MANAGEMENT OF ALFALFA (*MEDICAGO SATIVA* L.)
IN THE SOUTHERN PLAINS

By

JAMES RONALD SHOLAR

Bachelor of Science
University of Tennessee at Martin
Martin, Tennessee
1971

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1973

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1984

MANAGEMENT OF ALFALFA (MEDICAGO SATIVA L.)

IN THE SOUTHERN PLAINS

Thesis Approved:

Jimmy F. Stritzke
Thesis Adviser

Richard Berberet

Billy B. Tucker

John L. Caddel

Norman N. Durham
Dean of the Graduate College

PREFACE

I wish to express deep appreciation to my major adviser, Dr. J. F. Stritzke, for his support and constructive criticism throughout this study. Appreciation is expressed to Drs. John Caddel, Richard Berberet, and Billy Tucker for their willingness to give freely of their time as members of my graduate committee.

Thanks are extended to Dr. Wayne McNeil, Dr. Sam Rupp, Kim Winton, and Chris Rice for their assistance with field and laboratory work.

Thanks go to Melanie Bayles for clerical review and typing of this manuscript.

The author is indebted to Oklahoma State University Agronomy Department for providing the opportunity and facilities for this research.

My most sincere appreciation is reserved for my wife Linda and my children, Tessa and Jason. Without their encouragement, this work would not have begun and without their love and continuous support, it would not have been completed.

Chapters two through five of this thesis are separate manuscripts to be submitted for publication in Agronomy Journal, the journal of the American Society of Agronomy.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Table Page

CHAPTER V

CHAPTER I

GENERAL INTRODUCTION

Fall Harvest Management

Alfalfa (*Medicago sativa* L.) is the most important legume serving as feed for livestock in North America with more than 12 million hectares grown annually in the U.S. Oklahoma grows approximately 225,000 hectares annually. Alfalfa is a perennial plant which may live for as long as 30 years. Establishing alfalfa is expensive, therefore, it is essential producers maintain vigorous, productive stands for as many years as possible before stand reestablishment is required.

Alfalfa is able to survive in a wide range of environmental conditions. It is believed to have evolved in what is now Iran, a region with cold winters and hot, dry summers (3). Proper management of alfalfa is necessary to allow the crop to exploit the environment - producing high yields while preserving a vigorous stand.

Stage of growth at cutting, time interval between cuttings, relationship of new crown shoots and cutting, effects of stubble height, spring harvest management, and fall harvest management have been reviewed by Smith (31) as important management considerations in alfalfa production.

This author recognized fall harvest management to be one of the most important considerations in alfalfa production. Fall harvest management of alfalfa has been studied extensively in northern states and it has been found that the harvesting schedule 4 to 6 weeks prior to the first killing freeze is critical (31). Little research has been done with regard to the effects of fall management of alfalfa in southern latitudes and virtually none under conditions similar to the semi-arid southern plains.

Willard et al. (36) demonstrated as early as 1934 that harvesting alfalfa in late September and early October in Ohio was likely to be more detrimental than cutting in early November when no growing season remained to deplete carbohydrate storage in roots. Silkett et al. (29) reported as early as 1937 that due to the short growing season in Michigan, generally only two cuttings of alfalfa were taken in a season. Three- or four-cut regimes resulted in winterkilling, stand reduction, and a decrease in yield. They showed that September harvests were more detrimental to crown bud formation than October harvests and that there was a reduction in stem number the following spring with September harvests. They found that 15 and 30 September harvests resulted in 80 and 79 stems, respectively measured in 1 m strips in the subsequent spring while the check plot which was uncut in the fall had 104 stems/1 m strip. Graber and Sprague (11) reported decreased plant survival and reduced forage production in the subsequent year with fall harvesting in Wisconsin. They found late October or early November cuttings less detrimental to survival and yield than late September and early October cuttings and reasoned that this was because carbohydrate levels in the crowns were more favorable with late season harvests.

Brown and Munsell (5) found that mid September harvesting was more damaging to spring forage yields and stand than late August or mid October harvesting in Connecticut. In their study, roots contained 19.0, 16.7, 19.1, and 22.8% total carbohydrate when the third harvest was taken on 30 August, 20 September, 15 October, and no fall harvest, respectively.

The critical nature of fall management in northern states and its close association with the level of total nonstructural carbohydrates (TNC) in alfalfa roots has been supported by a large number of researchers (10, 12, 18, 30, 32). Root TNC has been shown to provide energy required during dormant seasons and early spring growth (5, 10, 18) and initial regrowth after each harvest (10, 12, 13, 18). Alfalfa root TNC has also been found to be closely associated with winter-hardiness and winter survival (10, 12, 13). Graumann et al. (13) showed that from 14 to 41% of the fall stored carbohydrates in alfalfa roots may be used up during winter months. These authors have been widely credited with early work on fall harvest management; however, their work dealt with stage of growth harvesting and did not address fall harvesting.

Fall harvesting was again studied extensively with the availability of newer and improved alfalfa cultivars. Kust and Smith (18) evaluated various cutting systems on 'Vernal' alfalfa, a winterhardy and wilt-resistant cultivar, which is grown in Wisconsin. They found that cutting in early fall (11 October) reduced root carbohydrate levels to 19% when measured in early November compared to a 30% TNC level where plants were not cut after early October. Forage yields were also reduced after 2 years of fall cutting.

Twamley (35) reported that autumn harvests in Ontario, Canada resulted in significant spring alfalfa yield reduction and observed differential varietal responses to fall harvest. The winterhardy cultivar, Vernal, was less damaged by fall harvesting than less winterhardy cultivars, 'Ranger' and 'Dupuits'.

Cultivar responses to fall harvest management have also been reported by other investigators. Brown (4) reported that September harvests resulted in spring yield reductions of 44, 23, and 15% for 'Buffalo', Dupuits, and Vernal, respectively. Late October harvests did not result in reduced spring forage yields or damaged stands. Mays and Evans (21) found that fall harvesting was much more detrimental to Dupuits, a wilt-susceptible cultivar, than to 'Williamsburg', a wilt-resistant cultivar. Final plant densities for Williamsburg were 45 plants/m^2 with no fall harvest and 57 plants/m^2 with a 1 October harvest. Final plant densities for Dupuits were 28 plants/m^2 with no fall harvest and 12 plants/m^2 with a 1 October harvest.

Among the few studies on fall harvest management of alfalfa in southern states, Reynolds (26) did not find a significant positive correlation between TNC levels at the end of the second year and forage yields in the third year of experimentation with Buffalo alfalfa in Tennessee. He suggested that the lack of a high positive correlation between TNC levels and forage yields might be due to the presence of green leaves on alfalfa plants during the winter months and mild daily maximum temperatures which enables photosynthetic activity and little difference in TNC levels across fall cutting dates. Mays and Evans (21) suggested a similar reason for stable TNC concentrations across fall cutting systems in Alabama. They suggested that cool and sunny weather combined with slowly regrowing alfalfa in October and November might enhance stable TNC levels in the southern states. More recently, Collins and Taylor (7) found TNC levels in alfalfa roots to be unaffected by fall harvest management in Kentucky. They also found fall harvesting to be less damaging to alfalfa yields than similar treatments in northern states.

Jackobs and Oldemeyer (15) studied fall management of alfalfa in Washington and found that fall harvesting did not result in reduced yields until after such treatments had been imposed for 2 years. Fall harvesting had no effect on alfalfa stands. They suggested that the climate of the Yakima Valley area, characterized by low rainfall and high light intensities, might enable alfalfa to be less detrimentally affected by fall harvesting than in midwestern states.

Recent research by Marten (20) in Minnesota has reopened to question the necessity of avoiding fall harvesting even in northern latitudes. He found that fall harvesting did not decrease spring forage yields and had no detrimental effect on stand persistence. He suggested that adequate soil fertility, use of winterhardy cultivars, and the presence of adequate snow cover during cold extremes should allow stands to remain full and productive even if the last harvest was made in September or early October.

Weed Control Effects on Alfalfa

Because alfalfa seed is broadcast or planted in narrow rows, cultivation for weed control is usually impossible without damaging or destroying alfalfa plants (17). Weed control with herbicides for alfalfa stand establishment has been studied extensively (14, 19, 22, 24). However, weed control as an important management consideration on established stands has not been fully researched.

Peters and Peters (23), in their review of weed control in alfalfa, suggested that weeds compete with alfalfa for nutrients, light, and soil moisture which may be expected to cause yield reductions. However, studies conducted to determine the effects of weed control on forage production have not shown consistent alfalfa yield increases.

Wilson (37) studied the effects of fall-applied herbicides on alfalfa and weed yields in established, dryland alfalfa in Nebraska. All herbicides tested were effective in controlling downy brome (*Bromus tectorum* L.) with control of cool season broadleaf weeds dependent on herbicide used. All herbicide treatments resulted in increased forage yields and protein concentration compared to an untreated check.

Swan (33) tested six soil-applied herbicides on established alfalfa on a coarse textured soil in Washington. Simazine [2-chloro-4,6-bis(ethylamino)-s-triazine], propham (isopropyl carbanilate), terbacil (3-tert-butyl-5-chloro-6-methyluracil), carbetamide [D-N-ethyllactamide carbanilate (ester)], pronamide [3,5-dichloro-N-(1,1-dimethyl-2-propynyl)benzamide], and secbumeton [N-ethyl-6-methoxy-N'-(1-methylpropyl)-1,3,5 triazine -2,4-diamine] were applied in December for 4 years. The weedy grass present was downy brome (*Bromus tectorum* L.) and broadleaf weeds were flixweed [*Descurainia sophia* (L.) Webb], prickly lettuce (*Lactuca serriola* L.), and shepherdspurse [*Capsella bursa-pastoris* (L.) Medic]. Propham, carbetamide, and pronamide provided good control of downy brome, but gave only 30 to 40% control of broadleaf weeds. Alfalfa production was not increased by any of the herbicide treatments. Weed populations were low in this study, averaging 5 plants/m^2 for downy brome and 2 plants/m^2 for broadleaf weeds. Also, on this coarse textured soil, terbacil and simazine at 0.45 kg/ha and a high rate of secbumeton (2.70 kg/ha) were phytotoxic to alfalfa.

Robison et al. (27) evaluated herbicides applied in November for weed control in established alfalfa stands in Utah. Herbicides were applied for 2 consecutive years for control of downy brome, shepherdspurse, and common dandelion (Taraxacum officinale Weber). Weeds in the untreated check averaged approximately 300 kg/ha. Herbicides used were cyanazine {2-[[4-chloro-6-(ethylamino)-s-triazin-2-yl] amino]-2-methyl-propionitrile}, cyprazine [2-chloro-4-(cyclopropylamino)-6-(isopropylamino)-s-triazine], diuron [3-(3,4-dichlorophenyl)-1,1-dimethyl-urea], metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazine-5-(4H)-one], paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), pronamide, secbumeton, simazine, and terbacil. They obtained increased weed-free alfalfa production in only one case. Secbumeton at 0.56 kg/ha resulted in significantly greater alfalfa production at first harvest than the untreated check. All other herbicide treatments resulted in decreased alfalfa yields compared to the untreated check.

Cords (8) found that weeds can reduce protein concentration and reduce palatability, digestibility, and acceptability of alfalfa forage. He suggested that the reduction in forage quality due to weeds is more important than yield reduction in contributing to loss in established alfalfa stands.

Klingman and Ashton (17) suggested that weeds encourage alfalfa stand decline. However, this does not appear to be documented in the scientific literature. Willard et al. (35) showed that weeds invade alfalfa stands which are declining due to improper harvest management in Ohio. Jung et al. (16) found increased weed infestations in West Virginia tests when alfalfa was harvested in October of the preceding year. Weed infestations following an early September harvest were 4 and 11%, respectively at two locations and increased to 19 and 26%, respectively for an October harvest.

Harvest Management Effects on Alfalfa Weevil

Berberet (1) reported that the alfalfa weevil *Hypera postica*, (Gyllenhal), is the most serious insect pest of alfalfa in Oklahoma. The presence of the alfalfa weevil has been confirmed in all 77 counties in Oklahoma.[1] Berberet et al. (2) found that each increase of one larva/stem in infestation level can result in alfalfa yield losses of an additional 190 kg/ha. Plant defoliation by larvae is the main cause of yield reduction, with reduced growth and delayed maturity also contributing to reduced productivity (2).

Cultural forms of weevil control received extensive attention in the early 1900's. Titus (34) studied a number

---

[1]Personal communication, D. L. Arnold, Survey Entomologist, Oklahoma State University.

of different cultural controls for the weevil in Utah. Pasturing of alfalfa with horses and sheep, cutting and burning of the first hay crop, use of brush drags to knock larvae to the ground, and use of wire sweeps and weevil gathering machines were early attempts to reduce the effects of the weevil. Limited or temporary success only was obtained with each of these methods. Consequences of some of these control practices were also undesirable since they damaged or destroyed the hay crop. Reeves and Hamlin (25) reported that timely harvesting of alfalfa during the growing season reduced larval populations by 94.2% and they attributed the reduction to larva exposure to heat from the sun and starvation.

Casagrande and Stehr (6) reported that the alfalfa weevil lays very few eggs in the fall in Michigan. They found that most eggs and larvae were present in the field at first harvest in the spring. They obtained a 79% reduction in weevil larvae by cutting alfalfa at 507 degree days (base 8.9^{o} C) with little weevil damage to the alfalfa crop.

The amount of fall regrowth left on a field has also been found to influence the alfalfa weevil population. Dively (9) examined overwintering of alfalfa weevil eggs in three alfalfa regrowth stages in New Jersey. He found significantly higher numbers of fall laid eggs in alfalfa in a 2.4 to 2.8 cm fall growth stage than in a fresh stubble stage (0.8 to 1.2 cm) and a bud stage (4.75 to 5.5 cm).

Senst and Berberet (28) reported that winter grazing of alfalfa with cattle reduced alfalfa weevil eggs by more than 70% and larvae by more than 50% in the subsequent spring. Alfalfa regrowth is frequently hayed or grazed during mid-September to late November in the southern plains.

The objectives of this research were to: (1) determine the effects of fall harvest management on alfalfa productivity, stand persistence, and weed infestations, (2) determine the effects of dormant season herbicide use on weed infestations, forage yield and quality, and stand persistence, and (3) determine if fall harvest management may be important as a cultural control measure for the alfalfa weevil.

LITERATURE CITED

1. Berberet, R. C. 1982. Integrated control of the alfalfa weevil. Okla. State Univ. Ext. Current Report No. 7179. 6 pp.

2. __________, R. D. Morrison, and K. M. Senst. 1981. Impact of the alfalfa weevil, Hypera postica (Gyllenhal) (Coleoptera:Curculionidae), on forage production in non-irrigated alfalfa in the southern plains. J. of the Kansas Entomol. Soc. 54(2):312-318.

3. Bolton, J. L., B. P. Goplen, and H. Baenziger. 1972. World distribution and historical developments. In C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:1-34. Am. Soc. of Agron., Madison, Wis.

4. Brown, B. A. 1963. Alfalfa varieties and their management. Connecticut Agric. Exp. Stn. Bull. 376.

5. __________ and R. I. Munsell. 1942. The effects of cutting systems on alfalfa. Connecticut Agric. Exp. Stn. Bull. 242.

6. Casagrande, R. A. and F. W. Stehr. 1973. Evaluating the effects of harvesting alfalfa on alfalfa weevil (Coleoptera:Curculionidae) and parasite populations in Michigan. Can. Ent. 105:1119-1128.

7. Collins, M. and T. H. Taylor. 1980. Yield and quality of alfalfa harvested during autumn and winter and harvest effects on the spring crop. Agron. J. 72:839-844.

8. Cords, H. P. 1973. Weeds and alfalfa hay quality. Weed Sci. 21:400-401.

9. Dively, G. P. 1970. Overwintering alfalfa weevil eggs in three stages of alfalfa grown in New Jersey. Ann. of the Entomol. Soc. of Am. 63:5, 1213-1216.

10. Graber, L. R., N. T. Nelson, W. A. Luekel, and W. B. Albert. 1927. Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants. Wisconsin Agric. Exp. Stn. Res. Bull. 80.

11. __________ and V. G. Sprague. 1938. The productivity of alfalfa as related to management. Jour. Amer. Soc. of Agron. 30:38-54.

12. Grandfield, C. O. 1935. The trend of organic food reserves in alfalfa roots as affected by cutting practices. J. Agric. Res. 50;697-709.

13. Graumann, H. O., J. E. Webster, C. L. Canode, and H. F. Murphy. 1954. The effect of harvest practices on the performance of alfalfa. Oklahoma Agric. Exp. Stn. Bull. B.-433.

14. Illnicki, R. D. and H. P. Wilson. 1968. Control of annual weeds in spring-seeded alfalfa with preplant, preemergence, and postemergence herbicides. Proc. Northeast Weed Control Conf. 22:300-304.

15. Jackobs, J. A. and D. L. Oldemeyer. 1955. The response of four varieties of alfalfa to spring clipping in the Yakima Valley. Agron. J. 47:169-170.

16. Jung, G. A., R. L. Reid, and J. A. Balasko. 1969. Studies on yield, management, persistence, and nutritive value of alfalfa in West Virginia. West Virginia Agric. Exp. Stn. Bull. 581T.

17. Klingman, G. C. and F. M Ashton. 1975. Weed science: principles and practices. John-Wiley and Sons. New York.

18. Kust, C. A. and D. Smith. 1961. Influence of harvest management on the level of carbohydrate reserves, longevity of stands, and yields of hay and protein from Vernal alfalfa. Crop Sci. 1:267-269.

19. Linscott, D. L., R. D. Hagin, and A. A. Akhavein. 1967. Weed control during establishment of alfalfa and birdsfoot trefoil. Proc. Northeast Weed Control Conf. p. 38.

20. Marten, G. C. 1980. Late autumn harvest of third crop alfalfa can allow long stand persistence in the north. Forage and Grassland Prog. 21:3-4.

21. Mays, D. A. and E. M. Evans. 1973. Autumn cutting effects on alfalfa yield and persistence in Alabama. Agron. J. 65:290-292.

22. Peters, E. J. 1967. Establishment of spring-sown alfalfa with preemergence and preplanting herbicides. Proc. North Cent. Weed Control Conf. p. 38.

23. __________ and R. A. Peters. 1972. Weeds and weed control In: C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:555-573.

24. Peters, R. A. and H. C. Yokum. 1962. Further evaluation of herbicides for weed control in new seedings of alfalfa. Proc. Northeast Weed Cont. Conf. 16:299-302.

25. Reeves, G. I. and J. C. Hamlin. 1931. The use of mathematics in alfalfa weevil investigations. Rept. Eighth Rocky Mt. Conf. Ent. p. 11-16.

26. Reynolds, J. H. 1971. Carbohydrate trends in alfalfa (Medicago sativa L.) roots under several forage harvest schedules. Crop Sci. 11:103-106.

27. Robison, L. R., C. F. Williams, and W. D. Laws. 1978. Weed control in established alfalfa (Medicago sativa L.). Weed Sci. 26:37-40.

28. Senst, K. M. and R. C. Berberet. 1980. Effects of winter grazing of dormant alfalfa stands on populations of Hypera postica (Gyllenhal) (Coleoptera:Curculionidae) and its parasite Bathyplectes curculionis (Thompson) (Hymenoptera: Ichneumonidae). J. of the Kansas Entomol Soc. 53(1):230-234.

29. Silkett, V. W., C. R. Mcgee, and H. C. Rather. 1937. The effect of late summer and early fall cutting on crown bud formation and winter hardiness of alfalfa. J. Am. Soc. Agron. 29:53-62.

30. Smith, D. 1962. Carbohydrate root reserves in alfalfa, red clover, and birdsfoot trefoil over several management schedules. Crop Sci. 2:75-78.

31. __________. 1972. Cutting schedules and maintaining pure stands. In C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:481-496. Am. Soc. of Agron., Madison, Wis.

32. Smith, E. and C. J. Nelson. 1967. Growth of birdsfoot trefoil and alfalfa. I. Responses to height and frequency of cutting. Crop Sci. 7:130-133.

33. Swan, D. G. 1978. Effects of repeated herbicide applications on alfalfa (Medicago sativa). Weed Sci. 26:151-153.

34. Titus, E. E. 1910. The alfalfa-leaf weevil. Utah Agric. Exp. Stn. Cir. 10:105-120.

35. Twamley, B. E. 1960. Variety, fertilizer, management interactions in alfalfa. Canadian J. Plant Sci. 40:130-138.

36. Willard, C. J., L. E. Thatcher, and J. S. Cutter. 1934. Alfalfa in Ohio. Ohio Agric. Exp. Stn. Bull. 540.

37. Wilson, R. G. 1981. Weed control in established dryland alfalfa (*Medicago sativa*). Weed Sci. 29:615-618.

CHAPTER II

FALL HARVEST MANAGEMENT OF ALFALFA IN THE SOUTHERN PLAINS

Abstract

Fall regrowth of alfalfa (*Medicago sativa* L.) frequently is harvested for hay in the southern plains. Possible detrimental effects of harvesting from mid-September to late November have not been studied. The objective of this research was to determine the effects of fall cutting dates on root total nonstructural carbohydrates (TNC) concentrations, productivity, and stand persistence of semi-dormant, dryland alfalfa in the southern plains. From 1978 to 1980, five fall cutting date treatments were imposed on a 4-year-old stand of 'Kanza' and 2-year-old stands of 'Arc' and 'Liberty' alfalfas grown under dryland conditions on a fine, mixed thermic, pachic Arguistolls (McClain silty clay loam). Three harvests per season were made at 10 to 25% bloom prior to the fall cutting date treatments which were made at fourth harvest of the season. Root carbohydrate analyses were made on roots dug 7 December of each year. Forage yields were taken during each growing season subsequent to fall cutting date treatments with a residual harvest taken in April 1981. Stand densities were

determined at initiation of the study in 1978 and each fall thereafter. Final stand densities were determined in May 1981. Only forage yields were determined for Liberty. Fall cutting date treatments had little effect on root carbohydrate reserves. Roots dug in 1978 had higher TNC percentages than those dug in 1979 or 1980; however, fall cutting date treatments significantly influenced TNC concentrations only in the fall of 1979. Fall cutting date treatments had a greater effect on first harvest in the subsequent spring than on total yields. Total yields for each season and total yields over the duration of the study for each cultivar indicate that harvesting could take place at any fall date with little effect on productivity in subsequent years. Stands of all cultivars declined over the course of the study and at the conclusion of the study in May, 1981 there were no differences in stand persistence that could be attributed to fall cutting date treatments.

Additional index words: Total nonstructural carbohydrates, _Medicago sativa_ L., Forage yield, Stand persistence.

Introduction

Many investigators have found that the harvesting schedule 4 to 6 weeks prior to the first killing frost is critical for alfalfa (_Medicago sativa_ L.) management in northern states (14). This critical nature of fall management has been found to be closely associated with the level of total nonstructural carbohydrates (TNC) in alfalfa roots (5, 6, 7, 8, 9, 13, 14, 15). Root TNC in alfalfa has been shown to provide energy required during dormant seasons, early spring growth, and initial regrowth after each harvest (5, 6, 7, 8). Alfalfa root TNC has also been found to be closely associated with winterhardiness and winter survival (5, 6, 7).

Most of the early studies on the effects of fall management of alfalfa were conducted in the humid, northern areas of the USA and only recently have studies been conducted in the humid southeast. Little attention to effects of fall management has been directed to alfalfa cultivars grown under the semi-arid conditions of the southern plains.

Silkett et al. (12) reported that due to the short growing season in Michigan, generally only two cuttings of alfalfa were taken in a season. Three- or four-cut regimes resulted in winterkilling, stand reduction, and a decrease in yield. Kust and Smith (8) evaluated various cutting systems on 'Vernal' alfalfa, a winter-hardy and wilt-resistant cultivar, grown under Wisconsin conditions. They found that cutting in early fall (11 October) reduced root carbohydrate levels to 19% when measured in early November compared to a 30% TNC level where plants were not cut after early October. Forage yields were also reduced after 2 years of fall cutting.

Among the few studies conducted on fall harvest management of alfalfa in southern states, Reynold (10) did not find a significant positive correlation between TNC levels at the end of the second year and forage yields in the third year of experimentation with Buffalo alfalfa in Tennessee. He suggested the lack of a high positive correlation between TNC levels and forage yields might be due to the presence of green leaves on alfalfa plants during the winter months and mild daily maximum temperatures which enables photosynthetic activity and little difference in TNC levels across fall cutting dates. Mays and Evans (9) suggested a similar reason for stable TNC levels across fall cutting systems in Alabama. More recently, Collins and Taylor (3) found that late harvesting in Kentucky was less detrimental to alfalfa than similar treatments in northern states.

The objective of this research was to determine the effects of fall cutting dates on root TNC concentrations, productivity, and stand persistence of semi-dormant, dryland alfalfa in the southern plains.

Materials and Methods

Three experiments were initiated in September 1978 near Chickasha, Okla., on a fine, mixed thermic, Pachic Arguistolls (McClain silty clay loam, 0 to 1% slope). A 4-year-old stand of 'Kanza' and 2-year-old stands of 'Arc' and 'Liberty' alfalfas were used for Experiments 1, 2, and 3, respectively. Soil analyses showed the following: Exp. 1--pH 6.8, 104 kg P/ha, and 546 kg K/ha; and Exp. 2 and 3--pH 7.4, 43 P kg/ha and 340 kg K/ha. An application of 67 kg P/ha and 22 kg K/ha was made in February 1979 for Exp. 2 and 3, but no fertilizer was applied to the site of Exp. 1.

Randomized complete block experimental designs were employed for each study with six, four, and six replications for Exp. 1, 2 and 3, respectively. Plot dimensions were 4.6 X 8.6 m, 4.6 X 4.3 m, and 4.6 X. 2.1 m for Exp. 1, 2 and 3, respectively.

Alfalfa was routinely harvested from all sites prior initiation of the studies in 1978. In 1978, 1979, and 1980 five fall cutting-date treatments were imposed on all experiments. The first through third harvests for all treatments of each growing season were made on normally accepted dates with the fourth (final harvest of season) made according to the schedule in Table 1. In 1981, residual effects of the previous harvest treatments were measured at the first spring harvest.

Forage yields only were determined for Exp. 3. Otherwise data collection procedures were identical in all experiments. Root TNC reserves were measured from alfalfa roots dug after the initial killing freeze (-5^{o}C) of each fall. Roots from 20 plants per plot were scraped free of soil and dried at 65^{o}C for 5 days. A 10-cm section of taproot immediately below the crown was retained for TNC analysis following the procedure used by Shroyer et al.

(11). Crown cover was measured by estimating the amount of ground surface area covered by alfalfa.

Forage was harvested with a flail harvester by clipping a 1 X 4.6 m strip from each plot at 10 to 25% bloom for all harvests prior to the fall cutting date treatments. Clipping height was approximately 4 cm. A sample of approximately 100 g dry weight was collected at each harvest from each plot and dried at 65^{o}C for dry matter determination. Stand densities were determined by estimating percent crown cover at the initiation of the experiments in the fall of 1978 and again in the fall of 1979 and 1980. Final stand densities were determined May 1981 by undercutting, uprooting, and counting alfalfa plants in a 0.46 X 4.6 m area from each plot.

Rainfall data for 1978-1981 indicate that the summers of 1979 and 1980 were extremely dry (Table 2). Rainfall during April through September of 1979 was 56.4 cm with more than one-half of the total or 31.4 cm falling during May and June. During April through September of 1980, 39.8 cm of rainfall were measured at the site of which 21.2 cm or 53% of the total amount for that period was received in June. Thirty-year records for Chickasha indicate an average of 49.7 cm rainfall for the April to September period. Temperature data collected at the site indicate the first hard freezing temperature (-5^{o}C), as defined by Curry (4) occurred 3 Dec. 1978, 12 Nov. 1979, and 19 Nov. 1980. Table 3 presents the number of days from each fall cutting date treatment to the first hard freeze. For the purpose of this study, -5^{o}C was observed to be the temperature at which the upright top growth of alfalfa was killed, signaling the end of the summer/fall type growth. Thereafter, green prostrate growth remained at the base of each alfalfa crown throughout the winter period. Recovery times from last fall harvest to the first hard freeze were nearly identical in 1978 and 1979; however, recovery times were substantially shorter in 1980.

Results and Discussion

Total Nonstructural Carbohydrates

Total nonstructural carbohydrate levels measured in roots dug on 7 December were not significantly affected ($P \leq 0.05$) by the last fall harvest in 1978 or 1980 (Table 4). In 1979, there was a significant reduction in TNC concentration in roots of Kanza from the treatment 5 cutting date. These plants were cut 6 Nov. 1979 and were allowed only 6 days for recovery before the first killing freeze (Table 3). There was no significant difference ($P \leq 0.05$) among the first four cutting date treatments where recovery times ranged from 27 to 76 days (Table 3). Concentrations of TNC in roots of Arc followed a similar trend as Kanza in Exp. 1 (Table 4); however, none of the differences were significant at the $P \leq 0.05$ level.

Levels of TNC in this study varied with year. The range was from a low of 20.7% for Arc in 1980 to a high of

39.7% for Arc in 1978. Total nonstructural carbohydrate concentrations in Kanza ranged from a low of 21.8% in 1980 to a high of 36.3% in 1978. Root carbohydrate concentrations tended to be higher in 1978 and 1979 than in 1980. Root TNC levels at the concentrations found in this study should be sufficiently high to allow for good stand persistence and little or no detrimental effect on forage yields in subsequent years.

Root TNC levels were generally higher and showed less influence due to fall cutting date than results reported from northern sites. For example, Brown and Munsell (2) found root carbohydrate levels of 16.7% for alfalfa cut 20 September and 22.8% TNC for alfalfa not harvested during the fall. Our results were similar to results from Kentucky where Collins and Taylor (3) found fall TNC levels were not consistently reduced by fall harvest treatments. Mays and Evans (9) suggested that cool and sunny weather combined with slowly regrowing alfalfa in October and November might enhance stable TNC levels in the southern states. In these experiments, regrowth subsequent to the last fall harvest and prior to the first hard freeze was characterized by prostrate, leafy growth. October and November in south central Oklahoma are characterized by good photosynthetic conditions. The combination of the presence of photosynthetic material and proper environmental conditions may be responsible for the similarity in TNC concentrations among treatments in alfalfa roots.

Forage Yields

Exp. 1--Kanza. Forage yields were analyzed statistically for individual harvests, total of the first three harvests of each year, and total forage produced during the study (Table 5). Yields at all individual harvests (second and third harvests, data not shown) and total for the first three harvests in 1979 was unaffected by variable fall cutting dates imposed in 1978. Forage yields were significantly affected ($P \leq 0.05$) by fall cutting date treatments at the fourth harvest in 1979 (variable fall cutting dates) due to the difference in growth interval between the third and fourth harvests. There were, however, no significant differences ($P \leq 0.05$) among cutting date treatments for the total season forage yields in 1979. First harvest forage yields in 1980 were significantly ($P \leq 0.05$) lower in plots cut 16 Oct. 1979 and 6 Nov. 1979; however, second and third harvests were unaffected. The dry growing conditions in the summer of 1980 produced variable topgrowth at the time the last cut treatments were made in the fall of 1980 (fourth harvest). The cutting date treatments were imposed in 1980; however, there was no attempt to determine forage yields for the last cut harvest due to the lack of uniform growth on the plots. A final uniform cutting on 29 Apr. 1981 revealed no residual differences at first harvest due to fall cutting date treatments in 1980 and showed no significant effect had built up over the 3 years of variable fall harvest management.

Exp. 2--Arc. Fall cutting date treatments (Table 5) did not significantly ($P \leq 0.05$) affect first harvest yields in 1979 although the 21 Sept. 1978 harvest (Treatment 1) tended to be better than other fall cutting dates. The 21 September harvest was significantly better ($P \leq 0.05$) than other treatments for the total of the first three harvests in 1979. Cutting date treatments in second and third harvest were not statistically different (data not shown). The 28 Aug. 1979 last harvest resulted in significantly higher yields at the first harvest in 1980 than other treatments; however, yields at second and third harvest (data not shown) and the total yield for the first three harvests were not statistically different. As in Exp. 1, forage yields were not determined for the last cut harvest (fourth harvest) in 1980. The residual harvest in 1981 showed no differences among treatments.

Exp. 3--Liberty. Last cut treatments imposed in the fall of 1978 and 1979 did not affect ($P \leq 0.05$) first, second, or third harvest yields or total season forage yields in 1979 and 1980 (Table 5). The stand declined to such an extent during the summer of 1980 that forage yields in 1981 were not measured, and no differences among fall harvest management treatments were observed. These three experiments showed that fall harvest date had little influence on the first harvest or seasonal yields in subsequent year.

Stand Persistence

Exp. 1--Kanza. Stand densities for all cutting date treatments are presented in Table 6. Uniform stands of approximately 60 to 80 plant/m^2 were present in all plots at the beginning of the study. This resulted in from 14 to 20% crown cover in December 1978. The increase in percent crown cover ratings from 1978 to 1979 resulted from an increase in crown size rather than an increase in plant numbers. Crown cover percentages which averaged about 11% were lower in December 1980 than in December 1979 when they were about 18%. The dry summer of 1980 contributed to an overall stand decline and percent crown cover in December 1980 declined in all treatments from 1979 measurements. Although there was an overall decline in stand density throughout the study, differential fall cutting date treatments did not influence stand density during any year of the experiment nor in the final plant counts in May 1981. Plant counts in May 1981 ranged from 26 to 32 plants/m^2 and showed no significant differences due to fall treatments.

Exp. 2--Arc. Stand in Exp. 2 (Table 6) followed a trend similar to Exp. 1. Uniform stands of approximately 50 to 70 plants/m^2 were present in all plots at the beginning of the study. Crown cover percentages were approximately 11%. Percent crown cover was higher in 1979 than in 1978 due to an increase in crown size. Crown cover declined dramatically in 1980 due to the dry summer. Final plant counts in May 1981 ranged from 16 to 20/m^2 and revealed no significant differences among treatments.

These data do not agree with conclusions reported by Brown (1) who found autumn harvests on 16 to 30 September to reduce alfalfa stands. These studies confirmed results of studies by Mays and Evans (9) who found stands in the South are more tolerant of late fall harvest than in northern regions.

LITERATURE CITED

1. Brown, B. A. 1963. Alfalfa varieties and their management. Connecticut Agric. Exp. Stn. Bull. 376.

2. __________ and R. I. Munsell. 1942. The effects of cutting systems on alfalfa. Connecticut Agric. Exp. Stn. Bull. 242.

3. Collins, M., and T. H. Taylor. 1980. Yield and quality of alfalfa harvested during autumn and winter and harvest effects on the spring crop. Agron. J. 72:839-844.

4. Curry, B. R. 1970. Freezing temperatures in Oklahoma. Oklahoma State University Coop. Ext. Ser. (Unnumbered Publ.).

5. Graber, L. F., N. T. Nelson, W. A. Luekel, and W. B. Albert. 1927. Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants. Wisconsin Agric. Exp. Stn. Res. Bull. 80.

6. Grandfield, C. O. 1935. The trend of organic food reserves in alfalfa roots as affected by cutting practices. J. Agric. Res. 50:697-709.

7. Graumann, H. O., J. E. Webster, C. L. Canode, and H. F. Murphy. 1954. The effect of harvest practices on the performance of alfalfa. Oklahoma Agric. Exp. Stn. Bull. B-433.

8. Kust, C. A., and D. Smith. 1961. Influence of harvest management on the level of carbohydrate reserves, longevity of stands, and yields of hay and protein from Vernal alfalfa. Crop Sci. 1:267-269.

9. Mays, D. A., and E. M. Evans. 1973. Autumn cutting effects on alfalfa yield and persistence in Alabama. Agron. J. 65:290-292.

10. Reynolds, J. J. 1971. Carbohydrate trends in alfalfa (*Medicago sativa* L.) roots under several forage harvest schedules. Crop Sci. 11:103-106.

11. Shroyer, J. P., J. F. Stritzke, and L. I. Croy. 1979. Carbohydrate levels and control on blackjack oak and winged elm treated with tebuthiuron and 2,4,5-T. J. Range Manage. 32:60-62.

12. Silkett, V. W., C. R. Megee, and H. C. Rather. 1937. The effect of late summer and early fall cutting on crown bud formation and winterhardiness of alfalfa. J. Am. Soc. Agron. 29:53-62.

13. Smith, D. 1962. Carbohydrate root reserves in alfalfa, red clover, and birdsfoot trefoil under several management schedules. Crop Sci. 2:75-78.

14. __________. 1972. Cutting schedules and maintaining pure stands. In C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:481-496. Am. Soc. of Agron., Madison, Wis.

15. __________ and C. J. Nelson. 1967. Growth of birdsfoot trefoil and alfalfa. I. Responses to height and frequency of cutting. Crop Sci. 7:130-133.

Table 1. Harvest schedule for fall harvest management studies, 1978 to 1981.

Harvest no.	Last cut treatment	1978	1979	1980	1981
1		-	7 May	6 May	29 April
2		-	14 June	4 June	-
3		15 July	17 July	12 July	-
4	1	21 Sept.	28 Aug.	1 Oct.	-
4	2	4 Oct.	13 Sept.	9 Oct.	-
4	3	18 Oct.	26 Sept.	23 Oct.	-
4	4	4 Nov.	16 Oct.	6 Nov.	-
4	5	21 Nov.	6 Nov.	20 Nov.	-

Table 2. Monthly rainfall during harvest management studies. Chickasha, Okla., 1978 to 1981.

	30 Year mean 1951-1980	1978	1979	1980	1981
	cm				
January	2.3	4.3	3.5	4.9	0.1
February	3.0	8.7	1.8	3.2	4.0
March	5.1	2.8	8.8	4.6	7.9
April	7.2	4.5	7.1	4.5	6.2
May	13.0	21.0	15.5	21.2	10.9
June	7.9	10.0	15.9	5.7	-
July	6.4	1.9	7.7	0.0	-
August	6.4	3.3	5.2	1.5	-
September	8.8	6.9	5.0	6.9	-
October	6.8	0.5	5.3	3.5	-
November	3.9	6.1	2.4	2.4	-
December	2.7	0.9	6.0	4.2	-
Annual Total	73.5	71.6	84.6	62.5	
Dev. from mean		-1.9	+11.1	-11.0	

Table 3. Recovery time from last harvest to first killing freeze (-5°C) for 1978 to 1980.+

Last cut treatment	Year 1978	1979	1980
	-------------days-------------		
1	73	76	49
2	60	60	41
3	46	47	27
4	29	27	13
5	12	6	0

+3 Dec. 1978, 12 Nov. 1979, and 19 Nov. 1980.

Table 4. Total nonstructural carbohydrate (TNC) concentration in alfalfa roots following fall cutting date treatments for Kanza and Arc in 1978, 1979, and 1980.

Last cut treatment	Year 1978	1979	1980
	-------------%TNC-------------		
Exp. 1--Kanza			
1	36.3	30.9	26.1
2	34.8	31.0	25.7
3	35.4	32.3	21.8
4	32.9	33.6	23.4
5	34.4	25.6	24.2
LSD (0.05)	NS	5.0	NS
Exp. 2--Arc			
1	39.0	32.2	22.7
2	39.7	33.0	24.6
3	36.2	32.6	20.7
4	35.8	33.0	20.7
5	38.2	30.9	23.3
LSD (0.05)	NS	NS	NS

Table 5. Forage dry matter yields following fall cutting date treatments for Kanza, Arc, and Liberty alfalfas, 1979 to 1981.

	1979				1980		1981	1979-81
Last cut treatment	First harvest	Total of first 3 harvests	Fourth harvest	Total of 4 harvests	First harvest	Total of first 3 harvests	First harvest	Total yield+
	Mg/ha							
Exp. 1--Kanza								
1	5.1	12.8	1.5	14.3	3.2	7.6	2.0	23.9
2	4.9	11.9	2.0	13.9	3.1	7.1	1.9	22.9
3	4.9	12.5	2.1	14.6	3.4	7.7	1.8	24.1
4	5.2	12.3	1.9	14.2	2.8	6.6	2.0	22.8
5	5.3	12.8	1.6	14.4	2.8	7.1	1.7	23.2
LSD (0.05)	NS	NS	0.2	NS	0.3	NS	NS	NS
Exp. 2--Arc								
1	4.9	11.2	0.8	12.0	3.6	7.6	2.0	21.6
2	4.7	10.4	1.8	12.2	3.1	6.7	2.0	20.9
3	4.4	10.6	1.9	12.5	3.3	7.6	2.2	22.3
4	4.3	10.4	1.7	12.1	3.0	6.9	1.9	20.9
5	4.4	10.8	1.4	12.2	3.0	6.8	2.1	21.1
LSD (0.05)	NS	0.4	0.3	NS	0.4	NS	NS	NS

Table 5. Continued.

	1979				1980		1981	1979-81
Last cut treatment	First harvest	Total of first 3 harvests	Fourth harvest	Total of 4 harvests	First harvest	Total of first 3 harvests	First harvest	Total yield+
	Mg/ha							
Exp. 3--Liberty								
1	5.1	11.0	1.5	12.5	4.1	7.8	-	20.3
2	4.6	10.1	2.1	12.2	3.6	6.8	-	19.0
3	4.3	9.3	2.4	11.7	3.7	7.1	-	18.8
4	4.7	10.2	2.2	12.4	4.1	7.6	-	20.0
5	4.9	10.7	1.8	12.5	3.6	7.0	-	19.5
LSD (0.05)	NS	NS	0.3	NS	NS	NS	-	NS

+Four harvests in 1979, three harvests in 1980, and one harvest in 1981 for Kanza and Arc. Four harvests in 1979 and three harvests in 1980 for Liberty.

Table 6. Percent crown cover following fall cutting date treatment for Kanza and Arc alfalfa in 1978, 1979, and 1980 and stand density following spring cutting in 1981.

	Date			
Last cut treatment	Dec. 1978	Dec. 1979	Dec. 1980	May 1981
	-----% crown cover------			$plants/m^2$
Exp. 1--Kanza				
1	14	18	11	32
2	15	19	12	28
3	20	19	11	31
4	17	17	10	28
5	18	18	9	26
Exp. 2--Arc				
1	11	17	3	20
2	13	17	5	20
3	10	13	5	18
4	11	14	4	17
5	10	13	3	16

CHAPTER III

EFFECTS OF FALL MANAGEMENT AND WEED CONTROL ON ALFALFA QUALITY AND STAND PERSISTENCE

Abstract

The relationship between weed infestations, weed control with herbicides, and fall harvest management of alfalfa (*Medicago sativa* L.) has not been defined for the southern plains. The objective of this research was to document the effects of fall harvest management on weed infestations and forage quality as measured by crude protein and to evaluate the effects of weed control on forage production, forage quality, and stand persistence of alfalfa. Starting in the fall of 1978 and repeated in 1979 and 1980, six fall cutting date treatments and two weed control treatments, terbacil (3-tert-buytl-5-chloro-6-methyluracil) and no terbacil, were imposed on established stands of 'Kanza' and 'Arc' alfalfa. These stands were grown under dryland conditions on a fine, mixed thermic, Pachic Arguistolls (McClain silty clay loam). Three harvests per season were made at 10 to 25% bloom prior to imposing the fall cutting date treatments which were made at fourth harvest of the season. Terbacil was applied during

February or March following cutting date treatments in the preceding fall. There was no interaction between fall cutting date and terbacil use. Terbacil was effective in controlling weeds present in this study, shepherdspurse [*Capsella bursa-pastoris* (L.) Medic.] and tansy mustard [*Descurainia pinnata* (Walt.) Britt]. As stands declined and weed infestations increased, terbacil use resulted in increased alfalfa forage yield, crude protein concentration, and total crude protein production. Fall cutting dates did not significantly ($P \leq 0.05$) influence weed infestations or forage quality. Stands declined in both cultivars during the study but there were no differences in stand persistence attributable to weed control.

Additional index words: *Medicago sativa* L., Last-cut treatments, Forage yield, Forage quality.

Introduction

The first alfalfa (*Medicago sativa* L.) harvest of the spring contributes 30 to 60% of the total season forage production under nonirrigated conditions (1, 2, 11, 12). For this reason, it is important to produce weed-free alfalfa at first harvest of the season.

Peters and Peters (9) in their review of weed control in alfalfa indicated that weeds compete with alfalfa for nutrients, light, and moisture causing a reduction in yield.

Studies conducted to determine the effects of weed control on alfalfa forage production have produced variable results (5, 10, 13, 16, 18). Swan (16) tested six soil-applied herbicides on established alfalfa on a coarse textured soil in Washington. Simazine [2-chloro-4,6-bis(ethylamino)-s-triazine], propham (isopropyl carbanilate), terbacil (3-tert-butyl-5-chloro-6-methyluracil), carbetamide [D-N-ethyl-actamide carbanilate (ester)], pronamide [3,5-dichloro(N-1,1-dimethyl-2-propynyl) benzamide], and secbumeton [N-ethyl-6-methoxy-N'(1-methylpropyl)-1,3,5-triazine-2,4-di-amine) were applied in December for 4 years. The weedy grass present was downy brome (Bromus tectorum L.) and broadleaf weeds were flixweed [Descurainia sophia (L.) Webb], prickly lettuce (Lactuca serriola L.), and shepherdspurse [Capsella bursa-pastoris (L.) Medic]. Propham, carbetamide, and pronamide provided good control of downy brome, but gave only 30 to 40% control of broadleaf weeds. Alfalfa production was not increased by any of the herbicide treatments. Weed populations were low in this study, averaging 5 plants/m^2 for downy brome and 2 plants/m^2 for broadleaf weeds. On this coarse textured soil, terbacil and simazine at 0.45 kg/ha and a high rate of secbumeton (2.70 kg/ha) were phytotoxic to alfalfa.

Robison et al. (10) evaluated herbicides applied in November for weed control in established alfalfa stands in Utah. Herbicides were applied for 2 consecutive years for control of downy brome, shepherdspurse, and common dandelion

(*Taraxacum officinale* Weber). Weeds in the untreated check averaged approximately 300 kg/ha. Herbicides used were cyanazine {2-[[4-chloro-6-(ethylamino)-s-triazin-2-yl] amino]-2-methyl-propionitrile}, cyprazine [2-chloro-4-(cyclopropylamino)-6-(isopropylamino)-s-triazine], diuron [3-(3,4-dichlorophenyl)-1,1-dimethyl-urea], metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazine-s-(4H)-one], paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), pronamide, secbumeton, simazine, and terbacil. They obtained increased weed-free alfalfa production in only one case. Secbumeton at 0.56 kg/ha resulted in significantly greater alfalfa production at first harvest than the untreated check. All other herbicide treatments resulted in decreased alfalfa yields compared to the untreated check.

Wilson (18) studied the effects of several fall-applied herbicides on alfalfa and weed yields in established, dryland alfalfa in Nebraska. Kochia [*Kochia scoparia* (L.) Roth] was the dominant species present; however, downy brome, tansy mustard [*Descurainia pinnata* (Walt.) Britt.], prickly lettuce, and Russian thistle (*Salsola kali* L.) were also present. The kochia population averaged 1330 plants/m^2. Kochia was differentially controlled by the herbicides tested and all herbicides used resulted in increased forage production over the untreated check.

In recent work on weed control in established alfalfa stands, Dutt et al. (5) studied the effects of seven dormant season herbicides alone or in combination with pronamide for perennial weed control at two locations in Iowa. Herbicides used alone and in combination with pronamide included secbumeton, simazine, cyanizine, terbacil, metribuzin, bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4-(3H)-one 2,2-dioxide], and S-0644 [N-benzyl-N-isopropyltrimethylacetamide/2-cyclopropanecarboxamide-5-(2-chloro-1,1-dimethyl ethyl)-1,3,4-thiadizole]. Weed infestations included quackgrass [Agropyron repens (L.) Beauv.], yellow rocket [Barbarea vulgaris R. Br.], hoary alyssum [Berteroa incana (L.) DC], and common dandelion (Taraxacum officinale) Weber.). Pronamide alone reduced the competitive effects of quackgrass on alfalfa and alfalfa yields were increased by 65 and 32% over untreated checks at the two locations. Common dandelion, hoary alyssum, and yellow rocket averaged 22, 12, and 12 plants/m^2, respectively at one location and common dandelion averaged 4 plants/m^2 at the second location. None of the treatments reduced comon dandelion and hoary alyssum infestations. Yellow rocket was reduced by secbumeton, terbacil, and bentazon. The broadleaf weeds increased at one location in thin alfalfa stands remaining after quackgrass had been controlled; however, at the other location where the alfalfa stand was dense, broadleaf weeds did not increase with quackgrass control. Sheaffer and Wyse (13) obtained similar results in Minnesota. They found that dormant season applied herbicides did not increase total forage production over the untreated check. They tested metribuzin, simazine, and buthidazole {3[5-(1,1-dimethyl-ethyl)-1,3,4-thiadizol-2-yl]-4-hydroxy-1-methyl-2-imidazolidinone} and 2,4-DB[4-(2,4-dichlorophenoxy)butryic acid]. Common dandelion populations ranged from 20 to 44 plants/m^2 across four locations for two years. Dandelion control did not consistently increase weed-free alfalfa production and generally did not increase crude protein concentration.

Cords (4) found that weeds reduce protein concentration of alfalfa forage with a high negative correlation between protein concentration in alfalfa and the amount of weeds present in the forage. Wilson (18) reported that protein concentration of alfalfa forage was increased by weed control with herbicides. Animal feeding trials have shown crude protein to be the best indicator for estimating performance of animals fed alfalfa hay (15).

Klingman and Ashton (7) suggested that weed encroachment encourages alfalfa stand decline. However, this does not appear to be documented in the scientific literature. Willard et al. (17) showed that weeds invade alfalfa stands which are declining due to improper harvest management in Ohio. Jung et al. (6) also found that harvesting of alfalfa in October resulted in increased weed infestations in West Virginia tests. Weed infestations at two locations amounted to 4 and 11% of total forage yields for an early September harvest and the weed component increased to 19 and 26%, respectively with an October harvest. Sholar et al. (14) found that fall harvesting had little effect on alfalfa productivity and stand persistence in the southern plains.

Timing of fall harvests also influences the amount of alfalfa regrowth. There have been references to this (8, 14) but these studies did not evaluate the effect on alfalfa quality in the following spring. Collins (3) evaluated the quality of fall produced forage in a harvest management study in Wisconsin but did not determine the effects fall regrowth had on quality in the subsequent spring.

The relationship between weed control with herbicides and fall harvest management has not been defined for the southern plains. The objective of this research was to document the effects of fall harvest management on weed infestations and forage quality and to evaluate the effects of weed control on forage production, forage quality, and stand persistence of alfalfa in the southern plains.

Materials and Methods

Two experiments were initiated in September, 1978 near Chickasha, Okla. on a fine, mixed thermic, Pachic Arguistolls (McClain silty clay loam, 0-1% slope). The site for Exp. 1 was a 4-year-old stand of 'Kanza' alfalfa. A soil test for Exp. 1 revealed the following: pH 6.8, 104 kg/ha of P, and 546 kg/ha of K. The site for Exp. 2 was a 2-year-old stand of 'Arc' alfalfa. A soil test for Exp. 2 revealed the following: pH 7.4, 43 P kg/ha, and 340 K kg/ha. Exp. 2 received an application of 67 kg/ha of P and 22 kg/ha K in February 1979.

The experimental design in both experiments was a split-plot with six fall cutting date treatments (Table 1) as main plots arranged in a randomized complete block design. Experiments 1 and 2 had six and four replications, respectively. Main plot size was 4.6 X 8.6 m in Exp. 1 and 4.6 X 4.3 in Exp. 2. Sub-plot size was 4.6 X 4.3 m in Exp. 1 and 4.6 X 2.1 m in Exp. 2. Sub-plots were randomized within main plots and consisted of two levels of herbicide usage-no herbicide and a dormant season application of terbacil at 0.84 kg/ha. Herbicide applications in both experiments were made on 10 Feb. 1979, 26 Feb. 1980, and 5 Mar. 1981 before active growth of alfalfa had begun in each year. The herbicide was mixed with water at a volume of 187 l/ha and applied by a CO_2 plot sprayer.

Alfalfa forage was routinely harvested from the site of both experiments prior to initiation of the study in 1978. The first, second, and third harvests of each growing season were made on common dates with the fourth (final harvest of season) made according to the schedule in Table 1. Forage yield samples were collected by clipping a 1 X 4.6 m strip of each sub-plot at 10-25% bloom for all harvests prior to the fall cutting date treatments.

Weed infestations were visually estimated immediately before each harvest. This involved estimating the percent of the total forage that was composed of weeds. Shepherdspurse and tansy mustard were the major weeds present and were in the late-bloom to green-seed stage at first harvest. Summer weed infestations did not develop, therefore, weed estimates were made only at first harvest of each year.

A sample of approximately 100 g dry weight was collected at each harvest from each sub-plot and dried at 65° C for dry matter determination. First harvest alfalfa production was adjusted to reflect the component consisting of alfalfa. Forage quality determinations as measured by crude protein were also made from these samples at first harvest in 1979, 1980, and 1981. Nitrogen was determined by the Kjeldahl method. Nitrogen percentages were then converted to crude protein percentages by multiplying by 6.25. Yield of crude protein at first harvest was determined by multiplying crude protein by total amount of forage produced.

Standard analysis of variance tests were performed on all data and means were compared by least significant difference (LSD) at the 5% level.

Results and Discussion

Forage Yields and Quality

There was no interaction between fall cutting date and terbacil treatment within any year of the studies. Weed infestation varied by year therefore studies could not be pooled over years. Weeds were a minor component of the forage in 1979 (Table 3) with no significant difference due to any of the treatments. Weed infestations in both studies increased dramatically in both 1980 and 1981, with all of the fall cutting date treatments with no significant differences attributed to cutting date treatments.

Terbacil was very effective in controlling both shepherdspurse and tansy mustard and as a result, weeds were not present at first harvest in any year in terbacil treated plots (Table 4). Although herbicide injury symptoms were not readily apparent, terbacil use resulted in reduced alfalfa yields at first harvest in Kanza in 1979. However, the decrease in forage yield probably is not a serious problem since there were no significant ($P \leq 0.05$) difference in forage yields between terbacil treated and untreated plots at second or third harvest (data not shown) in any year of the study. Also, terbacil use did not result in reduced forage yields in Arc with essentially weed free conditons of 1979.

There was no interaction between fall harvest date and terbacil treatment on forage crude protein concentration or total crude protein yield at first harvest in either experiment in any year of the study (Table 5). Fall cutting date treatment did not affect forage crude protein concentration in any year of the study. Fall growth in both experiments ranged from 4 to 23 cm in 1978, 4 to 46 cm in 1979, and 4 to 15 cm in 1980 across cutting date treatments. The 4 cm represents the stubble height at cutting. Although significant regrowth was present on plots with longer recovery periods, it was not important in forage quality as measured by crude protein in the subsequent spring. Most of the leaves dropped from the tallest fall regrowth during the winter months. This resulted in primarily dead stems remaining of the fall regrowth at the time of first harvest in the subsequent year. Apparently, these dead stems do not contribute significantly to total forage production since forage crude protein concentration was not significantly influenced by the amount of fall regrowth in any year.

Terbacil use did not significantly ($P \leq 0.05$) affect forage crude protein concentration or total crude protein yield of either cultivar at first harvest in 1979 when all plots in Kanza were weed-free and the weed component averaged only 3.7% in Arc. It is also worth noting that protein concentration was high enough in terbacil treated Kanza alfalfa at first harvest to offset the alfalfa forage yield reduction attributed to terbacil use (Table 4).

Total forage yield at first harvest in 1980 (second spring) in terbacil treated plots pooled over fall cutting dates averaged 3.1 and 3.3 Mg/ha for Kanza and Arc, respectively. Plots not treated with terbacil averaged 3.3 and 3.4 Mg/ha for Kanza and Arc, respectively. Cool season, broadleaf weed species in plots not treated with terbacil made up 15% of the total forage in Kanza at first harvest in 1980 while terbacil treated plots were weed-free. Plots not receiving the terbacil treatment in Arc had weed infestations ranging from 7 to 13% across cutting date treatments. Terbacil treated plots produced 0.3 and 0.2

Mg/ha more weed-free alfalfa than untreated plots in Kanza and Arc, respectively. Crude protein concentration of the harvested forage was also reduced by the weed infestation in untreated plots of Kanza but not in Arc in 1980. Crude protein concentration of Kanza was 21.1% for terbacil treated plots compared to 20.6% for untreated plots. However, this higher crude protein concentration of forage in terbacil treated plots of Kanza was offset by the higher total forage yields in untreated plots and as a result, total protein yield at first harvest from terbacil treated and untreated plots was not significantly ($P \leq 0.05$) different.

Total forage production at first harvest in 1981 was not significantly ($P \leq 0.05$) affected by terbacil treatment in Kanza but was significantly increased by terbacil use in Arc. Cool-season weeds in Kanza contributed an average of 35% of the total forage at first harvest in 1981 in plots not receiving the terbacil treatment. Although total forage yield was not reduced by the weed infestation, weed-free alfalfa production was significantly ($P \leq 0.05$) greater in terbacil treated plots. Terbacil treated plots produced 0.6 Mg/ha more weed-free forage than untreated plots. Due to the heavy weed infestation in untreated plots, crude protein concentration and total crude protein production were both significantly ($P \leq 0.05$) higher in terbacil treated plots than in untreated plots. Forage crude protein concentration was 19.1% in terbacil treated plots compared to 15.0% in untreated plots. Total protein production was 0.42 and 0.34 Mg/ha for terbacil treated and untreated plots, respectively.

Weed-free alfalfa yield in Arc was 0.7 Mg/ha greater in terbacil treated plots than in untreated plots at first harvest in 1981. Crude protein concentration was 19.1 and 16.7% in terbacil treated and untreated plots, respectively. Crude protein production was 0.52 and 0.38 Mg/ha for terbacil treated and untreated plots, respectively.

Stand Persistence

Plant densities based on pretreatment sampling varied from 50 to 80 plants/m^2 in both experiments at initiation of this study. There was no interaction between fall cutting date and terbacil treatment on alfalfa stand in any year with Kanza or Arc.

Crown cover in Kanza in December 1978 averaged 16% in all plots while crown cover in December 1979 averaged 17.5% (Table 6). There was a decrease in crown cover in December 1980 with crown cover estimated to be 10% in both terbacil treated and untreated plots. This decrease was attributed to drought conditions during the summer of 1980 (Table 2). Plant densities of Kanza declined in all plots during the study; however, the decline was not associated with weed infestations. Plant densities at termination of the study in May 1981 averaged 28 plants/m^2 in both terbacil treated and untreated plots.

Crown cover of Arc averaged 11% in all plots in December 1978. Crown cover increased to an average of 14.5% across herbicide treatments in 1979. Crown cover of Arc then declined in 1980 to an average of 4.5%. Final plant densities in May 1981 were 19 and 17 plants/m^2 in terbacil treated and untreated plots, respectively.

In these experiments, plant densities of 50 to 80 plants/m^2 at initiation of the study in 1978 were sufficiently competitive to compete effectively with weeds such as shepherdspurse and tansy mustard. However, as alfalfa stands declined, these weed species contributed to forage yields and as a result weed-free alfalfa yields, forage crude protein concentration, and total crude protein production were often depressed at first harvest. Terbacil was effective in controlling broadleaf weeds in these experiments and grass species did not develop on these sites. As alfalfa stands declined, first harvest alfalfa production was decreased by these broadleaf weeds but weed infestations had no effect on alfalfa stands as evidenced by the identical alfalfa plant densities in weed and weed-free plots at conclusion of this study (Table 6).

Our findings that weed infestations were not affected by fall cutting date do not agree with the results of Jung et al. (6) who found that October harvesting in West Virginia increased weed infestations. However, the increased weed infestations in their studies were probably due to alfalfa stand decline from the October cutting since

October harvests have usually been detrimental to alfalfa stands in the northeast. Since fall harvesting had no adverse effect on alfalfa stands in Oklahoma (14) we would not expect to see an increase in weed infestation due to fall harvesting.

LITERATURE CITED

1. Caddel, J. L., M. S. Rupp, and C. M. Taliaferro. 1980. Alfalfa variety tests in Oklahoma 1976-79. Oklahoma State Univ. Coop. Ext. Ser. Res. Rep. P799.

2. __________ and C. M. Taliaferro. 1979. Alfalfa variety tests in Oklahoma 1972-78. Oklahoma Agric. Exp. Stn. Res. Rep. P787.

3. Collins, M. 1983. Changes in composition of alfalfa, red clover, and birdsfoot trefoil during autumn. Agron. J. 75:287-291.

4. Cords, H. P. 1973. Weeds and alfalfa hay quality. Weed Sci. 21:400-401.

5. Dutt, T. E., R. G. Harvey, and R. S. Fawcett. 1983. Influence of herbicides on yield and botanical composition of alfalfa hay. Agron. J. 75:229-233.

6. Jung, G. A., R. L. Reid, and J. A. Balasko. 1969. Studies on yield, management, persistence, and nutritive value of alfalfa in West Virginia. West Virginia Agric. Exp. Stn. Bull. 581T.

7. Klingman, G. C., and F. M. Ashton. 1975. Weed science: principles and practices. John-Wiley and Sons. New York.

8. Nelson, C. J. and M. Mitchell. 1974. Alfalfa cutting management. Missouri Agric. Exp. Stn. Res. Rep.

9. Peters, E. J., and R. A. Peters. 1972. Weeds and weed control. In C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:555-573. Am. Soc. of Agron., Madison, Wis.

10. Robison, L. R., C. F. Williams, and W. D. Laws. 1978. Weed control in established alfalfa (Medicago sativa L.). Weed Sci. 26:37-40.

11. Rommann, L. R., J. L. Caddel, and D. R. Porter. 1983. 1982 Alfalfa variety yield trials. Oklahoma State Univ. Coop. Ext. Ser. Current Rep. 2075.

12. __________, __________, and M. S. Rupp. 1981. 1980 Alfalfa forage yield trials. Oklahoma State Univ. Coop. Ext. Ser. Current Rep. 2063.

13. Sheaffer, C. C. and D. L. Wyse. 1982. Common dandelion (*Taraxacum officinale*) control in alfalfa (*Medicago sativa*). Weed Sci. 30:216-220.

14. Sholar, J. R., J. L. Caddel, J. F. Stritzke, and R. C. Berberet. 1983. Fall harvest management of alfalfa in the southern plains. Agron. J. 75:619-622.

15. Speth, C. F., A. L. Lesperance, E. H. Jensen, and V. R. Bohman. 1967. Cattle gains estimated from protein content of alfalfa hay (Abstr.). J. Anim. Sci. 26:939.

16. Swan, D. G. 1978. Effects of repeated herbicide application on alfalfa (*Medicago sativa*). Weed Sci. 26: 151-153.

17. Willard, C. J., L. E. Thatcher, and J. S. Cutter. 1934. Alfalfa in Ohio. Ohio Agric. Exp. Stn. Bull. 540.

18. Wilson, R. G. 1981. Weed control in established dryland alfalfa (*Medicago sativa*). Weed Sci. 29:615-618.

Table 1. Harvest schedule for fall harvest management and weed control studies, 1978 to 1981.

Harvest no.	Last cut treatment	1978	1979	1980	1981
1		-	7 May	6 May	29 April
2		-	14 June	4 June	-
3		15 July	17 July	12 July	-
4	1	21 Sept.	28 Aug.	1 Oct.	-
4	2[1/]	21 Sept.	28 Aug.	1 Oct.	-
4	3	4 Oct.	13 Sept.	9 Oct.	-
4	4	18 Oct.	26 Sept.	23 Oct.	-
4	5	4 Nov.	16 Oct.	6 Nov.	-
4	6	21 Nov.	6 Nov.	20 Nov.	-

[1/] Treatment 2 was cut again on 7 December of each year.

Table 2. Monthly rainfall during harvest management studies. Chickasha, Okla., 1978 to 1981.

	30 Year mean	Year			
	1951-1980	1978	1979	1980	1981
	cm				
January	2.3	4.3	3.5	4.9	0.1
February	3.0	8.7	1.8	3.2	4.0
March	5.1	2.8	8.8	4.6	7.9
April	7.2	4.5	7.1	4.5	6.2
May	13.0	21.0	15.5	21.2	10.9
June	7.9	10.0	15.9	5.7	-
July	6.4	1.9	7.7	0.0	-
August	6.4	3.3	5.2	1.5	-
September	8.8	6.9	5.0	6.9	-
October	6.8	0.5	5.3	3.5	-
November	3.9	6.1	2.4	2.4	-
December	2.7	0.9	6.0	4.2	-
Annual Total	73.5	71.6	84.6	62.5	
Dev. from mean		-1.9	+11.1	-11.0	

Table 3. Weed infestation following fall harvesting, 1979 to 1981.

Last cut treatment	1979	1980	1981
	Year		
	-----% forage component-------		
Exp. 1--Kanza			
1	0	18	31
2	0	15	35
3	0	14	35
4	0	11	40
5	0	11	28
6	0	19	39
LSD (0.05)	NS	NS	NS
Exp. 2--Arc			
1	3	13	41
2	4	10	41
3	5	10	37
4	3	7	36
5	3	8	46
6	4	12	44
LSD (0.05)	NS	NS	NS

Table 4. Forage dry matter yields and crude protein following weed control treatments for Kanza and Arc alfalfa.

	1979					
	First harvest					Total of first 3 harvests
Terbacil treatment	Total forage yield	Alfalfa yield	Broadleaf weed yield	Protein concentration	Protein yield	Total forage yield
--kg/ha--	---------Mg/ha----------			%	Mg/ha	Mg/ha
Exp. 1--Kanza						
0	5.3	5.3	0	18.6	.99	12.6
0.84	5.0	5.0	0	18.9	.95	12.2
LSD (0.05)	0.2	0.2	-	NS	NS	0.2
Exp. 2--Arc						
0	4.5	4.4	0.1	19.2	.86	10.6
0.84	4.5	4.5	0	18.9	.85	10.8
LSD (0.05)	NS	NS	-	NS	NS	NS
	1980					
--kg/ha--	---------Mg/ha----------			%	Mg/ha	Mg/ha
Exp. 1--Kanza						
0	3.3	2.8	0.5	20.6	.68	6.7
0.84	3.1	3.1	0	21.1	.65	7.5
LSD (0.05)	0.2	0.2	-	0.4	NS	0.3
Exp. 2--Arc						
0	3.4	3.1	0.3	21.5	.73	7.1
0.84	3.3	3.3	0	21.6	.71	7.0
LSD (0.05)	NS	0.1	-	NS	NS	NS

Table 4. Continued.

Terbacil treatment	1981 First harvest Total forage yield	Alfalfa yield	Broadleaf weed yield	Protein concentration	Protein yield
--kg/ha--	---------Mg/ha---------			%	Mg/ha
Exp. 1--Kanza					
0	2.3	1.6	0.7	15.0	.34
0.84	2.2	2.2	0	19.1	.42
LSD (0.05)	NS	0.2	-	0.3	.03
Exp. 2--Arc					
0	2.3	1.4	0.9	16.7	.38
0.84	2.7	2.7	0	19.1	.52
LSD (0.05)	0.2	0.1	-	0.4	.04

Table 5. Crude protein concentration of forage at first harvest for Kanza and Arc alfalfa, 1979 to 1981.

Last cut treatment	1979 Herb.	1979 No herb.	1979 Avg.	1980 Herb.	1980 No herb.	1980 Avg.	1981 Herb.	1981 No herb.	1981 Avg.
	% crude protein								
Exp. 1--Kanza									
1	18.8	18.8	18.8	20.2	20.1	20.2	19.5	16.0	17.8
2	18.7	17.8	18.3	21.2	20.8	21.0	18.4	14.0	16.2
3	19.4	19.0	19.2	21.4	21.2	21.3	19.3	14.9	17.1
4	18.7	18.3	18.5	20.9	21.4	21.2	19.9	13.5	16.7
5	18.9	18.6	18.7	21.5	20.0	20.8	19.1	16.4	17.8
6	18.7	19.2	19.0	21.6	19.9	20.8	18.6	15.0	16.8
Avg.	18.9	18.6		21.1	20.6		19.1	15.0	
LSD (0.05)	NS			herb. = 0.4			herb. = 0.3		
Exp. 2--Arc									
1	17.9	19.6	18.8	21.3	21.2	21.3	17.5	17.8	17.6
2	20.1	19.4	19.8	21.6	21.8	21.7	20.2	18.4	19.3
3	18.2	17.9	18.1	21.0	21.0	21.0	19.4	17.2	18.3
4	21.1	19.4	20.3	21.6	22.0	21.8	18.9	15.0	17.0
5	18.7	19.1	18.9	22.2	21.3	21.8	19.1	14.7	16.9
6	19.1	18.1	18.6	21.6	21.6	21.6	19.4	17.2	18.3
Avg.	19.2	18.9		21.6	21.5		19.1	16.7	
LSD (0.05)	NS			NS			herb. = 0.3		

Table 6. Crown cover following fall cutting date treatments at two herbicide levels for Kanza and Arc alfalfa in 1978, 1979, and 1980 and stand density following spring cutting in 1981.

Last cut treatment	Dec. 1978	Dec. 1979			Dec. 1980			May 1981		
		Herb.	No herb.	Avg.	Herb.	No herb.	Avg.	Herb.	No herb.	Avg.
	% crown cover							plants/m^2		
Exp. 1--Kanza										
1	14	16	18	17	9	11	10	32	32	32
2	14	16	15	16	8	7	8	27	22	25
3	15	16	19	18	11	12	12	28	28	28
4	20	18	19	19	11	11	11	30	30	30
5	17	16	17	17	9	10	10	27	28	28
6	18	19	18	19	10	9	10	25	26	26
Avg.	16	17	18		10	10		28	28	
LSD (0.05)	NS		NS			NS			NS	
Exp. 2--Arc										
1	11	15	17	16	6	3	5	22	18	20
2	11	15	12	14	5	3	4	17	18	18
3	13	17	17	17	6	5	6	20	20	20
4	10	14	13	14	5	5	5	17	18	18
5	11	12	14	13	5	4	5	21	12	17
6	10	15	13	14	5	3	4	17	16	17
Avg.	11	15	14		5	4		19	17	
LSD (0.05)	NS		NS			NS			NS	

CHAPTER IV

RESPONSE OF NEWLY ESTABLISHED STANDS OF FOUR ALFALFA CULTIVARS TO FALL HARVESTING

Abstract

Alfalfa (*Medicago sativa* L.) producers in the southern plains frequently harvest hay in September and October from both old and newly established stands. Stands usually have not been lost from such practices but the consequences of fall harvesting of newly established stands have not been adequately documented for the southern plains. The main objective of this research was to test the hypothesis that newly established alfalfa stands in the southern plains can be harvested during mid-September to late November without detrimental effects on forage yields and stand persistence. A second objective was to determine if there is a differential response of alfalfa cultivars to fall harvesting. From 1980 to 1982, 12 fall harvest treatments were imposed at the last harvest of the season on spring-established stands of 'Arc', 'Buffalo', 'Dawson', and 'Riley' cultivars. To establish a height differential on which to impose the last harvest of the season, the next to last harvest was taken on one of two dates. The experiment

was conducted under supplement irrigation conditions on a fine, mixed thermic, pachic Arguistolls (McClain silty clay loam). Forage was harvested at 10-25% bloom for uniform harvests prior to imposing fall harvest treatments. Forage yields were determined during each growing season subsequent to rall harvest treatments. Because of variable fall recovery times over the three years of the study, forage yields were analyzed by fall harvest treatments and recovery period length (time between last harvest and first killing freeze). Plant heights were measured immediately prior to first harvest of each year. Root total nonstructural carbohydrate (TNC) reserves were measured in alfalfa roots dug after the initial killing freeze of each fall. Initial plant densities were determined in May, 1980 and final plant densities were determined in June, 1983. Stem densities were determined after second harvest of each year. Crown cover was measured by estimating the percent ground area covered by green, prostrate alfalfa in December of each year. With the exception of forage yields at one harvest, cultivar X fall harvest treatment interactions were not significant. Fall harvesting effects were greater at first harvest than at other uniform harvests. Fall harvest treatments which resulted in an average over years, of 29 and 14 recovery days tended to be highest yielding at first harvest and for total season forage yields. Total forage production for all harvests was unaffected by fall harvest treatments and recovery periods. Plant heights were significantly affected by fall harvest treatment each year with the effect varying with year. TNC concentrations were unaffected by fall harvest treatments in all years of the study. Plant and stem densities and crown cover declined during the study; however, there were no differences in these measurements which could be attributed to fall harvest management. With one exception for forage yield, these cultivars did not respond differentially in forage yield, plant height, TNC, or stand persistence to fall harvests.

Additional index words: *Medicago sativa* L., Total nonstructural carbohydrates, Forage yield, Stand persistence.

Introduction

Many studies have been conducted which have demonstrated the potential hazard of harvesting alfalfa (*Medicago sativa* L.) during the 4 to 6 week period preceding a killing freeze in the fall. Smith (9) presented a comprehensive review of the literature on the effects of fall harvest management on forage yield, stand persistence, and root total nonstructural carbohydrate reserves. These studies were conducted primarily in the humid midwest and northeast. Since his review in 1972, additional studies on fall harvest management of alfalfa have been conducted that reopen to question the necessity for avoiding fall harvests.

Collins and Taylor (2) studied the effects of fall harvesting on alfalfa in Kentucky. They reported that fall harvesting was less detrimental to alfalfa than similar treatments in northern states. They, however, chose new sites for each year of their study and did not follow the effects of fall harvesting over more than one season on the same alfalfa stand. Mays and Evans (5) found that fall harvesting for three seasons in Alabama was not damaging to 'Williamsburg' alfalfa in forage yield, root carbohydrates, or stand persistence. Sholar et al. (6) found that various fall harvesting treatments for three consecutive years had little effect on forage yields, root carbohydrates, or stand persistence of established alfalfa stands in the southern plains.

In addition, Marten (4) recently reported that forage yields and stands of newer, winterhardy cultivars of alfalfa grown in Minnesota were not detrimentally affected by fall harvesting. He suggested that adequate soil fertility, use of winterhardy cultivars, and the presence of adequate snow cover during cold extremes should allow stands to remain full and productive even if the last harvest was made in September or early October.

It appears to be well documented that fall harvesting has a differential effect on alfalfa cultivars. Twamley (10) reported as early as 1960 that fall harvests in Canada resulted in significant spring forage yield differences among cultivars. The winterhardy cultivar 'Vernal' was less damaged by fall harvesting than the less winterhardy cultivars, 'Ranger' and 'Dupuits'. Brown (1) also reported that a September harvest in Connecticut reduced stands of 'Buffalo', Dupuits, and Vernal by 37, 17, and 15%, respectively, compared to a late October harvest. Mays and Evans (5) found that fall harvesting was much more detrimental to Dupuits, a wilt-susceptible cultivar, than to Williamsburg, a wilt-resistant cultivar. Final plant densities for Williamsburg were 48 plants/m^2 with no fall harvest and 57 plants/m^2 where a 1 October harvest was made. Final plant densities for Dupuits were 28 plants/m^2 with no fall harvest and 12 plants/m^2 where a 1 October harvest was made.

Alfalfa producers in the southern plains frequently harvest hay in September and October from both new and established stands. Stands usually have not been lost from such practices, but the advantages and disadvantages of fall harvesting in the southern plains have not been adequately documented. The main objective of this research was to test the hypothesis that newly established alfalfa stands in the southern plains can be harvested during mid-September to late November without detrimental effects on forage yields and stand persistence. A second objective was to determine if there is a differential response of alfalfa cultivars to fall harvesting.

Materials and Methods

The experiment was initiated in April 1980 near Chickasha, Okla., on a fine, mixed thermic, Pachic Arguistolls (McClain silty clay loam). Phosphorous and potassium levels in the soil were adequate for alfalfa production therefore, no fertilizer was added during the study.

A 4 X 12 factorial arrangement of treatments in a randomized complete block design with six replications was used for the experiment. Plot size was 4.6 X 1.8 m. Four cultivars, 'Arc', Buffalo, 'Dawson', and 'Riley', were seeded at 22 kg/ha pure live seed on 4 Apr. 1980. Twelve fall harvest treatments were imposed at the last harvest of the season in 1980, 1981, and 1982 (Table 1). To establish a height differential on which to impose the fall harvest treatments, the next to last harvest of the season (indicated as harvest number four in Table 1) was made on one of two dates in 1980 and 1981. The two dates were 27 Aug. and 12 Sept. 1980, and 21 Aug. and 3 Sept. 1981. The 12 fall harvest treatments were divided into two groups with seven and five treatments imposed on the first and second date, respectively in each year. Because of inadequate growth in 1982 and the likelihood of little regrowth on which to impose fall harvest treatments (fifth harvest) if a second date were used, only one fourth harvest date (19 August) was used in 1982. Temperature data collected for three years at the experimental site indicate the first killing freeze (-5^{o}C) as defined by Curry (3) occurred 19 Nov. 1980, 17 Dec. 1981, and 24 Nov. 1982.

Monthly rainfall for the duration of the experiment is listed in Table 4. The study was conducted under supplemental irrigation conditions. Two flood irrigations of approximately 7.5 cm each were made during the driest part of the growing season of each year.

Uniform harvest dates were made at first harvest in 1980, first through third harvests in 1981 and 1982, and first and second harvest in 1983. The study was terminated after second harvest in 1983 (Table 1). Forage was harvested at 10-25% bloom from all plots for the uniform harvests. Only two harvests were made in 1980, the year of stand establishment, and fall harvest treatments were imposed at the second harvest. In 1981 and 1982, fall harvest treatments were imposed at fifth harvest.

All harvests were made with a self-propelled, flail-type harvester. Forage production was determined by clipping a 1 X 4.6 m strip of each plot with a clipping height of approximately 4 cm. A sample of approximately 100 g dry weight was retained at each harvest from each plot and dried at 65^{o}C for dry matter determinations.

Forage yields were first subjected to analysis of variance based on fall harvest treatments. There were large differences across years in the number of recovery days (time between the last harvest and the first killing freeze) for the various fall harvest treatments (Table 2).

Therefore, fall harvest treatments were grouped across years corresponding to similar numbers of days for recovery from fall harvest to the first killing freeze. Five similar recovery comparisons were possible. Forage yields were then subjected to analysis of variance based on five recovery periods. Means were compared by least significant difference (LSD) at the 5% level.

Plant heights were measured at six random positions within each plot immediately prior to first harvest in 1981, 1982, and 1983. Root total nonstructural carbohydrate (TNC) reserves were measured in alfalfa roots dug after the initial killing freeze of each fall from the seven fall harvest treatments made after the August cutting (Table 1). Roots from 20 plants per plot were cleaned free of soil and dried at 65^{o}C for 5 days. A 10 cm section of taproot immediately below the crown was retained for analysis following the procedure outlined by Shroyer et al. (7). Initial plant densities were determined in May, 1980 by counting the number of seedling plants in four, 0.1 m^2 quadrats per plot and final plant densities were determined in June, 1983 at conclusion of the study by undercutting, uprooting, and counting the plants in a 1.0 m^2 area. Stem densities were determined after second harvest of each year by counting the number of stems in four, 0.1 m^2 quadrats per plot. Crown cover was measured by estimating the percent ground area covered by green, prostrate alfalfa in four, 0.1 m^2 quadrats per plot in December of 1980, 1981, and 1982.

F tests were run on mean squares and when significant at the 5% level, least significant differences (LSD) were used to separate means.

Results and Discussion

Forage Yields

There was no year X cultivar X fall harvest treatment interaction on forage yields (Table 3). A significant ($P \leq 0.05$) year X fall harvest treatment interaction was observed at first harvest and for total season forage production (Table 3). This interaction was attributed to the widely varying number of days for recovery (time between last harvest and first killing freeze) for the same fall harvest treatments over years, since conversion of fall harvest treatments to fall recovery periods eliminated the year X fall harvest treatment interaction for both first harvest and total season production (Table 3). This indicates that the effects of a particular fall harvest treatment on forage yields in the subsequent spring cannot be predicted since the date of the first killing freeze cannot be predicted.

The only significant ($P \leq 0.05$) interaction between fall harvest treatment and cultivar for forage yield was at first harvest in 1981 (Table 3). Adjusting the fall harvest treatments to recovery periods did not remove this interaction. This interaction was attributed to the differential highly significant response of Arc in 1981 to fall harvesting in 1980 (Table 5). Forage yield of Arc at first harvest in 1981 ranged from a low of 3.1 Mg/ha for the late November harvest following August cutting, to a high of 4.2 Mg/ha for the late October and early November harvests following August cutting. In contrast, there was no effect of fall harvest treatments on first harvest yield of Dawson in 1981. Converting fall harvest dates to recovery periods did not change these results (Table 6). There was no cultivar X fall recovery period interaction on forage yields at any other harvest or for total season forage yields in any year of the study (Table 3).

The lack of a differential response of cultivars to the various fall harvest treatments of 1981 and 1982 means that the main effects of cultivars and fall harvest treatments can be evaluated for 1982 and 1983. The major significant effect of fall harvest treatments was on the yield at first harvest (Table 3). There was no significant effect on second and third harvest in any year. Forage yields at first harvest following fall harvest treatments tended to be higher with late October and early November harvest treatments in 1981 and 1983 (Table 5). Because of the later freeze date in 1982, this pattern was not consistent for all three years. In spite of the significant cultivar X fall harvest treatment interaction in 1981, it can be seen in Table 5 that in 1981 and 1983, plots harvested late in the season (after early October) tended to produce the highest yields.

When forage yields were analyzed as a response to recovery periods (Table 6), periods 3 and 4 (average of 29 and 14 recovery days, respectively over years) tended to be highest yielding at first harvest. Forage yields at first harvest for recovery period 4 pooled over cultivars were 3.8, 4.5, and 5.8 Mg/ha for 1981, 1982, and 1983, respectively. Yields at first harvest for recovery period 1 pooled over cultivars were 3.5, 4.1, and 5.6 Mg/ha for the same years. Based on other reported results (1, 8, 9), recovery period 1 should not have resulted in lower forage production. The reason for lower yields with the longest recovery periods is unclear. The fall and subsequent early spring months tended to be dry throughout this study (Table 4). It may be that recovery periods which allowed for the longest growing times were more likely to deplete soil moisture in the fall resulting in reduced forage yields at first harvest in the subsequent spring.

Significant ($P \leq 0.05$) differences in forage yields due to fall harvest treatment and recovery period were observed at fourth harvest in 1981 and fifth harvest (variable fall harvest) in 1981 and 1982 (Table 3). These differences were attributed to the two dates for fourth harvest in 1981 and the variable fall harvest treatments influencing fifth harvest.

Total season forage production was significantly influenced by fall harvest treatments and fall recovery periods in 1981 (total of five harvests) and 1983 (only two harvest made) (Tables 5 and 6). In both years, yields as a response to recovery period 4 (average of 17 days for the 2 years) were equal to or higher than all other recovery periods. Neither fall harvest treatment nor fall recovery period significantly influenced total season forage yields in 1982.

On the basis of total forage yields for all harvests, neither fall harvest treatments nor fall recovery periods were important in influencing alfalfa productivity during this study (Tables 7 and 8). Although fall harvests which provided long recovery periods tended to produce less forage at first harvest, they evidently yielded enough extra during later harvests to remove the effects of fall harvesting on total yields.

Arc tended to be the highest yielding cultivar at first harvest of the year for both fall harvest treatments and recovery periods (Tables 5 and 6). An exception to this was in 1981 when Dawson yielded 3.9 Mg/ha compared to 3.7 Mg/ha for Arc. In 1982, Arc yield at first harvest was 5.1 Mg/ha compared to 3.6, 3.9, and 4.2 Mg/ha for Buffalo, Dawson, and Riley, respectively. In 1983, first harvest yields for Arc and Riley were significantly ($P \leq 0.05$) higher than Buffalo and Dawson. Yields for Arc and Riley were both 5.8 Mg/ha compared to 5.5 Mg/ha for Buffalo and 5.6 Mg/ha for Dawson. Similar results for 1981 through 1983 were obtained as a response to fall harvest treatments (Table 5).

Total season forage yields were significantly ($P \leq 0.05$) affected by cultivar in 1981 (five harvests) and 1983 (two harvests) (Tables 5 and 6). Buffalo yielded 14.0 Mg/ha compared to 13.8, 13.4, and 13.1 Mg/ha for Dawson, Arc, and Riley, respectively in 1981 (Table 6). Total season forage yields were statistically equal for all cultivars in 1982 (Table 6). Despite the superior yields of Arc at first harvest in 1982 (5.1 Mg/ha compared to an average of 3.9 Mg/ha for other cultivars), compensation by other cultivars at subsequent harvests offset the higher yields of Arc at first harvest.

Total forage production during the study was not significantly affected by cultivar, whether considered by fall harvest treatment (Table 7) or fall recovery period (Table 8). This illustrates the ability of these well adapted cultivars to produce very similar yields when totaled over several years. Cultivars were differentially affected by fall harvest management and/or recovery period only at first harvest in 1981. Even in that case, late fall and/or short recovery periods were not more damaging to forage yields than fall harvests which resulted in the longest recovery periods.

Plant Height

There was no year X cultivar X fall harvest treatment, no year X fall harvest treatment, and no cultivar X fall harvest treatment interaction for plant height at first harvest. However, there was a significant year X cultivar interaction for plant height. For this reason the data for plant height are listed separately for the three years of the study (Table 9).

There was a significant ($P \leq 0.05$) effect of fall harvest treatment on plant height each year and it varied with year. Plant heights at first harvest in 1981 were significantly ($P \leq 0.05$) affected by fall harvest treatments applied in 1980 (Table 9). The late November harvest following the August cutting resulted in the tallest forage. The late September harvest following an August cutting resulted in forage that was significantly shorter than forage in the late November treatment. There was no significant difference among fall harvest treatments following a September cutting.

Plant heights in 1982 were significantly affected by fall harvest treatments in 1981. The late September harvest following an August cutting and the early December harvest produced the tallest forage. Among fall harvest treatments with a September cutting, harvests made in early October and early October + early December resulted in forage the following spring that was significantly taller than that produced by other fall harvest treatments.

Plant heights in 1983 were significantly affected by fall harvest treatments imposed in 1982. The early November fall harvest following an August cutting resulted in the tallest forage (60.7 cm) and these plants were significantly taller than plants in plots receiving a late September harvest. The shorter forage in the subsequent spring was generally from plots harvested earliest in the preceding fall.

There was also a significant year X cultivar interaction for plant height. In 1981 and 1983, forage produced by Riley was significantly ($P \leq 0.05$) shorter than all other cultivars. This may be because Riley is a more dormant cultivar and is slower in initial growth in the cool conditions of early spring. In 1982, Riley was not significantly ($P \leq 0.05$) different from Buffalo and Dawson; however, all three cultivars were significantly shorter than Arc. Plant height for Arc was 62.7 cm while the average for the remaining cultivars was 53.0 cm.

Total Nonstructural Carbohydrates

There was no year X cultivar X fall harvest treatment interaction and no year X fall harvest treatment interaction on TNC. There was also no cultivar X fall harvest treatment interaction on TNC (Table 10).

There was a significant year X cultivar interaction for TNC concentration. This was attributed to significantly ($P \leq 0.05$) higher TNC levels in Riley than in other cultivars in 1981 and 1982 with no difference among cultivars in 1980. Riley is classified as a dormant cultivar and although it has not been researched, it may accumulate TNC at a higher rate during fall rather than using carbohydrates for plant growth.

The range of TNC concentrations over the length of the study was from a low of 23.5% for Riley in 1980 with a late September harvest to a high of 41.8% for Riley in 1981 with an early October harvest. Carbohydrate concentrations were higher in 1981 and 1982 than in 1980, the year of establishment. This would be expected as roots should be less developed during the first year of the stand. Average TNC concentrations for all cultivars and cutting date treatments were 27.3, 36.0, and 30.5%, respectively, in 1980, 1981, and 1982.

Root TNC levels were not significantly ($P \leq 0.05$) affected by fall harvest treatment in any year of the study. A narrow range of TNC concentrations across fall cutting treatments was observed in each year. The TNC levels found were in the range of those reported previously by Sholar et al. (6). Conclusions by Brown (1) showing that harvesting during a critical fall period reduced root carbohydrates were not observed in our work. Our work indicates that a critical fall period for decreasing root carbohydrates in our study area does not exist. Mays and Evans' (5) suggestion that proper environmental conditions and slow regrowth of alfalfa in the fall in Alabama may enable stable TNC levels may also apply to the southern plains.

Stand Persistence

Plant and Stem Densities. Excellent stands existed in all cultivars after establishment in 1980 and prior to the time that fall harvest treatments were imposed (Table 11). There was a significant ($P \leq 0.05$) difference among cultivars in initial plant density. The range was from a low of 36 plants/$0.1m^2$ for Arc to a high of 64 plants/$0.1m^2$ for Riley. Initial plant counts revealed that there was no significant ($P \leq 0.05$) difference in plant density among plots within a cultivar.

There was no cultivar X fall harvest treatment interaction on final plant density in this study (Table 11). Overall stands declined during the study; however, the decline was not associated with fall harvesting or cultivar. Final plant counts ranged from 8 to 9 plants/$0.1m^2$ across fall harvest treatments. Plant densities in all fall harvest treatments remained adequate for good yields under growing conditions in the southern plains. Based on these findings, there appeared to be little difference in the ability of these cultivars to persist and no difference due to fall management.

There were no year X cultivar X fall harvest treatment, year X cultivar, year X fall harvest treatment, or cultivar X fall harvest treatment interactions on stem density. Fall harvest treatment did not significantly ($P \leq 0.05$) affect stem densities in any year of the study (Table 12). Silkett et al. (8) reported that their most detrimental fall harvest, 30 September, reduced stem densities by 29.8% from the uncut check treatment. Stem densities declined over years with our study, but the decline was never associated with the timing of the last fall harvest.

Arc had significantly ($P \leq 0.05$) fewer stems/0.1m^2 than other cultivars when stem densities were determined after second harvest in 1981. There was, however, no significant ($P \leq 0.05$) difference in stem densities as a response to cultivar in 1982. Arc was significantly ($P \leq 0.05$) lower in stem density in 1983 than other cultivars. Arc averaged 22 stems/0.1m^2 compared to an average of 28 stems/0.1m^2 for the remaining cultivars.

Crown Cover. There were no year X cultivar X fall harvest treatment, year X cultivar, year X fall harvest treatment, or cultivar X fall harvest treatment interactions on crown cover. Fall harvest treatment did not affect crown cover in any year of the study (Table 13). Crown cover ranged from 32 to 36% across fall harvest treatments in December 1982 when the last crown cover estimation was made. Significant ($P \leq 0.05$) differences among cultivars for percent crown cover existed at every fall evaluation for this parameter. Riley was consistently highest and Arc consistently lowest in crown cover. Little difference existed between crown cover estimations in Buffalo and Dawson. Despite significant differences in crown cover, the stands for all cultivars remained adequate for excellent yields when moisture was available.

These results with newly established alfalfa confirm studies by Collins and Taylor (2), Mays and Evans (5), and

Sholar et al. (6), which have shown that alfalfa grown in the South is more tolerant of fall harvests than in northern regions. Additionally, it was found that with one exception for yield, these cultivars did not respond differentially in forage yield, plant height, TNC, or stand persistence to late fall harvests and/or short fall recovery periods.

LITERATURE CITED

1. Brown, B. A. 1963. Alfalfa varieties and their management. Connecticut Agric. Exp. Stn. Bull. 376.

2. Collins, M., and T. H. Taylor. 1980. Yield and quality of alfalfa harvested during autumn and winter and harvest effects on the spring crop. Agron. J. 72:839-844.

3. Curry, B. R. 1970. Freezing temperatures in Oklahoma. Oklahoma State University Coop. Ext. Ser. (Unnumbered Publ.).

4. Marten, G. C. 1980. Late autumn harvest of third crop alfalfa can allow long stand persistence in the north. Forage and Grassland Prog. 21:3-4.

5. Mays, D. A., and E. M. Evans. 1973. Autumn cutting effects on alfalfa yield and persistence in alfalfa. Agron. J. 65:290-292.

6. Sholar, J. R., J. L. Caddel, J. F. Stritzke, and R. C. Berberet. 1983. Fall harvest management of alfalfa in the southern plains. Agron. J. 75:619-622.

7. Shroyer, J. P., J. F. Stritzke, and L. I. Croy. 1979. Carbohydrate levels and control of blackjack oak and winged elm treated with tebuthiuron and 2,4,5-T. J. Range Manage.32:60-62.

8. Silkett, V. W., C. R. Megee, and H. C. Rather. 1937. The effects of late summer and early fall cutting on crown bud formation and winterhardiness of alfalfa. J. Am. Soc. Agron. 29:53-62.

9. Smith, D. 1972. Cutting schedules and maintaining pure stands. In C. H. Hanson (ed.) Alfalfa science and technology. Agronomy 15:481-496. Am. Soc. of Agron., Madison, Wis.

10. Twamley, B. E. 1960. Variety, fertilizer, management interactions in alfalfa. Can. J. Plant Sci. 40:130-138.

Table 1. Dates for uniform and variable harvests, 1980 to 1983.

Harvest Number	Harvest Date Code	1980	1981	1982	1983
		Uniform harvests			
1		15 June	29 Apr.	10 May	6 May
2		---	12 June	22 June	23 June
3		---	20 July	20 July	---
		Variable harvests			
4		27 Aug.[+]	21 Aug.	19 Aug.	
5	Late Sept.	25 Sept.	25 Sept.	22 Sept.	
5	Ea. Oct.	9 Oct.	9 Oct.	7 Oct.	
5	Late Oct.	23 Oct.	22 Oct.	21 Oct.	
5	Ea. Nov.	6 Nov.	6 Nov.	4 Nov.	
5	Late Nov.	20 Nov.	20 Nov.	18 Nov.	
5	Ea. Dec.	5 Dec.	7 Dec.	1 Dec.	
5	Late Sept.+Ea. Dec.	25 Sept.+11 Dec.	25 Sept.+3 Dec.	22 Sept.+10 Dec.	
4		12 Sept.[+]	3 Sept.	19 Aug.	
5	Ea. Oct.	23 Oct.	9 Oct.	7 Oct.	
5	Late Oct.	6 Nov.	22 Oct.	21 Oct.	
5	Ea. Nov.	20 Nov.	6 Nov.	4 Nov.	
5	Late Nov.	5 Dec.	20 Nov.	18 Nov.	
5	Ea. Oct.+Ea. Dec.	23 Oct.+11 Dec.	9 Oct.+3 Dec.	7 Oct.+10 Dec.	

[+]There was only one uniform harvest made on the newly established stand in 1980; therefore, the fall harvest treatments were imposed at second harvest.

Table 2. Recovery days from last harvest to first killing freeze for the various fall harvesting treatments.

	Year			
	1980	1981	1982	Avg.
Harvest Date Code				
Aug.+				
Late Sept.++	55	83	63	67
Ea. Oct.	41	69	48	53
Late Oct.	27	56	34	39
Ea. Nov.	13	41	20	25
Late Nov.	0	27	6	11
Ea. Dec.	0	10	0	3
Late Sept.+Ea. Dec.	0	14	0	5
Sept.+				
Ea. Oct.++	27	69	48	48
Late Oct.	13	56	34	34
Ea. Nov.	0	41	20	20
Late Nov.	0	27	6	11
Ea. Oct.+Ea. Dec.	0	14	0	5
Recovery Periods				
1	55	56	63	58
2	41	41	48	43
3	27	27	34	29
4	13	10	20	14
5	0	14	0	5

+Next to last harvest

++Fall harvest treatments

Table 3. Significance of analysis of variance for cultivars and fall harvest treatments and cultivars and recovery periods.

Source of variation	Harvest 1	2	3	4	5	Total
	-----significance level-------					
			1981			
Cultivar (C)+	**	NS	**	**	**	**
Fall Harvest Treatment (FHT)	**	NS	NS	**	**	*
C X FHT	**	NS	NS	NS	NS	NS
Cultivar (C)++	**	NS	**	**	**	*
Recovery Period (RP)	**	NS	NS	**	**	*
C X RP	**	NS	NS	NS	NS	NS
			1982			
Cultivar (C)	**	**	**	**	**	NS
Fall Harvest Treatment (FHT)	*	NS	NS	NS	**	NS
C X FHT	NS	NS	NS	NS	NS	NS
Cultivar (C)	**	**	**	*	**	NS
Recovery Period (RP)	*	NS	NS	NS	NS	NS
C X RP	NS	NS	NS	NS	NS	NS
			1983			
Cultivar (C)	**	**	-	-	-	**
Fall Harvest Treatment (FHT)	**	NS	-	-	-	*
C X FHT	NS	NS	-	-	-	NS
Cultivar (C)	**	**	-	-	-	**
Recovery Period (RP)	**	NS	-	-	-	*
C X RP	NS	NS	-	-	-	NS
			Total Production During Study 1981-83			
Cultivar (C)	**	**	-	-	-	NS
Fall Harvest Treatment (FHT)	NS	NS	-	-	-	NS
C X FHT	NS	NS	-	-	-	NS
Year (Y)	**	**	-	-	-	**
Y X C	**	**	-	-	-	**
Y X FHT	*	NS	-	-	-	*
Y X C X FHT	NS	NS	-	-	-	NS

Table 3. (Continued)

Source of variation	Harvest 1	2	3	4	5	Total
	-----significance level-------					
Cultivar (C)	**	**	-	-	-	NS
Recovery Period (RP)	**	NS	-	-	-	NS
C X RP	NS	NS	-	-	-	NS
Year (Y)	**	**	-	-	-	**
Y X C	**	**	-	-	-	**
Y X RP	NS	NS	-	-	-	NS
Y X C X RP	NS	NS	-	-	-	NS

+Analysis based on fall harvest treatment

++Analysis based on five recovery periods

*,**Significant at the 0.05 and 0.01 levels, respectively.

Table 4. Monthly rainfall during harvest management studies, Chickasha, Okla., 1980 to 1983.

Month	30 Year Mean 1951-1980	Year 1980	1981	1982	1983
Jan.	2.3	4.9	0.1	7.0	5.4
Feb.	3.0	3.2	4.0	2.0	9.6
Mar.	5.1	4.6	7.9	3.3	5.5
Apr.	7.2	4.5	6.2	3.0	4.4
May	13.0	21.2	10.9	29.1	12.6
June	7.9	5.7	15.4	10.1	12.8
July	6.4	0.0	7.9	4.1	-
Aug.	6.4	1.5	9.8	2.9	-
Sept.	8.8	6.9	3.5	6.1	-
Oct.	6.8	3.5	19.3	2.4	-
Nov.	3.9	2.4	8.2	6.8	-
Dec.	2.7	4.2	0.2	4.5	-
Annual Total	73.5	62.5	93.4	80.6	
Dev. from Mean		-11.0	+19.9	+7.1	

Table 5. Forage dry matter yields for first harvest and total season for cultivars and fall harvest treatments, 1981 to 1983.

Fall harvest treatment	First harvest 1981 Cultivar					Total season production+ 1981 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	Mg/ha					Mg/ha				
27 Aug.										
Late Sept.	3.3	3.8	3.9	3.0	3.5	13.2	14.4	13.9	12.6	13.5
Ea. Oct.	3.5	3.9	4.0	3.4	3.7	13.0	13.7	13.3	12.5	13.1
Late Oct.	4.2	3.5	4.1	3.6	3.9	14.1	13.9	14.3	13.4	13.9
Ea. Nov.	4.2	3.8	3.7	3.6	3.8	13.7	14.4	14.1	13.7	14.0
Late Nov.	3.1	3.1	3.7	3.5	3.4	12.3	12.7	14.0	13.2	13.1
Ea. Dec.	3.8	3.1	3.7	3.4	3.5	13.9	12.5	13.6	13.1	13.3
Late Sept.+Ea. Dec.	3.3	3.4	3.8	3.3	3.5	12.8	13.6	13.6	13.2	13.3
12 Sept.										
Ea. Oct.	3.9	3.6	4.0	3.3	3.7	13.3	13.1	13.6	12.1	13.0
Late Oct.	3.7	3.9	4.0	3.7	3.8	13.0	14.5	13.7	13.7	13.7
Ea. Nov.	3.8	4.0	3.9	3.5	3.8	13.1	14.8	13.1	12.6	13.4
Late Nov.	3.7	3.6	4.1	3.5	3.7	12.8	13.3	13.4	13.9	13.3
Ea. Oct.+Ea. Dec.	3.7	3.6	3.9	3.5	3.7	12.6	13.4	13.4	12.5	13.0
Avg.	3.7	3.6	3.9	3.5		13.1	13.7	13.7	13.0	
LSD 0.05	Cultivar (C)				.1	Cultivar (C)				.3
	Fall Harvest Treatment (FHT)				.2	Fall Harvest Treatment (FHT)				.6
	C X FHT				.4	C X FHT				NS
	CV = 10.5%					CV = 7.8%				

Table 5. (Continued)

Fall harvest treatment	First harvest 1982 Cultivar: Arc	Buffalo	Dawson	Riley	Avg.	Total season production+ 1982 Cultivar: Arc	Buffalo	Dawson	Riley	Avg.
	Mg/ha					Mg/ha				
21 Aug.										
Late Sept.	5.3	3.6	3.9	4.5	4.3	14.7	14.0	14.1	15.6	14.6
Ea. Oct.	5.1	3.4	3.7	4.0	4.0	15.3	13.6	13.9	14.7	14.3
Late Oct.	4.9	3.8	3.7	4.2	4.1	14.7	14.9	14.5	14.2	14.6
Ea. Nov.	4.5	3.4	4.2	4.1	4.0	13.7	13.6	14.7	14.5	14.1
Late Nov.	5.4	3.1	3.8	3.9	4.1	14.3	13.2	13.7	14.1	13.8
Ea. Dec.	5.7	3.9	4.1	4.4	4.5	14.8	14.5	14.1	14.7	14.5
Late Sept.+Ea. Dec.	5.2	3.8	3.9	4.2	4.3	14.4	14.5	14.5	14.1	14.4
3 Sept.										
Ea. Oct.	5.2	3.8	4.1	4.6	4.4	14.6	14.6	15.0	15.8	15.0
Late Oct.	5.1	3.5	3.7	4.1	4.1	14.6	15.1	14.5	14.7	14.7
Ea. Nov.	4.5	3.6	3.9	4.4	4.1	13.4	14.3	14.3	14.6	14.2
Late Nov.	4.9	3.7	4.4	4.4	4.2	14.2	14.7	13.6	14.8	14.3
Ea. Oct.+Ea. Dec.	5.1	3.9	4.3	4.2	4.3	15.1	14.7	15.4	14.6	14.9
Avg.	5.1	3.6	4.0	4.2		14.5	14.3	14.3	14.7	
LSD 0.05	Cultivar (C)				.2	Cultivar (C)				NS
	Fall Harvest Treatment (FHT)				.3	Fall Harvest Treatment (FHT)				NS
	C X FHT				NS	C X FHT				NS
	CV = 13.9%					CV = 9.0%				

Table 5. (Continued)

Fall harvest treatment	First harvest 1983 Cultivar					Total season production+ 1983 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	Mg/ha					Mg/ha				
19 Aug.										
Late Sept.	5.7	5.5	5.5	5.7	5.6	9.6	9.8	9.8	10.0	9.8
Ea. Oct.	5.9	5.2	5.2	5.7	5.5	10.1	9.4	9.5	10.1	9.8
Late Oct.	5.9	5.6	5.5	5.8	5.7	10.4	10.1	9.9	9.8	10.1
Ea. Nov.	5.9	5.7	5.9	5.9	5.8	9.9	10.1	10.4	10.4	10.2
Late Nov.	5.9	5.7	5.6	5.8	5.8	10.2	10.0	9.8	10.2	10.0
Ea. Dec.	5.6	5.4	5.7	5.7	5.6	9.8	9.6	10.2	9.8	9.9
Late Sept.+Ea. Dec.	5.4	5.6	5.7	5.9	5.7	9.4	9.8	10.1	10.2	9.9
19 Aug.										
Ea. Oct.	5.6	5.5	5.7	6.1	5.7	9.9	9.7	10.0	11.1	10.1
Late Oct.	5.4	5.6	5.7	6.0	5.7	9.5	9.7	10.0	10.2	9.8
Ea. Nov.	6.0	5.6	6.0	5.9	5.9	10.3	9.9	10.4	10.2	10.2
Late Nov.	5.9	5.7	5.9	5.7	5.8	10.2	10.3	10.1	10.0	10.1
Ea. Oct.+Ea. Dec.	5.9	5.7	5.5	5.8	5.7	9.9	10.2	10.1	10.2	10.1
Avg.	5.8	5.6	5.6	5.8		9.9	9.9	10.0	10.2	

LSD 0.05	First harvest		Total season production	
	Cultivar (C)	.1	Cultivar (C)	.2
	Fall Harvest Treatment (FHT)	.2	Fall Harvest Treatment (FHT)	.3
	C X FHT	NS	C X FHT	NS
	CV = 6.5%		CV = 5.6%	

+Five harvests in 1981 and 1982, two harvests in 1983.

Table 6. Forage dry matter yields for first harvest and total season for cultivars and recovery periods, 1981 to 1983.

Fall recovery period		First harvest 1981 Cultivar					Total season production+ 1981 Cultivar				
	No. days	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
		Mg/ha					Mg/ha				
1	55	3.3	3.8	3.9	3.0	3.5	13.2	14.4	13.9	12.6	13.5
2	41	3.5	3.9	4.0	3.4	3.7	13.0	13.7	13.3	12.5	13.1
3	27	4.2	3.5	4.1	3.6	3.9	14.1	13.9	14.3	13.4	13.9
4	13	4.2	3.8	3.7	3.6	3.8	13.7	14.4	14.1	13.7	14.0
5	0	3.3	3.4	3.8	3.3	3.5	12.8	13.6	13.6	13.2	13.3
Avg.		3.7	3.7	3.9	3.4		13.4	14.0	13.8	13.1	
LSD 0.05		Cultivar (C)			.2		Cultivar (C)			.5	
		Recovery Period (RP)			.2		Recovery Period (RP)			.6	
		C X RP			.4		C X RP			NS	
		CV = 10.6%					CV = 7.5%				

Table 6. (Continued)

Fall recovery period		First harvest 1982 Cultivar					Total season production+ 1982 Cultivar				
		Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	No. days	Mg/ha					Mg/ha				
1	56	4.9	3.8	3.7	4.2	4.1	14.7	14.9	14.5	14.2	14.6
2	41	4.5	3.4	4.2	4.1	4.0	13.7	13.6	14.7	14.5	14.1
3	27	5.4	3.1	3.8	3.9	4.1	14.3	13.2	13.7	14.1	13.8
4	10	5.7	3.9	4.1	4.4	4.5	14.8	14.5	14.1	14.7	14.5
5	14	5.2	3.8	3.9	4.2	4.3	14.4	14.5	14.5	14.1	14.4
Avg.		5.1	3.6	3.9	4.2		14.4	14.1	14.3	14.3	
LSD 0.05		Cultivar (C)			.2		Cultivar (C)			NS	
		Recovery Period (RP)			.3		Recovery Period (RP)			NS	
		C X RP			NS		C X RP			NS	
		CV = 13.6%					CV = 8.2%				

Table 6. (Continued)

Fall recovery period		First harvest 1983 Cultivar					Total season production+ 1983 Cultivar				
	No. days	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
		Mg/ha					Mg/ha				
1	63	5.7	5.5	5.5	5.7	5.6	9.6	9.8	9.8	10.0	9.8
2	48	5.9	5.2	5.2	5.7	5.5	10.1	9.4	9.5	10.1	9.8
3	34	5.9	5.6	5.5	5.8	5.7	10.4	10.1	9.9	9.8	10.1
4	20	5.9	5.7	5.9	5.9	5.8	9.9	10.1	10.4	10.4	10.2
5	0	5.4	5.6	5.7	5.9	5.7	9.4	9.8	10.1	10.2	9.9
Avg.		5.8	5.5	5.6	5.8		9.9	9.8	9.9	10.1	
LSD 0.05		Cultivar (C)			.2		Cultivar (C)			.2	
		Recovery Period (RP)			.2		Recovery Period (RP)			.3	
		C X RP			NS		C X RP			NS	
		CV = 6.3%					CV = 5.1%				

+Five harvests in 1981 and 1982, two harvests in 1983.

Table 7. Total forage dry matter yield for cultivars and fall harvest treatments, 1981 to 1983.

Fall harvest treatment	Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.
	Mg/ha				
Aug.					
Late Sept.	37.4	38.2	37.8	38.3	37.9
Ea. Oct.	38.3	36.7	36.7	37.4	37.3
Late Oct.	39.3	38.9	38.7	37.5	38.6
Ea. Nov.	37.3	38.1	39.3	38.5	38.3
Late Nov.	36.8	36.0	37.6	37.5	37.0
Ea. Dec.	38.5	36.6	38.0	37.7	37.7
Late Sept. + Ea. Dec.	36.6	37.9	38.2	37.6	37.6
Sept.					
Ea. Oct.	37.7	37.4	38.6	38.9	38.1
Late Oct.	37.0	39.4	38.2	38.5	38.3
Ea. Nov.	36.8	39.1	37.8	37.4	37.8
Late Nov.	37.2	38.2	37.0	38.7	37.8
Ea. Oct. + Ea. Dec.	37.6	38.3	38.9	37.3	38.0
Average	37.6	37.9	38.1	37.9	
LSD 0.05	Cultivar (C)				NS
	Fall Harvest Treatment (FHT)				NS
	C X FHT				NS
	CV = 5.4%				

Table 8. Total forage dry matter yield for cultivars and fall recovery periods, 1981 to 1983.

Fall recovery period		Cultivar				
		Arc	Buffalo	Dawson	Riley	Avg.
	No. days+	Mg/ha				
1	58	37.5	39.1	38.2	36.9	37.9
2	43	36.8	36.7	37.6	37.2	37.1
3	29	38.8	37.2	38.0	37.4	37.8
4	14	38.4	39.1	38.7	38.8	38.7
5	5	36.6	37.9	38.2	37.6	37.6
Avg.		37.6	38.0	38.1	37.6	
LSD 0.05		Cultivar (C)			NS	
		Recovery Period (RP)			NS	
		C X RP			NS	
		CV = 4.7%				

+Average recovery days for three years, 1981 to 1983.

Table 9. Plant heights at first harvest following fall harvest treatments in 1980, 1981, and 1982.

Fall harvest treatment	1981 Cultivar					1982 Cultivar					1983 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	cm					cm					cm				
Aug.															
Late Sept.	43.3	42.5	44.4	35.9	41.5	63.6	51.9	52.2	59.0	56.7	56.8	59.2	57.7	54.7	57.1
Ea. Oct.	42.5	42.5	44.5	37.1	41.7	67.4	52.4	54.7	51.2	56.4	58.9	60.7	62.0	57.0	59.6
Late Oct.	43.5	46.3	47.3	35.8	43.0	63.3	49.0	51.5	51.6	53.9	59.7	58.9	59.8	56.1	58.6
Ea. Nov.	46.7	43.7	45.1	36.4	43.0	62.5	46.3	51.9	52.4	53.3	61.0	62.1	61.0	56.4	60.1
Late Nov.	48.6	45.7	44.0	38.7	44.3	56.4	50.8	57.2	50.6	53.8	63.9	60.6	61.4	57.2	60.7
Ea. Dec.	37.3	40.6	45.4	36.9	40.0	65.1	45.0	51.8	49.0	52.7	61.4	59.3	59.8	59.0	59.9
Late Sept.+Ea. Dec.	45.9	44.9	43.4	36.6	42.7	68.3	59.0	38.8	55.6	60.4	59.2	59.3	61.1	58.3	59.5
Sept.															
Ea. Oct.	50.1	45.5	46.1	37.5	44.8	63.1	57.2	56.5	56.0	58.2	58.9	59.3	58.6	57.6	58.6
Late Oct.	45.8	46.6	44.7	37.1	43.6	66.4	56.2	56.3	53.6	58.1	59.4	62.8	62.3	55.6	60.0
Ea. Nov.	44.9	46.9	47.1	38.7	44.4	58.9	52.2	54.1	52.7	54.5	60.3	60.5	62.0	57.0	60.0
Late Nov.	48.6	44.6	41.4	34.5	42.3	55.8	53.8	52.3	52.0	53.5	61.4	61.8	63.9	60.5	61.2
Ea. Oct.+Ea. Dec.	44.2	46.9	43.1	37.1	42.8	61.1	50.4	50.8	51.6	53.5	62.5	60.9	61.3	58.6	60.8
Avg.	45.1	44.6	44.7	36.9		62.7	52.1	54.0	53.0		60.3	60.4	60.9	57.3	

LSD 0.05	1981		1982		1983	
	Cultivar (C)	1.5	Cultivar (C)	2.0	Cultivar (C)	1.0
	Fall Harvest Treatment (FHT)	2.6	Fall Harvest Treatment (FHT)	3.5	Fall Harvest Treatment (FHT)	.7
	C X FHT	NS	C X FHT	NS	C X FHT	NS
	CV = 17%		CV = 22.3%		CV = 4.6%	

Table 10. Total nonstructural carbohydrate (TNC) concentration in alfalfa roots following fall harvest treatments in 1980, 1981, and 1982.

Fall harvest treatment	1981 Cultivar					1982 Cultivar					1983 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	%					%					%				
Aug.															
Late Sept.	25.5	30.5	24.9	23.5	26.1	33.6	36.6	39.8	39.7	37.4	31.9	32.4	29.3	32.6	31.6
Ea. Oct.	25.9	30.3	25.6	23.9	26.4	36.6	38.6	36.8	37.7	37.4	28.7	31.0	30.6	31.0	30.3
Late Oct.	28.9	25.6	28.5	28.6	27.9	35.3	38.6	33.8	41.8	37.4	29.8	33.1	30.8	32.3	31.5
Ea. Nov.	28.2	27.7	28.1	25.9	27.5	34.2	34.1	33.9	40.1	35.6	29.6	29.3	29.6	31.8	30.1
Late Nov.	27.1	25.9	29.3	26.6	27.2	35.1	31.3	34.9	40.2	35.4	28.5	30.1	29.8	31.7	30.0
Ea. Dec.	30.1	27.7	25.5	26.4	27.4	34.8	33.0	32.2	34.9	33.7	29.6	30.7	28.9	32.8	30.5
Late Sept.+Ea. Dec.	26.7	30.3	28.1	29.4	28.6	37.0	35.4	30.7	37.1	35.1	28.7	29.5	28.8	32.1	29.8
Avg.	27.5	28.3	27.1	26.3		35.2	35.4	34.6	38.8		29.5	30.9	29.7	32.0	
LSD 0.05	Cultivar (C)				NS	Cultivar (C)				2.1	Cultivar				1.2
	Fall Harvest Treatment (FHT)				NS	Fall Harvest Treatment (FHT)				NS	Fall Harvest Treatment (FHT)				NS
	C X FHT				NS	C X FHT				NS	C X FHT				NS
	CV = 15.6%					CV = 11.7%					CV = 8.5%				

Table 11. Initial plant density in May 1980 and final plant density in June 1983 after three years of fall harvest management.

Fall harvest treatment	1981 Cultivar Arc	Buffalo	Dawson	Riley	Avg.	1982 Cultivar Arc	Buffalo	Dawson	Riley	Avg.
	plants/0.1m^2					plants/0.1m^2				
Aug.										
Late Sept.	35	50	42	69	49	5	9	8	10	8
Ea. Oct.	37	49	44	70	50	6	9	10	9	8
Late Oct.	36	45	42	62	46	7	8	7	10	8
Ea. Nov.	36	54	42	60	48	5	9	9	8	8
Late Nov.	39	52	44	59	48	7	9	9	9	8
Ea. Dec.	37	54	44	67	50	5	10	9	10	8
Late Sept.+Ea. Dec.	29	53	41	71	48	5	9	8	9	8
Sept.										
Ea. Oct.	35	58	40	69	50	5	9	8	10	8
Late Oct.	36	54	41	56	46	5	11	8	8	8
Ea. Nov.	37	51	44	58	47	5	11	11	9	9
Late Nov.	36	58	48	65	51	7	10	9	11	9
Ea. Oct.+Ea. Dec.	34	47	40	58	45	7	8	9	9	8
Avg.	36	52	43	64		6	9	9	9	

LSD 0.05	1981		1982	
	Cultivar (C)	2.6	Cultivar (C)	.7
	Fall Harvest Treatment (FHT)	NS	Fall Harvest Treatment (FHT)	NS
	C X FHT	NS	C X FHT	NS
	CV = 23.5%		CV = 23.1%	

Table 12. Stem densities at second harvest following fall harvest treatments in 1980, 1981, and 1982.

Fall harvest treatment	1981 Cultivar					1982 Cultivar					1983 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	stems/0.1m^2					stems/0.1m^2					stems/0.1m^2				
Aug.															
Late Sept.	48	60	53	56	54	33	34	39	38	36	21	30	29	28	27
Ea. Oct.	47	59	55	52	53	31	31	40	41	36	24	28	31	30	28
Late Oct.	51	54	53	60	54	39	36	34	42	38	21	26	28	29	26
Ea. Nov.	49	55	53	55	53	38	36	34	40	37	22	27	27	28	26
Late Nov.	48	56	58	60	56	44	37	38	38	39	26	25	28	29	27
Ea. Dec.	45	56	58	60	55	34	41	35	38	37	22	29	27	29	27
Late Sept.+Ea. Dec.	45	55	58	55	53	36	36	37	39	37	21	28	27	31	27
Sept.															
Ea. Oct.	43	59	55	60	54	34	35	36	41	36	22	28	24	30	26
Late Oct.	50	53	50	55	52	38	40	35	39	38	21	28	26	29	26
Ea. Nov.	47	56	59	55	54	30	38	40	42	38	22	31	30	29	28
Late Nov.	49	51	55	55	53	34	38	37	40	37	22	27	29	30	27
Ea. Oct.+Ea. Dec.	49	52	52	55	52	35	37	37	40	37	25	29	32	30	29
Avg.	48	56	55	56		36	37	37	40		22	28	28	29	
	Cultivar (C)				2.4	Cultivar (C)				NS	Cultivar (C)				1.4
	Fall Harvest Treatment (FHT)				NS	Fall Harvest Treatment (FHT)				NS	Fall Harvest Treatment (FHT)				NS
	C X FHT				NS	C X FHT				NS	C X FHT				NS
	CV = 21.4%					CV = 18.5%					CV = 14.7%				

Table 13. Crown cover following fall harvest treatments in 1980, 1981, and 1982.

Fall harvest treatment	1981 Cultivar					1982 Cultivar					1983 Cultivar				
	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.	Arc	Buffalo	Dawson	Riley	Avg.
	%					%					%				
Aug.															
Late Sept.	49	47	49	52	49	47	47	46	50	48	26	34	34	39	33
Ea. Oct.	48	52	50	53	51	47	46	47	50	48	30	34	36	40	35
Late Oct.	45	47	56	51	47	48	49	48	50	49	30	37	34	44	36
Ea. Nov.	48	53	49	48	50	48	50	49	50	49	30	40	34	38	36
Late Nov.	39	48	43	51	45	47	50	50	50	49	29	36	36	38	35
Ea. Dec.	49	50	50	51	50	48	50	50	50	50	26	32	34	38	32
Late Sept.+Ea. Dec.	44	47	50	50	48	48	50	49	49	49	24	34	34	36	32
Sept.															
Ea. Oct.	44	47	48	51	48	48	50	48	50	49	27	34	32	44	34
Late Oct.	42	50	49	49	48	49	50	50	50	50	28	34	35	40	34
Ea. Nov.	43	47	45	48	46	48	49	48	49	49	24	36	41	42	36
Late Nov.	46	49	48	50	48	45	49	46	49	48	30	34	36	38	34
Ea. Oct.+Ea. Dec.	44	48	47	49	47	46	50	49	48	48	24	36	33	40	34
Avg.	45	49	48	50		48	49	48	50		27	35	35	40	

LSD 0.05	1981		1982		1983	
Cultivar (C)		1.4		.7		2.2
Fall Harvest Treatment (FHT)		NS		NS		NS
C X FHT		NS		NS		NS
	CV = 8.0%		CV = 3.8%		CV = 18.0%	

CHAPTER V

FALL MANAGEMENT OF ALFALFA FOR ALFALFA WEEVIL SUPPRESSION

Abstract

Alfalfa weevil [*Hypera postica* (Gyllenhal)] egg and larval densities were sampled in three experiments near Chickasha, Okla. Alfalfa cultivars with different levels of tolerance to the alfalfa weevil were subjected to various fall cutting date treatments to obtain a height differential in alfalfa regrowth. The objective of the study was to determine if fall harvest management may be important as a cultural control measure for the alfalfa weevil. In Exp. 1 - 'Kanza', removing alfalfa fall regrowth reduced weevil eggs in the subsequent spring in all three years of the experiment. Total weevil larval populations were not reduced in any year; however, fourth instar larvae were reduced by fall harvesting in two of three years of the study. In Exp. 2 - 'Arc', fall harvesting resulted in reduced weevil egg numbers in two of three years, but the differences were not significant ($P \leq 0.05$). In 1979, total weevil numbers in Exp. 2 were reduced 50% by fall harvesting in 1978 but no reduction was obtained in 1980 or 1981 as a result of fall harvesting in 1979 and 1980. Fourth instar

larvae were significantly reduced in 1979 and 1980 as a result of fall harvesting in 1978 and 1979. In Exp. 3 - Arc and 'Riley', weevil egg numbers were significantly reduced at one of two sampling dates in 1982 by fall forage removal in 1981 but reductions were not observed at either of two sampling dates in 1983. Larval populations in spring 1982 were not reduced by fall harvesting in 1981. In 1983, larval populations were 33% lower in plots which had fall regrowth removed in 1982 than in unharvested plots. There was no cultivar effect on egg or larval numbers at any sampling date in Exp. 3. Fall forage removal in 1981 resulted in a significantly lower damage rating in the spring of 1982 than where alfalfa was not harvested in the fall. There was no difference in damage ratings between fall harvests and uncut alfalfa in spring 1983. Arc had a significantly lower damage rating than Riley in 1983; however, there was no cultivar difference in damage rating in 1982.

Additional index words: *Medicago sativa* L., Cultural insect control, *Hypera postica* (Gyllenhal), Alfalfa management.

Introduction

Berberet (3) reported that the alfalfa weevil [*Hypera postica* (Gyllenhal)] is the most serious insect for alfalfa (*Medicago sativa* L.) production in Oklahoma. The presence of the alfalfa weevil has been confirmed in all 77 counties in Oklahoma.[1] Plant defoliation by larvae is the main cause of yield reduction, with reduced growth and stand density also contributing to reduced productivity (4). Berberet et al. (4) reported that yield losses of 190 kg/ha can occur for each larva/stem. Berberet (3) reported that chemical insecticides have been necessary to reduce weevil larval numbers when at peak densities to avoid large losses in alfalfa forage production.

Cultivar resistance to the alfalfa weevil has not been found. However, several cultivars have been described as having tolerance to alfalfa weevil feeding. These cultivars exhibit rapid and vigorous growth in early spring and extensive lateral branching which aids in compensating for weevil feeding in alfalfa terminals. Arc (6) and Team (2) are the only cultivars adapted to the southern plains which have been described in the literature as having tolerance to the alfalfa weevil.

Cultural forms of control offer another method for reducing the necessity for chemical control of the alfalfa weevil. Cultural forms of weevil control received extensive attention in the early 1900s. Titus (10) studied a number of cultural controls for the weevil in Utah. Pasturing of alfalfa with horses and sheep, cutting and burning the first hay crop, use of brush drags to knock larvae to the ground,

----

[1]Personal communication, D. L. Arnold, Survey Entomologist, Oklahoma State University.

and use of wire sweeps and weevil gathering machines were early attempts to reduce the effects of the weevil. Limited success was obtained with each of these methods. The consequences of some of these control measures were undesirable since they damaged or destroyed the hay crop.

Among more recent studies on cultural control of the alfalfa weevil, Casagrande and Stehr (5) reported that the weevil lays very few eggs in the fall in Michigan. They found that most eggs and larvae were present in the field at the time of first harvest in the spring. They obtained a 79% reduction in weevil larvae by cutting alfalfa at 507 degree days (base 8.9^{O}C) with little weevil damage to the alfalfa crop.

The amount of fall regrowth left on a field has also been found to influence the alfalfa weevil population. Dively (7) examined overwintering of alfalfa weevil eggs in three alfalfa regrowth stages in New Jersey. He found significantly higher numbers of fall laid eggs in alfalfa in a 2.4 to 2.8 cm fall growth stage than in a fresh stubble stage (0.8 to 1.2 cm) and a bud stage (4.75 to 5.5 cm).

Senst and Berberet (9) reported that winter grazing of alfalfa with cattle reduced alfalfa weevil eggs by more than 70% and larvae by more than 50% in the subsequent spring. Alfalfa regrowth is frequently hayed or grazed during mid-September to late November in the southern plains. Additional information is needed on the potential for removal of fall regrowth as a weevil reduction measure.

The objective of this study was to determine if fall harvest management may be important as a cultural control measure for the alfalfa weevil.

Materials and Methods

Exp. 1 and 2

Two experiments were initiated in September, 1978 near Chickasha, Okla. The site for Exp. 1 was a 4-year-old stand of 'Kanza' alfalfa, and the site for Exp. 2 was a 2-year-old stand of 'Arc' alfalfa. The experimental design was a randomized complete block design with treatments consisting of three fall harvest treatments (Table 1). The three treatments were applied at the last harvest of the season to obtain maximum, intermediate, and no fall regrowth (Table 1). There were four and six replications in Exp. 1 and 2, respectively. Plot size was 4.6 X 8.6 m in Exp. 1 and 4.6 X 4.3 m in Exp. 2. Forage was harvested with a flail type harvester at a height of approximately 4 cm.

Alfalfa forage was routinely harvested from the site of both experiments prior to initiation of the study. Egg and larval sampling dates for this study were selected based on results of weekly sampling in nearby plots. Dates were selected when egg and larval densities were expected to be near their peak. Four plant material samples of 0.025 m^2 each for egg determinations were removed at random from plots on 14 Mar. 1979, 26 Feb. 1980, and 27 Feb. 1981. A blender technique as described by Pass and Van Meter (8) was used to remove weevil eggs from plant material. The total numbers of eggs sampled in each fall growth stage were ranked, analyzed, and then submitted to analysis of variance. The LSD at the 5% level was used as a test for significance between means. Thirty stems/plot were collected 13 Apr. 1979, 22 Apr. 1980, and 26 Mar. 1981 and weevil larvae were extracted by using Berlese funnels (1). Larvae number/30 stems was converted to larvae number/stem. Ranking did not improve statistical significance so standard analysis of variance tests were performed on weevil larval populations and means were compared by the LSD ($P \leq 0.05$).

Exp. 3

A third experiment was initiated in September 1980 near Chickasha, Okla. A 2 X 3 (two alfalfa cultivars and three fall harvest treatments) factorial arrangement of treatments in a randomized complete block design was employed for the experiment. 'Arc' and 'Riley' cultivars were established in April 1980 and three fall harvest treatments were imposed to obtain maximum, intermediate, and no fall regrowth (Table 1). Plot size was 4.6 X 1.85 m and the experiment had six replications. Alfalfa forage was routinely harvested throughout each growing season. Four plant material samples of 0.025 m^2 each for alfalfa weevil egg determinations were collected 19 Jan. and 23 Feb. 1982 and 29 Jan. and 8 Mar. 1983. Egg removal from plant material was the same as in Exp. 1 and 2. Twenty-five stems/plot were collected 18 Mar.

1982 and 19 Apr. 1983, with larval population densities determined in the same manner as in Exp. 1 and 2. Ratings for damage caused by alfalfa weevil larvae were made on stem samples in 1982 and 1983. Damage ratings were made by visually estimating alfalfa defoliation as a result of weevil larvae feeding. A rating scale with 9 representing complete defoliation and 1 representing an undamaged condition was used to assess weevil damage. Ranking did not improve statistical significance and standard analysis of variance tests were performed for egg and larval densities and means compared by the LSD at the 5% level.

Results and Discussion

Exp. 1--Kanza

Fall forage removal in 1978 did not result in significantly different ($P \leq 0.05$) egg counts in the spring of 1979 (Table 2). Although some reduction in weevil egg and larval numbers was noted with late fall forage removal (treatment 2), low weevil numbers observed may have prevented detection of some of the real potential differences among treatments. Fall regrowth from fall 1979 was 46 cm in treatment 1 (not cut after August 1979), while there was no regrowth in treatment 3 which was last cut 7 December (after killing frost). The difference in fall regrowth resulted in a reduction in egg counts of 28/0.1 m^2 in treatment 3.

Fall regrowth significantly ($P \leq 0.05$) influenced egg numbers in the spring of 1981. Plant height in treatment 1 (uncut after 1 October) was 15 cm while there was no regrowth in treatment 3 (last cut 7 December). The plant regrowth difference resulted in weevil egg reduction in treatment 3 of 28/0.1 m^2. There was no significant ($P \leq 0.05$) difference between treatments 2 and 3.

Total larval numbers were not significantly different ($P \leq 0.05$) due to fall regrowth in any year. In 1979 and 1981 fourth instar larval counts were 0.3 and 0.4/stem lower, respectively, in treatment 3 than in treatment 1.

Exp. 2--Arc

As in Exp. 1, weevil population densities were low throughout the study. Alfalfa weevil egg densities were not significantly affected by fall cutting treatment in any year of the experiment (Table 2). Total larval numbers were significantly ($P \leq 0.05$) reduced by late fall harvesting only in 1979 when a reduction was obtained in treatment 3 compared to treatment 1. Fourth instar larvae were reduced by 0.5 and 0.2/stem in 1979 and 1980, respectively, by late fall harvesting (treatment 3).

Exp. 3--Arc and Riley

There was no cultivar X fall harvest treatment interaction at any sampling date. There was a significant difference ($P \leq 0.05$) in egg numbers at the first sampling date in 1982 as a result of fall harvest treatment. Regrowth of 8 and 7 cm resulted in a reduction of 332 and 309 eggs/0.1 m^2 compared to treatment 1 which had 13 cm regrowth. There were no differences due to cultivar at either sampling date and no differences due to fall harvest treatment at the second egg sampling or the larvae sampling in 1982. Regrowth amount as a result of fall harvest treatment and cultivars did not influence egg populations at either sampling date in 1983. Larval densities were reduced by 0.7 and 0.8 larvae/stem in treatments 2 and 3, respectively compared to treatment 1 with 15 cm of regrowth. Damage ratings indicated that Arc suffered significantly ($P \leq 0.05$) less defoliation than Riley. Treatment 1 with 15 cm of fall regrowth had a significantly ($P \leq 0.05$) higher damage rating than treatments 2 and 3 with 8 and 7 cm of fall growth, respectively.

Conclusion

While reduction in egg and larval numbers with fall forage removal was variable in these experiments, this practice demonstrated potential as an alfalfa weevil suppression measure. Population densities of the alfalfa weevil were low relative to numbers reported by Senst and Berberet (9) during the time this experiment was conducted. Additional research under heavier weevil populations is needed to more clearly determine the effects of this practice. These findings tend to support the conclusion of

Senst and Berberet (9) that winter forage removal can be an effective weevil control measure.

Our findings of the fall growth stage with the greatest number of weevil eggs differ with those of Dively (7). He found the greatest number of eggs in a 0.8 to 1.2 cm stubble fall growth stage whereas we found the largest number of eggs in the tallest fall growth stage. This difference was probably due to more severe cold extremes in New Jersey where Dively conducted his research. Eggs laid in taller fall regrowth in New Jersey were more exposed to adverse weather conditions than eggs laid in alfalfa stubble or new growth. Although not tested for viability, eggs found in taller regrowth in our studies did not appear to be lower in viability than eggs found in other fall regrowth stages.

LITERATURE CITED

1. Armbrust, E. J., H. B. Niemczyk, B. C. Pass, and M. C. Wilson. 1969. Standardized procedures adopted for cooperative Ohio Valley states alfalfa weevil research. J. Econ. Entomol. 62:250-251.

2. Barnes, D. K., C. H. Hanson, R. H. Ratcliffe, T. H. Busbice, J. A. Schillinger, and G. R. Buss. 1973. Registration of Team alfalfa. Crop Sci. 13:769.

3. Berberet, R. C. 1982. Integrated control of the alfalfa weevil. Okla. State Univ. Ext. Current Report No. 7179. 6 pp.

4. Berberet, R. C., R. D. Morrison, and K. M. Senst. 1981. Impact of the alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera:Curculionidae), on forage production in nonirrigated alfalfa in the southern plains. J. of the Kansas Entomol. Soc. 54(2):312-318.

5. Casagrande, R. A. and F. W. Stehr. 1973. Evaluating the effects of harvesting alfalfa on alfalfa weevil (Coleoptera: Curculionidae) and parasite populations in Michigan. Can. Ent. 105:1119-1128.

6. Devine, T. E., R. H. Ratcliffe, C. M. Rincker, D. K. Barnes, S. A. Ostazeski, T. H. Busbice, C. H. Hanson, J. A. Schillinger, G. R. Buss, and R. W. Cleveland. 1975. Registration of Arc alfalfa. Crop Sci. 15:97.

7. Dively, G. P. 1970. Overwintering alfalfa weevil eggs in three stages of alfalfa growth in New Jersey. Ann. of the Entomol. Soc. of Am. 63:5, 1214-1216.

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

9. Senst, K. M. and R. C. Berberet. 1980. Effects of winter grazing of dormant alfalfa stands on populations of *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) and its parasite *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae). J. of the Kansas Entomol. Soc. 53(1):230-234.

10. Titus, E. G. 1910. The alfalfa-leaf weevil. Utah Agric. Exp. Stn. Cir. 10:105-120.

Table 1. Fall harvest treatments and fall regrowth for Exp. 1, 2, and 3.

	Exp. 1 and 2					
Treatment	1978		1979		1980	
	-Date-	Regrowth -cm-	-Date-	Regrowth -cm-	-Date-	Regrowth -cm-
1	21 Sept	23	28 Aug	46	1 Oct	15
2	21 Nov	8	6 Nov	13	20 Nov	8
3	7 Dec	4	7 Dec	4	7 Dec	4

	Exp. 3			
Treatment	1982		1983	
	-Date-	Regrowth -cm-	-Date-	Regrowth -cm-
1	25 Sept	13	22 Sept	15
2	22 Oct	8	21 Oct	8
3	20 Nov	7	18 Nov	7

Table 2. Alfalfa weevil egg and larval population densities following fall harvest date treatments for Kanza and Arc alfalfa, 1979 to 1981.

			Weevil larvae instar				
Last cut treatment	Plant height	Weevil eggs	1	2	3	4	total
	cm	no./0.1m^2	--------no./stem--------				
1979							
Exp. 1--Kanza							
1	23	11	0	.1	.2	.5	.8
2	8	5	0	.1	.3	.5	1.0
3	4	3	0	.1	.2	.2	.5
LSD (0.05)		NS	NS	NS	NS	.2	NS
Exp. 2--Arc							
1	23	19	0	.2	.5	.7	1.4
2	8	10	0	.2	.4	.5	1.2
3	4	5	0	.2	.3	.2	.7
LSD (0.05)		NS	NS	NS	.1	.1	.2
1980							
Exp. 1--Kanza							
1	46	41	.2	.3	.3	.3	1.1
2	13	47	.1	.2	.2	.4	.9
3	4	13	.1	.2	.2	.4	.9
LSD (0.05)		12.6	NS	NS	NS	NS	NS
Exp. 2--Arc							
1	46	39	.1	.2	.2	.4	.8
2	13	25	0	.2	.2	.4	.8
3	4	12	.1	.2	.2	.2	.7
LSD (0.05)		NS	.03	NS	NS	.1	NS

Table 2. Continued.

Last cut treatment	Plant height	Weevil eggs	Weevil larvae instar 1	2	3	4	total
		1981					
	cm	no./0.1m^2	--------no./stem--------				
Exp. 1--Kanza							
1	15	49	0	.3	1.8	1.0	3.1
2	8	19	0	.3	1.6	.7	2.5
3	4	21	0	.2	1.3	.6	2.1
LSD (0.05)		12.6	NS	NS	NS	.2	NS
Exp. 2--Arc							
1	15	4	0	.1	.4	.6	1.1
2	8	6	0	.1	.3	.3	.7
3	4	9	0	.1	.4	.3	.8
LSD (0.05)		NS	NS	NS	NS	NS	NS

Table 3. Alfalfa weevil infestations in 1982 following fall cutting date treatments in 1981.

Last cut treat-ment	Fall plant height	Eggs 19 Jan. Arc	Eggs 19 Jan. Riley	Eggs 19 Jan. Avg.	Eggs 23 Feb. Arc	Eggs 23 Feb. Riley	Eggs 23 Feb. Avg.	Larvae 18 Mar. Arc	Larvae 18 Mar. Riley	Larvae 18 Mar. Avg.	Damage rating 18 Mar. Arc	Damage rating 18 Mar. Riley	Damage rating 18 Mar. Avg.
	-cm-	---eggs/0.1m^2---			---eggs/0.1m^2---			--larvae/stem--			----rating-----		
1	13	668	612	640	209	210	210	7.8	6.6	7.2	5.2	4.6	4.9
2	8	278	338	308	187	188	188	7.3	7.9	7.6	5.4	5.2	5.3
3	7	290	373	331	246	189	218	5.8	6.6	6.2	5.2	5.4	5.3
Avg.		412	441		214	196		7.0	7.0		5.3	5.1	
LSD (0.05)		Last cut treatment = 143			NS			NS			NS		

Table 4. Alfalfa weevil infestations in 1983 following fall cutting date treatments in 1982.

Last cut treatment	Fall plant height	Eggs 19 Jan. Arc	Eggs 19 Jan. Riley	Eggs 19 Jan. Avg.	Eggs 23 Feb. Arc	Eggs 23 Feb. Riley	Eggs 23 Feb. Avg.	Larvae 18 Mar. Arc	Larvae 18 Mar. Riley	Larvae 18 Mar. Avg.	Damage rating 18 Mar. Arc	Damage rating 18 Mar. Riley	Damage rating 18 Mar. Avg.
	-cm-	---eggs/0.1m^2---			---eggs/0.1m^2---			--larvae/stem--			----rating-----		
1	15	17	21	19	30	25	28	2.1	2.2	2.1	3.0	3.6	3.3
2	8	7	32	20	25	33	29	1.2	1.6	1.4	2.4	3.0	2.7
3	7	16	8	12	20	24	22	1.2	1.4	1.3	2.6	2.6	2.6
Average		13	20		25	27		1.5	1.7		2.7	3.1	
LSD (0.05)		NS			NS			Last cut treatment = 0.4			Cultivar = 0.4 Last cut treatment = 0.4		

ᐟ

VITA

James Ronald Sholar

Candidate for the Degree of

Doctor of Philosophy

Thesis: MANAGEMENT OF ALFALFA (*MEDICAGO SATIVA* L.) IN THE SOUTHERN PLAINS

Major Field: Crop Science

Biographical:

Personal Data: Born June 27, 1949, in Stewart County, Tennessee, the son of Mr. and Mrs. Rymon L. Sholar.

Education: Graduated from Stewart County High School, Dover, Tennessee, in June, 1967; received the Bachelor of Science degree from the University of Tennessee at Martin, Martin, Tennessee, in June, 1971; received the Master of Science degree from Oklahoma State University, Stillwater, Oklahoma, in May, 1973; completed requirements for the Doctor of Philosophy degree in Crop Science at Oklahoma State University, Stillwater, Oklahoma, in July, 1984.

Professional Experience: Officer U. S. Army, 1973-1975; Area Specialized Agent - Agronomy, Oklahoma State University, Stillwater, Oklahoma, 1975-1978; Extension Pest Management Specialist, Oklahoma State University, Stillwater, Oklahoma, 1978-1981; Extension Crops Specialist, Oklahoma State University, Stillwater, Oklahoma, 1981 to present.

Member: American Peanut Research and Education Society, Executive Officer; American Society of Agronomy; Weed Science Society of America; Southern Weed Science Society; Board of Directors Oklahoma Soybean Association.