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Eric Spandl

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James J. Kells
Major professor

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WEED COMPOSITION AND FORAGE PRODUCTION IN ALFALFA SEEDED WITH OAT AND PERENNIAL FORAGE GRASSES

By

Eric Spandl

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ABSTRACT

WEED COMPOSITION AND FORAGE PRODUCTION IN ALFALFA SEEDED WITH OAT AND PERENNIAL FORAGE GRASSES

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Eric Spandl

Establishing alfalfa with a perennial forage grass may reduce weed invasion. Including a small grain companion crop with the mixtures at establishment may also suppress weed growth. This study documented the effects of seeding alfalfa with a forage grass and an oat companion crop on weed and component yields, weed and alfalfa density, and forage quality. Alfalfa was seeded alone, with weeds controlled (weed-free alfalfa) and without weed control (weedy alfalfa), and in binary mixtures with bromegrass, orchardgrass, timothy, or Kentucky bluegrass. All forages were seeded with and without oat in sites with low and high weed pressure. In an existing study, measurements were taken in the third and fourth years of the stand where alfalfa was seeded alone and with bromegrass, orchardgrass, or timothy.

In new stands, forage grasses had no consistent effect on yields, plant densities, or forage quality in the seeding year. Bromegrass and timothy were nearly eliminated from the stand after the first harvest in the second year. In established stands, orchardgrass and Kentucky bluegrass often decreased alfalfa yields. Total forage yields of mixtures were often greater than the weedy alfalfa at the spring harvest and similar at subsequent harvests. Orchardgrass and Kentucky bluegrass reduced weed yield at one harvest in the second year and more consistently the following year. Both grasses reduced dandelion density in the fall

of the third year. Alfalfa density was usually unaffected by the grasses in the first three years of the stand.

Responses of the mixtures, weedy alfalfa, and weed-free alfalfa to the oat companion were often similar. Oat reduced weed yield at both harvests in the seeding year. Seeding with oat increased forage yields at the first harvest and decreased yields at the second harvest. Forage quality was reduced by the oat at first harvest and increased at the second harvest. Few residual effects of the oat were seen on weed invasion or alfalfa density in an environment with adequate soil moisture.

In the existing stand, orchardgrass consistently reduced weed yields. Average weed content was 24, 17, 2, and 15% for the weedy alfalfa, alfalfa-bromegrass, alfalfa-orchardgrass, and alfalfa-timothy, respectively. Crude protein was decreased, and acid and neutral detergent fiber increased by the orchardgrass at the spring harvest and neutral detergent fiber increased at subsequent harvests.

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CHAPTER ONE

An Oat Companion Crop Influences Weed Invasion, Component Yields, Forage Quality, and Plant Density in Alfalfa Seeded with Perennial Forage Grasses.

ABSTRACT

Small grain companion crops are widely used in spring establishment of forages. Potential advantages of seeding with a companion crop include weed suppression, soil and water conservation, and increased forage yield. Most research has focused on the effects of companions on pure seeded alfalfa. There are, however, many producers that grow mixtures of alfalfa with a perennial forage grass. These studies determined what effects an oat companion crop had on weed yield and density, component yields, forage quality, and alfalfa density. Field experiments were seeded in spring of 1993 and 1994 at sites with high and low weed pressure. Treatments included alfalfa seeded alone, with and without weed control, and in binary mixtures with bromegrass, orchardgrass, timothy, or Kentucky bluegrass. All forages were seeded with and without an oat companion. Measurement were taken during the first three years of the stand. Oat significantly reduced weed yield at both harvests in the seeding year but had little effect on weed yields in subsequent years. Weed density was, at times, reduced by the oat during the initial growth and not affected in regrowth or established stands. Under high weed pressure, forage quality and plant density was less consistent in response to oat. Yield of components, forage quality, and plant density response to seeding with oat was often similar in the mixtures, the weed-free alfalfa, and the weedy alfalfa. Oat consistently suppressed weed growth but effects on forage yield and quality were harvest dependent in the seeding year. Few effects of oat were noted on plant density after establishment or alfalfa density in an environment with adequate soil moisture.

INTRODUCTION

Companion crops, primarily small grains, are widely used in spring seedings of alfalfa (*Medicago sativa* L.). An estimated 60% of alfalfa acreage planted in the north central and north eastern USA is seeded with a companion crop (55). In Minnesota, companion crops are used by up to 85% of forage producers (48).

Potential advantages of including companion crops with forages at seeding include reduced soil erosion, increased economic return, increased forage yield, reduced insect pests, and suppression of weeds. Reduced erosion was given as the primary reason Minnesota forage producers used companion crops (48). Companion crops are also seeded with forages to provide economic return from the silage or grain and straw (6,21). Seeding alfalfa with companion crops generally results in greater forage yield compared to alfalfa seeded alone with herbicides (23,25,43,49). Forage yields when alfalfa is seeded without weed control vary, depending on weed growth, but may even exceed that of the oat (*Avena sativa* L.)/alfalfa (46). Lamp (24) found that seeding alfalfa with oat reduced potato leafhopper (*Empoasca fabae*) numbers.

A companion crop may be seeded with the forage to suppress weed growth. Weed competition can reduce alfalfa yield in the seeding year and in established stands (14,26,33,39,44,46,58). Total forage yield, however, may not be affected (34) but the weeds may compose a large proportion of the dry matter (33,53). Also, intense weed competition

in the seeding year may result in a stand failure (45). Forage quality may or may not be reduced by the presence of weeds (12,13,16,20,27,29,31,33,36,47). Additionally, weeds may reduce palatability (29), have potentially toxic levels of nitrates (5), decrease the rate of drying (11), and provide seeds or vegetative propagules that result in increased weed pressure in subsequent crops (30).

During the initial growth of the forages in the seeding year, weed yield (content) and density may be reduced by the companion crop (25,28,49). Residual effects of the companion on weed density or content in subsequent harvests in the seeding year and establishment years are inconsistent. Lanini et al. (25) found weed content in the second year of an alfalfa stand was reduced 30 to 50% depending on alfalfa seeding rate. In contrast, weed content was greater in established stands of alfalfa-bromegrass (*Bromus inermis* Leyss.)(35) and timothy (*Phleum pratense* L.)(28) when seeded with a companion crop.

Alternative methods of weed control in the seeding year include using herbicides, clipping (mowing), or altering the seeding date. Herbicides effectively control weeds (17,19,20,43,59) and are used increasingly as a method of weed control in pure alfalfa seedings (55). Clipping requires accurate timing to reduce broadleaf competition and minimize damage to the forage (25,32). Grass weeds may not be controlled since their growing point is often below the height of cutting.

Altering seeding date is also an effective method for controlling weeds. In the North Central region, spring seedings have heavy weed pressure primarily from summer annuals such as common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and giant foxtail (*Setaria faberi* Hermm.). In late summer seedings, summer

annual weed pressure is lower and of less concern since frost will kill those weeds. Winter annual weed pressure, however, will be greater (15). Inadequate soil moisture in summer may result in stand failure (40). Spring seedings may be preferred to maximize forage and nutrient yields in the year of establishment.

Seeding forages with a companion crop also has potential disadvantages. Competition provided by the companion may reduce alfalfa yield and density in the seeding year (35,49,25,57,37,46) and alfalfa yield or persistence in subsequent years (3,35,38,41). Additionally, forage quality may be reduced at the initial harvest. Forage quality of companion crops decreases as the plants mature (2,8,22). Companion crops are generally lower in quality and their inclusion will reduce forage quality unless harvested at the flag leaf stage (2). Harvest at the early boot stage may provide forage that is 50% higher in feeding value than that harvested for grain (55). Producers must also have a use for the silage or grain and straw.

Seeding alfalfa with a companion crop also requires special considerations and changes in management practices. Reduced seeding rates of the companion are often recommended to decrease the competitiveness with alfalfa (9,55). Reduced rates of the companion may, however, result in greater weed density or content (25,52). Timing of harvest is also critical to the alfalfa density (establishment). As the companion crop matures, initial and subsequent alfalfa yields and plant density may be reduced (22,49). Often, it is recommended that the forage (companion, alfalfa, and weeds) be removed in the boot stage or at 60 to 70 days after seeding regardless of growth stage (1,55). Early removal may allow for an additional harvest in the seeding year and provide higher quality forage at the initial

harvest.

The most commonly used companion crop is oat (38,48,52). Oat has been the preferred companion crop due to reduced competitiveness compared to other companions (37,55). Familiarity and experience with the companion also contribute to crop selection (48). Plant morphology and maturity influence the competitiveness of the companion. Cultivars with a less dense canopy, shorter stature, or earlier maturity may be less competitive with the forage and more resistant to lodging (37,49,51). However, under severe weed pressure, greater weed growth may result (4). In addition, other companions may provide forage that is greater in nutritive value than that of oat (2,7,8).

An oat companion is generally recommended for use only in spring seedings of forages. Use of a companion crop in summer provides excessive competition at a time when soil moisture is limiting and may result in a failed stand (54). One exception is to seed alfalfa with oat in summer and then kill the oat with a herbicide before 15 cm of growth. This method had been shown to be effective and may reduce potential for erosion while providing acceptable stand establishment (1).

To date, most research using companion crops in forage establishment has focused on pure seeded alfalfa. There are, however, many producers that grow mixtures of forages such as alfalfa with a perennial forage grass. In the North Central region, up to 20% of alfalfa is seeded with a grass (50).

Options for weed control when seeding alfalfa with grasses are limited. Few, if any, herbicides are labeled in the U.S. for application to alfalfa-grass mixtures (10). Weed control by clipping or delayed seeding are viable options but may not maximize economic return in

the seeding year.

Using a companion crop at seeding may be an effective way to reduce weed competition in alfalfa-grass mixtures. Limited data are available to define how weeds, yields, forage quality, and plant density of alfalfa-perennial forage grass mixtures are affected by seeding with a companion crop. These studies were designed to determine how an oat companion crop influences the weeds, and subsequently forage yield, quality, and plant density in alfalfa seeded with smooth bromegrass, orchardgrass (*Dactylis glomerata* L.), timothy, or Kentucky bluegrass (*Poa pratensis* L.).

MATERIALS AND METHODS

Field experiments were established in the spring of 1993 and 1994 at the Michigan State University Agronomy Farm in East Lansing, Michigan on a Capac Loam soil (fine-loamy, mixed, mesic, Aeric Ochraqualfs). Two studies were seeded in each year. Sites were chosen on the basis of weed pressure. These sites will be referred to as low and high weed pressure. Prior to seeding, fertilizer was applied to fields based on soil test recommendations (Appendix Table A1). In established stands, annual additions of fertilizer were applied in spring based on soil tests (Appendix Table A2). Seedbed preparation included conventional tillage and cultipacking. Treatments were established in mid-May with a drill using 18 cm rows followed by press wheels in 3.3 by 6.1 m plots (Tables 1 and 2). In 1994, recently seeded plots were irrigated due to droughty conditions.

Each study was arranged as a randomized complete block with a split-plot arrangement. Whole plots consisted of seeding with or without an oat companion crop.

Sub-plots included alfalfa seeded alone, with weeds controlled (weed-free alfalfa) and without weed control (weedy alfalfa), and in binary mixtures with bromegrass, orchardgrass, timothy, or Kentucky bluegrass. Bromegrass, orchardgrass, and timothy were included because they are commonly used in mixtures with alfalfa. Kentucky bluegrass was included since it often invades established stands of alfalfa. Identical studies were established under low and high weed pressure in both years. Dominant weed species present at seeding were redroot pigweed and common lambsquarters (Table 3). Weed control in the weed-free alfalfa plots consisted of 1.12 kg ha^{-1} of 2,4-DB [4-(2,4-Dichlorophenoxy) butyric acid] applied postemergence, supplemented with handweeding. Hexazinone [3-cyclohexyl-6-(dimethyslamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione] was applied in spring in the first or second year after seeding to remove additional weed growth. Insecticides were applied as needed to control potato leafhopper and alfalfa weevil (*Hypera postica*).

Seeding rate for 'Newdak' oat was 54 kg ha^{-1}. 'Apollo Supreme' alfalfa was seeded in all plots at 17.9 kg ha^{-1}. 'Common' bromegrass, 'Common' orchardgrass, 'Climax' timothy, and 'Common' Kentucky bluegrass were seeded at 3.4, 1.1, 4.5, and 6.7 kg ha^{-1}, respectively. In studies with high weed pressure, combine screenings which were composed mostly of pigweed species were overseeded by hand at 3.1 kg ha^{-1} prior to cultipacking to ensure high numbers of summer annual weeds.

Weed, perennial forage grass, and alfalfa densities were measured on each plot six weeks after seeding (6WAS). Newly germinated weeds were also counted four weeks after the first harvest (4WAH). A 0.25 m^2 quadrat was randomly placed at two locations within each plot and densities were determined within that area. Alfalfa density was also counted

in the fall of the seeding year and one and two years after seeding. Two rows one meter in length were selected from within each plot. Plants were excavated and only live plants were counted. Dandelion (*Taraxacum officinale* Weber) density was counted in the fall two years after seeding on fields seeded in 1993. A 1 m^2 quadrat was placed within each plot and the number of live plants were counted.

Forage was harvested in the seeding year at 60-70 days after seeding when the oat was in late boot to soft dough stage and again approximately 60 days later. In the years following establishment, plots were harvested four times annually when alfalfa reached the bud to one-tenth bloom stage. A flail mower was used to harvest the forage . A 0.9 x 15.5 m strip was harvested from each plot and weighed. A 500 g subsample was taken by hand, weighed fresh, dried in a forced air dryer at 60°C for 72 h, and weighed again. Fresh and dry weights were used to calculate yields on a dry matter basis.

Weed, perennial grass, and alfalfa content (% of total dry matter) were determined by hand separations on samples taken from each plot at all harvests. A 0.5 m^2 area was selected within each plot and all plant material above 5 cm collected. Half the sample was used for hand separations and the remaining used for forage quality analysis. Once separated, components were dried and weighed.

Forage samples for quality analyses were dried immediately after sampling and ground to pass a 2 mm screen in a cyclone mill. Forage quality analyses included determinations of crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentration. Micro Kjeldahl procedures were used to determine total N which was multiplied by 6.25 to get crude protein concentration. Fiber concentration was determined

by using the sequential fiber analysis procedures of Van Soest et al. (56).

All data were analyzed using PROC ANOVA procedures of SAS (42). Data were combined across seeding years since any interactions present between seeding year and treatments did not alter the results or conclusions. Tables with data from two years after seeding contain data from 1993 seedings only. Comparisons were made between the weed-free alfalfa, weedy alfalfa, and binary mixtures seeded with oat and those seeded without oat. Differences were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Component Yields

Seeding year

Low weed pressure. At the first harvest in the seeding year, all forages seeded with oat were greater in total forage yield and lower in alfalfa yield than those seeded without oat (Table 4). Yields of forage grass were lower in mixtures seeded with oat than in those seeded without oat. Total weed yield was lower in the weedy alfalfa and in the mixtures when seeded with oat. When oat was seeded with the forages, the oat composed 95% or greater of the total yield. Data of Peters (41) confirms that, in the initial harvest, the oat component dominates alfalfa and weeds. Seeding with oat reduced weed content to 2% or less of total yields. Without oat, weed content was 65% in the mixtures and 70% in the weedy alfalfa.

At the second harvest, all forages seeded with oat were lower in forage yield than those seeded without oat (Table 4). Alfalfa yield was lower in the weed-free alfalfa when seeded with oat but not reduced in the weedy alfalfa or in the mixtures. Forage grass yield

in the mixtures and weed yield in the weedy alfalfa were lower when planted with oat. Reductions in alfalfa yields at subsequent harvests in the seeding year were noted by Lanini et al. (25). Weed yield was reduced in the mixtures by seeding with oat from 27% to 15%. Weed yield (content) in the weedy alfalfa was reduced from 42% to 18%. In both harvests, oat was effective at reducing weed content. Simmons et al. (49) found that barley (*Hordeum vulgare* L.) and oat companion crops greatly suppressed weed growth in the establishment year. Weed yield in forages established with oat increased from the first to second harvest. Although alfalfa yield in the mixtures was greater in plots established with oat, forage yield was reduced due to the reductions in forage grass and weeds. In the weedy alfalfa, reductions in forage yield were attributed to lower weed yield. Reduced yield of the weed-free alfalfa may be due primarily to previous competition with oat but may also have been reduced due to the 2,4-DB which showed injury after application. Second harvest forage yields were reduced by residual effects of oats, but large increases in forage yields at first harvest resulted in annual forage yields which were greater in all forage types seeded with the oat companion.

High weed pressure. At the first harvest, all forages seeded with oat were greater in total forage yields than those seeded without oat (Table 5). Alfalfa yield was reduced by seeding with oat in the weed-free alfalfa and weedy alfalfa. Yield of alfalfa was not reduced in the mixtures by seeding with oat. Forage grass yield was also reduced in mixtures seeded with oat. Seeding with oat reduced weed yields in the weedy alfalfa and the mixtures. In plots seeded with oat, the oat comprised 94% or greater of the total yield. Weed yields did not exceed 5% of the total yields. Without oat, weed content in the mixtures was 91% and in the

weedy alfalfa was 93%.

At the second harvest, seeding with oat reduced forage yields in the weed-free alfalfa, weedy alfalfa, and in the mixtures (Table 5). Reduced forage yields in the mixtures and weedy alfalfa were attributable mostly to a reduction in weed yields, although, forage grass yields were also reduced. Seeding with oats reduced alfalfa yields in the weed-free alfalfa but not in the weedy alfalfa or the mixtures. Forage grass yields in the mixtures were reduced by seeding with oat. Total weed yields in the weedy alfalfa and in the mixtures were also reduced when seeded with oat. Weed yields comprised 13% of the mixtures and 11% of the weedy alfalfa when seeded with oat. Seeded without oat, weed yield comprised 39% of the mixtures and 34% of the weedy alfalfa. The large increase in forage yields due to the oat at the first harvest overcame the reduction in yields at the second harvest resulting in greater annual yield for all forages seeded with oat.

One year after seeding

Low weed pressure. In the year after seeding, there were no residual effects of companion crop on forage yield in any individual harvest or annually (Table 6). With one exception, alfalfa yields in all harvests also were not affected by seeding with the oat companion. Seeding with oat reduced forage grass yield in the first and third harvests but not in the second and fourth harvests. At all harvests, total weed yields were similar when mixtures or the weedy alfalfa were initially seeded with or without oat. Weed content at any harvest did not exceed 3% of the total forage. Residual effects of seeding the forage with an oat companion crop appeared primarily at the first harvest in the year following establishment.

High weed pressure. Seeding with oat had no residual effects on forage, alfalfa, or weed yields in any individual harvest or for the annual totals (Table 7). Weed yields did not exceed 4% of the total yields at any harvest. Forage grass yield, however, was reduced by seeding with oat at the first and second harvests. Grass yields in the third and fourth harvests were not affected by initially seeding with the oat companion crop. Total yields of weeds were greatest at the first harvest but accounted for no more than 3% of the total yield.

Two years after seeding

Low weed pressure. Establishing with oat had no effect on forage, alfalfa, or perennial grass yield in any individual harvest or for annual totals (Table 8). Weed yields were different in only one instance. Mixtures seeded with oat were lower in weed yield than those seeded without oat at the first harvest. The reduction in weed yield was 31 kg ha^{-1} which is negligible considering the total forage yield involved. In contrast, data from Canada (35) showed weed yields in the second through fourth years of an alfalfa-bromegrass stand were increased as a result of seeding with barley. Weed content did not exceed 5% at any given harvest.

High weed pressure. Seeding with oat had no effect on forage, alfalfa, grass, or weed yields two years after seeding (Table 9). The weed yield was less than 7% of the total at any given harvest. Effects of companion crop may be seen in spring in the first year after seeding but are often not found beyond that time.

Forage Quality

Low weed pressure

At the first harvest in the seeding year, planting with oat reduced CP and increased ADF and NDF in the weed-free alfalfa, weedy alfalfa, and the mixtures (Table 10). Therefore, seeding with an oat companion reduced forage quality. A reduction in forage quality at the first harvest is common since oat comprises a majority of the forage and may be lower in quality than alfalfa. When plants were harvested at the dough stage of the oat, the alfalfa was greater in CP than was oat (41). At the second harvest, all forages seeded with oat were higher in CP and lower in ADF and NDF and thus forage quality was greater than in forages initially seeded without oat. Increased forage quality may be attributed to alfalfa maturity and weed content. In all plots, alfalfa seeded with oat was less mature at the first harvest and subsequently less mature at the second harvest (visual observations). As alfalfa matures, quality declines (18). Since alfalfa in the forage seeded with oat was less mature, the forage quality was higher. Alfalfa maturity probably had the greatest effect on the difference in forage quality at the second harvest since it comprised the largest part or all of the forages. Weed content was also lower in mixtures and the weedy alfalfa seeded with oat.

High weed pressure

Seeding with oat reduced forage quality in most but not all cases at the first harvest in the seeding year. Planting with oat reduced CP in the weed-free alfalfa, weedy alfalfa, and the mixtures (Table 11). Seeding with oat increased ADF in the weed-free alfalfa plots but had no effect in the weedy alfalfa or mixtures. Weedy alfalfa and mixtures contained

perennial grasses and/or weeds which can be greater in ADF than alfalfa. The weed and/or grass content increased ADF in the weedy alfalfa and mixtures to levels similar to forages seeded with oat. Neutral detergent fiber was higher for all forages when seeded with oat. Crude protein and ADF were at times similar between forages seeded with or without oat. In these cases, the forages with weeds (seeded without oat) had similar chemical composition to that of the forages seeded with oats. However, NDF was reduced by the oat companion in all forages. A clear reduction in NDF may be attributed to a greater hemicellulose level in oat than in weeds. Marten and Andersen (29) found that grassy weeds and oat contained greater levels of hemicellulose than the forbs which included redroot pigweed and common lambsquarters. The result is reduced quality in forages seeded with oat even though the forages seeded without oat were composed of over 91% weeds.

At the second harvest, all forages seeded with oat were higher in CP and lower in ADF and NDF (Table 11). Thus, forage quality was greater in forages initially seeded with oat. As stated previously, the difference in forage quality may be attributed to alfalfa maturity and weed content. Alfalfa seeded with oat was less mature at both harvests and consequently higher in quality. Alfalfa maturity probably influenced forage quality more than did the reduced weed content, although, both contributed to an increase in forage quality in plots established with oat.

Plant Density

Low weed pressure

At 6WAS, seeding with an oat companion reduced alfalfa plant density in the weed-free alfalfa, weedy alfalfa, and mixtures (Table 12). Perennial forage grass density in the mixtures was also reduced by seeding with oat. Competition provided by the oat reduced alfalfa and grass density. Simmons et al. (49) showed increased alfalfa mortality during establishment when seeded with oat or barley. Total weed density, however, was not affected by the oat in the weedy alfalfa or in the mixtures. Effects of companion crops on weed density are less consistent than effects on alfalfa or grass density. The forage plants are seeded at the same time as the oat and often germination is relatively uniform. Therefore, competition among plant species occurs throughout the growth cycle. The weed seed bank provides an ample supply of seeds that may germinate opportunistically throughout the forage growth cycle. The uneven germination of weeds through this cycle resulted in a large range of weed maturity from seedling emergence to full maturity at the time when density was determined.

At 4WAH, seeding with oat had no residual effect on weed density in the weedy alfalfa or in the mixtures. A reduction in weed density as a result of initially seeding with oat was not expected since weeds counted at 4WAH were those that germinated after the first harvest and no companion was present to provide competition.

The oat companion crop had no effect of alfalfa plant density measured in fall of the seeding year in the weed-free alfalfa, weedy alfalfa, or mixtures (Table 13). This was consistent for all three fall measurements. Alfalfa densities in the year after establishment

were also similar, whether seeded with or without oat at 18 kg ha^{-1} , in a study by Lanini et al. (25). By the late fall measurement in the seeding year, the differences seen at 6WAS had diminished. Alfalfa density in plots seeded without oat declined due to seedling mortality. Density apparently increased from 6WAS to the late fall period in plots seeded with oat. Additional alfalfa seed may have germinated after the first count at 6WAS resulting in the increase in density. Alfalfa plant density decreased in all plots, after the initial fall measurement, as the stand aged.

Oat had no effect on dandelion density, two years after seeding, in the weedy alfalfa or in the mixtures. In the weedy alfalfa, the were 6.3 and 8.3 dandelions m^2 when seeded without or with oat. Dandelion density was 4.1 and 6.1 plants m^2 in mixtures seeded without and with oat. In both cases, these differences were not significant. In established stands, effects of a companion crop are not commonly seen on weed density or content. Although, Moyer et al. (35) found that weed yields in established stands (primarily dandelions) were greater as a result of companion crop.

High weed pressure

At 6WAS, seeding with oat increased alfalfa plant density in the weedy alfalfa but did not affect the density in the weed-free alfalfa or in the mixtures (Table 14). Perennial forage grass density was not reduced by seeding with oat. A reduction in alfalfa and grass density may be expected as occurred in the low weed pressure experiment. Weed competition, however, may have been of equal or greater intensity than that of the oat resulting in similar or lower forage plant densities. Weed density was lower when seeded with oats in the weedy alfalfa and in the mixtures. At 4WAH, seeding initially with oat did

not affect weed density in the weedy alfalfa or mixtures.

With one exception, the oat companion crop had no effect on alfalfa plant density in the weed-free alfalfa, weedy alfalfa, or mixtures at all three fall measurements (Table 15). The exception was in the fall of the seeding year where the weedy alfalfa initially seeded with oats had higher alfalfa plant density than that seeded without oat. This also occurred at 6WAS. Again, it may not be an effect of oat increasing alfalfa density but weed competition reducing alfalfa density more than that of the oat. Only in weed-free alfalfa seeded with oats did alfalfa density appear greater at the fall timing than at 6WAS. Alfalfa plant density for all forages, after the first fall, decreased as the stand aged.

Oat had no effect on dandelion density, two years after seeding, in the weedy alfalfa or in the mixtures. The weedy alfalfa seeded without oat had 12.5 dandelions m^2 while seeding with oat resulted in 9.5 plants m^2 . In mixtures, dandelion density was 6.6 and 7.3 plants m^2 when seeded without and with oat. These differences in density were not significant.

SUMMARY

Yield, forage quality, and plant density response to seeding with oat was often similar in weed-free alfalfa, the weedy alfalfa, and in the binary mixtures regardless of weed pressure at seeding. Inconsistencies in response between high and low weed pressure experiments occurred for seeding year measurements on plant density and forage quality. Inconsistencies among the forages in response to the oat companion occurred most often during initial growth.

Seeding with oat increased forage yields in the first harvest, lowered yields in the second harvest, and increased annual yields in the seeding year. Alfalfa yields were often reduced by oat at the first harvest but not consistently affected in the second harvest of the seeding year. Perennial forage grass and weed yields were reduced at both harvests as a result of the oat companion. Total and component yields one and two years after seeding were seldom affected by the initial oat companion. If yield was reduced, as a residual effect of oat, it often occurred in the early harvests in the year following seeding.

Seeding with oat often reduced forage quality at the initial harvest in the seeding year. In the experiment with high weed pressure, CP and ADF levels were at times similar among forages seeded with and without oat. As such, seeding with oat was not always disadvantageous to forage quality. At the second harvest, forages initially seeded with oat were higher in quality than those seeded alone. In the experiment with low weed pressure, alfalfa and grass density in the initial growth were reduced by the oat companion. Weed densities and subsequent alfalfa densities were not altered as a result of seeding with oat. Under high weed pressure, differences in plant densities due to oat during the initial growth were inconsistent. In most cases, oat did not affect alfalfa or grass density. Weed density tended to be lower in forages seeded with oat. After the initial growth weed and alfalfa density were usually not affected by seeding with the oat companion.

In general, the response of the binary mixtures to the oat companion was similar to that of the weed-free alfalfa or weedy alfalfa. Weed pressure appeared to affect the consistency of response to the companion crop. Forages seeded under high weed pressure were more variable in response to the oat companion in forage quality and plant density

measurements. Seeding with oat significantly reduced weed content at both harvests in the seeding year while the effects of oat on forage quality and yield varied by specific harvest. Few residual effects of seeding with oat on yields or plant densities were seen one or two years after seeding. Producers considering an oat companion for seeding with alfalfa-perennial grass mixtures or alfalfa alone must take into account the oats effect on forage yield and quality, the weed pressure, and the potential use of the forage.

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Table 1. Dates of field operations for 1993 seedings.

Operation	Weed pressure	
	Low	High
	---------- 1993 ----------	
Seeded	13 May	15 May
Herbicide applied	12 June	12 June
Plant density measured	29 June	1 July
Insecticide applied	21 July	21 July
First harvest	27 July	28 July
Insecticide applied	18 August	18 August
Weed density measured	24 August	25 August
Second harvest	30 September	1 October
Alfalfa density measured	4 November	16 November
	---------- 1994 ----------	
Fertilizer applied	11 April	11 April
First harvest	3 June	7 June
Second harvest	13 July	14 July
Insecticide applied	8 August	8 August
Third harvest	30 August	30 August
Fourth harvest	13 October	13 October
Alfalfa density measured	8 November	10 November
	---------- 1995 ----------	
Herbicide applied	30 March	30 March
Fertilizer applied	1 April	1 April
First harvest	31 May	31 May
Second harvest	11 July	11 July
Insecticide applied	25 July	25 July
Third harvest	18 August	18 August
Fourth harvest	10 October	10 October
Alfalfa density measured	23 October	23 October
Dandelion density measured	25 October	25 October

Table 2. Dates of field operations for 1994 seedings.

Operation	Weed pressure	
	Low	High
	---------- 1994 ----------	
Seeded	10 May	13 May
Irrigation	19 May	19 May
Herbicide applied	9 June	9 June
Irrigation	10 June	10 June
Plant density measured	22 June	23 June
Insecticide applied	20 June	25 June
First harvest	20 July	22 July
Weed density measured	16 August	18 August
Second harvest	29 September	29 September
Alfalfa density measured	10 November	11 November
	---------- 1995 ----------	
Herbicide applied	30 March	30 March
Fertilizer applied	1 April	1 April
First harvest	30 May	30 May
Insecticide applied	3 July	3 July
Second harvest	11 July	11 July
Insecticide applied	25 July	25 July
Third harvest	16 August	16 August
Fourth harvest	10 October	10 October
Alfalfa density measured	23 October	23 October

Table 3. Weed density in the year of seeding.

		Low weed pressure		High weed pressure	
Timing	Weed	1993	1994	1993	1994
		---------- plants / m^2 ----------			
6WAS[a]	Broadleaves[b]	153[c]	28	257[d]	146[d]
	Grasses	0	3	2	33
4WAH	Broadleaves	42	26	49	32
	Grasses	2	1	8	8

[a] 6WAS, 6 weeks after seeding; 4WAH, 4 weeks after first harvest.
[b] Dominant weeds: common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.)
[c] Dominant weed: common lambsquarters.
[d] Dominant weed: redroot pigweed.

Table 4. Total and component yields in the year of seeding (average of 1993 and 1994 seedings) with low weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Annual total
			---------- kg ha^{-1} ----------		
Total forage	mixtures	no	3396	2780	6176
		with	6595	2235*	8830*
	weedy alfalfa	no	3451	2688	6139
		with	6357*	2167*	8524*
	weed-free	no	1907	2693	4600
		with	6490*	2130*	8620*
Alfalfa	mixtures	no	903	1533	-
		with	116*	1718*	-
	weedy alfalfa	no	1073	1558	-
		with	104*	1769	-
	weed-free	no	1907	2693	-
		with	175*	2130*	-
Forage grass	mixtures	no	284	446	-
		with	6*	215*	-
Weeds	mixtures	no	2209	737	-
		with	126*	336*	-
	weedy alfalfa	no	2378	1130	-
		with	196*	398*	-

* Statistical difference ($P<0.05$) between levels of oat companion.

Table 5. Total and component yields in the year of seeding (average of 1993 and 1994 seedings) with high weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Annual total
			kg ha^{-1}		
Total forage	mixtures	no	3334	2609	5943
		with	6216*	1999*	8215*
	weedy alfalfa	no	3333	2434	5767
		with	6407*	1917*	8324*
	weed-free	no	499	2413	2912
		with	7081*	1776*	8857*
Alfalfa	mixtures	no	255	1386	-
		with	75	1699	-
	weedy alfalfa	no	238	1600	-
		with	68*	1700	-
	weed-free	no	499	2413	-
		with	96*	1776*	-
Forage grass	mixtures	no	49	193	-
		with	14*	44*	-
Weeds	mixtures	no	3030	1030	-
		with	290*	256*	-
	weedy alfalfa	no	3095	834	-
		with	237*	217*	-

* Statistically different ($P<0.05$) between levels of oat companion.

Table 6. Total and component yields one year after seeding (average of 1993 and 1994 seedings) with low weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
			kg ha^{-1}				
Total forage	mixtures	no	5196	2966	2440	1431	12033
		with	5089	3115	2584	1452	12240
	weedy alfalfa	no	4566	3273	2568	1547	11954
		with	4670	3134	2509	1437	11750
	weed-free	no	4701	3418	2647	1519	12285
		with	4378	3342	2583	1526	11829
Alfalfa	mixtures	no	3567	2600	2175	1281	-
		with	4022*	2839	2402	1344	-
	weedy alfalfa	no	4526	3205	2540	1540	-
		with	4581	3061	2470	1425	-
	weed-free	no	4701	3418	2647	1519	-
		with	4378	3342	2583	1526	-
Forage grass	mixtures	no	1556	360	247	142	-
		with	1017*	255	146*	104	-
Weeds	mixtures	no	73	6	18	8	-
		with	50	21	36	4	-
	weedy alfalfa	no	40	68	27	7	-
		with	89	73	39	12	-

* Statistically different ($P<0.05$) between levels of oat companion.

Table 7. Total and component yields one year after seeding (average of 1993 and 1994 seedings) with high weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
			kg ha^{-1}				
Total forage	mixtures	no	5147	2971	2606	1680	12404
		with	4938	3049	2598	1663	12248
	weedy alfalfa	no	4634	3020	2501	1642	11797
		with	4770	3171	2724	1751	12416
	weed-free	no	4521	3118	2802	1707	12148
		with	4428	3243	2616	1637	11924
Alfalfa	mixtures	no	4038	2651	2408	1568	-
		with	4188	2803	2444	1570	-
	weedy alfalfa	no	4479	2967	2441	1628	-
		with	4620	3147	2710	1748	-
	weed-free	no	4521	3118	2802	1707	-
		with	4428	3243	2616	1637	-
Forage grass	mixtures	no	1025	267	176	104	-
		with	686*	222*	122	82	-
Weeds	mixtures	no	84	10	22	8	-
		with	64	24	32	11	-
	weedy alfalfa	no	155	53	60	14	-
		with	150	24	14	3	-

* Statistically different ($P<0.05$) between levels of oat companion.

Table 8. Total and component yields two years after seeding year (1993 seeding only) with low weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
			kg ha^{-1}				
Total forage	mixtures	no	4138	2628	1433	859	9058
		with	4060	2525	1424	833	8842
	weedy alfalfa	no	3894	3015	1707	928	9544
		with	3733	2623	1556	961	8873
	weed-free	no	3390	3431	2056	1090	9967
		with	3532	3113	1921	1003	9569
Alfalfa	mixtures	no	3476	2316	1283	693	-
		with	3502	2289	1246	690	-
	weedy alfalfa	no	3775	2963	1680	925	-
		with	3572	2559	1495	941	-
	weed-free	no	3390	3431	2056	1090	-
		with	3532	3113	1921	1003	-
Forage grass	mixtures	no	577	253	144	163	-
		with	504	220	160	138	-
Weeds	mixtures	no	85	59	6	3	-
		with	54*	17	18	5	-
	weedy alfalfa	no	119	53	27	1	-
		with	161	64	61	20	-

* Statistically different ($P<0.05$) between levels of oat companion.

Table 9. Total and component yields two years after seeding year (1993 seeding only) with high weed pressure.

Component	Forage	Oat	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
			kg ha^{-1}				
Total forage	mixtures	no	4115	2510	2004	1272	9901
		with	4135	2557	2065	1363	10120
	weedy alfalfa	no	3786	2538	2042	1290	9656
		with	3948	2500	2092	1384	9924
	weed-free	no	3345	2777	2258	1413	9793
		with	3585	2536	2037	1289	9447
Alfalfa	mixtures	no	3348	2233	1796	1089	-
		with	3504	2198	1852	1155	-
	weedy alfalfa	no	3539	2473	1953	1259	-
		with	3817	2399	2047	1360	-
	weed-free	no	3585	2777	2258	1413	-
		with	3345	2536	2037	1289	-
Forage grass	mixtures	no	683	242	196	169	-
		with	568	281	203	193	-
Weeds	mixtures	no	84	35	12	14	-
		with	63	78	10	15	-
	weedy alfalfa	no	247	65	89	31	-
		with	131	101	45	24	-

* Statistically different ($P<0.05$) between levels of oat companion.

Table 10. Forage quality characteristics in the seeding year (average of 1993 and 1994 seedings) with low weed pressure.

Characteristic	Forage	Oat	Harvest 1	Harvest 2
			---------- g kg^{-1} ----------	
CP[a]	mixtures	no	139	183
		with	92*	210*
	weedy alfalfa	no	145	182
		with	95*	218*
	weed-free	no	175	183
		with	93*	211*
ADF	mixtures	no	281	314
		with	348*	288*
	mixtures	no	272	320
		with	341*	299*
	weedy alfalfa	no	244	344
		with	346*	299*
NDF	mixtures	no	453	476
		with	586*	415*
	weedy alfalfa	no	436	466
		with	579*	418*
	weed-free	no	353	469
		with	587*	417*

[a] CP, crude protein concentration; ADF, acid detergent fiber concentration; NDF, neutral detergent fiber concentration.

* Statistically different ($P<0.05$) between levels of oat companion.

Table 11. Forage quality characteristics in the seeding year (average of 1993 and 1994 seedings) with high weed pressure.

Characteristic	Forage	Oat	Harvest 1	Harvest 2
			---------- g kg^{-1} ----------	
CP[a]	mixtures	no	99	181
		with	82*	289*
	weedy alfalfa	no	96	166
		with	81*	236*
	weed-free	no	147	209
		with	85*	232*
ADF	mixtures	no	318	304
		with	334	276*
	weedy alfalfa	no	310	310
		with	330	262*
	weed-free	no	174	308
		with	329*	272*
NDF	mixtures	no	516	497
		with	570*	404*
	weedy alfalfa	no	505	474
		with	566*	388*
	weed-free	no	283	428
		with	573*	385*

[a] CP, crude protein concentration; ADF, acid detergent fiber concentration; NDF, neutral detergent fiber concentration.

* Statistically different ($P<0.05$) between levels of oat companion.

Table 12. Plant density in the seeding year (average of 1993 and 1994 seedings) at sites with low weed pressure.

Component	Forage	Oat	6WAS*	4WAH
			---------- plants / m^2 ----------	
Alfalfa	mixtures	no	267	-
		with	162*	-
	weedy alfalfa	no	298	-
		with	144*	-
	weed-free	no	336	-
		with	148*	-
Forage grass	mixtures	no	101	-
		with	44*	-
Weeds	mixtures	no	97	29
		with	95	39
	weedy alfalfa	no	101	32
		with	83	39

* 6WAS, 6 weeks after seeding; 4WAH, 4 weeks after first harvest.
* Statistically different ($P<0.05$) between levels of oat companion.

Table 13. Alfalfa plant density in fall with low weed pressure.

Forage	Oat	Years after seeding		
		0	1	2
		plants / m^2		
Mixtures	no	224	136	108
	with	251	142	106
Weedy alfalfa	no	222	169	148
	with	222	156	101
Weed-free	no	210	178	106
	with	222	171	102

* Statistically different ($P<0.05$) between levels of oat companion.

Table 14. Plant density in the seeding year (average of 1993 and 1994 seedings) with high weed pressure.

Component	Forage	Oat	6WAS[a]	4WAH
			---------- plants / m^2 ----------	
Alfalfa	mixtures	no	255	-
		with	262	-
	weedy alfalfa	no	231	-
		with	276*	-
	weed-free	no	300	-
		with	259	-
Forage grass	mixtures	no	66	-
		with	56	-
Weeds	mixtures	no	210	43
		with	182*	48
	weedy alfalfa	no	253	46
		with	185*	52

[a] 6WAS, 6 weeks after seeding; 4WAH, 4 weeks after first harvest.
* Statistically different ($P<0.05$) between levels of oat companion.

Table 15. Alfalfa plant density in fall with high weed pressure.

		Years after seeding		
Forage	Oat	0	1	2
		plants / m^2		
Mixtures	no	251	160	124
	with	262	174	117
Weedy alfalfa	no	229	163	123
	with	274*	178	134
Weed-free	no	280	171	129
	with	276	174	137

* Statistically different ($P<0.05$) between levels of oat companion.

CHAPTER TWO

Weed Invasion in New Stands of Alfalfa Seeded with Perennial Forage Grasses.

ABSTRACT

Weed invasion in alfalfa may be reduced by seeding with a perennial forage grass. This study documented the effects of perennial forage grasses on weed and component yields, plant densities, and forage quality. Alfalfa was seeded alone (weedy alfalfa) and in binary mixtures with bromegrass, orchardgrass, timothy, or Kentucky bluegrass. All forages were established with and without an oat companion crop in sites with low and high weed pressure in 1993 and 1994. Measurements were taken during the first three years of the stand. Seeding grasses with alfalfa had no consistent effect on total or component yields or plant densities in the seeding year. Grasses had little effect on forage quality in the seeding year. Crude protein was not altered and, in a few cases, fiber content was changed by the grasses. Most differences in fiber content occurred at the second harvest. There were a few instances in which alfalfa-grass mixtures were lower in weed density or content than that of the weedy alfalfa. After the first harvest in the second year, bromegrass and timothy contributed little to total yields. In the established stands, orchardgrass and Kentucky bluegrass often reduced alfalfa yields and occasionally reduced alfalfa plant density. However, total forage yields were often greater in the mixtures than the weedy alfalfa at the spring harvest and similar at subsequent harvests. Seeding alfalfa with Kentucky bluegrass resulted in reduced forage yields in the third year of the stand. Orchardgrass or Kentucky bluegrass with alfalfa reduced weed content at one harvest in the second year and more consistently in the third year of the stand. In the third year, the maximum weed content of

the weedy alfalfa did not exceed 5% of the total dry matter and maximum reduction in weed yield by any forage grass was 182 kg ha^{-1}. Dandelion density was also reduced in the third year of the stand by these two grasses. Seeding alfalfa with forage grasses can be effective at reducing weed invasion. This effect likely will become more evident as the stand ages and is dependent upon grass species and harvest management. Orchardgrass and Kentucky bluegrass were able to persist with four annual harvests and subsequently reduced weed invasion. Therefore, stands must be managed appropriately and grass maintained as a large component of the forage for effective reduction in weed invasion. The effects of the forage grass on quality and yield must also be considered prior to seeding.

INTRODUCTION

Seeding perennial forage grasses with alfalfa (*Medicago sativa* L.) may help to reduce weed invasion. Weed competition can reduce alfalfa yield in seeding year and established stands (7,11,17,20,25,26,33). Total forage yield may not be affected (18) but the weeds may compose a large proportion of the dry matter (17,30).

Forage quality may or may not be reduced by the presence of weeds (4,5,6,8,10,12,13,15,17,19,27). The degree to which forage quality is affected is dependent on the weed species, maturity, and proportion in the forage. Weeds also may be less palatable (13), toxic to animals (2), and slow the drying rate of the forage (4). Additionally, weeds may provide seeds or vegetative propagules that invade subsequent crops (14).

Weeds may be controlled or suppressed by tillage, herbicides, mowing, altering the seeding date, or using companion crops. An annual or perennial crop may be seeded with the forage to suppress weed growth. Annual companion crops, primarily small grains, are widely used in spring seedings of alfalfa to reduce soil erosion and suppress weeds. Perennial forage grasses may also reduce weed invasion in alfalfa. A reduction in weed invasion or enhanced weed control has been given as a potential advantage of including a forage grass (3) but little data is available to support this statement. In one study, seeding annual ryegrass (*Lolium spp.*) or a fescue (*Festuca spp.*) into established alfalfa showed a

trend towards reducing weed competition (1). Willard (34) and Sollenberger et al. (29) also found that growing orchardgrass (*Dactylis glomerata* L.) with alfalfa was effective at keeping weeds out of the stand. As alfalfa stands age, plant density decreases (16) thereby allowing favorable conditions for weed growth. As alfalfa-grass stands age, the alfalfa plant density decreases and grasses become dominant (28,31) which may reduce weed invasion.

Including grass in mixture with alfalfa may reduce forage quality (22). The extent to which forage quality is reduced is dependent on the specific harvest, grass species, and proportion of grass in the forage. Earlier harvest of mixtures may be required to maintain high forage quality.

The potential for interseeded perennial forage grasses to reduce weed invasion has been mentioned in numerous articles as a potential advantage. Data to support this statement, however, are not abundant. Objectives of this research were to determine how interseeding smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass, timothy (*Phleum pratense* L.), or Kentucky bluegrass (*Poa pratensis* L.) with alfalfa affect weed and component yields, plant densities, and forage quality.

MATERIALS AND METHODS

Field experiments were established in the spring of 1993 and 1994 at the Michigan State University Agronomy Farm in East Lansing, Michigan on a Capac Loam soil (fine-loamy, mixed, mesic, Aeric Ochraqualfs). Two studies were seeded in each year. Sites were chosen on the basis of weed pressure. These sites will be referred to as low and high weed pressure. Prior to seeding, fertilizer was applied to fields based on soil test recommendations

(Appendix Table A1). In established stands, annual additions of fertilizer were applied in spring based on soil tests (Appendix Table A2). Seedbed preparation included conventional tillage and cultipacking. Treatments were established in mid-May with a drill using 18 cm rows followed by press wheels in 3.3 by 6.1 m plots (See Tables 1 and 2 in Chapter 1). In 1994, newly seeded plots were irrigated due to droughty conditions.

Each study was arranged as a randomized complete block with a split-plot arrangement. The whole plot consisted of seeding with or without an oat companion crop. Sub-plots included alfalfa seeded alone without weed control (weedy alfalfa), and in binary mixtures with bromegrass, orchardgrass, timothy, or Kentucky bluegrass. Bromegrass, orchardgrass, and timothy were included because they are commonly used in mixtures with alfalfa. Kentucky bluegrass was included since it often invades established stands of alfalfa. Identical studies were established under low and high weed pressure in both years. Dominant weed species present at seeding were redroot pigweed and common lambsquarters (See Table 3 in Chapter 1). Insecticides were applied as needed to control potato leafhopper (*Empoasca fabae*) and alfalfa weevil (*Hypera postica*).

Seeding rate for 'Newdak' oat was 54 kg ha^{-1}. 'Apollo Supreme' alfalfa was seeded in all plots at 17.9 kg ha^{-1}. 'Common' bromegrass, 'Common' orchardgrass, 'Climax' timothy, and 'Common' Kentucky bluegrass were seeded at 3.4, 1.1, 4.5, and 6.7 kg ha^{-1}, respectively. In studies with high weed pressure, combine screenings which were composed mostly of pigweed species were overseeded by hand at 3.1 kg ha^{-1} prior to cultipacking to ensure high numbers of summer annual weeds.

Weed, perennial forage grass, and alfalfa densities were measured on each plot six

weeks after seeding (6WAS). Newly germinated weeds were also counted four weeks after the first harvest (4WAH). A 0.25 m^2 quadrat was randomly placed at two locations within each plot and densities determined within that area. Alfalfa plants were also counted in the fall of the seeding year and one and two years after seeding. Two rows one meter in length were selected from within each plot. Plants were excavated and only live plants were counted. Dandelion (*Taraxacum officinale* Weber) density was determined in the fall two years after seeding on fields seeded in 1993. A 1 m^2 quadrat was placed within each plot and the number of live plants were counted.

Forage was harvested in the seeding year at 60-70 days after seeding when the oat was in late boot to soft dough stage and again approximately 60 days later. In the years following establishment, plots were harvested four times annually when alfalfa reached the bud to one-tenth bloom stage. A 0.9 x 15.5 m strip was harvested from each plot with a flail mower and weighed. A 500 g subsample was taken by hand, weighed fresh, and after drying in a forced air dryer at 60°C for 72 h. Fresh and dry weights were used to calculate yields on a dry matter basis.

Weed, perennial grass, and alfalfa content (% of total dry matter) were determined by hand separations on samples taken from each plot at all harvests. A 0.5 m^2 area was selected within each plot and all plant material above 5 cm collected. Half the sample was used for hand separations and the remaining used for forage quality analysis. Once separated, components were dried and weighed.

Forage samples used for quality analyses were dried immediately after sampling and ground to pass a 2 mm screen in a cyclone mill. Forage quality analyses included

determinations of crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentration. Micro Kjeldahl procedures were used to determine total N which was multiplied by 6.25 to get crude protein concentration. Fiber concentration was determined by using the sequential fiber analysis procedures of Van Soest et al. (32).

All data were analyzed using PROC ANOVA procedures of SAS (24) and the means separated using Duncans multiple range test. Differences were considered significant at $P<0.05$. Data were combined across seeding years or whole plots where interactions were not present or when combining did not alter the results or conclusions. All tables with data from two years after seeding contain information from the 1993 seedings only. Percentages of each component are included in Appendix tables A3 through A8 and are given in the same format as the component yields.

RESULTS AND DISCUSSION

Component Yields

Seeding year

Low weed pressure. At the first harvest in the seeding year, including a forage grass had no effect on total, alfalfa, or weed yields (content) in plots seeded with or without an oat companion crop (Table 1). Yield of bromegrass was greater than that of the other three grasses when seeded without oat. Grass yields seeded with oat were similar but negligible.

At the second harvest, total and alfalfa yields were not influenced by interseeding grass. In plots established without oat, weed yields were lower in plots seeded with bromegrass, orchardgrass, and timothy than in the weedy alfalfa or alfalfa-Kentucky

bluegrass. When these forages were seeded with oat, weed yields were similar between the alfalfa and the mixtures. Weed yields were, however, lower in the mixture with orchardgrass than in the one with timothy. Among the grasses, Kentucky bluegrass was lower yielding than the others in plots established without oat and lower yielding than orchardgrass in plots seeded with oat.

Individual harvest and total yields in the seeding year were similar among all forages. Seeding the grasses with alfalfa had no influence on forage yields. The maximum contribution by grass at the first harvest was by bromegrass, in mixtures seeded without oat, which comprised 20% of the total forage. This appears to be an exception since orchardgrass is usually more competitive than bromegrass. Weed yields comprised up to 74% of the total forage in plots seeded without oat and 3% of the forage in plots seeded with oat. The grasses did not influence weed yield at the first harvest. Alfalfa yields were also similar among forages at the first harvest. Oat and weed competition during the initial growth were extensive enough in all plots to prevent any differences among forages. Second harvest grass growth was generally greater than at first harvest and more consistent among bromegrass, orchardgrass, and timothy. Weed yields in the weedy alfalfa plots, initially seeded without oat, comprised 40% of the total forage. The increase in the three grasses, in plots initially seeded without oat, resulted in reduced weed content. In plots initially seeded with oat, weed yields comprised up to 21% of the forage.

High weed pressure. With one exception, including grass with alfalfa did not affect total, alfalfa, grass, or weed yields at the first harvest of the seeding year (Table 2). Weed yields accounted for up to 92 and 5% of total yields in forages seeded without and with oat. Seeded

without oat, bromegrass yields were greater than orchardgrass or Kentucky bluegrass yields.

At the second harvest, total and alfalfa yields were similar among forages in plots seeded with oat. Without oat, total yields were greater in alfalfa-orchardgrass than the weedy alfalfa while alfalfa yields were greater in the weedy alfalfa than in alfalfa-Kentucky bluegrass. Kentucky bluegrass yields were lower than that of the other grasses. Weed yields were not influenced by seeding with a forage grass. In forage initially established with or without oat, weeds comprised up to 14 and 47% of the total yield.

Seeding alfalfa with forage grasses had no effect on total annual yields although the addition of orchardgrass did provide enough added growth to increase total yields over the weedy alfalfa at the second harvest. Kentucky bluegrass contributions to yield were negligible at either harvest. Forage grasses did not provide enough growth at either harvest to suppress weeds.

One year after seeding

Low weed pressure. At the first harvest in the year after seeding, total yields in mixtures containing bromegrass, orchardgrass, and timothy were greater and alfalfa yields lower than that of the weedy alfalfa or alfalfa-Kentucky bluegrass (Table 3). Weed yields in the mixtures were similar to that of the weedy alfalfa. Although, the alfalfa-bromegrass was higher in weed yield than the other mixtures. Among the grasses, orchardgrass yield was greater than that of bromegrass and timothy which were in turn greater than Kentucky bluegrass.

Second harvest total and alfalfa yields in alfalfa-timothy were lower than those of the weedy alfalfa. Alfalfa yields in the weedy alfalfa were also greater than in the mixtures

containing orchardgrass, timothy, or Kentucky bluegrass. Orchardgrass yield was greater than the other grasses. Weed yields in all mixtures were on average 57 kg ha^{-1} lower than that of the weedy alfalfa.

Including grass with alfalfa did not influence third harvest total forage yields. Total yields were lower in alfalfa-Kentucky bluegrass than in alfalfa-timothy. Yields of the mixtures were similar to that of the weedy alfalfa. Alfalfa yields in mixtures with orchardgrass or Kentucky bluegrass were lower than the other mixtures or the weedy alfalfa. Orchardgrass yield was again superior to all grasses followed in descending order by Kentucky bluegrass, bromegrass, and timothy. Weed yields were similar between the weedy alfalfa and the mixtures but were 61 kg ha^{-1} lower in alfalfa-orchardgrass than in alfalfa-bromegrass.

At the fourth harvest, total forage and weed yields were similar among all forages. Alfalfa yields were lower in the forage with orchardgrass or Kentucky bluegrass than in the weedy alfalfa or alfalfa-timothy. Orchardgrass yield was greater than that of all other grasses, Kentucky bluegrass yield was intermediate, and bromegrass and timothy lowest yielding.

Including bromegrass with alfalfa provided greater total annual forage yields than the weedy alfalfa or the alfalfa-Kentucky bluegrass. The alfalfa-Kentucky bluegrass was also lower yielding than all other mixtures. Increased annual forage yield of mixtures over alfalfa seeded alone are generally the result of greater yields at the initial spring harvest. With the exception of Kentucky bluegrass, the grasses contributed 59 to 91% of the annual yields at the first harvest. Kentucky bluegrass yield at the first harvest was 44% of the annual total.

The reduced percentage in spring and reductions in total growth of Kentucky bluegrass relative to the other grasses contributed to the reduced annual yield.

Orchardgrass growth was superior to the other grasses at all harvests. The increased growth of orchardgrass always reduced alfalfa yield compared to the weedy alfalfa and often reduced alfalfa yield in comparison to the other mixtures. Including any grass with alfalfa also reduced weed yield at one of the harvests. Differences in weed yields were also seen between the alfalfa-bromegrass and the other mixtures. This may have been due primarily to weedy grass contamination in the bromegrass seed. No consistent reduction in weed yield was attributable to grass. Weed yields did not exceed 159 kg ha^{-1} (3%) of the total yield at any harvest.

High weed pressure. Alfalfa seeded with bromegrass, orchardgrass, and timothy provided greater first harvest total yields than the weedy alfalfa (Table 4). Alfalfa yields in the three mixtures were lower than the weedy alfalfa or alfalfa-Kentucky bluegrass. Orchardgrass was greatest, bromegrass and timothy intermediate, and Kentucky bluegrass lowest in yield. Weed yields were not affected by seeding with a forage grass.

At the second through fourth harvests, total yields were similar among forages, alfalfa yields were lower in alfalfa-orchardgrass than in all other forages, and orchardgrass yields superior to the other grasses. In descending order, grass yields were orchardgrass, Kentucky bluegrass, bromegrass and timothy. Weed yields at the second harvest were lower in all mixtures than in the weedy alfalfa. Average reduction in weed yield was 17 kg ha^{-1}. Weed yields were not reduced by forage grasses in the remaining harvests. Although, weed yield was lower in alfalfa-orchardgrass than alfalfa-Kentucky bluegrass at the final harvest.

Although mixtures were often greater in first harvest yields, the total annual yields were similar for all forages. In the first harvest, alfalfa yields were reduced in alfalfa-bromegrass, alfalfa-orchardgrass, and alfalfa-timothy, while total forage yields were increased due to the addition of grass. Reduction in alfalfa yield by orchardgrass was consistent at all harvests. Increased yields at the first harvest but not at subsequent harvests is due to grass growth being greatest in spring. Yields of all grasses were greatest in spring and accounted for over 54% of annual growth except for Kentucky bluegrass in which 38% of annual yield was at the first harvest. Orchardgrass yield was consistently greater than that of the other grasses at all harvests. Except for the first harvest, Kentucky bluegrass yields were greater than bromegrass or timothy. Effects of grasses on weed growth were not consistent with the trend in grass yields. All grasses reduced weed yields only at the second harvest. The maximum reduction in weed yield was 21 kg ha^{-1}. Weed content at any harvest did not exceed 152 kg ha^{-1} (3.2%) of the total forage.

Two years after seeding

Low weed pressure. Two years after seeding, the first harvest total yields of alfalfa-orchardgrass were greater than all other forages (Table 5). Alfalfa yields in the alfalfa-orchardgrass were lower than that of the weedy alfalfa or alfalfa-timothy. Orchardgrass yield was superior to all grasses, Kentucky bluegrass yield intermediate, and bromegrass and timothy lowest in yield at all harvests. Weed yields in the mixtures with orchardgrass or Kentucky bluegrass were lower than the weedy alfalfa or the other mixtures. The average reduction in weed yields from the weedy alfalfa was 127 kg ha^{-1}.

Second harvest total yields of alfalfa-Kentucky bluegrass were lower than that of the

weedy alfalfa or alfalfa-timothy. Forages with orchardgrass or Kentucky bluegrass were lower in alfalfa yields than the others. Grasses did not reduce weed yields compared to the weedy alfalfa. Alfalfa-orchardgrass was lower in weed yield than alfalfa-bromegrass.

In the third harvest, alfalfa-orchardgrass and alfalfa-Kentucky bluegrass total and alfalfa yields were lower than that of the other forages. Weed yields in these two mixtures were also lower than in the weedy alfalfa or alfalfa-bromegrass.

In the final harvest, total yields of alfalfa-Kentucky bluegrass were lower than that of all other forages. Alfalfa yields in mixtures with orchardgrass or Kentucky bluegrass were lower than in the other forages. Weed yield was lower in alfalfa-orchardgrass and alfalfa-Kentucky bluegrass than in the weedy alfalfa or alfalfa-timothy.

Seeding grass with alfalfa did not increase total annual forage yields. Seeding alfalfa with Kentucky bluegrass resulted in lower yields than that of the weedy alfalfa. Yields of alfalfa-orchardgrass were superior to alfalfa-bromegrass and alfalfa-Kentucky bluegrass. The greater annual yield was attributable mostly to greater first harvest yields of alfalfa-orchardgrass.

Orchardgrass yield was superior to all grasses at all harvests. Kentucky bluegrass was next highest in yields at all harvests. Both orchardgrass and Kentucky bluegrass growth was greatest in the spring providing 53 and 42% of their annual yields at the spring growth. Bromegrass and timothy yields were negligible at all harvests and were all but eliminated from the stand. This was likely due to the harvest management. Rhykerd et al. (21, 23) found that four annual cuts removed bromegrass and timothy apices before basal buds were developed and bromegrass and timothy were eliminated from the stand by late in the third

year of the stand while orchardgrass persisted. The orchardgrass and Kentucky bluegrass with alfalfa resulted in significant reductions in weed growth compared to the weedy alfalfa at three of four harvests. Although significant, the greatest reduction in weed growth was only 128 kg ha^{-1} by the orchardgrass at the spring growth and 44 kg ha^{-1} in regrowth. Total weed content at any harvest did not exceed 140 kg ha^{-1} (3.7%) of any forage. Additionally, seeding with orchardgrass consistently reduced alfalfa yields compared to the weedy alfalfa. High weed pressure. Two years after seeding, orchardgrass with alfalfa increased first harvest total yield compared to that of the weedy alfalfa and the other mixtures (Table 6). Subsequently, alfalfa yield in alfalfa-orchardgrass was lower than that of the weedy alfalfa and also lower than that of alfalfa-bromegrass or alfalfa-timothy. Orchardgrass yield was superior to the other grasses. Weed yields in alfalfa-orchardgrass and alfalfa-Kentucky bluegrass were lower than in the weedy alfalfa or alfalfa-bromegrass. Weed content was reduced an average of 176 kg ha^{-1} by the two mixtures in comparison to the weedy alfalfa.

Second harvest total yields of mixtures were similar to the weedy alfalfa except for alfalfa-Kentucky bluegrass which was lower than that of all other forages. Alfalfa yields in alfalfa-orchardgrass and alfalfa-Kentucky bluegrass were lower than the other forages. Weed yields were similar between the weedy alfalfa and the mixtures but lower in alfalfa-orchardgrass than in alfalfa-bromegrass. Orchardgrass yields were greatest, Kentucky bluegrass yields intermediate, and bromegrass and timothy yields lowest at harvests two through four.

Third harvest total yield of alfalfa-Kentucky bluegrass was lower than all forages except alfalfa-orchardgrass. Alfalfa yields were reduced by orchardgrass in comparison to

the weedy alfalfa or the mixtures. Weed yields were 37 to 67 kg ha^{-1} lower in mixtures than in the weedy alfalfa.

At the fourth harvest, total yields were similar among the forages while alfalfa yield was lower in alfalfa-orchardgrass than the other forages. Weed yield was lower in mixtures with orchardgrass, timothy, and Kentucky bluegrass than the one with bromegrass but not different than that of the weedy alfalfa.

Reduction in total yield in the alfalfa-Kentucky bluegrass forage at individual harvests resulted in a reduction in total annual yield compared to the other mixtures but not to the weedy alfalfa. Including grass did not consistently affect total yields. Including orchardgrass did provide greater spring yields but this did not affect annual totals. In two of four harvests, the alfalfa-Kentucky bluegrass was lower in yield which lead to lower annual yields. Alfalfa yields in alfalfa-orchardgrass were always lower than that of the weedy alfalfa and often lower than in alfalfa-bromegrass or alfalfa-timothy. Yield of bromegrass and timothy were minimal in all harvests. Orchardgrass and Kentucky bluegrass yields were greatest at the first harvest. Including orchardgrass or Kentucky bluegrass reduced weed content at the first and third harvests. The maximum reduction, occurring at the first harvest, was 182 kg ha^{-1}. The maximum weed content two years after seeding was 189 hg ha^{-1} (4.9%) in the weedy alfalfa at first harvest. In both experiments, weed content was reduced at some but not all harvests. This is similar to results of Bendixen and Lanini (1) where ryegrass and fescue seeded into established alfalfa reduced weed competition but varied by harvest and year.

Forage Quality

Low weed pressure

Seeding grass with alfalfa had no effect on CP at the first harvest of the seeding year (Table 7). In plots seeded without oat, ADF was similar among the forages. Acid detergent fiber was greater in alfalfa-timothy than the weedy alfalfa or alfalfa-Kentucky bluegrass in plots with oat. When seeded without oat, NDF of alfalfa-bromegrass was greater than that of the weedy alfalfa, alfalfa-orchardgrass, and alfalfa-timothy. The increase in NDF of alfalfa-bromegrass in plots seeded without oat over the other forages at the first harvest is due to the bromegrass which accounted for 20% to the total forage. Alfalfa-orchardgrass and alfalfa-timothy were greater in NDF than alfalfa-Kentucky bluegrass. Differences in forages seeded with oat may be due to differences in the oat since alfalfa, grass, and weeds contributed little to the total yield and were similar among the forages.

At the second harvest, CP was similar among forages regardless of the companion and ADF and NDF similar among forages when seeded without oat. Acid detergent fiber was greater in the weedy alfalfa than all mixtures except alfalfa-orchardgrass where initially seeded with oat. Among the mixtures, alfalfa-orchardgrass was higher in ADF than alfalfa-timothy and alfalfa-Kentucky bluegrass. Neutral detergent fiber was greater in alfalfa-orchardgrass than the weedy alfalfa, alfalfa-timothy, and alfalfa-Kentucky bluegrass in plots initially seeded with oat.

Reductions in ADF and NDF of alfalfa-timothy and alfalfa-Kentucky bluegrass over the weedy alfalfa at the second harvest, when initially seeded with oat, could not be explained by differences in weed or alfalfa content. Timothy or bromegrass may have been

lower in fiber than the other plants contributing to the reduced fiber content. Differences in fiber content at the second harvest were not consistently in favor of the weedy alfalfa or the mixtures. Also, differences in fiber content between the weedy alfalfa and mixtures did not exceed 18 g kg^{-1} . A difference this small may be of little relative importance. Without a companion crop, grass contribution to the forage was not great enough to influence forage quality at either harvest.

High weed pressure

Seeding with a forage grass had no effect on forage CP, ADF, or NDF at the first harvest in the seeding year (Table 8). Crude protein was also unaffected at the second harvest. In plots established without oat, ADF was greater in alfalfa-Kentucky bluegrass than in the alfalfa-bromegrass or alfalfa-orchardgrass. When initially seeded with oat, ADF was greater in alfalfa-bromegrass and alfalfa-Kentucky bluegrass than the weedy alfalfa and forage quality was reduced. Neutral detergent fiber was higher and forage quality lower in alfalfa-bromegrass than the weedy alfalfa in plots initially seeded with oat. Seeded without oat, no differences in NDF were observed.

Including grass with alfalfa had no effect on any forage quality characteristic at the first harvest but did affect fiber content at the second harvest. Greater ADF of alfalfa-Kentucky bluegrass than of alfalfa-bromegrass or alfalfa-orchardgrass may have been due to alfalfa and weed content. Alfalfa content was lower and weed content greater, although not statistically significant, in the mixture containing Kentucky bluegrass than in the other two mixtures. Differences in fiber content between mixtures and the weedy alfalfa could not be explained by alfalfa, grass, or weed yield differences. Overall, few differences in forage

quality were evident as a result of including grass with alfalfa.

Plant density

Low weed pressure

At 6WAS, alfalfa density was not reduced by seeding with grass but alfalfa density was greater in the mixture with bromegrass than the weedy alfalfa or the other forages when seeded with oat (Table 9). A difference in alfalfa density in plots seeded with oat was not expected. A reduction in alfalfa density in mixtures in comparison to the weedy alfalfa was expected. Grass density in plots without oat were greatest for bromegrass and Kentucky bluegrass, intermediate for orchardgrass, and lowest for timothy. High Kentucky bluegrass density is due to high seeding rate and number of seeds per kilogram in relation to orchardgrass or timothy. The seeding rates of bromegrass, orchardgrass, timothy, and Kentucky bluegrass were approximately 100, 150, 1220, and 3260 seeds m^2, respectively. The high bromegrass density was unexpected since seeding rate was lower and seed size greater than the other grasses. Seeded with oat, the only difference was that Kentucky bluegrass density was greater than that of bromegrass. Grass density was usually lower in plots seeded with oat than in those seeded without oat. Greater density of Kentucky bluegrass did not lead to a greater grass yield. Greater bromegrass density may have been the primary cause of greater yields at first harvest. Weed densities were similar among all forages at 6WAS and at 4WAH. Addition of grasses to alfalfa, or differences among grasses, were insufficient to reduce weed density in the seeding year.

Alfalfa plant density was not affected by seeding with grasses in the fall of the seeding year or two years later in plots established in 1993 (Table 10). One year after seeding, alfalfa density in alfalfa-Kentucky bluegrass was lower than in the weedy alfalfa or alfalfa-timothy. In forages seeded in 1994, alfalfa density in fall of that year was greater in alfalfa-bromegrass and alfalfa-timothy than in the weedy alfalfa. Density was also greater in alfalfa-bromegrass than alfalfa-orchardgrass or alfalfa-Kentucky bluegrass. The following year, mixtures with orchardgrass or Kentucky bluegrass were lower in alfalfa density than the weedy alfalfa. There were no consistent differences in density among the mixtures. While not always statistically different, alfalfa density in alfalfa-orchardgrass and alfalfa-Kentucky bluegrass tended to be lower than in the other forages. Alfalfa density in alfalfa-bromegrass and alfalfa-timothy were not expected to be greatly reduced since those grasses were not maintained in the stands. Alfalfa density decreased in all forages as the stand aged.

In the fall two years after seeding, alfalfa with orchardgrass or Kentucky bluegrass was lower in dandelion density compared to the weedy alfalfa or the other two mixtures (Table 11). Dandelion densities in the weedy alfalfa, alfalfa-orchardgrass, and alfalfa-Kentucky bluegrass were 7.3, 3.5, and 1.5 plants m^2. Both grasses made large contributions to yield and were effective at reducing dandelion density. Reduction in dandelion density by bromegrass or timothy would not be expected since these two grasses were all but eliminated from the stand.

High weed pressure

Alfalfa plant density at 6WAS was not influences by the grasses (Table 12). Orchardgrass density was lower than the other grasses in plots established without oat.

Lower orchardgrass density is expected since seeding rate was lower. Kentucky bluegrass density was greatest, timothy intermediate, and bromegrass and orchardgrass density lowest when seeded with oat. This distribution of density parallels what may be expected given the seeding rates of each grass. Unlike the experiment with low weed pressure, more differences in grass density were seen in plots seeded with than without oat. Weed competition may have been great enough to limit grass emergence or growth and thereby minimized differences. Weed density was reduced by 59 and 57 plants m^2 in mixtures containing bromegrass or orchardgrass in comparison to the weedy alfalfa when seeded without oat. This difference did not result in reduced weed yields at the first harvest. With oat, weed density was greater in alfalfa-Kentucky bluegrass than in alfalfa-bromegrass. At 4WAH, weed density in alfalfa-Kentucky bluegrass was greater than in alfalfa-timothy when seeded without oat. With oat, no differences in weed density were seen among the forages. Although differences in grass density were evident, including grasses with alfalfa most often had no effect on alfalfa or weed density in the seeding year.

In the fall of the seeding year, alfalfa density was similar among the forages seeded with or without grasses (Table 13). One year after seeding, the 1993 forages were also similar in plant density. Alfalfa density one year after seeding was lower in alfalfa-orchardgrass than in all other forages except alfalfa-Kentucky bluegrass in the 1994 seeding. Two years after the 1993 establishment, alfalfa density in alfalfa-Kentucky bluegrass was lower than that of the weedy alfalfa. One and two years after establishment, alfalfa density in alfalfa-orchardgrass and alfalfa-Kentucky bluegrass tended to be lower (not always significantly) than the weedy alfalfa. Alfalfa plants also appeared to be smaller (visual

observations) in the alfalfa-Kentucky bluegrass mixture. Alfalfa density in alfalfa-bromegrass and alfalfa-timothy was similar to the weedy alfalfa in both years.

Dandelion density was lower in alfalfa seeded with orchardgrass or Kentucky bluegrass than in the weedy alfalfa (Table 11). Dandelion density in the weedy alfalfa, alfalfa-orchardgrass, and alfalfa-Kentucky bluegrass were 11, 5.4, and 6.1 plants m^2, respectively. No differences in density were observed among the mixtures. Where grasses made significant contributions to forage yield, dandelion density was reduced. In these experiments, orchardgrass and Kentucky bluegrass reduced the density of dandelion which is a simple perennial. Similar results may be seen with other simple perennials. If a creeping perennial such as quackgrass (*Elytrigia repens* L. Nevski) was the dominant weed invading the stand, results might be different.

SUMMARY

In the seeding year, including forage grasses with alfalfa had no consistent effect on total forage, alfalfa, and weed yields or plant densities. In a few instances, weed yields or densities were reduced by seeding with a grass. Including forage grasses had no effect on forage CP while a few differences in fiber content were seen in the seeding year. These differences occurred primarily at the second harvest in plots initially established with oat. In the following years, including grass generally resulted in greater forage yields at the first harvest than that of the weedy alfalfa but this did not always result in greater annual totals. Orchardgrass and Kentucky bluegrass provided significant yields in all harvests through the second year after seeding (third year of the stand). Bromegrass and timothy contributed little

to yield after the first harvest in the second year of the stand. Increased orchardgrass and Kentucky bluegrass yields often resulted in reduced alfalfa yields. Alfalfa-Kentucky bluegrass forage yields were also often lower than the weedy alfalfa or the other mixtures by the third year of the stand.

At times, alfalfa density was reduced by seeding with orchardgrass or Kentucky bluegrass. These two grasses reduced weed content in one harvest in the second year of the stand and in two or three harvests, depending on weed pressure, the following year. Additionally, orchardgrass and Kentucky bluegrass reduced dandelion density in fall two years after seeding. Forage grasses appeared to be more effective at reducing weed invasion as the stand aged. This may be attributable to the amount of grass in the forage. Orchardgrass and Kentucky bluegrass continued to grow and compete while bromegrass and timothy were essentially eliminated from the stand by the four annual harvests. By the end of the third growing season, weed content did not exceed 5% of the total dry matter in the weedy alfalfa. It is likely that as the stand ages, forage grasses will become dominant and weed content should be reduced in comparison to the alfalfa seeded alone. The producer must determine the acceptability of weed versus grass content in the forage and the subsequent effects on forage quality and yield.

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Table 1. Component yields in the year of seeding (average of 1993 and 1994 seedings) with low weed pressure.

Component	Oat	Alfalfa	Harvest 1	Harvest 2	Annual total
			kg ha^{-1}		
Total	Absent	Weedy	3452	2685	6137
		+ bromegrass	3447	2640	6087
		+ orchardgrass	3381	2792	6173
		+ timothy	3625	2840	6465
		+ Kentucky bluegrass	3130	2850	5980
	Present	Weedy	6357	2167	8524
		+ bromegrass	6204	2205	8409
		+ orchardgrass	6917	2204	9121
		+ timothy	6621	2358	8979
		+ Kentucky bluegrass	6639	2174	8813
Alfalfa	Absent	Weedy	1073	1558	-
		+ bromegrass	917	1531	-
		+ orchardgrass	925	1333	-
		+ timothy	1006	1654	-
		+ Kentucky bluegrass	764	1615	-
	Present	Weedy	104	1769	-
		+ bromegrass	166	1655	-
		+ orchardgrass	104	1711	-
		+ timothy	78	1719	-
		+ Kentucky bluegrass	117	1788	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 1. (Cont'd).

Component	Oat	Alfalfa	Harvest 1	Harvest 2	Annual total
			---------- kg ha^{-1} ----------		
Grass	Absent	Weedy	-	-	-
		+ bromegrass	703a[a]	563a	-
		+ orchardgrass	135b	715a	-
		+ timothy	261b	631a	-
		+ Kentucky bluegrass	38b	131b	-
	Present	Weedy	-	-	-
		+ bromegrass	10	214ab	-
		+ orchardgrass	2	339a	-
		+ timothy	10	150ab	-
		+ Kentucky bluegrass	1	19b	-
Weeds	Absent	Weedy	2379	1127a	-
		+ bromegrass	1827	546b	-
		+ orchardgrass	2321	744b	-
		+ timothy	2358	555b	-
		+ Kentucky bluegrass	2328	1104a	-
	Present	Weedy	196	397ab	-
		+ bromegrass	68	335ab	-
		+ orchardgrass	111	153b	-
		+ timothy	178	488a	-
		+ Kentucky bluegrass	147	367ab	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 2. Component yields in the year of seeding (average of 1993 and 1994 seedings) with high weed pressure.

Component	Oat	Alfalfa	Harvest 1	Harvest 2	Annual total
			---------- kg ha^{-1} ----------		
Total	Absent	Weedy	3333	2435b[a]	5768
		+ bromegrass	3404	2515ab	5919
		+ orchardgrass	3020	2816a	5836
		+ timothy	3446	2625ab	6071
		+ Kentucky bluegrass	3467	2479ab	5945
	Present	Weedy	6407	1917	8324
		+ bromegrass	6338	1993	8331
		+ orchardgrass	5797	1996	7793
		+ timothy	6287	2018	8305
		+ Kentucky bluegrass	6442	1989	8431
Alfalfa	Absent	Weedy	238	1600a	-
		+ bromegrass	266	1469ab	-
		+ orchardgrass	235	1359ab	-
		+ timothy	275	1477ab	-
		+ Kentucky bluegrass	243	1240b	-
	Present	Weedy	68	1700	-
		+ bromegrass	62	1663	-
		+ orchardgrass	85	1730	-
		+ timothy	62	1673	-
		+ Kentucky bluegrass	90	1733	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 2. (Cont'd).

Component	Oat	Alfalfa	Harvest 1	Harvest 2	Annual total
			---------- kg ha^{-1} ----------		
Grass	Absent	Weedy	-	-	-
		+ bromegrass	117a	279a	-
		+ orchardgrass	27b	244a	-
		+ timothy	46ab	224a	-
		+ Kentucky bluegrass	6b	26b	-
	Present	Weedy	-	-	-
		+ bromegrass	14	56a	-
		+ orchardgrass	25	51a	-
		+ timothy	11	58a	-
		+ Kentucky bluegrass	5	10b	-
Weeds	Absent	Weedy	3095	835	-
		+ bromegrass	3021	767	-
		+ orchardgrass	2758	1213	-
		+ timothy	3125	924	-
		+ Kentucky bluegrass	3218	1213	-
	Present	Weedy	237	217	-
		+ bromegrass	286	275	-
		+ orchardgrass	287	215	-
		+ timothy	333	287	-
		+ Kentucky bluegrass	253	247	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 3. Component yields one year after seeding (average of 1993 and 1994 seedings) with low weed pressure.

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
		kg ha^{-1}				
Total	Weedy	4619b[a]	3203a	2538ab	1492	11852bc
	+ bromegrass	5193a	3165 ab	2614ab	1441	12413a
	+ orchardgrass	5371a	3013ab	2424ab	1452	12260ab
	+ timothy	5204a	2939b	2641a	1484	12268ab
	+ Kentucky bluegrass	4797b	3045ab	2370b	1390	11601c
Alfalfa	Weedy	4554a	3133a	2505a	1482a	-
	+ bromegrass	3693bc	2939ab	2460a	1378ab	-
	+ orchardgrass	3351c	2388c	1944b	1149c	-
	+ timothy	3858b	2825b	2603a	1466a	-
	+ Kentucky bluegrass	4270a	2726b	2149b	1257bc	-
Grass	Weedy	-	-	-	-	-
	+ bromegrass	1341b	206bc	92c	46c	-
	+ orchardgrass	1996a	614a	479a	302a	-
	+ timothy	1317b	103c	18d	13c	-
	+ Kentucky bluegrass	492c	308b	196b	131b	-
Weeds	Weedy	65ab	70a	33ab	10	-
	+ bromegrass	159a	20b	62a	17	-
	+ orchardgrass	24b	11b	1b	1	-
	+ timothy	29b	11b	20ab	5	-
	+ Kentucky bluegrass	35b	11b	25ab	2	-

[a]Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 4. Component yields one year after seeding (average of 1993 and 1994 seedings) with high weed pressure.

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
		kg ha^{-1}				
Total	Weedy	4701b[a]	3095	2612	1697	12101
	+ bromegrass	5091a	3023	2706	1679	12499
	+ orchardgrass	5144a	2979	2465	1666	12254
	+ timothy	5068a	2975	2600	1703	12346
	+ Kentucky bluegrass	4867ab	3065	2636	1637	12206
Alfalfa	Weedy	4549a	3057a	2575a	1688a	-
	+ bromegrass	4087b	2871a	2605a	1655a	-
	+ orchardgrass	3750b	2476b	2036b	1387b	-
	+ timothy	4091b	2835a	2558a	1689a	-
	+ Kentucky bluegrass	4523a	2813a	2506a	1545a	-
Grass	Weedy	-	-	-	-	-
	+ bromegrass	893b	132c	44c	16c	-
	+ orchardgrass	1361a	486a	417a	276a	-
	+ timothy	914b	127c	22c	9c	-
	+ Kentucky bluegrass	256c	233b	111b	72b	-
Weeds	Weedy	152	34a	37	9ab	-
	+ bromegrass	111	20b	57	8ab	-
	+ orchardgrass	33	17b	12	3b	-
	+ timothy	63	13b	20	6ab	-
	+ Kentucky bluegrass	88	19b	19	20a	-

[a]Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 5. Component yields two years after seeding (1993 seeding only) with low weed pressure.

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
		kg ha^{-1}				
Total	Weedy	3814b[a]	2818a	1631a	945a	9208ab
	+ bromegrass	3710b	2613ab	1571a	938a	8832b
	+ orchardgrass	4743a	2530ab	1425b	844a	9542a
	+ timothy	3894b	2789a	1607a	948a	9238ab
	+ Kentucky bluegrass	4050b	2374b	1111c	654b	8189c
Alfalfa	Weedy	3674a	2760a	1587a	934a	-
	+ bromegrass	3535ab	2522a	1542a	929a	-
	+ orchardgrass	3172b	1876b	1027b	505b	-
	+ timothy	3755a	2736a	1579a	933a	-
	+ Kentucky bluegrass	3496ab	2076b	908b	399b	-
Grass	Weedy	-	-	-	-	-
	+ bromegrass	49c	6c	3c	4c	-
	+ orchardgrass	1559a	646a	398a	338a	-
	+ timothy	13c	1c	6c	5c	-
	+ Kentucky bluegrass	540b	292b	202b	254b	-
Weeds	Weedy	140a	58ab	44a	11a	-
	+ bromegrass	126a	85a	26a	5ab	-
	+ orchardgrass	12b	8b	0b	1b	-
	+ timothy	126a	52ab	22ab	10a	-
	+ Kentucky bluegrass	14 b	6b	1b	1b	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 6. Component yields two years after seeding (1993 seeding only) with high weed pressure.

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Annual total
		kg ha^{-1}				
Total	Weedy	3867b[a]	2519a	2067a	1337	9790ab
	+ bromegrass	4003b	2742a	2112a	1380	10237a
	+ orchardgrass	4688a	2522a	2019ab	1311	10540a
	+ timothy	3939b	2715a	2225a	1374	10253a
	+ Kentucky bluegrass	3871b	2155b	1781b	1204	9011b
Alfalfa	Weedy	3678ab	2436a	2000a	1309a	-
	+ bromegrass	3784a	2576a	2070a	1327a	-
	+ orchardgrass	2869c	1742b	1459b	890b	-
	+ timothy	3754ab	2629a	2211a	1363a	-
	+ Kentucky bluegrass	3299bc	1916b	1555a	909b	-
Grass	Weedy	-	-	-	-	-
	+ bromegrass	59b	41c	12c	9c	-
	+ orchardgrass	1812a	774a	560a	419a	-
	+ timothy	77b	23c	4c	1c	-
	+ Kentucky bluegrass	553b	208b	221b	294b	-
Weeds	Weedy	189a	83ab	67a	28ab	-
	+ bromegrass	160a	125a	30b	44a	-
	+ orchardgrass	7b	6b	0b	2b	-
	+ timothy	108ab	63ab	10b	10b	-
	+ Kentucky bluegrass	19b	31ab	5b	1b	-

[a] Means within a column and forage followed by the same letters are not significantly different ($P<0.05$).

Table 7. Forage quality characteristics in the seeding year (average of 1993 and 1994 seedings) with low weed pressure.

		Harvest 1		Harvest 2	
		Oat			
Characteristic	Alfalfa	absent	present	absent	present
		---------- g kg^{-1} ----------			
CP[a]	Weedy	145	95	182	218
	+ bromegrass	137	96	187	212
	+ orchardgrass	138	95	174	205
	+ timothy	145	90	189	207
	+ Kentucky bluegrass	135	90	182	217
ADF	Weedy	272	341bc[b]	320	299a
	+ bromegrass	288	347abc	316	290bc
	+ orchardgrass	271	352ab	315	297ab
	+ timothy	283	356a	316	281c
	+ Kentucky bluegrass	283	337c	311	282c
NDF	Weedy	436b	579ab	466	418b
	+ bromegrass	475a	588ab	480	420ab
	+ orchardgrass	437b	595a	482	429a
	+ timothy	444b	593a	477	407c
	+ Kentucky bluegrass	456ab	570b	468	402c

[a] CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.

[b] Means within a column and characteristic followed by the same letters are not significantly different ($P<0.05$).

Table 8. Forage quality characteristics in the seeding year (average of 1993 and 1994 seedings) with high weed pressure.

		Harvest 1		Harvest 2	
		Oat			
Characteristic	Alfalfa	absent	present	absent	present
		---------- g kg^{-1} ----------			
CP[a]	Weedy	96	81	166	236
	+ bromegrass	99	82	185	221
	+ orchardgrass	97	80	186	236
	+ timothy	100	83	176	232
	+ Kentucky bluegrass	100	82	178	226
ADF	Weedy	310	330	310ab[b]	262b
	+ bromegrass	322	332	297b	278a
	+ orchardgrass	316	334	298b	269ab
	+ timothy	317	339	307ab	274ab
	+ Kentucky bluegrass	318	332	315a	281a
NDF	Weedy	505	566	474	388b
	+ bromegrass	516	571	577	413a
	+ orchardgrass	511	569	451	396ab
	+ timothy	513	573	475	402ab
	+ Kentucky bluegrass	523	570	483	405ab

[a] CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.

[b] Means within a column and characteristic followed by the same letters are not significantly different ($P<0.05$).

Table 9. Plant density in the seeding year (average of 1993 and 1994 seedings) with low weed pressure.

		6WAS[a]			4WAH
Oat	Alfalfa	Alfalfa	Grass	Weeds	Weeds
		plants m^2			
Absent	Weedy	298	-	101	32
	+ bromegrass	278	129a[b]	108	26
	+ orchardgrass	262	87b	95	34
	+ timothy	274	52c	95	28
	+ Kentucky bluegrass	254	135a	89	31
Present	Weedy	144b	-	83	39
	+ bromegrass	193a	23b	82	39
	+ orchardgrass	157b	37ab	103	37
	+ timothy	144b	52ab	107	45
	+ Kentucky bluegrass	156b	65a	90	36

[a] 6WAS, 6 weeks after seeding; 4WAH, 4 weeks after first harvest.
[b] Means within a column and oat followed by the same letters are not significantly different ($P<0.05$).

Table 10. Alfalfa plant density in fall with low weed pressure.

	Years after seeding				
	0		1		2
	Seeding year				
Alfalfa	1993	1994	1993	1994	1993
	plants m^2				
Weedy	242	202c[a]	145a	180a	124
+ bromegrass	243	257a	128ab	154ab	115
+ orchardgrass	266	208bc	136ab	137b	100
+ timothy	240	247ab	143a	169ab	114
+ K. bluegrass	228	212bc	110b	134b	101

[a] Means within a column followed by the same letters are not significantly different ($P<0.05$).

Table 11. Dandelion density in fall two years after establishment (1993 seedings only).

Forage	Weed pressure	
	Low	High
	---------- Plants m^2 ----------	
Weedy alfalfa	7.3a[a]	11.0a
Alfalfa + bromegrass	8.0a	8.6ab
Alfalfa + orchardgrass	3.5b	5.6b
Alfalfa + timothy	7.4a	8.5ab
Alfalfa + Kentucky bluegrass	1.5b	4.9b

[a] Means within a column followed by the same letters are not significantly different ($P<0.05$).

Table 12. Plant density in the seeding year (average of 1993 and 1994 seedings) with high weed pressure.

		6WAS[a]			4WAH
Oat	Alfalfa	Alfalfa	Grass	Weeds	Weeds
		plants m^2			
Absent	Weedy	231	-	253a[b]	46ab
	+ bromegrass	264	78a	194b	41ab
	+ orchardgrass	264	29b	196b	44ab
	+ timothy	249	77a	224ab	38b
	+ Kentucky bluegrass	241	80a	227ab	50a
Present	Weedy	276	-	185ab	52
	+ bromegrass	255	38c	149b	51
	+ orchardgrass	271	23c	177ab	49
	+ timothy	283	70b	178ab	46
	+ Kentucky bluegrass	238	91a	225a	48

[a] 6WAS, 6 weeks after seeding; 4WAH, 4 weeks after first harvest.
[b] Means within a column and oat followed by the same letters are not significantly different (P<0.05).

Table 13. Alfalfa plant density in fall with high weed pressure.

	Years after seeding				
	0		1		2
	Seeding year				
Alfalfa	1993	1994	1993	1994	1993
	plants m^2				
Weedy	252	252	139	202a[a]	128ab
+ bromegrass	280	259	164	198a	142a
+ orchardgrass	256	265	150	158b	116bc
+ timothy	257	232	142	205a	122b
+ K. bluegrass	257	249	139	181ab	101c

[a] Means within a column followed by the same letters are not significantly different (P<0.05).

CHAPTER THREE

Weed Invasion in Established Stands of Alfalfa Seeded with Perennial Forage Grasses

ABSTRACT

Establishing alfalfa with perennial forage grasses may reduce weed invasion as the stand ages. Data to support this potential advantage are not abundant. This study determined the effect of seeding perennial forage grasses with alfalfa on weed and component yields and on forage quality in established stands. Alfalfa was seeded alone (weedy alfalfa) and in binary mixtures with bromegrass, orchardgrass, or timothy. Yields and forage quality were determined at three annual harvests in the third and fourth years after seeding. Weed yields in alfalfa seeded with orchardgrass were often lower than those in the weedy alfalfa. Average weed content was 24, 17, 2, and 15% for the weedy alfalfa, alfalfa-bromegrass, alfalfa-orchardgrass, and alfalfa-timothy, respectively. Seeding alfalfa with orchardgrass increased first harvest and annual forage yields while reducing alfalfa yield. Crude protein was reduced and acid detergent fiber and neutral detergent fiber increased by orchardgrass primarily at the first harvest. Neutral detergent fiber was greater in alfalfa-orchardgrass than in the weedy alfalfa at most harvests. Yields of orchardgrass often exceeded those of bromegrass or timothy. There were no consistent differences among the weedy alfalfa and the other mixtures in yields or quality. Of the perennial grasses seeded with alfalfa, only orchardgrass consistently reduced weed invasion. The producer must determine the acceptability of high weed or orchardgrass content in the forage and subsequent effects on forage quality, yield, and stand life.

INTRODUCTION

Seeding perennial forage grasses with alfalfa (*Medicago sativa* L.) may help to reduce weed invasion in subsequent years. Perennial forage grasses with alfalfa may also be advantageous for reducing insect damage, soil and water conservation, and supplying a consistent yield across a wide range of environments (5,16,35,54). Competition provided by weeds may reduce alfalfa yields, stand persistence, and forage quality. Weed competition can reduce alfalfa yield in the seeding year and in established stands (12,21,28,32,38,40,52). Total forage yield, however, may not be affected (29) but the weeds may compose a large proportion of the dry matter (28,48). Intense weed competition in the seeding year may result in a stand failure (39).

Forage quality may or may not be reduced by the presence of weeds (9,10 11,14,19,22,23,25,28,30,42). Generally, forage quality is affected most in the seeding year and in old stands where weeds are more prevalent. The degree to which forage quality is affected depends on the weed species present, maturity of the weed plants, and the proportion of weeds in the forage (3,4,7,8,10,25). Although similar in forage quality, weeds may be less palatable (23) or potentially toxic to animals (4). This may be especially important for producers growing hay for specialty markets. In addition, moisture content of weeds may be greater than alfalfa and slow the drying rate (9) and weeds may provide seeds or vegetative propagules that invade subsequent crops (24).

Weeds may be controlled in forages using chemical, mechanical, or cultural methods. Herbicides have proven effective at controlling weeds (15,18,19,37,55) and are used increasingly for weed control in pure alfalfa seedings (49). In established stands, herbicides are not commonly used since the effect is often temporary and alfalfa yields and forage quality may not be consistently increased (8,42). Tillage, alone or in combination with herbicides, can be used prior to and at stand establishment to control weeds (1). Mechanical control (clipping or mowing) requires accurate timing to reduce broadleaf competition and minimize damage to alfalfa (20,26). Weed grasses may not be controlled since their growing point is below the height of cutting. In established stands, mowing can be effective at preventing seed production and decreasing infestation of certain perennial weeds (33).

Cultural methods of controlling weeds include prevention, altered planting time, tillage, and using companion crops. Preventative measures such as using weed-free seed and cleaning equipment between fields will limit weed introductions (33). Altering the seeding date is also an effective method for controlling weeds. Seeding in early spring, in the North Central region, results in heavy weed pressure primarily from the summer annuals such as common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and giant foxtail (*Setaria faberi* Hermm.). Seeding in late summer reduces summer annual weed pressure but may increase winter annual weed pressure (13) or result in a failed stand if soil moisture is not adequate (33). Producers may choose spring seeding in preference to summer seeding to increase forage yields in the year of establishment.

An annual or perennial crop may be seeded with the forage to suppress weed growth. Annual companion crops, primarily small grains, are widely used in spring seedings of

alfalfa. An estimated 60% of alfalfa acreage planted in the north central and north eastern USA was seeded with a companion crop (49). Oat (*Avena sativa* L.) is the most commonly used companion crop (31,43,45). In addition, small grain companion crops may reduce soil erosion, increase forage yield, and increase economic return.

Perennial forage grasses may reduce weed invasion in alfalfa. A reduction in weed invasion or enhanced weed control has been given as a potential advantage of including a forage grass (5) but little data is available to support this statement. In one study, seeding annual ryegrass (*Lolium spp.*) or a fescue (*Festuca spp.*) into established alfalfa showed a trend towards reducing weed competition (2). Willard (53) and Sollenberger et al. (46) found that growing orchardgrass (*Dactylis glomerata* L.) with alfalfa was effective at keeping weeds out of the stand. As alfalfa stands age, plant density decreases (27) thereby allowing favorable conditions for weed growth. As alfalfa-grass stands age, the alfalfa plant density decreases and grasses become dominant (44,50) which may reduce weed invasion.

Including grass in mixtures with alfalfa may reduce forage quality (34). Generally, grasses mature faster than alfalfa and by harvest (bud to one-tenth bloom) may already be in the flowering stage and quality will be reduced (49). The extent to which forage quality is reduced is dependent on the specific harvest, grass species, and proportion of grass in the forage. Including perennial grasses was shown to reduce forage quality primarily in spring growth (47). Combinations of alfalfa with different species of grass resulted in differences in forage quality among the combinations (41). Depending on the species and its specific quality, the degree to which forage quality is changed results from the proportion of grass in the stand. Earlier harvest of mixtures may be required to maintain high forage quality.

The potential for interseeded perennial forage grasses to reduce weed invasion has been mentioned in numerous articles as a potential advantage. Data to support this statement, however, are not abundant. Objectives of this research were to determine how interseeding smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass, or timothy (*Phleum pratense* L.) with alfalfa affected weed content and component yields and forage quality.

MATERIALS AND METHODS

Field experiments were established in summer 1990 at the Michigan State University Botany farm in East Lansing, Michigan on a Capac loam soil (fine-loamy, mixed, mesic Aeric Ochraqualfs). Soil test data were used to determine fertilizer additions at seeding. Fertilizer in the established stand was applied as needed based on soil tests.

Bentazon [3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] was applied at 1.12 kg a.i. ha^{-1} with crop oil at 0.38 l ha^{-1} in June prior to seeding to control yellow nutsedge (*Cyperus esculentus* L.). Glyphosate [N-(phosphonomethyl) glycine] was applied at 1.68 kg a.i. ha^{-1} in early August prior to tillage to control quackgrass (*Elytrigia repens* L. Nevski). Conventional tillage was used in seedbed preparation. Treatments were seeded with a drill using 18 cm rows in mid-August in 9.9 by 13.7 m plots.

Treatments included alfalfa seeded alone (weedy alfalfa), and in binary mixtures with bromegrass, orchardgrass, or timothy. 'Big Ten' alfalfa was seeded at 14.6 kg ha^{-1} in all plots. 'Common' bromegrass, 'Common' orchardgrass, and 'Common' timothy were seeded at 5.6, 1.1, and 4.5 kg ha^{-1}, respectively. Experimental design was a randomized complete block with four replications. Data were analyzed using PROC ANOVA of SAS (36) and

means separated with Duncans multiple range test. Differences were judged significant at $P<0.05$.

In 1993 and 1994, plots were harvested three times annually at bud to one-tenth bloom stage of alfalfa. Harvest dates in 1993 were 10 June, 26 July, and 8 September. Harvest dates in 1994 were 1 June, 12 July, and 30 August. A 0.9 by 6.1 m strip was collected with a flail harvester at each date and weighed. Approximately 500 g of fresh forage was collected from the harvested sample and dried at 60°C for 72 h in a forced air dryer to determine dry matter content. Forage yields were then calculated on a dry matter basis. Following each harvest, remaining forage was removed with field equipment.

Two random samples were collected by hand from each plot. Samples were cut at a height of 5 cm. One sample was hand separated into the following components: alfalfa, perennial forage grass, broadleaf weeds, and grass weeds. Individual components were dried and weighed to determine the specific components proportion of total forage. Percentages of each component are included in Appendix Tables A9 and A10. The second sample was dried and ground in a cyclone mill to pass a 2mm screen. This sample was analyzed in duplicate for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF). Crude protein concentration was determined by using micro-Kjeldahl analysis to measure total N and multiplying that number by 6.25. Fiber concentration was determined by the modified sequential fiber analysis procedure of Van Soest et al. (51).

RESULTS

Component Yields

At the first harvest in 1993 and in annual totals, alfalfa-orchardgrass was greater in forage yield than the weedy alfalfa (Table 1). No differences in total forage yield among treatments were seen at the second or third harvests. Alfalfa yields in the mixtures containing orchardgrass or timothy were lower than those of alfalfa-bromegrass or the weedy alfalfa at the first harvest. In the second and third harvests, alfalfa yields in the alfalfa-orchardgrass were lower than all other treatments. At all three harvests, yields of orchardgrass were greater than bromegrass or timothy. Total weed content was lower in the alfalfa-orchardgrass mixture at the first harvest and in all the mixtures at the third harvest than in the the weedy alfalfa. At the second harvest, weed yields were not statistically different.

In the spring harvest of 1994, mixtures with bromegrass or orchardgrass were greater in total forage yield than the weedy alfalfa (Table 2). At the second harvest no mixtures were greater in yield than the weedy alfalfa, but alfalfa-timothy was lower in forage yield than all other treatments. In the third harvest alfalfa-bromegrass yielded more forage than the weedy alfalfa. Mixtures of alfalfa with bromegrass or orchardgrass were higher in annual forage yields than those of alfalfa-timothy or the weedy alfalfa.

Alfalfa yields were lower in mixtures containing orchardgrass or timothy than in the weedy alfalfa in the spring harvest but not in the second harvest. At the third harvest, alfalfa yield in the alfalfa-timothy was less than that in the alfalfa-bromegrass or the weedy alfalfa. Orchardgrass yield was greater than that of timothy at all three harvests and greater than that

of bromegrass at the first and third harvests. Total weed yield was lower in the mixtures containing orchardgrass than in the weedy alfalfa at the second and third harvests.

Total forage yields of alfalfa with orchardrass were greater than the weedy alfalfa at the initial harvest and annually. Orchardgrass increased annual yields by an average 1657 kg ha^{-1}. Average annual yield increases due to the orchardgrass were 16% which is close to Chamblee and Collins (6) estimate of 10 to 15%. Alfalfa yields in the alfalfa-orchardgrass were often lower than that of the weedy alfalfa. Alfalfa, as a percentage of total forage, ranged from 26 to 68% in the alfalfa-orchardgrass. In all but one harvest, yields of orchardgrass were greater than those of bromegrass or timothy. Orchardgrass percentage was greater than the other grasses at all harvests and ranged from 30 to 73% of the total. As alfalfa-grass stands age, the grass component tends to become dominant as shown by orchardgrass. Jung and Baker (17) stated that orchardgrass is generally more tolerant of environmental extremes than timothy but less so than bromegrass. Greater orchardgrass growth also may be due to harvest schedule. In a three cut system, the first harvest is taken in early June and the orchardgrass has reached heading stage while bromegrass is in the boot stage and timothy in the stem elongation stage (6). Harvest at this time can result in poor regrowth because grasses have not reached maturity. Weed yields were often lower in the alfalfa-orchardgrass than in the the weedy alfalfa (Tables 1 and 2). Weed dry matter was found to decrease from 1.0 t ha^{-1} to 0.05 t ha^{-1} when orchardgrass was included with alfalfa (46). Average weed content for the weedy alfalfa, alfalfa-bromegrass, alfalfa-orchardgrass, and alfalfa-timothy were 24, 17, 2, and 15%, respectively. In Ohio, Sollenberger et al. (46) found that weed content of alfalfa-orchardgrass did not exceed 0.2% of the stand while

alfalfa sown alone may contain over 50% weeds at the first harvest. Lack of significant differences among weed yields in some harvests was due to high variability in the hand separation samples. The hand samples were representative of the larger field since grass dispersion was not uniform.

Forage Quality

The alfalfa-orchardgrass mixture was lower in CP, higher in ADF and NDF at the first harvest, and higher in NDF at the second and third harvests than the weedy alfalfa in 1993 (Table 3). As a result, forage quality was often lower in the alfalfa-orchardgrass than in the weedy alfalfa. Alfalfa-bromegrass was lower in CP and higher in NDF while alfalfa-timothy was lower in CP than the weedy alfalfa at the first harvest only.

In 1994, all alfalfa-grass mixtures were lower in CP and higher in fiber content than the weedy alfalfa at the first harvest (Table 4). Fiber content was also greater in the alfalfa-orchardgrass than the weedy alfalfa at the third harvest.

The mixtures were often lower in forage quality than the weedy alfalfa at the first harvest (Tables 3 and 4). The alfalfa-orchardgrass was also lower in quality, at times, in the third harvest. Average grass content for each consecutive harvest was 48, 16, and 27%. Forage quality reductions were due in part to the grass proportion of the total forage. Average bromegrass, orchardgrass, and timothy content was 17, 54, and 22%. Given the large orchardgrass content in the forage, the reduction in forage quality was not surprising.

SUMMARY

Seeding alfalfa with perennial forage grasses did not provide a consistent increase in forage yield although total yield was increased by orchardgrass at the first harvest and annually. Alfalfa yields were generally lower in the alfalfa-orchardgrass mixtures than in other forages. Orchardgrass yields were often greater than those of bromegrass or timothy. Including orchardgrass with alfalfa was effective at reducing weed content. Forage quality, however, was also reduced by the orchardgrass. The effect of perennial grasses on weed invasion depended on the grass species. Harvest management must favor a high level of grass in the stand for effective reductions in weed content. The producer is faced with determining if a forage with an average of 24% weeds is more or less desirable than one with 54% orchardgrass, potentially greater yields, and reduced quality.

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Table 1. Component yields three years after seeding (1993).

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Annual total
		kg ha^{-1}			
Total	Weedy	4649b[a]	3231	2786	10666b
	+ bromegrass	5030ab	3406	2586	11022ab
	+ orchardgrass	6045a	3369	2759	12173a
	+ timothy	4978ab	3323	2811	11112ab
Alfalfa	Weedy	3993a	2976a	2202a	-
	+ bromegrass	3729a	2917a	2117a	-
	+ orchardgrass	1574c	1885b	1379b	-
	+ timothy	2896b	2844a	2340a	-
Grass	Weedy	-	-	-	-
	+ bromegrass	783c	131b	293b	-
	+ orchardgrass	4400a	1483a	1352a	-
	+ timothy	1797b	340b	305b	-
Total weeds	Weedy	656a	255	584a	-
	+ bromegrass	518ab	358	176b	-
	+ orchardgrass	71b	1	28b	-
	+ timothy	285ab	139	166b	-

[a] Means within a column and component followed by the same letters are not significantly different ($P<0.05$).

Table 2. Component yields four years after seeding (1994).

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3	Annual total
		kg ha^{-1}			
Total	Weedy	4528b[a]	3471a	2584bc	10583b
	+ bromegrass	6041a	3772a	3125a	12938a
	+ orchardgrass	5787a	3567a	3036ab	12390a
	+ timothy	5356ab	2949b	2341c	10646b
Alfalfa	Weedy	3540a	2517	1335a	-
	+ bromegrass	2474ab	2485	1608a	-
	+ orchardgrass	1540b	2410	1264ab	-
	+ timothy	2074b	2337	709b	-
Grass	Weedy	-	-	-	-
	+ bromegrass	2333b	699a	367b	-
	+ orchardgrass	4223a	1068a	1629a	-
	+ timothy	2557b	117b	535b	-
Total weeds	Weedy	988	954a	1249a	-
	+ bromegrass	1234	588ab	1150ab	-
	+ orchardgrass	24	89b	143b	-
	+ timothy	725	495ab	1097ab	-

[a] Means within a column and component followed by the same letters are not significantly different ($P<0.05$).

Table 3. Forage quality characteristics three years after seeding (1993).

Characteristic	Alfalfa	Harvest 1	Harvest 2	Harvest 3
		g kg^{-1}		
CP[a]	Weedy	198a[b]	183	189
	+ bromegrass	156b	181	199
	+ orchardgrass	90c	170	174
	+ timothy	158b	174	201
ADF	Weedy	356b	332	318
	+ bromegrass	368b	337	318
	+ orchardgrass	431a	331	313
	+ timothy	356b	326	318
NDF	Weedy	476c	465b	479b
	+ bromegrass	544b	475b	454b
	+ orchardgrass	699a	515a	520a
	+ timothy	531bc	470b	454b

[a] CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.
[b] Means within a column and characteristic followed by the same letters are not significantly different ($P<0.05$).

Table 4. Forage quality characteristics four years after seeding (1994).

Characteristic	Alfalfa	Harvest		
		1	2	3
		g kg^{-1}		
CP[a]	Weedy	167a[b]	189	186
	+ bromegrass	146b	181	186
	+ orchardgrass	138b	180	172
	+ timothy	138b	176	194
ADF	Weedy	288c	295	247b
	+ bromegrass	348a	318	280ab
	+ orchardgrass	352a	325	305a
	+ timothy	321b	302	281ab
NDF	Weedy	391b	414	358b
	+ bromegrass	552a	470	442ab
	+ orchardgrass	557a	477	498a
	+ timothy	535a	432	432ab

[a] CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.
[b] Means within a column and characteristic followed by the same letters are not significantly different ($P<0.05$).

APPENDIX

Table A1. Soil fertility at seeding.

	Low weed pressure		High weed pressure	
Characteristics	1993	1994	1993	1994
	---------- kg ha^{-1} ----------			
Phosphorus	46	76	105	121
Potassium	224	170	314	367
Calcium	3405	3666	4527	4480
Magnesium	521	566	681	660
pH	7.5	7.5	7.1	7.4
Texture	loam	loam	loam	loam

Table A2. Fertilization information.

		Low weed pressure		High weed pressure	
Fertilizer	kg/ha	1993 seeding	1994 seeding	1993 seeding	1994 seeding
		---------- 1993 ----------			
0-14-42	448	10 May	-	-	-
		---------- 1994 ----------			
0-0-60	392	11 April	-	11 April	-
0-0-60	134	-	5 May	1 April	5 May
		---------- 1995 ----------			
0-14-42	392	1 April	1 April	1 April	1 April

Table A3. Component percentages in the seeding year (average of 1993 and 1994 seedings) with low weed pressure.

		Harvest			
		1		2	
		Oat			
Component	Alfalfa	absent	present	absent	present
		% of total dry matter			
Alfalfa	Weed free	100	2.4	100	100
	Weedy	31.7	1.7	60.2	81.2
	+ bromegrass	27.6	2.4	58.6	75.2
	+ orchardgrass	29.6	1.4	49.1	77.6
	+ timothy	29.1	1.2	60.5	74.7
	+ Kentucky bluegrass	25.2	1.7	57.4	83.1
Grass	+ bromegrass	21.5	0.2	21.1	9.4
	+ orchardgrass	4.1	0.1	25.7	15.7
	+ timothy	7.9	0.2	20.6	7.4
	+ Kentucky bluegrass	1.2	0.0	4.5	0.9
Weeds	Weedy	68.3	3.4	39.8	18.8
	+ bromegrass	50.9	1.2	20.3	15.4
	+ orchardgrass	66.3	1.7	25.2	6.7
	+ timothy	63.0	2.9	18.9	17.9
	+ Kentucky bluegrass	73.6	2.6	38.1	16.0
Oats	Weed free	-	97.6	-	-
	Weedy	-	94.9	-	-
	+ bromegrass	-	96.2	-	-
	+ orchardgrass	-	96.8	-	-
	+ timothy	-	95.7	-	-
	+ Kentucky bluegrass	-	95.7	-	-

Table A4. Component percentages in the seeding year (average of 1993 and 1994 seedings) with high weed pressure.

		Harvest			
		1		2	
		Oat			
Component	Alfalfa	absent	present	absent	present
		% of total dry matter			
Alfalfa	Weed free	100	1.5	100	100
	Weedy	7.9	1.1	65.8	88.3
	+ bromegrass	7.6	1.0	58.5	82.9
	+ orchardgrass	8.5	1.5	51.4	87.3
	+ timothy	7.7	1.0	57.4	83.1
	+ Kentucky bluegrass	7.6	1.4	51.9	86.9
Grass	+ bromegrass	3.4	0.2	11.2	2.8
	+ orchardgrass	0.9	0.4	9.5	2.6
	+ timothy	1.5	0.2	8.5	2.9
	+ Kentucky bluegrass	0.2	0.1	1.0	0.5
Weeds	Weedy	92.1	3.6	34.2	11.7
	+ bromegrass	89.0	4.4	30.3	14.3
	+ orchardgrass	90.6	4.8	39.1	10.1
	+ timothy	90.8	4.7	34.1	14.0
	+ Kentucky bluegrass	92.2	3.8	47.1	12.6
Oats	Weed free	-	98.5	-	-
	Weedy	-	95.3	-	-
	+ bromegrass	-	94.4	-	-
	+ orchardgrass	-	93.3	-	-
	+ timothy	-	94.1	-	-
	+ Kentucky bluegrass	-	94.7	-	-

Table A5. Component percentages in the year after seeding (average of 1993 and 1994 seedings) with low weed pressure.

Component	Alfalfa	Harvest			
		1	2	3	4
		% of total dry matter			
Alfalfa	Weedy	98.6	97.6	98.7	99.1
	+ bromegrass	71.1	91.3	93.2	93.0
	+ orchardgrass	62.8	77.7	75.4	72.7
	+ timothy	74.1	94.9	98.1	98.0
	+ Kentucky bluegrass	89.1	87.9	88.0	85.8
Grass	+ bromegrass	26.0	8.1	5.5	6.0
	+ orchardgrass	36.7	21.9	24.5	27.3
	+ timothy	25.3	4.7	1.3	1.5
	+ Kentucky bluegrass	10.2	11.7	11.3	14.1
Weeds	Weedy	1.4	2.4	1.3	0.9
	+ bromegrass	2.9	0.6	1.3	0.9
	+ orchardgrass	0.5	0.4	0.1	0.1
	+ timothy	0.6	0.4	0.6	0.5
	+ Kentucky bluegrass	0.7	0.4	0.7	0.1

Table A6. Component percentages in the year after seeding (average of 1993 and 1994 seedings) with high weed pressure.

Component	Alfalfa	Harvest			
		1	2	3	4
		% of total dry matter			
Alfalfa	Weedy	96.7	98.6	98.5	99.3
	+ bromegrass	80.3	94.7	95.8	98.0
	+ orchardgrass	75.4	81.8	81.2	82.5
	+ timothy	79.7	94.7	98.4	98.9
	+ Kentucky bluegrass	92.5	90.5	94.3	93.5
Grass	+ bromegrass	17.1	4.6	2.4	1.6
	+ orchardgrass	24.0	17.6	18.4	17.3
	+ timothy	18.7	4.8	0.9	0.7
	+ Kentucky bluegrass	5.8	8.8	5.1	5.5
Weeds	Weedy	3.3	1.4	1.5	0.7
	+ bromegrass	2.6	0.7	1.8	0.4
	+ orchardgrass	0.6	0.6	0.4	0.2
	+ timothy	1.6	0.5	0.7	0.4
	+ Kentucky bluegrass	1.7	0.7	0.6	1.0

Table A7. Component percentages two years after seeding (1993 seeding only) with low weed pressure.

Component	Alfalfa	Harvest 1	2	3	4
		% of total dry matter			
Alfalfa	Weedy	96.2	97.7	97.1	98.7
	+ bromegrass	95.3	96.8	98.1	98.8
	+ orchardgrass	67.3	73.4	72.1	58.9
	+ timothy	96.3	98.2	98.2	98.2
	+ Kentucky bluegrass	86.5	87.4	81.8	61.4
Grass	+ bromegrass	1.3	0.2	0.2	0.5
	+ orchardgrass	32.4	26.3	27.9	41.0
	+ timothy	0.3	0.1	0.4	0.6
	+ Kentucky bluegrass	13.2	12.4	18.1	38.5
Weeds	Weedy	3.8	2.3	2.9	1.3
	+ bromegrass	3.4	3.0	1.7	0.7
	+ orchardgrass	0.3	0.3	0.0	0.1
	+ timothy	3.4	1.7	1.4	1.2
	+ Kentucky bluegrass	0.3	0.2	0.1	0.1

Table A8. Component percentages two years after seeding (1993 seeding only) with high weed pressure.

Component	Alfalfa	Harvest 1	2	3	4
		% of total dry matter			
Alfalfa	Weedy	95.1	96.6	96.7	98.0
	+ bromegrass	94.6	94.2	98.0	96.4
	+ orchardgrass	61.4	68.7	72.4	68.2
	+ timothy	95.4	96.8	99.4	99.2
	+ Kentucky bluegrass	85.2	88.9	87.5	75.4
Grass	+ bromegrass	1.4	1.4	0.6	0.6
	+ orchardgrass	38.5	31.0	27.6	31.7
	+ timothy	1.9	0.9	0.2	0.1
	+ Kentucky bluegrass	14.3	9.7	12.4	24.5
Weeds	Weedy	4.9	3.4	3.3	2.0
	+ bromegrass	4.0	4.4	1.4	3.0
	+ orchardgrass	0.1	0.3	0.0	0.1
	+ timothy	2.7	2.3	0.4	0.7
	+ Kentucky bluegrass	0.5	1.4	0.3	0.1

Table A9. Component percentages three years after seeding (1993).

Component	Alfalfa	Harvest 1	Harvest 2	Harvest 3
		% of total dry matter		
Alfalfa	Weedy	85.5	92.2	79.3
	+ bromegrass	73.8	85.9	81.9
	+ orchardgrass	25.9	56.9	50.0
	+ timothy	58.5	85.4	83.1
Grass	Weedy	-	-	-
	+ bromegrass	15.7	3.9	11.3
	+ orchardgrass	72.7	43.0	48.9
	+ timothy	35.8	10.4	10.9
Total weeds	Weedy	14.5	7.8	20.7
	+ bromegrass	10.5	10.2	6.8
	+ orchardgrass	1.4	0.1	1.1
	+ timothy	5.7	4.2	6.0
Broadleaves	Weedy	9.4	2.8	4.1
	+ bromegrass	4.6	0.6	3.2
	+ orchardgrass	0.5	0.0	0.8
	+ timothy	4.8	3.1	2.0
Grass weeds	Weedy	5.1	5.0	16.6
	+ bromegrass	5.9	9.6	3.6
	+ orchardgrass	0.9	0.1	0.3
	+ timothy	0.9	1.1	4.0

Table A10. Component percentages four years after seeding (1994).

Component	Alfalfa	Harvest		
		1	2	3
		% of total dry matter		
Alfalfa	Weedy	76.9	72.2	51.3
	+ bromegrass	40.5	65.1	51.8
	+ orchardgrass	26.5	67.5	41.7
	+ timothy	38.7	79.7	30.4
Grass	Weedy	-	-	-
	+ bromegrass	39.9	18.2	11.6
	+ orchardgrass	73.1	29.9	53.5
	+ timothy	47.6	4.2	23.4
Total weeds	Weedy	23.1	27.8	48.7
	+ bromegrass	19.6	16.7	36.6
	+ orchardgrass	0.4	2.6	4.8
	+ timothy	13.7	16.1	46.2
Broadleaves	Weedy	10.7	15.7	21.3
	+ bromegrass	5.3	8.4	21.7
	+ orchardgrass	0.3	1.6	3.4
	+ timothy	13.7	8.3	21.3
Grass weeds	Weedy	12.4	12.1	27.4
	+ bromegrass	14.3	8.3	14.9
	+ orchardgrass	0.1	1.0	1.4
	+ timothy	0.0	7.8	24.9