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ALTERNATIVE METHODS OF ALFALFA ESTABLISHMENT

By

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ABSTRACT

ALTERNATIVE METHODS OF ALFALFA ESTABLISHMENT

By

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Research was conducted in 1989 and 1990 to compare establishment methods for alfalfa. Similar forage yields were obtained between conventional tillage and no-tillage. In the first harvest, forage yield was generally higher where no herbicide was applied compared to where a herbicide was applied; however, alfalfa yield was often decreased. The effect of establishment herbicide was greatest in the first and second harvest of the establishment year. No effect of establishment herbicide was observed in the year following establishment. Weed yields in the year following establishment were generally reduced where alfalfa was seeded with a grass compared to alfalfa seeded alone. When alfalfa was seeded with oats, alfalfa yield in the first harvest was reduced compared to alfalfa seeded alone. In the year following establishment, alfalfa yield was often reduced where oats were harvested for grain.

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CHAPTER 1

REVIEW OF LITERATURE

ALFALFA PRODUCTION

In the past decade, seasonal average hay yield throughout the state of Michigan has increased from 6278 kg ha^{-1} in 1979 to 8071 kg ha^{-1} in 1989 (Michigan Agricultural Statistics, 1990). This may be a result of better management practices. Michigan State University recommends the following keys for high quality, high yielding forage (Helsel et al., 1980):

1) establish superior stands of high yielding variety;
2) provide adequate annual fertilization;
3) harvest early;
4) control pests (weeds, insects, and disease);
5) harvest and store properly.

Selection of variety should be based upon a) yield potential, b) maturity, c) stand persistence and d) pest resistance (Helsel et al., 1980). Seeding rate should be 13.5 to 18 kg ha^{-1} and for long term stands 18 kg ha^{-1} is recommended (Copeland et al., 1988; Tesar, 1984). Results from Faix et al. (1979) show a significantly higher alfalfa density the seeding year, where seeding rate was 13.5 kg ha^{-1} as compared to 7 kg ha^{-1}. The year following establishment no difference was observed. Seeds should be inoculated with specific rhizobia bacteria before planting (Tesar, 1984). This insures nodulation on the roots that take free nitrogen from the air and incorporate it into the plant (Tesar, 1984). Studies at Michigan

State University have shown no benefit from lime coated seed when planted in soil pH of 6.8 or higher, as recommended for good alfalfa production (Tesar, 1984). To obtain top yields, alfalfa should be established on well drained productive soils (Helsel et al., 1980). In the spring, plowing and one secondary tillage operation is adequate for seedbed preparation (Tesar, 1984). Band seeding or drilling alfalfa versus surface placement resulted in two to four times as many seedlings initially established and up to 2000 kg ha^{-1} more yield during the first season (Mueller and Chamblee, 1984; Tesar, 1984).

A soil test should be taken prior to seeding and recommendations followed. If pH is below 6.8, lime should be applied and incorporated 3 to 6 months before seeding to adjust the pH to 6.8 or higher (Tesar, 1984). Although a soil test annually would be optimal, a method of calculating nutrient removal may be used to calculate annual fertilization needs would be adequate (Helsel et al., 1980). At seeding time, high phosphorus levels are important for rapid root growth and strong seedling development (Tesar, 1984). Potassium increases alfalfa vigor, thus providing for winter hardiness and a productive stand for many years (Helsel et al., 1980; Tesar, 1984).

Cutting management is the next key to high producing forage. A 4-cut system (3 cuts by late August and a 4th in mid to late October) in southern Michigan will produce about 10% more forage than a 3-cut system, and a 3-cut system will produce approximately 25% more forage than a 2-cut system (Helsel et al., 1980). Recommended cutting schedules are based on a compromise of yield, quality, and stand persistence. If harvest is early, quality will be higher, but yield and stand vigor may be decreased. As harvest is delayed, forage quality continues to decline, yields may increase or may even decrease if leaves drop and future cuttings may be lost due to insufficient regrowth time.

Pest control begins with the first 3 keys, a good stand of quality alfalfa, proper fertilization to maintain vigor, and good cutting management. However, there are times when cultural practices need to be supplemented with herbicides, insecticides, and fungicides for pest control (Helsel et al., 1980). An annual grass companion crop seeded with the alfalfa may reduce the effects of weed competition of the seedling stand (Wolf et al., 1985).

Proper moisture is probably the most important factor involved in harvesting and storage (Helsel et al., 1980). Harvest losses increase as the forage dries because of leaf shattering from mechanical harvesting. However, storage losses decline as the moisture level of the forage decreases.

Alfalfa hay was produced on over 526,000 hectares in Michigan which was about 20 percent of the total land in field crop production in 1989 (Michigan Agricultural Statistics 1990). Approximately 263,000 hectares in Michigan are considered highly erodible[1]. Conservation tillage practices that result in stand establishment without disturbing the soil would be beneficial in reducing soil losses (Roth et al., 1985). In Michigan, no-tillage alfalfa establishment was up 116 percent to a total of 11,400 hectares in 1990 over 1989 (Grigar, 1990).

[1]Grigar, J. January 21, 1991. Personal Communication. United States Department of Agriculture, Soil Conservation Service, East Lansing, MI.

NO-TILLAGE CROP PRODUCTION

Soil tillage has played an important role in crop production. The primary reason for its use has been weed control. Spring tillage will destroy vegetation and create an even-start condition for crop and weed seeds (Staniforth and Wiese, 1985). Tillage has also been important for incorporation of herbicides and fertilizers, control of insects and diseases, for soil aeration, and removal of previous crop residue (Phillips and Phillips, 1984). Crop producers generally believe that a well prepared seedbed is necessary to promote rapid crop germination.

According to Sprague and Triplett (1986), conventional tillage systems may have only 2 to 5 percent soil surface coverage by crop residue in the spring following corn or soybeans. In no-tillage, crop residues may cover 60 to 80 percent of the soil surface the following spring. The absence of tillage may also increase soil water content (Thomas, 1986; Phillips and Phillips, 1984; Unger and McCalla, 1980). This is attributed, in part, to increased water infiltration due to improved soil structure and increased soil porosity (Triplett et al., 1986). Thomas (1986) reported that increased plant residue acts as a barrier which prevents diffusion of water vapor from the soil. This residue also reflects more incoming light than bare soil, resulting in decreased soil temperature and reduced water evaporation.

No-tillage crop production, often called no-tillage, zero till, or direct drill, is crop production without the use of tillage prior to planting. No-tillage crop production has many advantages and disadvantages compared to conventional tillage systems. Phillips and Phillips (1984) noted these advantages:

1. reduced soil erosion.
2. ability to crop erosive soils.

3. decreased labor requirements (up to 50%).

4. decreased fuel consumption.

5. decreased equipment costs.

The ability to reduce both soil erosion and crop production inputs has become increasingly important to crop producers. Phillips and Phillips (1984) also noted several disadvantages to no-tillage crop production. No-tillage planting operations are sometimes delayed due to high soil moisture content and lower soil temperatures as compared to conventional tillage systems. Incidence of diseases, insects, and rodent damage are also more prevalent in no-tillage crop production. The large quantity of crop residue remaining on the soil surface in no-tillage production favors the incidence of insects and diseases which overwinter in these residues. The use of tillage will bury residues thus generally reducing the incidence of insects and disease.

NO-TILLAGE ALFALFA PRODUCTION

No-tillage alfalfa seedings have been successful in a wide range of planting situations (Buhler and Proost, 1987; Faix et al., 1979; Grant et al., 1982; Linscott et al., 1969; Mueller-Warrant and Koch, 1983; Peters et al., 1984; Sprague, 1952; Taylor and Allinson, 1983; Wolf and Edmisten, 1989; Wolf and White, 1984). Successful alfalfa establishment by either conventional tillage or no-tillage depends on adequately controlling competing vegetation (Tesar and Jackobs, 1972; Martin et al., 1983; Wolf and White, 1984). Buhler and Proost have reported in preliminary work that alfalfa can be successfully established into untilled corn stubble, and that first year yields were similar to those attained with conventional seedings (data unreplicated). From this work they concluded that weed control may be one of the biggest problems with no-tillage alfalfa seedings following row crops.

Wolf and White (1984) reported that for successful establishment of alfalfa without tillage the following requirements must be met:

1. living competition must be eliminated.
2. heavy thatch and plant growth tall enough to shade the soil surface must be removed.
3. seedings must be protected against a wide spectrum of insects.
4. seeds must be completely covered with soil but no deeper than 2.5 centimeters.
5. soil fertility must be medium to high with pH 6.4 or higher.

There have been many successful attempts of establishing alfalfa without tillage into a perennial grass sod (Taylor and Allinson, 1983; Peters and Zaprzalka, 1981; Mueller-Warrant and Koch, 1983; Hagood, 1988; Martin et al., 1983; Roth et al. 1985). Sprague (1952) worked with chemical sod suppression for no-tillage pasture renovation prior to 1952, TCA was used to control the sod, and an adequate stand of ladino clover and orchardgrass was established.

WEED CONTROL IN ALFALFA

Control of existing vegetation is an essential part of establishing alfalfa, because alfalfa is generally slow to establish. (Tesar and Jackobs, 1972; Martin et al., 1983; Wolf and White, 1984). There are two general means of controlling existing vegetation prior to planting: a) cultural/mechanical and b) chemical. Cultural/mechanical control can include both tillage and mowing (Peters, 1964). Chemical control of existing vegetation, generally involves the use of contact herbicides, such as paraquat or glyphosate (Peters, 1964; Peters and Lowance, 1972; Wilson, 1986; Linscott, 1978; Roth et al., 1985). Peters (1964) reported mowing did not control broadleaf weeds to the same degree as did herbicides, but alfalfa yields from mowing after the first harvest were similar to herbicide treatments. Where perennial weeds are involved, a herbicide application of paraquat or glyphosate followed by double disking 3 days after application may be recommended (Linscott et al., 1969; Linscott et al., 1978). In a no-tillage situation, options are limited to mowing and herbicides to control existing vegetation. A combination of chemicals and mowing may be needed to kill and then remove the residue so shading of young seedlings does not occur. Paraquat and glyphosate have both been reported as giving adequate suppression of existing vegetation to allow for alfalfa establishment (Martin et al., 1983; Roth et al., 1985; Vogel, 1983; Wolf et al., 1989). Sod suppression with paraquat had no initial effect on alfalfa stand density and alfalfa yield, however about 20% less forage was obtained where paraquat was applied (Mueller and Chamblee, 1984). The reduction in forage yield appeared to be from weeds controlled by paraquat. Glyphosate generally only requires one application, but requires adequate coverage of leaf area for absorption and translocation (Wolf et al., 1989). For hard to control perennial weeds, such as quackgrass with paraquat, usually requires at least a split application approximately 6 weeks apart (Wolf et al., 1989), and is not recommended for this use (Kells and Renner, 1991).

EPTC and benefin may be used in conventional tillage for control of annual grasses and certain annual broadleaf weeds (Peters, 1964; Wilson, 1986). EPTC and benefin must be mechanically incorporated immediately after application, therefore neither are currently options for no-tillage. EPTC can effectively control weeds without reducing stand density or causing significant injury to the alfalfa (Wilson, 1986; Peters, 1964).

Postemergence herbicides are options for both conventional tillage and no-tillage. 2,4-DB and bromoxynil are two postemergence herbicides that selectively control annual broadleaf weeds. Excellent control with 2,4-DB has been reported (Wilson, 1986; Peters, 1964; Peters and Lowance, 1972). Bromoxynil also provides excellent control of annual broadleaf weeds, however if air temperature exceeds 21 C within 3 days after application unacceptable injury may occur (Kells and Renner, 1991; Cosgrove, 1990). Sethoxydim is a selective postemergence herbicide which controls most annual grasses in alfalfa (Cosgrove, 1990; Kells and Renner, 1991). Grasses must be actively growing for best results.

With the use of herbicides, a weed control program may be designed to control most weed problems, but in alfalfa is herbicidal weed control necessary? Forage yield in the first cutting are sometimes reduced where a herbicide is applied (Dutt et al., 1983; Wilson, 1986; Fawcett and Harvey, 1978). The yield reductions probably reflected reductions in weed populations due to herbicide treatments (Wilson, 1986; Fawcett and Harvey, 1978). Wilson (1986) also reported that second cutting forage yields were higher where EPTC and 2,4-DB was applied compared to the untreated plots. Annual weeds did not affect stand density.

Wilson (1986) also reported herbicide treatments did not affect crude protein content of first or second cutting forage. Annual weeds were found by Martin and Anderson (1975) to differ in crude protein content. Redroot pigweed (24%), common lambsquarters (26%), and common cocklebur (24%) had similar crude protein content similar to alfalfa (26%), while crude protein content of yellow foxtail (22%) and barnyardgrass (22%) was significantly lower than that of alfalfa. Peters et al. (1984) reported alfalfa yield to be similar where herbicides were applied compared to the untreated plots. Controlling broadleaf weeds with herbicides such as 2,4-DB generally increased yield of grassy weeds (Peters, 1964). The year following establishment, alfalfa yield and alfalfa stand density were not significantly different due to treatments of EPTC or 2,4-DB (Peters, 1964).

Are weeds a problem in established stands? In some studies, weed control has resulted in increased alfalfa yields (Harvey et al., 1976; Kapusta and Stricker, 1976) and in others, yields were similar or reduced from the control (Robins et al., 1978; Swan, 1978). Cosgrove and Barrett (1987) reported that alfalfa yield may be increased by weed control in established stands of alfalfa, but these increases are dependent on stand density and the degree of weed infestation. In a case of severe weed infestation, removal of the weed component of the total forage by a herbicide application may cause a decrease in first harvest forage yield. However, this will increase the percentage of alfalfa. If the weed infestation is light, very little benefit is realized from herbicide application, since alfalfa percentage is already high and weed infestation is not limiting production. Wilson (1981) has reported controlling weeds in established alfalfa may increase yield and quality.

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CHAPTER 2

COMPARISON OF TILLAGE SYSTEMS AND WEED CONTROL PROGRAMS FOR ALFALFA ESTABLISHMENT

ABSTRACT

Research was conducted in 1989 and 1990 to compare establishment systems for alfalfa. Treatments included a comparison of conventional tillage and no-tillage for establishment of alfalfa in the spring following corn harvested for silage. Within each tillage system a series of four weed control programs varying in herbicide intensity were compared. Alfalfa plant densities 45 days after planting were higher for conventional tillage than no-tillage in 1989; however in 1990 alfalfa plant densities were not significantly different between tillage systems. By the fall of both years, there were no differences in alfalfa plant density. Total forage yield was not significantly different between tillage systems in the establishment year for both years, or the year following establishment for the 1989 seeding. In the first harvest with conventional tillage in 1989, there was a higher total forage yield when no herbicide was used than where a herbicide was used; however, there was no difference in pure alfalfa yield between weed control programs. In no-tillage, there was no significant difference in total forage yield; however, there was a higher pure alfalfa yield where the intense herbicide program was used than the no herbicide program. By the third harvest of the 1989 seeding and the second harvest of the 1990 seeding of the establishment year, there were no differences in forage yield or alfalfa yield between herbicide programs. In the first harvest

with no-tillage, there was a significantly higher total forage yield when no herbicide was used than the intense herbicide program; however the intense herbicide program had a higher alfalfa yield than the no herbicide program in both years. In 1989 in the third harvest, there was no difference in total forage yield between weed control programs, but the intense herbicide program still had a higher alfalfa yield than the no herbicide program. In 1990 by the second harvest, there were no differences in forage yield or alfalfa yield between weed control programs. No significant differences were observed between herbicide programs in either tillage system the year following establishment of the 1989 seeding.

Nomenclature: alfalfa, *Medicago sativa* L.; corn, *Zea mays* L.

INTRODUCTION

Alfalfa establishment has been accomplished by seeding into a conventionally tilled seedbed, usually prepared by both primary and secondary tillage operations. Preplant incorporated herbicides or an annual grass companion crop have been used to reduce the effect of weed competition with the alfalfa seedlings (Wolf et al., 1985). Seed is usually broadcast or drilled, followed by packing to create adequate seed to soil contact. This type of establishment would leave the soil vulnerable to erosion. With nearly 10 percent of Michigan's land in crop production classified as highly erodible, it would be very desirable to establish alfalfa without tillage[1].

No-tillage seedings have been successful in a wide range of planting situations (Mueller-Warrent and Koch, 1980; Wolf et. al., 1985). Research has shown that yields of alfalfa established without tillage using either glyphosate [N-(phosphonomethyl)glycine] or paraquat (1,1'-dimethyl-4-4'-bibyridinium ion) were equivalent or better than yields obtained from conventional seeding (Roth et. al. 1985). Most research has involved seeding alfalfa into a grass sod or permanent pasture, while comparatively little research has been reported for alfalfa seedings following corn. Buhler and Proost (1987) reported first year forage yields were similar to those attained with conventional seeding following corn (data unreplicated).

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[1]Grigar, J. January 21, 1991. Personal Communication. United States Department of Agriculture, Soil Conservation Service, East Lansing, MI.

From this preliminary work, they concluded that weed control may be one of the biggest problems with no-tillage alfalfa seedings.

Non-selective herbicides are appropriate to control existing vegetation prior to planting. Paraquat has been shown to provide control of existing vegetation before planting (Taylor et. al., 1969; Martin et.al., 1983). The use of selective herbicides is limited to post emergence herbicides. EPTC (S-ethyl dipropylcarbamothioate) is a common preplant incorporated herbicide that is very effective in controlling annual grasses. However since EPTC must be mechanically incorporated it is not an option in a no-tillage system. Sethoxydim[2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] and 2,4-DB [(2,4-dichlorophenoxy)acetic acid] are two common selective herbicides used in alfalfa. Sethoxydim is used to control most annual grasses, and 2,4-DB is used to control broadleaf weeds. Research has shown that 2,4-DB does not increase alfalfa plant density, however alfalfa yield was significantly higher where 2,4-DB had been applied (Sand and McCarthy, 1959; Peters and Lowance, 1971).

Wilson (1986) reported annual weeds did not reduce alfalfa stand density compared to where herbicides were used to control the weeds. Where weeds were controlled by herbicides in seedling alfalfa, total forage yield was reduced compared to the untreated in the first harvest (Dutt et al., 1983; Fawcett and Harvey, 1978; Wilson, 1986). Wilson (1986) also reported that second cutting forage yields were higher where herbicides were applied than where no herbicide was applied. However, Peters et al. (1984) reported similar alfalfa yield where herbicides were applied compared to the untreated plots.

The objectives of this study were: 1) to determine the effects of establishment methods (no-tillage verses conventional tillage) for alfalfa on plant density, and forage yield, and 2) to study the effect of weed control systems on alfalfa density, weed density, forage yield and its components in both conventional tillage and no-tillage.

MATERIALS AND METHODS

Research was conducted in adjacent experimental areas in 1989 and 1990 at the Kellogg Biological Station, Hickory Corners, Michigan. The soil type was a Kalamazoo sandy loam (coarse-loamy, mixed, mesic Typic Hapludalf). Results from two soil tests taken in the fall of 1988 and spring of 1990, for both experimental areas, are summarized in Table 1. Lime was applied on November 3, 1988 at 2240 kg ha^{-1}, to both experimental areas, to adjust soil pH. Proper potassium level was obtained through the addition of 448 kg ha^{-1} of K_2O in the form of 0-0-60 on April 24, 1990 to the 1990 experimental area. Potassium was not required for the 1989 experimental area. Glyphosate was applied to both experimental areas at 2.2 kg ha^{-1} on September 27, 1988 and to the 1990 experimental area on September 29, 1989 to control quackgrass.

The study was conducted in a split plot design with four replications. Main plots consisted of two tillage systems, conventional tillage and no-tillage. Sub-plots consisted of four weed control programs varying in herbicide intensity. Plots were 2.4 meters wide and 9.1 meters in length.

'Big Ten' alfalfa was seeded on May 5 and May 2 for the 1989 and 1990 seedings, respectfully. In 1989, a seeder[2] equipped with power coulters spaced 12.3 cm apart was

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[2]John Deere Power-Till Drill, John Deere Co. Inc., Moline, Illinois.

Table 1. Results of soil tests for the 1989 and 1990 experimental areas.

	1989 Experimental Area		1990 Experimental Area	
	1988 Soil Test	1990 Soil Test	1988 Soil Test	1990 Soil Test
pH	6.1	6.3	5.8	5.9
Organic Matter (%)	2.3	2.3	2.1	2.1
Calcium (kg/ha)	1971	1971	1971	1707
Magnesium (kg/ha)	395	385	403	358
Phosphorus (kg/ha)	309	314	371	475
Potassium (kg/ha)	517	380	369	248

used, and in 1990 a seeder[3] utilizing a fluted coulter and double disk openers spaced 12.3 cm apart was used. Both seeders were calibrated to deliver 16.8 kg ha^{-1}, and place seed 0.5 cm deep. The conventional tillage seedbed was prepared by moldboard plowing in the spring followed immediately with one pass with a tandem disk about one week before planting. Two passes with a shovel cultivator at a depth of 7.5 cm was used to prepared the final seedbed and also provide incorporation for preplant incorporated herbicide treatments. The no-tillage seedbed consisted of corn residue that was harvested for silage in the fall prior to seeding.

Herbicides were applied with a tractor mounted compressed air sprayer. All applications utilized 8003 flat fan[4] nozzles which delivered 206 L ha^{-1} at a spray pressure of 248 kPa. Herbicide programs included: 1) no herbicide; 2) paraquat (.5 kg ha^{-1}); 3) paraquat (.5 kg ha^{-1}) + 2,4-DB (1.1 kg ha^{-1}); 4) EPTC (3.3 kg ha $^{-1}$) + paraquat (.5 kg ha^{-1}) + 2,4-DB (1.1 kg ha^{-1}). EPTC treatments were applied preplant incorporated in conventional tillage plots and surface applied in no-tillage plots, on May 3 and May 1 for the 1989 and 1990 seedings, respectfully. Non ionic surfactant was added to all paraquat treatments at 0.25% v/v. Paraquat treatments were surface applied immediately prior to seeding. 2,4-DB was applied postemergence to alfalfa at the 1 to 2 trifoliolate leaf stage on June 6 and June 7 for the 1989 and 1990 seedings, respectfully.

The herbicide treatments were chosen so that the study would provide data on both herbicide programs and tillage systems. One herbicide treatment within each tillage system is considered impractical, however they were included to complete the factorial design and to allow for direct comparisons between tillage systems.

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[3]Tye No-Tillage Drill, The Tye Co., Lockney, Texas.

[4]Spraying Systems Co., North Ave. and Schmale Road, Wheaton, IL 60188.

Populations of alfalfa and the three dominant weed species were determined on June 19 and June 18, for the 1989 and 1990 seedings, respectfully. Dominant weed species were redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.), and velvetleaf (*Abutilon theophrasti* Medicus) in 1989, and common chickweed (*Stellaria media* (L.) Vill.), common lambsquarters, and velvetleaf in 1990. Plant populations are reported as the mean of three 1 m^2 quadrats per plot selected at random. Alfalfa populations were also determined in the fall of the establishment year on November 20, 1989 and November 9, 1990. For the 1989 seeding, alfalfa plant density was evaluated in the spring of the year following establishment on April 24, 1990.

Three forage harvests were made in the year of establishment for both the 1989 and 1990 seedings, and four harvests were made in the year following establishment for the 1989 seeding. Harvest dates for the 1989 seeding were July 14, August 23, and October 10, 1989, and May 30, July 5, August, 14 and October 23, 1990. Harvest dates for the 1990 seeding July 25, September 4, and October 23, 1990. An area 1.2 meters wide and 9.1 meters in length was harvested from the center of each plot with a mechanical flail harvester[5]. The total forage fresh weight from this area was measured. A random sub-sample was collected from the harvested forage and the fresh weight of the sub-sample was measured. Sub-samples were oven dried and dry weights were measured. Total forage dry weight yield was calculated.

A sample was also collected at each harvest to determine forage composition. Samples were collected by cutting a strip along the edge of the harvested area 20 cm wide and 9.1 meters in length, then randomly collecting a 300 to 400 gram sample. Samples were separated into fractions of alfalfa, dominant weed species, other broadleaf weeds and other

[5]Carter Manufacturing Co. Inc., Brookston, IN.

grassy weeds. Dominant weeds were redroot pigweed, common lambsquarters, and velvetleaf in 1989, and common lambsquarters, velvetleaf, and common chickweed in 1990. Samples were oven dried and weights measured. Weights were used to calculate percent forage composition.

Analyses of variance were performed on the data and means were separated by least significant difference at the 5% level of significance.

RESULTS AND DISCUSSION

Comparison of Tillage Systems. At the spring evaluation for the 1989 seeding, conventional tillage treatments had on average 77 plants m^{-2} more alfalfa plants than no-tillage treatments (Table 2). This difference may be due to the seeder used in 1989. This seeder did not adequately close the slot to produce good seed to soil contact in the no-tillage area. At the fall evaluation and the spring following the year of establishment, no significant difference in alfalfa density was observed. No significant difference was observed at either the spring or fall evaluation in the year of establishment for the 1990 seeding, however in the spring there was a trend towards a higher plant density in no-tillage. Wolf and White (1984) reported significantly higher alfalfa plant densities in no-tillage than conventional tillage in the spring following establishment. At the fall evaluation, the alfalfa density between the two years was nearly identical.

In the 1989 seeding, redroot pigweed and common lambsquarters density was higher in conventional tillage than no-tillage where no herbicide, and paraquat + 2,4-DB had been applied (Table 3). Common lambsquarters also had a higher plant density in conventional

Table 2. **Influence of tillage systems and herbicide programs on alfalfa densities seeded in the spring of 1989 and 1990 at the Kellogg Biological Station, Hickory Corners, Michigan.**

Establishment Program	Year of Establishment Spring	Year of Establishment Fall	Year following Establishment Spring
	(plants m^{-2})		
	1989 Seeding		
Conventional Tillage			
No Herbicide	233	136	91
Paraquat	192	151	95
Paraquat + 2,4-DB	185	132	86
EPTC + Paraquat + 2,4-DB	208	147	109
No-Tillage			
No Herbicide	101	101	84
Paraquat	151	108	89
Paraquat + 2,4-DB	137	109	81
EPTC + Paraquat + 2,4-DB	121	116	87
$LSD_{(.05)}$[a]	70.9	N.S.	N.S.
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.
	1990 Seeding		
Conventional tillage			
No Herbicide	193	102	--
Paraquat	194	101	--
Paraquat + 2,4-DB	195	97	--
EPTC + Paraquat + 2,4-DB	165	110	--
No-Tillage			
No Herbicide	204	109	--
Paraquat	269	111	--
Paraquat + 2,4-DB	290	114	--
EPTC + Paraquat + 2,4-DB	270	106	--
$LSD_{(.05)}$[a]	N.S.	N.S.	--
$LSD_{(.05)}$[b]	N.S.	N.S.	--

[a]Comparisons valid between tillage systems within herbicide programs and years.
[b]Comparisons valid between herbicide programs within tillage systems and years.

Table 3. Influence of tillage systems and herbicide programs on dominant weed specie densities in 1989 and 1990 seedings of alfalfa at Kellogg Biological Station, Hickory Corners, Michigan.

	1989 Seeding			1990 Seeding		
	AMARE[a]	CHEAL[a]	ABUTH[a]	CHEAL[a]	ABUTH[a]	STEME[a]
	(plants m^{-2})					
Conventional Tillage						
No Herbicide	133	30	59	4	92	125
Paraquat	62	30	22	2	67	120
Paraquat + 2,4-DB	161	18	20	3	70	147
EPTC + Paraquat + 2,4-DB	8	0	1	1	16	11
No-Tillage						
No Herbicide	4	17	2	1	0	18
Paraquat	32	1	4	1	3	13
Paraquat + 2,4-DB	24	0	4	1	1	25
EPTC + Paraquat + 2,4-DB	7	0	2	0	1	10
$LSD_{(.05)}$[b]	50.0	11.5	N.S.	N.S.	N.S.	45.4
$LSD_{(.05)}$[c]	57.2	17.0	N.S.	N.S.	N.S.	65.1

[a]AMARE=redroot pigweed; CHEAL=common lambsquarters; ABUTH=velvetleaf; STEME= common chickweed.
[b]Comparisons valid between tillage systems within herbicide programs.
[c]Comparisons valid between herbicide programs within tillage systems.

than no-tillage where paraquat was applied. In 1990, common chickweed density was higher in conventional tillage where no herbicide, paraquat, and paraquat + 2,4-DB had been applied. Common lambsquarters density was not significantly different between tillage systems in 1990. Velvetleaf density in both the 1989 and 1990 seedings was not significantly different, however there was a trend toward a higher plant density in conventional tillage than no tillage. Buhler and Daniel (1988) reported that velvetleaf density in corn 56 days after planting was 120 plants m^{-2} in conventional tillage compared to 20 plants m^{-2} in no tillage. In the no-tillage system, there were more winter annual and simple perennial weeds, such as horseweed and curly dock, however weed species were variable throughout the plot area. The higher density of winter annual and perennial weeds in no-tillage may have impeded the germination of the summer annual weeds.

In the year of establishment, no differences were observed in total forage yield and alfalfa yield between tillage systems (Table 4). This is similar to research conducted by Buhler and Proost (1987), Wolf and Edmisten (1989), Wolf et al., (1985), and Wolf and White, (1984). In the first harvest of the 1989 seeding, where no herbicide was applied, a lower yield of broadleaf weeds and total weeds was observed in conventional tillage compared to no-tillage. This is consistent with the weed density data. This difference was not observed in the 1990 seeding (Table 5). At the second and third harvest for both years, no differences were observed in yield of total broadleaf weeds, total grassy weeds, and total weeds, except in the third harvest of 1989 where paraquat was applied, there was a lower total grassy weed yield in conventional tillage than in no-tillage. In the 1989 seeding, no significant difference in yield of redroot pigweed or common lambsquarters was observed between tillage systems at any harvest of the establishment year (Table 4). In the 1990 seeding, no significant difference in yield of common lambsquarters or common chickweed

Table 4. Influence of tillage systems and herbicide programs on total forage, alfalfa and weed yields for the year of establishment of the 1989 alfalfa seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Establishment Program	Yield: Forage	Alfalfa	AMARE[a]	CHEAL[a]	ABUTH[a]	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})							
Harvest 1								
Conventional Tillage								
No Herbicide	410	223	46	116	1	176	11	187
Paraquat	425	298	34	60	4	122	5	127
Paraquat + 2,4-DB	297	282	1	0	0	8	7	15
EPTC + Paraquat + 2,4-DB	280	273	0	0	0	4	3	7
No-Tillage								
No Herbicide	481	77	11	62	0	400	4	404
Paraquat	311	186	62	7	3	119	6	125
Paraquat + 2,4-DB	275	254	5	0	0	8	13	21
EPTC + Paraquat + 2,4-DB	264	251	2	0	0	12	1	13
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	115	N.S.	115
$LSD_{(.05)}$[c]	84	94	27	77	N.S.	117	N.S.	119
Harvest 2								
Conventional Tillage								
No Herbicide	236	203	12	9	0	21	12	33
Paraquat	197	164	6	0	0	12	21	33
Paraquat + 2,4-DB	251	218	3	0	0	1	32	33
EPTC + Paraquat + 2,4-DB	260	255	0	1	0	1	4	5
No-Tillage								
No Herbicide	174	125	11	8	0	40	9	49
Paraquat	238	164	27	0	0	14	60	74
Paraquat + 2,4-DB	273	177	68	0	0	15	81	96
EPTC + Paraquat + 2,4-DB	247	235	9	0	0	2	10	12
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}$[c]	49	40	N.S.	N.S.	N.S.	15	41	43
Harvest 3								
Conventional Tillage								
No Herbicide	165	162	0	0	0	2	1	3
Paraquat	170	170	0	0	0	0	0	0
Paraquat + 2,4-DB	168	165	0	0	0	0	3	3
EPTC + Paraquat + 2,4-DB	189	189	0	0	0	0	0	0
No-Tillage								
No Herbicide	109	102	0	0	0	2	5	7
Paraquat	125	114	0	0	0	1	10	11
Paraquat + 2,4-DB	157	152	0	0	0	1	4	5
EPTC + Paraquat + 2,4-DB	141	141	0	0	0	0	0	0
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	6	7
$LSD_{(.05)}$[c]	N.S.	32	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid between tillage systems within herbicide programs.
[c]Comparisons valid between herbicide programs within tillage systems.

Table 5. Influence of tillage systems and herbicide programs on total forage, alfalfa and weed yields for the year of establishment of the 1990 alfalfa seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Establishment Program	Yield: Forage	Alfalfa	CHEAL[a]	ABUTH[a]	STEME[a]	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})							
Harvest 1								
Conventional Tillage								
No Herbicide	351	196	69	32	0	149	6	155
Paraquat	367	172	5	76	0	193	2	195
Paraquat + 2,4-DB	274	251	0	0	0	12	11	23
EPTC + Paraquat + 2,4-DB	319	306	0	1	0	13	0	13
No-Tillage								
No Herbicide	372	216	18	4	0	152	4	156
Paraquat	335	294	22	0	0	36	5	41
Paraquat + 2,4-DB	299	289	0	0	0	8	2	10
EPTC + Paraquat + 2,4-DB	312	303	0	0	0	3	6	9
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	31	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}$[c]	46	82	29	26	N.S.	50	N.S.	48
Harvest 2								
Conventional Tillage								
No Herbicide	295	269	0	0	0	7	19	26
Paraquat	255	240	0	0	0	6	9	15
Paraquat + 2,4-DB	297	256	0	0	0	13	28	41
EPTC + Paraquat + 2,4-DB	287	285	0	0	0	0	2	2
No-Tillage								
No Herbicide	245	229	0	0	0	3	13	16
Paraquat	248	243	0	0	0	0	5	5
Paraquat + 2,4-DB	297	286	0	0	0	6	5	11
EPTC + Paraquat + 2,4-DB	262	255	0	0	0	0	7	7
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}$[c]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	22
Harvest 3								
Conventional Tillage								
No Herbicide	144	142	0	0	0	2	0	2
Paraquat	160	154	0	4	0	6	0	6
Paraquat + 2,4-DB	147	146	0	0	0	0	1	1
EPTC + Paraquat + 2,4-DB	170	170	0	0	0	0	0	0
No-Tillage								
No Herbicide	149	143	0	0	0	3	3	6
Paraquat	149	148	0	0	0	0	1	1
Paraquat + 2,4-DB	174	173	0	0	0	0	1	1
EPTC + Paraquat + 2,4-DB	159	159	0	0	0	0	0	0
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}$[c]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[a]CHEAL = common lambsquarters; ABUTH = velvetleaf; STEME = common chickweed.
[b]Comparisons valid between tillage systems within herbicide programs.
[c]Comparisons valid between herbicide programs within tillage systems.

was observed between tillage systems at any harvest of the establishment year (Table 5). Velvetleaf yield at the first harvest was higher in conventional tillage than in no-tillage where paraquat had been applied. After the first harvest, no significant differences were observed in velvetleaf yield.

In the year following the 1989 seeding, there were no significant differences in total broadleaf weed yield, total grassy weed yield, or total weed yield between tillage systems at any of the four harvests (Table 6). In the first harvest, there was no difference in total forage yield between tillage systems. However, where paraquat had been applied, there was a higher alfalfa yield in conventional tillage than no-tillage. In the second harvest, there was a higher total forage yield and alfalfa yield in conventional tillage than without tillage where paraquat, or paraquat + 2,4-DB were applied. In the third and fourth harvests, there were no differences between tillage systems for total forage yield and alfalfa yield. Reasons for these occasional differences between tillage systems in the year following establishment are not understood.

Comparison of Herbicide Programs within Conventional Tillage. At each evaluation time for alfalfa density, no differences were observed among herbicide programs in conventional tillage (Table 2). Wilson (1986) reported that herbicides did not affect alfalfa plant density. There were no significant differences between herbicide systems in forage yield, alfalfa yield, and weed yield in the third harvest of the establishment year and the year following establishment for the 1989 seeding, or the second and third harvest of the establishment year for the 1990 seeding (Tables 4, 5).

In the first harvest in both the 1989 and 1990 seedings, there was a higher forage yield where only paraquat was applied as compared to where paraquat + 2,4-DB and EPTC + paraquat + 2,4-DB was applied (Tables 4, 5). Wilson (1986) also reported lower forage yields where herbicides were applied compared to untreated areas. In 1989, pure alfalfa

Table 6. Influence of tillage systems and herbicide programs on total forage, alfalfa and weed yields for the year following establishment, of the 1989 alfalfa seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Establishment Program	Forage	Alfalfa	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	Yield (10 kg ha^{-1})				
	Harvest 1				
Conventional Tillage					
No Herbicide	539	521	7	12	19
Paraquat	588	570	14	4	18
Paraquat + 2,4-DB	587	566	3	18	21
EPTC + Paraquat + 2,4-DB	542	540	1	1	2
No-Tillage					
No Herbicide	527	482	26	19	45
Paraquat	577	491	8	78	86
Paraquat + 2,4-DB	559	540	1	18	19
EPTC + Paraquat + 2,4-DB	608	570	1	37	38
$LSD_{(.05)}^{b}$	N.S.	61	N.S.	N.S.	N.S.
$LSD_{(.05)}^{c}$	N.S.	N.S.	N.S.	N.S.	N.S.
	Harvest 2				
Conventional Tillage					
No Herbicide	374	363	8	3	11
Paraquat	406	392	6	8	14
Paraquat + 2,4-DB	399	392	0	7	7
EPTC + Paraquat + 2,4-DB	381	381	0	0	0
No-Tillage					
No Herbicide	324	292	4	28	32
Paraquat	330	313	0	17	17
Paraquat + 2,4-DB	340	331	2	7	9
EPTC + Paraquat + 2,4-DB	360	350	0	10	10
$LSD_{(.05)}^{b}$	54	58	N.S.	N.S.	N.S.
$LSD_{(.05)}^{c}$	N.S.	N.S.	N.S.	N.S.	N.S.
	Harvest 3				
Conventional Tillage					
No Herbicide	307	289	7	11	18
Paraquat	304	297	0	7	7
Paraquat + 2,4-DB	293	279	0	14	14
EPTC + Paraquat + 2,4-DB	311	310	1	0	1
No-Tillage					
No Herbicide	286	274	1	11	12
Paraquat	281	264	2	15	17
Paraquat + 2,4-DB	291	281	0	10	10
EPTC + Paraquat + 2,4-DB	303	278	0	25	25
$LSD_{(.05)}^{b}$	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}^{c}$	N.S.	N.S.	N.S.	N.S.	N.S.

Continued next page.

Table 6. (continued).

Establishment Program	Yield: Forage	Alfalfa	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	------------------------------------(10 kg ha^{-1})------------------------------------				
	Harvest 4				
Conventional Tillage					
No Herbicide	277	246	1	30	31
Paraquat	253	249	0	4	4
Paraquat + 2,4-DB	263	254	8	1	9
EPTC + Paraquat + 2,4-DB	249	246	0	3	3
No-Herbicide					
No Herbicide	244	226	1	17	18
Paraquat	262	236	1	25	26
Paraquat + 2,4-DB	238	228	0	10	10
EPTC + Paraquat + 2,4-DB	242	219	1	22	23
$LSD_{(.05)}$[a]	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.

[a]Comparisons valid between tillage systems within herbicide programs.
[b]Comparisons valid between herbicide programs within tillage systems.

yield was not significantly affected by the herbicide treatment, however in 1990 where paraquat was applied alone pure alfalfa yield was 43 percent lower than where EPTC + paraquat + 2,4-DB was applied. Peters et al. (1984) reported similar alfalfa yields where herbicides were applied compared to untreated areas.

No significant differences were observed in forage yield, alfalfa yield and weed yield between the no herbicide treatment and the paraquat alone treatment at all harvests except the first harvest of the 1990 seeding. Common lambsquarters had a higher yield where no herbicide was applied. In contrast, velvetleaf had a higher yield where paraquat was applied. The basis of these differences are not clear. Paraquat is strongly adsorbed onto soil particles and rendered inactive (Ashton and Crafts, 1981; Coats et al., 1966; Corbin et al., 1965). The contribution of these weed species to the total broadleaf weed yield resulted in no significant difference in total broadleaf weed yield between these two herbicide treatments.

Broadleaf weed yields were significantly reduced in the first harvest where 2,4-DB was applied in both 1989 and 1990. No significant differences were observed in grassy weed yield at any harvest between herbicide systems (Tables 4, 5). This may be due to low grass density in the experimental area, however there is a trend in both years that EPTC did control most of the grass, and in the 1989 some of the broadleaf weeds. Since there was no difference in grass yield, total weed yield followed a similar pattern to the broadleaf weed yield.

In the second harvest in 1989, lower forage yield and alfalfa yield was obtained where paraquat was applied alone than where paraquat + 2,4-DB or EPTC + paraquat + 2,4-DB was applied (Tables 4, 5). There were no significant differences in total broadleaf weed yield, grassy weed yield, or total weed yield. Therefore, this yield reduction might be related to intense weed pressure prior to the first harvest. In 1990, no significant differences were observed in the second harvest for forage yield, alfalfa yield, total broadleaf weeds yield or total grassy weed yield.

In the third harvest of the establishment year, for both the 1989 and 1990 seedings, there were no significant differences in yield of individual species or groups of species (Tables 4, 5). This trend continued through the year following establishment (Table 6). Peters has also reported similar results of no differences in yield the year following establishment due to herbicide treatments.

Comparisons of Herbicide Programs within No-Tillage. As was observed in conventional tillage, alfalfa densities were not significantly different between herbicide programs at any evaluation time (Table 2). No differences were observed in redroot pigweed, common lambsquarters, or velvetleaf density between herbicide programs in 1989, or common chickweed, common lambsquarters, or velvetleaf density in 1990 (Table 3). This may be due to the low and variable density of these species in the no-tillage treatments.

In the first harvest of the 1989 seeding, forage yield, total broadleaf yield, and total weed yield was higher where no herbicide was applied as compared to where a herbicide was applied (Table 4). In 1990, total forage yield where no herbicide was applied was not significantly different than where paraquat was applied alone (Table 5). However where a 2,4-DB application followed paraquat, total forage yield was significantly lower compared to the no herbicide treatment. Alfalfa yield in 1990 was not significantly different among no herbicide, paraquat, and paraquat + 2,4-DB. This is consistent with Peters (1964) and also the results found in conventional tillage. Other than a reduction in redroot pigweed yield in the first harvest there was no significant effect of the addition of 2,4-DB over paraquat applied alone in either year.

In the second harvest for the 1989 seeding, a lower forage yield and alfalfa yield was observed where no herbicide was applied compared to all other herbicide programs (Table

4). In the second harvest of the 1990 seeding, no significant yield differences were observed (Table 5). In the third harvest of the 1989 seeding, alfalfa yield was significantly lower where no herbicide was applied compared to where paraquat + 2,4-DB was applied. No other differences were observed in the third harvest of the 1989 seeding, and no differences were observed in the third harvest of the 1990 seeding. In the year following establishment for the 1989 seeding, no difference existed among herbicide programs (Table 6).

No significant differences were observed between paraquat + 2,4-DB and EPTC + paraquat + 2,4-DB treatments at any harvest except the second harvest of the establishment year in the 1989 seeding (Table 4). Alfalfa yield was significantly increased where EPTC + paraquat + 2,4-DB was applied over all other treatments. Also, significantly lower grass yield and total weed yield compared with the paraquat and paraquat + 2,4-DB treatments was observed. The EPTC surface-applied to the no-tillage plots may have been incorporated by rainfall of 1 cm on May 4, 1989, before the EPTC was lost due to volatilization.

Economic Comparisons of Tillage Systems and Weed Control Programs. Included in this section is a no herbicide treatment and the intense herbicide treatment within each tillage system. In conventional tillage, all treatments reported received an application of paraquat; however, this cost is not reflected in the herbicide cost. Where no herbicide was applied and where paraquat was applied in conventional tillage, alfalfa yield was not significantly different at any harvest (Tables 4,5,6). Therefore, the no herbicide treatment in this section was previously referred to as the paraquat treatment.

The economic comparisons are based of seasonal total pure alfalfa yield. This comparison may only be used for comparison purposes, since it is impossible to separate alfalfa from weeds and only sell the pure alfalfa. Gross revenue was calculated using the following equation.

$$\text{Pure Alfalfa Yield} * \text{Price per Mg} = \text{Gross Revenue}$$

Gross revenue was calculated at three different prices received for the hay. Prices were: \$66.09 Mg^{-1} (\$60 T^{-1}(US)), \$82.62 Mg^{-1} (\$75 T^{-1}(US)), and \$99.14 Mg^{-1} (\$90 T^{-1}(US)). Tillage and seeding costs, and herbicide costs are summarized in Table 7. Net revenue was calculated using the following equation.

$$\text{Gross Revenue} - (\text{Tillage and Seeding Cost} + \text{Herbicide Cost}) = \text{Net Revenue}$$

Not included in this economic analysis are costs that would not change between tillage systems and among herbicide programs, such as seed, fertilizer, and harvesting.

Economic Comparisons within Conventional Tillage. Seasonal alfalfa yield was significantly different between the no herbicide program and the intense herbicide program at the 10% level in both the 1989 and 1990 seedings (Tables 8, 9). At all three price levels received for the hay in both years, gross revenue was higher where an intense herbicide program was used compared to where no herbicide was used. In 1989 when a low price was received for the hay, net revenue was higher where no herbicide was applied compared to the intense herbicide program. When an intermediate price was received for the hay, net revenue was similar among herbicide programs; however, when a high price was received for the hay, net revenue was higher where EPTC + 2,4-DB was applied than where no herbicide was applied. In 1990, at all three price levels received for the hay, net revenue was higher where the intense herbicide program was used compared to where no herbicide was used. As the price level received for the hay increased, the margin of return was greater.

Table 7. **Establishment cost estimates for alfalfa seeding using conventional tillage and no-tillage.**

Operation	Cost	
	Conventional Tillage	No-Tillage
	----$ ha^{-1}----	
Tillage		
Moldboard Plowing	30	--
Disking	21	--
Field Cultivating	15	--
Seeding		
Drilling	17	28
Herbicide		
Paraquat	--	28
2,4-DB	31	31
EPTC	24	--
Application	10	10

Table 8. Economic comparisons of tillage systems and weed control programs for 1989 alfalfa seeding at the Kellogg Biological Station, Hickory Corners, Michigan.

	Total Seasonal Alfalfa	Gross Revenue	Tillage and Seeding Cost	Herbicide Cost	Net Revenue
	--Mg/ha--	---$/ha---			
		$66.09/Mg[a]			
Conventional Tillage					
No Herbicide	6.3	416	83	0	333
EPTC + 2,4-DB	7.2	476	83	75	318
No-Tillage					
No Herbicide	3.0	198	28	0	171
Paraquat + 2,4-DB	5.8	383	28	79	276
		$82.62/Mg[a]			
Conventional Tillage					
No Herbicide	6.3	521	83	0	438
EPTC + 2,4-DB	7.2	595	83	75	437
No-Tillage					
No Herbicide	3.0	248	28	0	220
Paraquat + 2,4-DB	5.8	479	28	79	372
		$99.14/Mg[a]			
Conventional Tillage					
No Herbicide	6.3	625	83	0	542
EPTC + 2,4-DB	7.2	714	83	75	556
No-Tillage					
No Herbicide	3.0	297	28	0	269
Paraquat + 2,4-DB	5.8	575	28	79	468

[a]$66.09/Mg=$60/T(US), $82.82/Mg=$75/T(US), $99.14/Mg=$90/T(US).

Table 9. Economic comparisons of tillage systems and weed control systems for 1990 alfalfa seeding at the Kellogg Biological Station, Hickory Corners, Michigan.

	Total Seasonal Alfalfa	Gross Revenue	Tillage and Seeding Cost	Herbicide Cost	Net Revenue
	--Mg/ha--	---------------------------$/ha---------------------------			
		$66.09/Mg[a]			
Conventional Tillage					
No Herbicide	5.7	377	83	0	294
EPTC + 2,4-DB	7.6	502	83	75	344
No-Tillage					
No Herbicide	5.9	390	28	0	362
Paraquat + 2,4-DB	7.5	496	28	79	389
		$82.62/Mg[a]			
Conventional Tillage					
No Herbicide	5.7	471	83	0	388
EPTC + 2,4-DB	7.6	628	83	75	470
No-Tillage					
No Herbicide	5.9	487	28	0	459
Paraquat + 2,4-DB	7.5	620	28	79	537
		$99.14/Mg[a]			
Conventional Tillage					
No Herbicide	5.7	565	83	0	482
EPTC + 2,4-DB	7.6	753	83	75	595
No-Tillage					
No Herbicide	5.9	585	28	0	557
Paraquat + 2,4-DB	7.5	744	28	79	637

[a]$66.09/Mg = $60/T(US), $82.62/Mg = $75/T(US), $99.14/Mg = $90/T(US).

Economic Comparisons within No-Tillage. Pure alfalfa yield was significantly higher where paraquat + 2,4-DB was applied than where no herbicide was applied in both years (Tables 8, 9). In both years at all three price levels received for the hay, gross revenue and net revenue was higher where paraquat + 2,4-DB was applied than where no herbicide was applied.

Conclusions. Alfalfa plant densities varied in the spring after establishment between tillage systems; however, by the fall no differences were observed. There were also no differences in forage yield, or alfalfa yield between tillage systems. In conclusion, alfalfa may be planted without tillage following corn. In this study, differences did exist between herbicide programs. When no herbicide was applied, there was a higher total forage yield than where an intense herbicide program was used; however, a higher percentage of the forage was weeds. This effect was mainly seen in the first cutting of the establishment year. The year following establishment no yield differences were observed between herbicide programs.

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CHAPTER 3

ALTERNATIVE METHODS OF ESTABLISHING ALFALFA WITHOUT TILLAGE

ABSTRACT

Research was conducted in 1989 and 1990 to compare alfalfa and alfalfa-grass mixture establishment systems. Treatments included alfalfa seeded alone with three herbicide levels, three alfalfa-grass mixtures varying in grass species, and three oat companion crop seedings varying in oat removal methods. Alfalfa plant densities in the spring of the establishment year were higher where paraquat was applied than where no herbicide or paraquat + 2,4-DB was applied for both years. By the fall of the establishment year for both years and the year following establishment for the 1989 seeding, alfalfa plant densities were similar among herbicide programs. Alfalfa plant density was not significantly different among alfalfa-grass mixtures or among oat companion crop seedings in either the spring or fall of the establishment year for both 1989 and 1990 or the spring of the year following establishment for the 1989 seeding. In 1989, forage yield in the first harvest decreased as herbicide intensity increased, and pure alfalfa yield was greater. In the first harvest of the 1990 study, total forage yield was higher where paraquat was applied than where no herbicide was applied; however, alfalfa yield was similar. In the second and third harvest for the 1989 seeding,

total forage yield was lower where no herbicide was used compared to where paraquat + 2,4-DB was applied. In the 1990 seeding, no differences in total forage yield or alfalfa yield were observed between herbicide programs. In the year of establishment for each harvest, total forage yield and alfalfa yield were similar among alfalfa-grass mixtures and alfalfa seeded alone. In the second, third, and fourth harvests of the year following establishment alfalfa + orchardgrass had lower alfalfa yield than alfalfa + smooth bromegrass, or alfalfa + timothygrass, while maintaining similar total forage yields. Alfalfa yield was lower in the first harvest where oats were seeded with the alfalfa. The longer the oats were allowed to remain in the field the greater the alfalfa yield reduction in the first harvest. Total forage yield and alfalfa yield was reduced in the second and third harvests where oats were harvested for grain compared to alfalfa seeded alone in 1989. In 1990, total forage yield and alfalfa yield in the second and third harvests were similar between alfalfa seeded with oats harvested for grain and alfalfa seeded alone. **Nomenclature:** paraquat, 1,1'-dimethyl-4-4'-bibyridinium ion; 2,4-DB, 4-(2,4-dichlorophenoxy)butanoic acid; alfalfa, *Medicago sativa* L.; oat, *Avena sativa* L.; orchardgrass, *Dactylis glomerata* L.; smooth bromegrass, *Bromus inermis* Leyss.; timothygrass, *Phleum pratense* L.

INTRODUCTION

No-tillage alfalfa seedings have been successful in a wide range of planting situations (Mueller-Warrant and Koch, 1980; Wolf et al., 1985). Research has shown that yields of alfalfa established without tillage using either glyphosate [N-(phosphonomethyl)glycine] or paraquat were equivalent or better than yields obtained from conventional seedings (Roth et al., 1985). This has led to an increase of 116 percent in no-tillage seedings of hay and pasture land in Michigan in 1990 compared to 1989 (Grigar, 1990).

Herbicides are commonly used to control weeds when establishing alfalfa. Where weeds were controlled by herbicides in seedling alfalfa, total forage yield was reduced compared to the untreated plot in the first harvest (Dutt et al., 1983; Fawcett and Harvey, 1978; Wilson, 1986). Wilson (1986) reported second harvest forage yields were higher where herbicides were applied than where no herbicide was applied. Peters et al. (1984) reported similar alfalfa yields were obtained where herbicides were applied compared to where no herbicide was applied. Alfalfa stand density was neither increased or decreased where herbicides were used compared to where no herbicide was used (Wilson, 1986).

Establishing alfalfa with a forage grass is an alternative to seeding pure alfalfa. Forage grasses can maintain weed control throughout the life of the alfalfa-grass mixture, as the alfalfa stand begins to thin the forage grass invades the thin areas, thus controlling weeds and maintaining forage yield (Tesar and Marble, 1988). Alfalfa-grass mixtures, such as alfalfa + orchardgrass, alfalfa + smooth bromegrass, and alfalfa + timothygrass, have been reported to produce a higher total forage yield than forage grass alone (Johnson et al., 1965; Castler and Drolson, 1984). In another study, alfalfa-grass mixtures have been shown to produce more forage than alfalfa seeded alone (Smith, 1960).

Alfalfa-grass mixtures have also been shown to reduce the chances of bloat when used as a pasture (Johnson et al., 1965). Another advantage is reduced soil erosion that may occur with pure stands of alfalfa (Drolson et al., 1967).

A companion crop seeded with alfalfa may provide another alternative to establishment herbicides (Peters, 1961; Tesar, 1984). Oats are a good choice for a companion crop, because they may be harvested early and they are not as competitive as certain other small grains such as wheat (*Triticum aestivum* L.) (Tesar, 1984). Oats may be harvested for silage or grain. When oats are allowed to mature for grain, alfalfa yield is often reduced in the year of establishment (Klebesadel and Smith, 1960; Smith, 1960).

The objectives of this study were: 1) to determine the effect of alfalfa-grass mixtures on plant density and forage yield; 2) to determine the effect of an oat companion crop and different times of removal on plant density and forage yield; and 3) to compare weed control provided by alfalfa-grass mixtures, and oat companion crop seedings to establishing pure alfalfa with herbicides.

MATERIALS AND METHODS

Research was conducted in adjacent experimental areas in 1989 and 1990 at the Kellogg Biological Station, Hickory Corners, Michigan. The soil type was a Kalamazoo sandy loam. Results from two soil tests taken in the fall of 1988 and spring of 1990, for both experimental areas, are summarized in Table 1. Lime was applied on November 3, 1988 at 2240 kg ha^{-1} to both experimental areas to adjust the pH. Proper potassium level was obtained through the addition of 448 kg ha^{-1} of $K_2 0$ in the form of 0-0-60 on April 24, 1990 to the 1990 experimental area. Potassium was not required for the 1989 experimental area. Glyphosate was applied to both experimental areas at 2.2 kg ha^{-1} on September 27, 1988 and to the 1990 experimental area on September 29, 1989 to control quackgrass. The previous crop in the experimental area was corn (*Zea mays* L.) that had been removed as silage.

The study was conducted in a randomized complete block design. Plots were 2.4 meters wide and 9.1 meters in length. Seeding was conducted on May 5 and May 2 for the 1989 and 1990 seedings, respectfully. In 1989, a seeder[1] equipped with power coulters spaced 12.3 cm apart was used, and in 1990 a seeder[2] utilizing a fluted coulter and double disk openers spaced 12.3 cm apart was used. Both seeders were adjusted to place seeds 0.5 cm deep. Treatments are summarized in Table 2. All treatments were seeded without tillage for seedbed preparation.

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[1]John Deere Power-Till Drill, John Deere Co. Inc., Moline, Illinois.

[2]Tye No-Tillage Drill, The Tye Co., Lockney, Texas.

Table 1. Results of soil tests for the 1989 and 1990 experimental areas.

	1989 Experimental Area		1990 Experimental Area	
	1988 Soil Test	1990 Soil Test	1988 Soil Test	1990 Soil Test
pH	6.1	6.3	5.8	5.9
Organic Matter (%)	2.3	2.3	2.1	2.1
Calcium (kg/ha)	1971	1971	1971	1707
Magnesium (kg/ha)	395	385	403	358
Phosphorus (kg/ha)	309	314	371	475
Potassium (kg/ha)	517	380	369	248

Table 2. Summary of treatments.

Crop Seeded	Seeding Rate	Oat Removal Method	Herbicide and Rate
	($kg\ ha^{-1}$)		-----------($kg\ ha^{-1}$)-----------
Alfalfa	16.8	--	--
Alfalfa	16.8	--	Paraquat[a] (0.5)
Alfalfa	16.8	--	Paraquat[a] (0.5) + 2,4-DB (1.1)
Alfalfa + Smooth Bromegrass	16.8 + 6	--	Paraquat[a] (0.5)
Alfalfa + Orchardgrass	16.8 + 2	--	Paraquat[a] (0.5)
Alfalfa + Timithygrass	16.8 + 2	--	Paraquat[a] (0.5)
Alfalfa + Oats	15 + 54	killed with herbicide	Paraquat[a] (0.5) + Sethoxydim[b] (0.3)
Alfalfa + Oats	15 + 54	harvested for silage	Paraquat[a] (0.5)
Alfalfa + Oats	15 + 54	harvested for grain	Paraquat[a] (0.5)

[a]Paraquat treatments included non ionic surfactant at 0.25% v/v.
[b]Sethoxydim treatments included crop oil concentrate at 2.3 $l\ ha^{-1}$.

Paraquat was applied on May 4 and May 1 for the 1989 and 1990 seedings, respectfully. 2,4-DB was applied postemergence to alfalfa at the 1 to 2 trifiolate leaf stage on June 6 and June 7 for the 1989 and 1990 seedings, respectfully. Sethoxydim [2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] was applied to 7.5 to 9.6 cm tall oats on June 6 and June 7 for the 1989 and 1990 seedings, respectfully.

Populations of alfalfa and two dominant weed species were determined on June 19 and June 18, for the 1989 and 1990 seedings, respectfully. Dominant weed species were redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.) in 1989, and velvetleaf (*Abutilon theophrasti* Medicus) and common lambsquarters in 1990. Plant populations are reported as the mean of three 1 m^2 quadrats per plot selected at random. Alfalfa populations were also determined in the fall of the establishment year on November 20 and November 9 for the 1989 and 1990 seedings, respectfully. For the 1989 seeding, alfalfa plant density was evaluated in the spring of the year following establishment on April 24, 1990.

Three forage harvests were made in the year of establishment for both the 1989 and 1990 seedings, and four harvests were made in the year following establishment for the 1989 seeding. Harvest dates for the 1989 seeding were July 14, August 23,and October 10, 1989, and May 30, July 5, August 14, and October 23, 1990. Harvest dates for the 1990 seeding were July 25, September 4, and October 23, 1990. An area 1.2 meters wide and 9.1 meters in length was harvested from the center of each plot with a mechanical flail harvester[3]. The total forage fresh weight from this area was measured. A random sub-sample was collected from the harvested forage, and the fresh weight of the sub-sample measured. Sub-samples were oven dried, and dry weights measured. Total forage dry weight yield was calculated.

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[3]Carter Manufacturing Co. Inc., Brookston, Indiana.

A sample was also collected at each harvest to determine forage composition. Samples were collected by cutting a strip along the edge of the harvested area 20 cm wide and 9.1 meters in length, then randomly collecting a 300 to 400 gram sample. Samples were separated into fractions of alfalfa, forage grass, dominant weed species, other broadleaf weeds, and other grassy weeds. Samples were oven dried and weights measured. Weights were used to calculate percent forage composition.

Analyses of variance were preformed on the data, and means were separated by least significant difference at the 5% level of significance.

RESULTS AND DISCUSSION

Effect of herbicides on alfalfa establishment. The discussion in this section will include the three herbicide treatments. There was no significant difference in alfalfa plant density where no herbicide was applied compared to where paraquat + 2,4 DB was applied (Table 3). Alfalfa plant densities, evaluated in the spring of the establishment year, were significantly higher where paraquat was applied than where no herbicide or paraquat + 2,4-DB was applied in both years (Table 3). Weed pressure where no herbicide was applied may have reduced alfalfa plant density, and the 2,4-DB where paraquat + 2,4-DB was applied, may have reduced alfalfa plant density. However, this is in contrast to Wilson (1986), who reported that in conventional tillage, herbicides, in particular, 2,4-DB, did not reduce alfalfa plant density. By the fall of the establishment year, no significant differences were observed in alfalfa plant density among herbicide treatments in both years (Table 3). No differences in alfalfa plant density were observed the year following establishment for the 1989 seeding (Table 3).

Table 3. Influence of establishment herbicides on alfalfa density, seeded in the spring of 1989 and 1990 at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Year of Establishment		Year following Establishment
	Spring	Fall	Spring
	----------(plants m^{-2})----------		
	1989 Seeding		
No Herbicide	100	104	79
Paraquat	161	120	85
Paraquat + 2,4-DB	108	96	82
$LSD_{(.05)}$[a]	44	N.S.	N.S.
	1990 Seeding		
No Herbicide	220	113	--
Paraquat	318	126	--
Paraquat + 2,4-DB	260	122	--
$LSD_{(.05)}$[a]	51	N.S.	--

[a]Comparisons valid within columns and years.

Redroot pigweed yield was not significantly different among herbicide programs; however, there was a trend of higher redroot pigweed yield where a herbicide was applied compared to where no herbicide was applied in 1989 (Table 4). In contrast, common lambsquarters density was significantly higher where no herbicide was applied compared to where a herbicide was applied (Table 4). Common lambsquarters may have been emerged and therefore controlled by the paraquat application. Control of common lambsquarters may have allowed the redroot pigweed to become established. In 1990, common lambsquarters density appeared higher where paraquat was applied than where no herbicide or paraquat + 2,4-DB was applied; however, this difference was not significant (Table 4). This would suggest that another weed species may have been eliminated by the paraquat application which then provided an opportunity for common lambsquarters to become established. Postemergence application of 2,4-DB controlled the common lambsquarters. Velvetleaf was not significantly different between herbicide programs in 1990 (Table 4).

Total forage yield was significantly higher where no herbicide was applied than where a herbicide was applied in the first harvest of the 1989 seeding (Table 5). Alfalfa yield was significantly lower where no herbicide was applied compared to where a herbicide was applied in 1989. Total broadleaf weeds attributed to the reduction in alfalfa yield and the higher total forage yield. Common lambsquarters yield, total broadleaf weed yield and total weed yield were significantly higher where no herbicide was applied than where a herbicide was applied. Total forage yield was significantly reduced where paraquat + 2,4-DB was applied compared to where paraquat was applied; however, alfalfa yields were similar. This suggests that weeds made up the difference in total forage yield.

Total forage yield was significantly higher where paraquat was applied than where no herbicide was applied in the first harvest of the 1990 seeding (Table 6). This is in contrast to what was observed in 1989. Alfalfa yields were not significantly different

Table 4. Influence of establishment herbicides on dominant weed specie densities in 1989 and 1990 seedings at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	1989 Seeding		1990 Seeding	
	AMARE[a]	CHEAL[a]	CHEAL[a]	ABUTH[a]
	---(plants m^{-2})---			
No Herbicide	1	5	1	2
Paraquat	28	0	16	2
Paraquat + 2,4-DB	12	0	0	1
$LSD_{(.05)}$[b]	N.S.	3	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns.

Table 5. Influence of establishment herbicides on total forage, alfalfa, and weed yields for the year establishment of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Yield						
	Forage	Alfalfa	AMARE[a]	CHEAL[a]	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	($10\ kg\ ha^{-1}$)						
Harvest 1							
No Herbicide	427	88	28	78	336	3	339
Paraquat	268	212	24	12	53	3	56
Paraquat + 2,4-DB	202	197	2	0	3	2	5
$LSD_{(0.05)}$[b]	61	85	N.S.	65	94	N.S.	98
Harvest 2							
No Herbicide	159	138	1	0	20	1	21
Paraquat	230	191	2	0	10	29	39
Paraquat + 2,4-DB	249	219	3	0	17	13	30
$LSD_{(0.05)}$[b]	51	77	N.S.	N.S.	N.S.	N.S.	N.S.
Harvest 3							
No Herbicide	141	135	0	0	3	3	6
Paraquat	172	164	0	0	1	7	8
Paraquat + 2,4-DB	186	183	0	0	0	3	3
$LSD_{(0.05)}$[b]	39	41	N.S.	N.S.	N.S.	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters.
[b]Comparisons valid within columns and harvests.

Table 6. **Influence of establishment herbicides on total forage, alfalfa, and weed yields for the year of establishment of the 1990 seeding at Kellogg Biological Station, Hickory Corners, Michigan.**

Alfalfa Establishment Program	Yield						
	Forage	Alfalfa	CHEAL[a]	ABUTH[a]	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})						
			Harvest 1				
No Herbicide	285	223	3	34	57	5	62
Paraquat	374	310	5	50	64	0	64
Paraquat + 2,4-DB	301	301	0	0	0	0	0
$LSD_{(0.05)}$[b]	85	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
			Harvest 2				
No Herbicide	232	219	0	2	4	9	13
Paraquat	284	279	0	0	1	4	5
Paraquat + 2,4-DB	261	252	0	0	0	9	9
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
			Harvest 3				
No Herbicide	146	142	0	0	3	1	4
Paraquat	199	199	0	0	0	0	0
Paraquat + 2,4-DB	190	190	0	0	0	0	0
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[a]CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns and harvests.

between herbicide programs, however there is a trend toward a higher alfalfa yield where herbicide was applied than where no herbicide was applied. Weed yields were not significantly different between herbicide treatments, but a trend toward lower total broadleaf yields and total weed yield was observed where paraquat + 2,4-DB was applied compared to where no herbicide or paraquat was applied.

In the second harvest of the 1989 seeding, a lower total forage yield was obtained where no herbicide was applied than where a herbicide was applied (Table 5). Alfalfa yield was significantly lower where no herbicide was applied than where paraquat + 2,4-DB was applied. No significant differences were observed in total forage yield or alfalfa yield between the paraquat and paraquat + 2,4-DB treatments. Weed yields were not significantly different between herbicide programs. In 1990, herbicide programs had no significant effect on total forage yield, alfalfa yield, or weed yields in the second harvest (Table 6).

In the third harvest of the 1989 seeding, a lower total forage yield and alfalfa yield was observed where no herbicide was applied than where paraquat + 2,4-DB was applied. No significant differences were observed in weed yields (Table 5). In the third harvest of the 1990 seeding, no significant differences were observed in total forage yield, alfalfa yield, or weed yields (Table 6).

No significant differences were observed in total forage yield, or alfalfa yield in any harvest, the year following establishment of the 1989 seeding (Table 7). In the first harvest, total broadleaf weeds were significantly lower where paraquat + 2,4-DB was applied compared to where paraquat was applied. In the second, third and fourth harvest, weeds were not significantly different, and were not a major problem. Grassy weed yield was significantly higher in the second harvest where paraquat was applied than where no herbicide was applied, and in the third and fourth harvest significantly higher than where

Table 7. Influence of establishment herbicides on total forage, alfalfa, and weed yields for the year following establishment, of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

	Yield				
Alfalfa Establishment Program	Forage	Alfalfa	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	----------------	----------------	(10 kg ha^{-1})	----------------	----------------
		Harvest 1			
No Herbicide	569	549	16	4	20
Paraquat	579	542	37	0	37
Paraquat + 2,4-DB	579	570	3	6	9
$LSD_{(0.05)}$[a]	N.S.	N.S.	26	N.S.	N.S.
		Harvest 2			
No Herbicide	327	319	5	3	8
Paraquat	358	341	1	16	17
Paraquat + 2,4-DB	342	333	0	9	9
$LSD_{(0.05)}$[a]	N.S.	N.S.	N.S.	12	N.S.
		Harvest 3			
No Herbicide	302	298	1	3	4
Paraquat	280	257	1	22	23
Paraquat + 2,4-DB	304	300	0	4	4
$LSD_{(0.05)}$[a]	N.S.	N.S.	N.S.	14	N.S.
		Harvest 4			
No Herbicide	253	249	2	2	4
Paraquat	262	233	1	28	29
Paraquat + 2,4-DB	263	252	0	10	11
$LSD_{(0.05)}$[a]	N.S.	N.S.	2	18	18

[a]Comparisons valid within columns and harvests.

no herbicide or paraquat + 2,4-DB was applied. Broadleaf weeds were not significantly different in the first, second, and third harvests; however, in the fourth harvest grass weed yield contributed enough where paraquat was applied to make total weed yield higher where paraquat was applied compared to where no herbicide or paraquat + 2,4-DB was applied.

Effect of Alfalfa-Grass Mixtures on Establishment. The discussion in this section will include the three alfalfa mixtures and alfalfa seeded alone where paraquat was applied. Alfalfa plant density was not significantly different among alfalfa-grass mixtures at the spring or fall evaluation for the 1989 and 1990 seedings or the spring of the year following establishment for the 1989 seeding (Table 8). Alfalfa plant density was reduced where alfalfa was seeded with smooth bromegrass or orchardgrass compared to alfalfa seeded alone in the spring evaluation for the 1989 seeding. In 1990, alfalfa plant density was reduced where alfalfa was seeded with a grass compared to alfalfa seeded alone. No significant difference was observed in alfalfa plant density at the fall evaluation for the 1989 or 1990 seedings or the spring evaluation of the year following establishment for the 1989 seeding.

No significant differences were observed in weed densities between alfalfa grass mixtures and alfalfa seeded alone in the spring following establishment for either the 1989 or the 1990 seeding (Table 9). In 1989, the alfalfa grass mixtures appeared to have no effect on redroot pigweed density or common lambsquarters density; however, in 1990 a trend toward a lower common lambsquarters density was observed where alfalfa-grass mixtures were seeded compared to alfalfa seeded alone.

Total forage yield was not significantly different between alfalfa grass mixtures and alfalfa seed alone at any harvest in the 1989 seeding (Table 10). Alfalfa yield in the first harvest was reduced where alfalfa was seeded with smooth bromegrass compared to alfalfa

Table 8. Influence of alfalfa-grass mixtures on alfalfa density seeded in the spring of 1989 and 1990 at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Year of Establishment		Year following Establishment
	Spring	Fall	Spring
	(plants m^{-2})		
1989 Seeding			
Alone	161	120	85
+ Smooth Bromegrass	102	106	83
+ Orchardgrass	108	89	83
+ Timothygrass	145	93	83
$LSD_{(.05)}$[a]	44	N.S.	N.S.
1990 Seeding			
Alone	318	126	--
+ Smooth Bromegrass	223	127	--
+ Orchardgrass	202	102	--
+ Timothygrass	248	111	--
$LSD_{(.05)}$[a]	51	N.S.	--

[a]Comparisons valid within columns and years.

Table 9. Influence of alfalfa-grass mixtures on dominant weed specie densities in 1989 and 1990 seedings at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	1989 Seeding		1990 Seeding	
	AMARE[a]	CHEAL[a]	CHEAL[a]	ABUTH[a]
	(plants m^{-2})			
Alone	28	0	16	2
+ Smooth Bromegrass	34	1	1	3
+ Orchardgrass	25	1	1	0
+ Timothygrass	36	1	0	3
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns.

Table 10. Influence of alfalfa-grass mixtures on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Yield							
	Forage	Alfalfa	AMARE[a]	CHEAL[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})							
Harvest 1								
Alone	268	213	24	12		53	2	55
+ Smooth bromegrass	226	96	58	3	10	117	3	120
+ Orchardgrass	280	185	39	8	7	85	3	88
+ Timothygrass	262	165	51	1	5	85	7	92
$LSD_{(0.05)}$[b]	N.S.	85	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 2								
Alone	230	191	2	0		10	29	39
+ Smooth bromegrass	233	193	4	13	7	21	12	33
+ Orchardgrass	245	167	2	13	3	21	54	75
+ Timothygrass	229	186	5	6	6	18	19	37
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 3								
Alone	172	164	0	0		1	7	8
+ Smooth bromegrass	190	164	0	0	20	2	4	6
+ Orchardgrass	184	148	0	0	34	2	0	2
+ Timothygrass	196	184	0	0	3	1	8	9
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters.
[b]Comparisons valid within columns and harvests.

seeded with orchardgrass, timothygrass or alone. Weed yields were not significantly different between alfalfa-grass mixtures and alfalfa seeded alone.

A significantly higher total forage yield was obtained where alfalfa was seeded with smooth bromegrass compared to where alfalfa was seeded with orchardgrass or timothygrass in the first harvest of the 1990 seeding (Table 11). No significant differences were observed where alfalfa was seed alone compared to alfalfa seeded with a grass. Alfalfa yield or weed yields were not significantly different among alfalfa-grass mixtures and alfalfa seeded alone.

A trend appeared in the first harvest of the 1989 and 1990 seeding that total broadleaf weed yield was suppressed where alfalfa was seeded with orchardgrass or timothygrass compared to alfalfa seeded with smooth bromegrass (Tables 10, 11). This trend may have influenced the significantly lower alfalfa yield in the 1989 seeding, and the higher total forage yield in the 1990 seeding with the alfalfa-smooth bromegrass mixture.

In the second harvest of the 1989 and 1990 seedings, and the third harvest of the 1989 seeding, no significant differences were observed in total forage yield, alfalfa yield, or weed yields between alfalfa-grass mixtures and alfalfa seeded alone (Tables 10, 11). Total forage yield, alfalfa yield, and total broadleaf weed yield was not different among alfalfa grass mixtures and alfalfa seeded alone in the third harvest of the 1990 seeding (Table 11). Grassy weed yield was significantly higher where alfalfa was seeded with timothygrass compared to alfalfa seeded alone, or with smooth bromegrass or orchardgrass. A trend similar to this appeared in the 1989 seeding. Timothygrass appeared to not grow as vigorously in the fall of the establishment year, which may have allowed room for grassy weeds to appear.

Total forage yield, alfalfa yield, total grassy weed yield and total weed yield was not significantly different in the first harvest the year following establishment for the 1989 seeding (Table 12). Broadleaf yield was significantly reduced where alfalfa was seeded with

Table 11. Influence of alfalfa-grass mixtures on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1990 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Yield							
	Forage	Alfalfa	CHEAL[a]	ABUTH[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})							
			Harvest 1					
Alone	374	310	5	50		64	0	64
+ Smooth bromegrass	454	365	3	24	17	68	4	72
+ Orchardgrass	328	263	7	0	29	28	8	36
+ Timothygrass	338	296	2	4	8	24	9	34
$LSD_{(0.05)}$[b]	85	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
			Harvest 2					
Alone	284	279	0	0		1	4	5
+ Smooth bromegrass	301	288	0	0	0	2	11	13
+ Orchardgrass	274	201	0	0	56	1	16	17
+ Timothygrass	278	260	0	0	13	0	5	5
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
			Harvest 3					
Alone	199	199	0	0		0	0	0
+ Smooth bromegrass	204	197	0	0	6	1	0	1
+ Orchardgrass	186	139	0	0	47	0	0	0
+ Timothygrass	184	169	0	0	0	1	14	15
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	5	10

[a]CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns and harvests.

Table 12. Influence of alfalfa-grass mixtures on total forage, alfalfa, forage grass, and weed yields for the year following establishment, of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Yield					
	Forage	Alfalfa	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	---(10 kg ha^{-1})---					
Harvest 1						
Alone	579	542		36	1	37
+ Smooth bromegrass	622	540	82	0	0	0
+ Orchardgrass	620	509	109	2	0	2
+ Timothygrass	599	546	51	2	0	2
$LSD_{(0.05)}$[a]	N.S.	N.S.		26	N.S.	29
Harvest 2						
Alone	358	341		1	16	17
+ Smooth bromegrass	325	308	5	2	10	12
+ Orchardgrass	340	294	46	0	0	0
+ Timothygrass	327	322	3	1	1	2
$LSD_{(0.05)}$[a]	N.S.	32		N.S.	12	14
Harvest 3						
Alone	280	257		1	22	23
+ Smooth bromegrass	324	313	6	3	2	5
+ Orchardgrass	308	245	63	0	0	0
+ Timothygrass	331	323	1	1	6	7
$LSD_{(0.05)}$[a]	50	52		N.S.	14	N.S.
Harvest 4						
Alone	262	233		1	28	29
+ Smooth bromegrass	259	253	1	2	3	5
+ Orchardgrass	262	201	48	0	13	13
+ Timothygrass	269	266	0	0	3	3
$LSD_{(0.05)}$[a]	N.S.	38		2	18	18

[a]Comparisons valid within columns and harvests.

a grass compared to alfalfa seeded alone. The competition from the grass may have suppressed germination of the weeds.

Total forage yield was not different among alfalfa-grass mixtures and alfalfa seeded alone in the second harvest (Table 12). Alfalfa yield was lower where alfalfa was seeded with smooth bromegrass or orchardgrass compared to alfalfa seeded alone. Grassy weed yield and total weed yield was significantly higher where alfalfa was seeded alone than alfalfa seeded with orchardgrass or timothygrass.

Alfalfa seeded with timothygrass had higher total forage yield than alfalfa seeded alone in the third harvest (Table 12). Alfalfa yield was significantly higher where alfalfa was seeded with smooth bromegrass, or timothygrass compared to alfalfa seeded alone, or with orchardgrass. Grassy weed yield was significantly higher where alfalfa was seeded alone compared to alfalfa seeded with a grass. This may explain the lower alfalfa yield where alfalfa was seeded alone. The alfalfa yield reduction may be lower where alfalfa was seeded with orchardgrass due to the high yield of orchardgrass.

Total forage yield in the fourth harvest was not significantly different between alfalfa-grass mixtures and alfalfa seeded alone (Table 12). Alfalfa yield was reduced where alfalfa was seeded with orchardgrass compared to alfalfa seeded with smooth bromegrass or timothygrass. The combination of orchardgrass and grassy weeds may be the cause of the alfalfa reduction. Total grassy weeds were significantly higher where alfalfa was seeded alone compared to alfalfa seeded with smooth bromegrass or timothygrass.

Effects of Companion Crop Alfalfa Establishment. The discussion in this section will include the three alfalfa companion crop seeding and alfalfa seeded alone where paraquat was applied. Alfalfa plant density was not significantly different among oat companion crop removal methods; however alfalfa plant density was significantly lower where alfalfa was seeded with a companion crop compared to alfalfa seeded alone in the spring evaluation of the establishment year for both the 1989 and 1990 seedings (Table 13). No significant difference was observed in alfalfa plant density between oat removal methods or alfalfa seeded alone in the fall evaluation for the 1989 and 1990 seedings or the spring of the year following establishment for the 1989 seeding.

No significant differences in weed densities were observed among oat removal methods or with alfalfa seeded alone in the spring following establishment for both the 1989 and the 1990 seedings (Table 14). In 1989, the alfalfa-oat companion crop appeared to have no effect on common lambsquarters density; however, redroot pigweed density appears to be higher where alfalfa was seeded alone or oats were killed with herbicide compared to where oats were harvested as silage or grain. In 1990, a trend toward a lower common lambsquarters density was observed where alfalfa was seeded with an oat companion crop compared to alfalfa seeded alone. Data suggests the oats may have suppressed common lambsquarters germination.

Forage was not harvested where oats were harvested for grain at the first harvest after establishment. Where oats were harvested as silage, a higher total forage yield and a lower alfalfa yield was observed compared to where alfalfa was seeded alone and where oats were killed with herbicide in the first harvest in the 1989 seeding (Table 15). Redroot pigweed yield was significantly lower where oats were harvested for silage than where oats were killed with herbicide. No other significant differences were observed in weed yield among oat removal methods and alfalfa seeded alone. However where oats were harvested for silage, there was a trend toward a lower broadleaf weed yield than where oats were killed with herbicide.

Total forage yield was significantly lower where oats were killed with herbicide compared to oats harvested as silage or alfalfa seeded alone in the first harvest of the 1990

Table 13. Influence of alfalfa-companion crop seedings on alfalfa density seeded in the spring of 1989 and 1990 at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Year of Establishment		Year following Establishment
	Spring	Fall	Spring
	(plants m^{-2})		
	1989 Seeding		
Alone	161	120	85
+ Oats (killed with herb)	74	85	87
+ Oats (silage)	113	100	88
+ Oats (grain)	72	73	63
$LSD_{(.05)}$[a]	44	N.S.	N.S.
	1990 Seeding		
Alone	318	126	--
+ Oats (killed with herb)	195	129	--
+ Oats (silage)	166	103	--
+ Oats (grain)	189	111	--
$LSD_{(.05)}$[a]	51	N.S.	--

[a]Comparisons valid within columns and years.

Table 14. Influence of alfalfa-companion crop seeding on dominant weed specie densities in 1989 and 1990 seedings at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	1989 Seeding		1990 Seeding	
	AMARE[a]	CHEAL[a]	CHEAL[a]	ABUTH[a]
	(plants m^{-2})			
Alone	28	0	16	2
+ Oats (killed with herb)	33	0	0	1
+ Oats (silage)	11	1	0	0
+ Oats (grain)	15	2	1	0
$LSD_{(.05)}$[b]	N.S.	N.S.	N.S.	N.S.

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns.

Table 15. Influence of alfalfa-companion crop seeding on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Alfalfa Establishment Program	Yield							
	Forage	Alfalfa	AMARE[a]	CHEAL[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	($10\ kg\ ha^{-1}$)							
Harvest 1								
Alone	268	212	24	12		53	3	56
+ Oats (killed with herb.)	243	145	74	3		98	0	98
+ Oats (silage)	406	31	2	0	343	29	3	32
+ Oats (grain)								
$LSD_{(0.05)}$[b]	61	85	63	N.S.		N.S.	N.S.	N.S.
Harvest 2								
Alone	230	191	2	0		10	29	39
+ Oats (killed with herb.)	196	177	1	2		19	0	19
+ Oats (silage)	168	147	1	0		16	5	21
+ Oats (grain)	175	119	11	0		18	38	56
$LSD_{(0.05)}$[b]	51	N.S.	8	N.S.		N.S.	N.S.	N.S.
Harvest 3								
Alone	172	164	0	0		1	7	8
+ Oats (killed with herb.)	159	158	0	0		1	0	1
+ Oats (silage)	166	155	0	0		9	2	11
+ Oats (grain)	103	85	0	0		2	16	18
$LSD_{(0.05)}$[b]	39	41	N.S.	N.S.		6	8	11

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters.
[b]Comparisons valid within columns and harvests.

seeding (Table 16). Alfalfa yield followed the same pattern as the 1989 seeding where alfalfa yield was reduced where oats were harvested as silage compared to oats killed with herbicide or alfalfa seeded alone. No significant differences were observed in weed yield among oat removal methods and alfalfa seeded alone. It appears that velvetleaf yield was reduced where alfalfa was seeded with an oat companion crop compared to alfalfa seeded alone; however, no significant differences were observed due to the high degree of variability in weed yield.

In the second harvest of the 1989 seeding, total forage yield was not significantly different among oat removal methods; however, where oats were harvested for silage or grain total forage yield was significantly lower than where alfalfa was seeded alone (Table 15). Alfalfa yield was not significantly different among oat removal methods and alfalfa seeded alone; however, a trend in the data suggest that alfalfa yield was lower where oats were harvested for silage or grain compared to alfalfa seeded alone. Redroot pigweed yield was significantly higher where oats were harvested for grain compared to oats killed with herbicide or harvested for silage or alfalfa seeded alone. No significant differences were observed in total broadleaf weed yield, total grassy weed yield, or total weed yield among oat removal methods and alfalfa seeded alone.

In 1990, no significant differences were observed in total forage yield, alfalfa yield, or weed yield in the second harvest (Table 16). The same trend appeared in the 1990 seeding that appeared in the 1989 seeding that alfalfa yield appeared to be lower where oats were harvested for silage or grain than alfalfa seeded alone.

Total forage yield and alfalfa yield in the third harvest of the 1989 seeding was significantly lower where oats were harvested for grain compared to where alfalfa was seeded alone or oats were killed with herbicide or harvested for silage (Table 15). Total broadleaf weed yield was higher where oats were harvested for silage than alfalfa seeded

Table 16. **Influence of alfalfa-companion crop seeding on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1990 seeding at Kellogg Biological Station, Hickory Corners, Michigan.**

Alfalfa Establishment Program	Yield							
	Forage	Alfalfa	CHEAL[a]	ABUTH[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	$(10\ kg\ ha^{-1})$							
Harvest 1								
Alone	374	310	5	50		64	0	64
+ Oats (killed with herb.)	214	209	0	2		5	0	5
+ Oats (silage)	327	24	0	0	293	10	0	10
+ Oats (grain)								
$LSD_{(0.05)}$[b]	85	103	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 2								
Alone	284	279	0	0		1	4	5
+ Oats (killed with herb.)	273	271	0	0		2		2
+ Oats (silage)	210	169	0	0	26	2	13	15
+ Oats (grain)	311	198	0	0	102	0	11	11
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 3								
Alone	199	199	0	0		0	0	0
+ Oats (killed with herb.)	193	192	0	0		1	0	1
+ Oats (silage)	151	148	0	0		1	2	3
+ Oats (grain)	192	177	0	0		1	14	15
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	5	10

[a]CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns and harvests.

alone, or where oats were killed with herbicide or harvested for grain. Total grassy weed yield was significantly higher where oats were harvested for grain compared to alfalfa seeded alone, or where oats were killed with herbicide or harvested for silage.

No significant differences were observed in total forage yield, alfalfa yield, or total broadleaf weed yield in the third harvest of the 1990 seeding (Table 16). Grassy weeds followed a similar pattern in the 1990 seeding compared to the 1989 seeding, where total grassy weed yield was significantly higher where oats were harvested for grain compared to alfalfa seeded alone, or where oats were killed with herbicide or harvested for silage.

Total forage yield and alfalfa yield in the first harvest of the year following establishment for the 1989 seeding was significantly lower where oats were harvested for grain than where alfalfa was seeded alone or where oats were killed with herbicide or harvested for silage (Table 17). Total broadleaf weed yield was higher where alfalfa was seeded alone or where oats were harvested for grain compared to where oats were killed with herbicide. Total grassy weed yield and total weed yield was significantly higher where oats were harvested for grain compared to alfalfa seeded alone or where oats were killed with herbicide or harvested as silage.

Total forage yield and alfalfa yield in the second harvest of the year following establishment for the 1989 seeding was significantly lower where oats were harvested for grain compared to alfalfa seeded alone or where oats were killed with herbicide (Table 17). Total broadleaf weeds were lower where alfalfa was seeded alone compared to where oats were harvested as silage or grain. Where alfalfa was seeded alone, a higher total grassy weed yield was observed compared to alfalfa seeded with oats.

In the third harvest, no significant differences in total forge yield were observed among oat removal methods and alfalfa seeded alone (Table 17). Alfalfa yield was

Table 17. Influence of alfalfa-companion crop seeding on total forage, alfalfa, forage grass, and weed yields for the year following establishment, of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan

Alfalfa Establishment Program	Yield: Forage	Alfalfa	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})					
Harvest 1						
Alone	579	542		37	0	37
+ Oats (killed with herb.)	609	600		9	0	9
+ Oats (silage)	567	547		13	7	20
+ Oats (grain)	486	418		36	32	68
$LSD_{(0.05)}$[a]	59	68		26	15	29
Harvest 2						
Alone	358	341		1	16	17
+ Oats (killed with herb.)	355	348		7	0	7
+ Oats (silage)	337	323		10	4	14
+ Oats (grain)	309	294		12	3	15
$LSD_{(0.05)}$[a]	34	32		9	12	N.S.
Harvest 3						
Alone	280	257		1	22	23
+ Oats (killed with herb.)	298	298		0	0	0
+ Oats (silage)	328	324		2	2	4
+ Oats (grain)	305	296		1	8	9
$LSD_{(0.05)}$[a]	N.S.	52		N.S.	14	N.S.
Harvest 4						
Alone	261	232		1	28	29
+ Oats (killed with herb.)	240	240		0	0	0
+ Oats (silage)	257	253		2	2	4
+ Oats (grain)	258	250		3	5	8
$LSD_{(0.05)}$[a]	N.S.	N.S.		2	18	18

[a]Comparisons valid within columns and harvests.

significantly higher where oats were harvested as silage compared to alfalfa seeded alone. Total grassy weed yield was higher where alfalfa was seeded alone compared to alfalfa seeded with oats.

In the fourth harvest, total forage yield and alfalfa yield was not significantly different among oat removal methods and alfalfa seeded alone (Table 17). Total grassy weed yield and total broadleaf weed yield was higher where alfalfa was seeded alone compared to oat removal methods. A complete set of data is included in the appendix.

Conclusion. By the fall of the establishment year, alfalfa plant densities were similar among herbicide programs. Generally in the first harvest where herbicides were applied, there was a higher percentage of alfalfa than where no herbicide was applied. Forage yield and alfalfa yield may be reduced in the second and third harvest of the establishment year where no herbicide is applied compared to where herbicides are applied.

Alfalfa-grass mixtures may be seeded successfully without tillage and similar or better forage yields maintained compared to alfalfa seeded alone. By the fall of the establishment year, alfalfa plant densities were similar among alfalfa-grass mixtures and alfalfa seeded alone.

Companion crop alfalfa seeding was also successful without tillage. Similar alfalfa plant densities were observed in the fall of the establishment year. In the first harvest where oats were seeded, alfalfa yield was reduced compared to alfalfa seeded alone. Generally where oats were harvested for grain, there was a greater amount of weeds in the forage than where oats were removed earlier in the second and third harvest of the establishment year.

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APPENDIX

Appendix Table 1. Influence of establishment program on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Establishment Program	Yield							
	Forage	Alfalfa	AMARE[a]	CHEAL[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	(10 kg ha^{-1})							
Harvest 1								
No Herbicide	427	88	28	78		336	3	339
Paraquat	268	212	24	12		53	3	55
Paraquat + 2,4-DB	203	197	2	0		3	2	5
Alfalfa + Smooth Brome	226	95	58	3	11	117	3	120
Alfalfa + Orchardgrass	280	185	39	8	8	85	3	88
Alfalfa + Timothygrass	262	165	51	1	5	85	7	92
Oats (killed with herb.)	242	144	74	3		98	0	98
Oats (harv. for silage)	406	31	2	0	343	29	3	32
Oats (harv. for grain)								
$LSD_{(0.05)}$[b]	61	85	63	65		94	N.S.	98
Harvest 2								
No Herbicide	160	138	1	1		20	1	21
Paraquat	230	191	2	0		10	29	39
Paraquat + 2,4-DB	249	219	3	0		17	13	30
Alfalfa + Smooth Brome	233	193	4	13	7	21	12	33
Alfalfa + Orchardgrass	245	167	2	13	4	22	54	75
Alfalfa + Timothygrass	229	186	5	6	6	18	20	37
Oats (killed with herb.)	195	177	1	2		19	0	19
Oats (harv. for silage)	168	147	1	0		17	5	21
Oats (harv. for grain)	175	119	11	0		18	39	56
$LSD_{(0.05)}$[b]	51	77	8	N.S.		N.S.	49	N.S.
Harvest 3								
No Herbicide	141	135	0	0		3	3	6
Paraquat	172	164	0	0		1	7	8
Paraquat + 2,4-DB	187	183	0	0		0	3	3
Alfalfa + Smooth Brome	190	164	0	0	21	2	4	6
Alfalfa + Orchardgrass	184	148	0	0	34	2	0	2
Alfalfa + Timothygrass	196	184	0	0	3	1	8	9
Oats (killed with herb.)	159	158	0	0		1	0	1
Oats (harv. for silage)	166	155	0	0		9	2	11
Oats (harv. for grain)	103	85	0	0		2	16	18
$LSD_{(0.05)}$[b]	39	41	N.S.	N.S.		6	9	11

[a]AMARE = redroot pigweed; CHEAL = common lambsquarters.
[b]Comparisons valid within columns and harvests.

Appendix Table 2. Influence of establishment program on total forage, alfalfa, forage grass, and weed yields for the year of establishment of the 1990 seeding at Kellogg Biological Station, Hickory Corners, Michigan.

Establishment Program	Yield							
	Forage	Alfalfa	CHEAL[a]	ABUTH[a]	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	$(10\ kg\ ha^{-1})$							
Harvest 1								
No Herbicide	285	223	3	34		58	5	62
Paraquat	374	310	5	50		64	0	64
Paraquat + 2,4-DB	301	301	0	0		0	0	0
Alfalfa + Smooth Brome	454	365	3	24	18	68	4	72
Alfalfa + Orchardgrass	329	263	7	0	29	28	8	36
Alfalfa + Timothy Grass	338	296	2	4	8	24	9	34
Oats (killed with herb.)	214	209	0	2		5	0	5
Oats (harv. for silage)	327	24	0	0	294	10	0	10
Oats (harv. for grain)								
$LSD_{(0.05)}$[b]	85	103	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 2								
No Herbicide	232	219	0	2		4	10	13
Paraquat	284	279	0	0		1	4	5
Paraquat + 2,4-DB	261	252	0	0		0	9	9
Alfalfa + Smooth Brome	301	288	0	0	0	2	11	13
Alfalfa + Orchardgrass	274	201	0	0	56	1	16	17
Alfalfa + Timothy Grass	278	260	0	0	13	0	5	5
Oats (killed with herb.)	273	271	0	0		2	0	2
Oats (harv. for silage)	210	169	0	0	27	2	13	15
Oats (harv. for grain)	310	198	0	0	102	0	11	11
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
Harvest 3								
No Herbicide	146	142	0	0		3	1	4
Paraquat	199	199	0	0		0	0	0
Paraquat + 2,4-DB	190	190	0	0		0	0	0
Alfalfa + Smooth Brome	204	197	0	0	6	1	0	1
Alfalfa + Orchardgrass	186	139	0	0	47	0	0	0
Alfalfa + Timothy Grass	184	169	0	0	0	1	14	16
Oats (killed with herb.)	193	192	0	0		1	0	1
Oats (harv. for silage)	151	148	0	0		1	2	2
Oats (harv. for grain)	192	177	0	0		1	15	15
$LSD_{(0.05)}$[b]	N.S.	N.S.	N.S.	N.S.		N.S.	5	10

[a]CHEAL = common lambsquarters; ABUTH = velvetleaf.
[b]Comparisons valid within columns and harvests.

Appendix Table 3. **Influence of establishment program of total forage, alfalfa, forage grass, and weed yields for the year following establishment, of the 1989 seeding at Kellogg Biological Station, Hickory Corners, Michigan.**

Establishment Program	Yield: Forage	Alfalfa	Forage Grass	Total Broadleaf Weeds	Total Grassy Weeds	Total Weeds
	($10\ kg\ ha^{-1}$)					
Harvest 1						
No Herbicide	569	549		16	4	20
Paraquat	579	542		37	1	37
Paraquat + 2,4-DB	579	570		3	6	9
Alfalfa + Smooth Brome	622	540	82	0	0	0
Alfalfa + Orchardgrass	620	509	109	2	0	2
Alfalfa + Timothy Grass	599	545	51	2	0	2
Oats (killed with herb.)	608	600		9	0	9
Oats (harv. for silage)	567	547		13	7	20
Oats (harv. for grain)	486	418		36	32	68
$LSD_{(0.05)}$[a]	59	68		26	15	29
Harvest 2						
No Herbicide	328	319		5	3	8
Paraquat	358	341		1	16	17
Paraquat + 2,4-DB	342	333		0	9	9
Alfalfa + Smooth Brome	325	308	6	2	10	12
Alfalfa + Orchardgrass	340	294	46	0	0	0
Alfalfa + Timothy Grass	327	322	3	1	2	1
Oats (killed with herb.)	355	348		7	0	7
Oats (harv. for silage)	337	323		10	4	14
Oats (harv. for grain)	310	294		12	3	15
$LSD_{(0.05)}$[a]	334	32		9	12	14
Harvest 3						
No Herbicide	302	298		1	3	4
Paraquat	281	257		1	22	23
Paraquat + 2,4-DB	304	300		0	4	4
Alfalfa + Smooth Brome	324	313	6	3	2	5
Alfalfa + Orchardgrass	308	245	63	0	1	1
Alfalfa + Timothy Grass	331	323	1	1	6	7
Oats (killed with herb.)	298	298		0	0	0
Oats (harv. for silage)	328	324		2	2	4
Oats (harv. for grain)	306	296		1	8	9
$LSD_{(0.05)}$[a]	50	52		N.S.	14	N.S.
Harvest 4						
No Herbicide	253	249		2	2	4
Paraquat	262	232		1	28	29
Paraquat + 2,4-DB	263	253		0	10	11
Alfalfa + Smooth Brome	259	253	1	2	3	5
Alfalfa + Orchardgrass	262	201	49	0	13	13
Alfalfa + Timothy Grass	269	265	0	0	3	3
Oats (killed with herb.)	240	240		0	0	0
Oats (harv. for silage)	258	253		2	2	4
Oats (harv. for grain)	258	250		3	6	8
$LSD_{(0.05)}$[a]	N.S.	38		2	18	18

[a]Comparisons valid within columns and harvests.