE) from February to April – Experiment 1 – Grady Co. 1999 (P< 0.05; LSD).

Harvest method	Alfalfa weevil larvae stem $^{-1}$				
and treatment	Feb 18[a]	Feb 23[b]	Mar 4[c]	Apr 8	Apr 19
Grazed					
No over-seeding	1.7 ± 0.4b	1.3 ± 0.1b	1.9 ± 0.1c	0.5 ± 0.2b	0.2 ± 0.1b
Over-seeded with Ryegrass	2.3 ± 0.2ab	2.5 ± 0.3a	3.5 ± 0.4a	0.5 ± 0.2b	0.3 ± 0.1b
Over-seeded with Wheat	2.7 ± 0.1a	1.5 ± 0.1b	2.8 ± 0.2b	0.5 ± 0.1b	0.2 ± 0.1b
Hayed					
No pesticides	2.6 ± 0.4ab	1.5 ± 0.2b	1.7 ± 0.2c	3.4 ± 1.1a	0.6 ± 0.2a
Herbicides + Insecticides	2.2 ± 0.1ab	1.3 ± 0.2b	0.2 ± 0.1d	0.1 ± 0.1b	0.1 ± 0.1b
LSD	0.9	0.6	0.6	1.4	0.9

[a] Means followed by the same letter are not significantly different within sampling date (Fishers protected LSD, P< 0.05).

[b] Cyfluthrin (0.045 kg ha^{-1}) application made to Herbicide + Insecticide plots after sampling on this date.

[c] 24 day grazing period, for grazed plots only, was initiated after sampling on 4 March 1999.

Table 3. Effect of grazing (with and without over-seeded wheat or ryegrass) and haying harvest methods on alfalfa weevil larval populations (MEAN ± SE) from February to April – Experiment 2 – Grady Co. 1999 (P< 0.05; LSD).

Harvest method and treatment	Alfalfa weevil larvae stem^{-1}			
	Feb 18[a]	Feb 23[b]	Mar 23[c]	Apr 17
Grazed				
No over-seeding	5.0 ± 1.0a	4.5 ± 0.8a	1.6 ± 0.2ab	0.2 ± 0. 1a
Over-seeded with Ryegrass	4.6 ± 0.8a	5.4 ± 1.2a	2.0 ± 0.3a	0.2 ± 0. 1a
Over-seeded with Wheat	4.8 ± 1.0a	4.6 ± 0.6a	2.0 ± 0.4a	0.2 ± 0. 1a
Hayed				
No pesticides	3.9 ± 1.0a	5.1 ± 0.9a	0.9 ± 0.3b	0.2 ± 0. 1a
Herbicides + Insecticides	4.6 ± 0.7a	4.2 ± 1.0a	0.1 ± 0.1b	0.2 ± 0. 1a
LSD	2.4	3.1	0.8	0.3

[a] Means followed by the same letter are not significantly different within sampling date (Fishers protected LSD, P< 0.05).

[b] Cyfluthrin (0.045 kg ha^{-1}) application made to Herbicide + Insecticide plots after sampling on this date and permethrin (0.11 kg ha^{-1}) applied to all other plots to suppress weevil larvae until grazing could be initiated.

[c] 14 day grazing period, for grazed plots only, was initiated after sampling on 23 March 1999.

Table 4. **Effect of grazing (with and without over-seeded wheat or ryegrass) and haying harvest methods on alfalfa weevil larval populations from February to April – Experiment 3 – Garvin Co. 1999 (P< 0.05; LSD).**

Harvest method and treatment	Alfalfa weevil larvae stem $^{-1}$			
	Feb 18[a]	Feb 23[b]	Mar 23[c]	Apr 17
Grazed				
No over-seeding	4.1 ± 0.7a	3.3 ± 0.2b	3.1 ± 0.2a	0.8 ± 0.4ab
Over-seeded with Ryegrass	6.1 ± 3.0a	6.0 ± 1.7ab	4.7 ± 1.2a	0.3 ± 0.1ab
Over-seeded with Wheat	3.6 ± 1.1a	6.5 ± 0.9a	4.7 ± 0.4a	0.3 ± 0.1b
Hayed				
No pesticides	5.4 ± 0.7a	6.0 ± 0.8ab	2.8 ± 0.2a	0.9 ± 0.2a
Herbicides + Insecticides	4.9 ± 0.5a	4.9 ± 0.5ab	0.3 ± 0.1b	0.4 ± 0.2ab
LSD	3.5	3.0	2.1	0.6

[a] Means followed by the same letter are not significantly different within sampling date (Fishers protected LSD, P< 0.05).

[b] Cyfluthrin (0.045 kg ha^{-1}) application made to Herbicide + Insecticide plots after sampling on this date.

[c] 9 day grazing period, for grazed plots only, was initiated after sampling on 23 March 1999.

Table 5. Effect of grazing (with and without over-seeded wheat or ryegrass) and haying harvest methods on first harvest alfalfa stem density at two experiments in Grady Co. and one experiment in Garvin Co., OK 1999.

Harvest method and treatment	Experiment 1 Grady Co. Stem density †	Experiment 2 Grady Co. Stem density †	Experiment 3 Garvin Co. Stem density †
	—— stems $0.1m^{-2}$ ——	—— stems $0.1m^{-2}$ ——	—— stems $0.1m^{-2}$ ——
Grazed			
No over-seeding	18.02b	9.63b	10.26b
Over-seeded with Ryegrass	11.66d	9.68b	5.20d
Over-seeded with Wheat	15.77c	9.15b	9.50bc
Hayed			
No pesticides	17.08bc	10.49b	7.31cd
Herbicides + Insecticides	25.92a	13.99a	12.89a

† Means followed by the same letter are not significantly different within location (General Linear Models Procedure, $P< 0.05$).

Table 6. Effects of grazing (with and without over-seeded ryegrass or wheat) and haying harvest methods on alfalfa production, over-seeded cool-season grass production, weedy grass production, and broadleaf weed production in established alfalfa – Experiment 1 – Grady Co. 1999

	Spring forage production †					Season forage production ‡				
Harvest method and treatment	Alfalfa	Over-seeded grass	Weedy grass	Broadleaf weeds	Total	Alfalfa	Over-seeded grass	Weedy grass	Broadleaf weeds	Total
	Mg ha^{-1}					Mg ha^{-1}				
Grazed	Includes March and May harvests									
No over-seeding	2.59a	0.00b	0.29a	0.22a	3.11b	9.43b	0.00c	2.17a	0.27a	11.87b
Over-seeded with Ryegrass	1.68b	4.95a	0.05a	0.16a	6.83a	6.92c	5.42a	2.62a	0.18ab	15.14a
Over-seeded with Wheat	2.84a	4.39a	0.07a	0.04b	7.35a	7.53bc	4.39b	2.60a	0.09bc	14.60a
Hayed	Includes only April harvest									
No pesticides	0.74b	----	0.63a	0.16a	1.52b	7.86bc	0.00c	2.71a	0.20a	10.77b
Herbicides + Insecticides	2.46a	----	0.09b	0.02a	2.57a	11.67a	0.00c	0.49b	0.02c	12.18b

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P< 0.05).

‡ Means followed by the same letter are not significantly different (Fisher's Protected LSD, P< 0.05).

Table 7. Effects of grazing (with and without over-seeded ryegrass or wheat) and haying harvest methods on alfalfa production, over-seeded cool-season grass production, weedy grass production, and broadleaf weed production in established alfalfa – Experiment 2 – Grady Co. 1999

Harvest method and treatment	Alfalfa	Over-seeded grass	Weedy grass	Broadleaf weeds	Total
			Spring forage production †		
			Mg ha^{-1}		
Grazed			Includes March and May harvests		
No over-seeding	0.69b	0.00b	2.04b	0.67b	3.40d
Over-seeded with ryegrass	1.41a	4.05a	0.51c	0.34c	6.32ab
Over-seeded with wheat	1.23ab	4.26a	0.67c	0.38bc	6.56a
Hayed			Includes only May harvest		
No pesticides	0.76b	—	3.92a	0.69b	5.38bc
Herbicides + insecticides	1.43a	—	2.53b	1.21a	5.17c

† Means followed by the same letter are not significantly different (General Linear Models Procedure, P< 0.05). Only cool-season forage production was analyzed at this location. The study was discontinued in June.

Table 8. Effects of grazing (with and without over-seeded ryegrass or wheat) and haying harvest methods on alfalfa production, over-seeded cool-season grass production, weedy grass production, and broadleaf weed production in established alfalfa – Experiment 3 – Garvin Co. 1999

Harvest method and treatment	Spring forage production †					Season forage production ‡				
	Alfalfa	Over-seeded grass	Weedy grass	Broadleaf weeds	Total	Alfalfa	Over-seeded Grass	Weedy grass	Broadleaf weeds	Total
	Mg ha^{-1}					Mg ha^{-1}				
Grazed	Includes March and May harvests									
No over-seeding	1.43a	0.00c	1.54a	1.59a	4.57b	3.29a	0.00c	1.66a	2.37b	7.32b
Over-seeded with ryegrass	1.01a	8.56a	0.22b	0.04b	9.83a	2.44ab	8.56a	0.31c	0.29c	11.60a
Over-seeded with wheat	2.91a	5.94b	0.27ab	0.33b	9.45a	3.72a	5.94b	0.56bc	0.29c	10.50a
Hayed	Includes only May harvest									
No pesticides	0.63a	----	3.56a	1.12a	5.31a	1.84b	0.00c	1.34a	3.58a	6.76b
Herbicides + insecticides	2.46a	----	1.52a	1.12a	5.11a	3.63a	0.00c	1.12ab	1.57b	6.32b

† Means followed by the same letter are not significantly different within harvest method (Fishers Protected LSD, P< 0.05).

‡ Means followed by the same letter are not significantly different (General Linear Models Procedure, P< 0.05).

Table 9. Effects of grazing (with and without over-seeded ryegrass or wheat) and haying harvest methods on crude protein, acid detergent fiber, neutral detergent fiber and total dietary nutrients (LSMEAN ± SE) on established alfalfa in March– Experiment 1 – Grady Co., OK 1999

Harvest method	Forage analysis (March 1999)				
and treatment	Crude protein	ADF	NDF	TDN	RFV
	%	%	%	%	index
Grazed					
No over-seeding	26b	24ab	32b	72b	237a
Over-seeded with ryegrass	13c	22b	36b	74a	216a
Over-seeded with wheat	15c	25a	41a	71b	181b
Hayed					
No pesticides	24b	26a	35b	71b	237a
Herbicides + insecticides	30a	25a	32b	71b	224a

‡ Means followed by the same letter are not significantly different (General Linear Models Procedure, $P< 0.05$).
Forage was not harvested from the hayed treatments at this date. Data is only included for comparison.

Table 10. Effect of grazing (with and without over-seeded wheat or ryegrass) and haying harvest methods on profitability from February to April at two experiments in Grady Co. and one experiment in Garvin Co., OK 1999

Harvest method and treatment	Net return above investment[a] Experiment 1	Experiment 2	Experiment 3
		$ $ ha^{-1}$	
Grazed			
No over-seeding	376.10b	360.42d	691.23b
Over-seeded with Ryegrass	655.06a	555.63c	925.53a
Over-seeded with Wheat	757.51a	613.45bc	814.76ab
Hayed			
No pesticides	123.21d	822.40a	809.63ab
Herbicides + Insecticides	229.70c	785.88ab	633.88b
LSD	42.03	76.76	75.16

[a] Means followed by the same letter are not significantly different within experiment number (Fishers protected LSD, P< 0.05).

VITA

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Master of Science

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