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Establishment of Alfalfa (Medicago sativa L.) and Birdsfoot Trefoil (Lotus corniculatus L.) in Various Grass Sods as Affected by Date and Method of Seeding, and Herbicide Application
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ESTABLISHMENT OF ALFALFA *(MEDICAGO SATIVA L)* AND BIRDSFOOT TREFOIL *(LOTUS CORNICULATUS L)* IN VARIOUS GRASS SODS AS AFFECTED BY DATE AND METHOD OF SEEDING, AND HERBICIDE APPLICATION

By

Clive William Holland

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ABSTRACT

ESTABLISHMENT OF ALFALFA *(MEDICAGO SATIVA L.)* AND BIRDSFOOT TREFOIL *(LOTUS CORNICULATUS L.)* IN VARIOUS GRASS SODS AS AFFECTED BY DATE AND METHOD OF SEEDING, AND HERBICIDE APPLICATION

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Michigan has in excess of one million hectares of permanent pastureland with a large portion that is generally low in productivity and too steep for conventional tillage. Introducing legumes into these pastures without tillage would greatly increase forage production and prevent erosion. Poor legume stands have been obtained without suppression of the existing grass swards and were considered to be a direct result of grass competition. The objectives of this study were (1) to consider seeding methods that could be used to renovate existing low producing pastures, (2) to determine the type of herbicide and rate of application needed to effectively suppress these pastures for good legume germination and establishment, and (3) to compare the date of seeding that would best suit Michigan climatic conditions.

Four experiments were conducted, one in northern and three in central Michigan. Two were on a loam soil in central Michigan on sods of preplanted grasses of bromegrass *(Bromus inermis L.)*, orchardgrass

(Dactylis glomerata L.), tall fescue *(Festuca arundinacea L.)*, reed canarygrass *(Phlaris arundinacea L.)*, and Kentucky bluegrass *(Poa pratensis L.)*. Two other experiments were conducted, one in each location, on sandy loam soils on existing sods of quackgrass *(Agropyron repens L.)*.

Birdsfoot trefoil and/or alfalfa were/was broadcast on the five preplanted grasses after the sods were suppressed at various rates of application with *N-(phosphonomethyl) glycine* (glyphosate), or *3,5-dichloro(N-1,1-dimethyl-2-propynyl) benzamide* (pronamide). Stand density and yields were compared to those from the recommended treatments of band seeding in a tilled seedbed or drilling the seed 1 cm deep in a herbicide-suppressed sod. Alfalfa was seeded in the quackgrass sods after treatment with glyphosate and pronamide applied at various rates and *1,1'-dimethyl-4,4'-bipyridinium ion* (paraquat) at the recommended rate.

Excellent stands of legumes were established by drilling or broadcasting seeds on the preplanted grass sods when the grasses were suppressed by a herbicide and seedings were made by 24 April. Drilling the seed 1 cm deep in herbicide-suppressed sods in late May produced good stands and excellent subsequent yields but broadcasting the legume seed was unsatisfactory at this late date. Seedings made by drilling or broadcasting legumes on unsuppressed grass sods produced poor stand densities and extremely low yields.

When alfalfa was seeded by drilling or broadcasting on a quackgrass sod, herbicide suppression of the untilled sods was essential for good alfalfa establishment and production. The lower rates of herbicide were more satisfactory for good stands and yields of alfalfa after

tilling and band seeding than when alfalfa was seeded on an undisturbed herbicide-treated sod.

Glyphosate applications were successful and consistent in suppressing quackgrass; pronamide was less effective. Paraquat did not suppress quackgrass adequately for successful sod seeding of alfalfa.

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INTRODUCTION

Production of many permanent pastures is limited because of a lack of adequate legumes in the sward. Kentucky bluegrass pastures and other low producing grasses are an integral part of many forage programs, particularly in the northcentral and northeastern United States. Efforts for many years have been made to improve production of this land through pasture renovation ranging from improved and increased fertilizer applications, better grazing management, to a complete kill of the existing sod by tillage to enable legumes and more productive grasses to be seeded.

Over the last 50 years an improvement in productivity of a pasture by any cultural practice has been known as a regeneration or renovation procedure. Graber (1936) worked extensively in improving unproductive pastures and he first called pasture renovation "the establishment of dry weather legumes in grass sods without plowing." Pasture renovation is defined by the Crop Science Society of America as "the improvement of a pasture by the partial or complete destruction of the sod, plus liming, fertilizing, seeding, and weed control as may be required to establish desirable forage plants" (Decker et al., 1973). With the development in recent years of suitable chemical herbicides, pasture renovation has become know more generally as the establishment or re-establishment of high yielding and well adapted legumes or grasses in an existing sod without completely

destroying the stand. In most cases this involves the establishment of a legume in a grass sod.

Michigan has over one million hectares of permanent grass pastures and hayfields which are generally low in productivity (Tesar, 1975). Yields of these pastures and grassy hayfields, according to Tesar, can be doubled or tripled by establishing productive legumes or grasses in them. Plowing and field cultivation has been the most traditional, and considered the best method for re-establishing unproductive pastures and farmland, particularly when there has been no consideration for the cost of establishment or interruption to production. This method has been a more conventional and assured way of gaining a good stand. There are however, many areas of farmland that are too steep for plowing or too rough for conventional cultivating and seeding machinery. Renovation is particularly suited to the steeper slopes and to soils more susceptible to erosion, where exposure of the bare soil surface is not desirable.

Research over many years has shown that suppression of the existing sod is essential to enable introduced seedlings to become established. Fribourg (1962) states that grass competition can be reduced by close grazing or clipping, followed by repeated diskings, but with the advent of plant killing chemicals it is now possible to substitute chemical for mechanical suppression or destruction of the sod. In the past renovation has been recommended and used mainly on pastures unsuitable for plowing. Repeated surface tillage to break the sod sufficiently to expose the soil but leaving a mulch substancial enough to prevent erosion have been the usual practices to retard vegetative regrowth of unwanted plants. This has necessitated the use

of heavy equipment not normally found on most farms, and long hours of costly tractor labor. Separate repeated diskings or surface cultivation of some type, at critical intervals throughout the sunny dry portion of the year are essential to its success. This is one of the greatest reasons for the failure of mechanical renovations as a farmer generally finds it difficult to schedule this work into an already busy farm program.

The objectives of this study were (1) to consider seeding methods that a farmer with little or no cultivating machinery could use to renovate existing low producing pastures, at a minimum of cost, time, and effort, (2) to determine the type of herbicide and rate of application needed to effectively suppress existing sods for good legume germination and establishment, and (3) to compare the date of seeding that would best suit Michigan climatic conditions.

LITERATURE REVIEW

In recent years in many parts of the world considerable emphasis has been placed on the improvement of permanent pastures and unproductive areas of land. Many thousands of pasture hectares in the United States are producing forage yields well below potential. In the humid region more than 75% of the pastures are located on land too steep for safe conventional tillage which is necessary for complete pasture renovation (USDA, 1971). Sod seeding, or the more generally understood minimum tillage renovation of these areas offers an excellent alternative for improving forage production and quality without the threat of large scale erosion problems.

Sod seeding is not new as the practice and equipment to do the job have been available for many years. Dudly and Wise (1953) reported on equipment and practices for introducing cereals into grass swards to extend the grazing season and improve forage yields. Early studies of improving pastures were carried out by Carrier and Oakely (1914) where they disked, harrowed, plowed, and reseeded bluegrass sods in an unsuccessful endeavor to overcome sod binding. Brown and Slate (1929) claim early pasture improvement in the United States consisted largely of cutting brush, which was a perennial task to prevent pastures reverting to woodlands, and its removal by hand was a major deterrent to improving pastures.

Research on the improvement of unproductive permanent bluegrass

pastures without plowing was begun in Wisconsin in 1925 (Graber, 1953). Graber experienced great difficulty in dealing with the thick bluegrass sod as it kept introduced (broadcast) legume seeds from contacting the soil. The seeds would sprout in the sod but without soil contact they dried up and died. During the years of 1925, 1926, and 1927 he burned excess top growth of bluegrass sod in early March while it was still frozen. With control areas immediately adjacent he planted plots of sweet, red, and alsike clovers and alfalfa. Almost negligible stands were obtained on the untreated bluegrass sods in comparison to the vigorous legume growth on the burned areas (Graber, 1927). The principle of reducing competition from the existing sod for successful seedings was formulated by Graber at this time. In 1928 he reported that "where burning is not feasible, cultivation of pasture lands by means of a disk or spring tooth harrow will be a requirement for such soil contact and for successful seeding on dense sods." Bluegrass yields were trebled with the introduction of sweet clover on the burned sod as compared with the adjacent bluegrass where sweet clover was not grown (Graber, 1928).

During the same period Wiggans (1926) found that plowing and reseeding without fertilizer gave no improvement in pasture yield. Harrowing and reseeding gave the same poor results which helped him conclude that the physical condition of the soil rather than the pasture was the major problem with low productivity. The discovery that June beetles *(Phyllophaga spp)* did not lay eggs where alfalfa and sweet clover grew abundantly in bluegrass sods greatly enhanced interest in the work of interseeding legumes into grass sods without plowing (Fluke, 1932; Graber, 1953).

Ahlgren et al. (1944) reported that in the year after seeding legumes into a bluegrass sod, production of the renovated pastures was five times that of untreated areas. This decreased to only twice the yield in the second year mainly because of inadequate control of the bluegrass by the spring cultivation. Weed populations of sods were dramatically reduced by interseeding legumes in 27 pastures after scarification renovation methods in Wisconsin (Fuelleman and Graber, 1938; Ahlgren et al., 1946). Nearly all work done on improving pasture productivity during the early 1940s involved mechanical suppression of existing sods. It was generally accepted and understood by most researchers that successful renovation of unproductive pastures was dependent on three major items as reported by Sprague et al. (1947):

1. Lime and fertilizer must be provided to meet requirements of species used.
2. A seedbed must be prepared in which existing vegetation is killed or subdued sufficiently to prevent serious competition with the seeded species.
3. Management after seeding and establishment of introduced species to provide favorable growing conditions.

Sprague and his associates concluded that surface tillage was preferred to plowing because it left a mulch that prevented soil crusting from heavy rain and helped absorb moisture, preventing runoff. Smith et al. (1944) worked with mechanical suppression of sods as did Borst and Yoder (1943) who claimed that sod seeding failures were almost wholly a result of inadequate suppression of existing grass sods. This showed a need for a method or effective system of controlling or eliminating vegetation competition for new seedlings. Brown and co-workers undertook preliminary investigations

in 1945 testing the ability of 15 different chemicals to eliminate perennial grass species prior to seeding Ladino clover (Sprague, 1952). Sprague began trials also in 1949 using chemicals to suppress grass swards, before disking the sod for a seedbed. However, as early as 1929 pasture researchers had tried various chemicals to eliminate woody plants and control brush that grew in pastures in the eastern USA. These efforts were not very successful even though huge quantities of chemicals were used per acre (Aldous, 1929).

As a result of his work with chemicals, Sprague proposed a new principle for use in pasture renovation. This was to use only a minimum amount of tillage after suppressing existing vegetation with chemicals. Many other researchers in Canada (Winch et al., 1969; Watkin and Winch, 1969, 1970, and 1972; Watkin et al., 1970), England (Elliot, 1960; Copeman and Roberts, 1960), New Zealand (Blackmore, 1958b; Mathews, 1959; Cullen, 1970; White, 1970), Australia (Murtagh, 1963; Cocks, 1965; Dowling et al., 1971; Campbell, 1976a, 1976b; Dowling, 1976), and the United States (Harrington and Washko, 1960; Smith, 1960; Sprague, 1960; Sprague et al., 1960; Burcalow, 1961; Peters, 1965; Taylor et al., 1969; Scholl et al., 1970; Triplett et al., 1975; Decker and Dudly, 1976; Peters, 1976; Van Keuren, 1976; Triplett et al., 1977; Moshier and Penner, 1978; Tesar, 1975a, 1975b, 1978) have worked extensively with chemical suppression of sods and reported their findings. All research clearly indicates the need to suppress the existing vegetation before introducing new species to the sward.

The method of establishment of legumes and grasses has also received much attention (Williams, 1953; Tesar et al., 1954; Smith, 1960; Tesar and Triplett, 1960; Campbell, 1969; McWilliam and Dowling,

1970; Van Keuren and Triplett, 1970; Cullen, 1971; Tesar and Jackobs, 1972; Campbell and Swain, 1973; Decker, 1973; Decker et al., 1973; Myers and Triplett, 1973; Dowling and Sykes, 1975; Tesar, 1975a, 1975b; Peters, 1976; Suckling, 1976; Underwood and Clay, 1976; Triplett and Van Doren, 1977). Complete tillage with compaction of the seed above a band of fertilizer has been shown to give higher establishment of species than from broadcasting the seed (Tesar et al., 1954; Oohara et al., 1965). Tesar and Jackobs (1972) state that the two general methods of seeding alfalfa are broadcasting on the surface of the soil or band seeding. Haynes and Thatcher, as reported by Tesar and Jackobs (1972), pioneered the practice of band seeding. This method utilizes a specially adapted seed drill that drops the seed on the soil surface two to six centimeters above a band of fertilizer. This operation is used exclusively on completely tilled areas.

The broadcast method of seeding is the distribution of the seed on the soil surface in no specific pattern or placement. This method has been used on all types of seedbeds with varying success (Tesar et al., 1954; Copeman and Roberts, 1960; Winch et al., 1966; Campbell, 1968; Watkin and Winch, 1969, 1970, and 1972; Cullen, 1970; McWilliam and Dowling, 1970; Watkin et al., 1970; Dowling et al., 1971; Dowling and Sykes, 1975; Campbell, 1968, 1976a, 1976b; Campbell and Swain, 1973; Dowling, 1976). Campbell (1969) claims that successful establishment following surface seeding of any species is greatly dependent on the reliability of effective rain falling after seeding. Moisture availability and allowing existing vegetation to provide plant litter to create a favorable micro-environment aid greatly in

the establishment of broadcast seedings according to McWilliam and Dowling (1970). McGinnies (1960) found that surface seeded range grasses can germinate reasonably well under relatively high levels of moisture stress, if the temperature is favorable. He suggested that future research on surface seeding should be directed towards finding methods of warming the soil in such ways as growing tall stubble. However, McWilliam and Dowling (1970) found no differences in temperature close to the soil surface due to various amounts of plant litter. One disadvantage of broadcast seeding as reported from Australia is the consuming of the seed by insects (Campbell, 1966).

Sod seeding was developed in the USA, Australia, and New Zealand around the same time (Summer and Kepner, 1951; Breakwell and Jenkins, 1953; Blackmore, 1958a). It is an inexpensive and rapid method of pasture establishment carried out by the introduction of the seeded species into the soil of a sward without destroying the existing sod. This method is not without problems as the mulch of the sward harbors damaging insects (Braithwaite et al., 1958; Tesar, 1979a), and legume feeding snails (Kalmbacher et al., 1979). Decker et al. (1964) found it more difficult to establish birdsfoot trefoil by sod seeding due in part to the species lower vigor and the covering too deeply of the seed by the soil flap of the slit created by the seeding machinery.

Special powered equipment is now available that forms a miniature trench from two to six centimeters wide in the existing sod. Legumes are introduced into this area by the same machine that is also equipped with press wheels to compact the seed into the soil (Ackley, 1975). Hill lands and erosion-prone areas are most suited to this

sod seeding method of species establishment. Although it is considered essential to suppress the existing sod to reduce competition to the introduced seedings, an effective barrier to erosion still remains in the form of roots and a surface mulch. Chemical suppression is considered to be superior, more efficient and an integeral part of any successful sod seeding program. Pasture renovation utilizing chemicals and the sod seeding method has been reported on from various aspects by many researchers (Harrington and Washko, 1960; Peters, 1960; Sprague et al., 1960; Murtagh, 1963; Sprague, 1960; Decker et al., 1964, 1969; Decker and Dudly, 1976; Taylor et al., 1969; Van Keuren and Triplett, 1970; Watkin et al., 1970; White, 1970, 1973; Decker, 1973; Myers and Triplett, 1973; Hoffman, 1975; Tesar, 1975a, 1975b; Myers, 1975; Triplett et al., 1975; Decker and Dudly, 1976; Swain, 1976; Underwood and Clay, 1976; Van Keuren, 1976; Triplett and Van Doren, 1977; Moshier and Penner, 1978; Kalmbacher et al., 1980).

Band seeding in a prepared seedbed, broadcasting on a sod, or drilling into a sod, are the most common methods of seeding small seeded grasses and legumes. Of these three, band seeding in a prepared seedbed is considered by farmers and researchers alike to be the most desirable method of seedling establishment under nonerodible and suitable tillage conditions (Decker et al., 1973; Tesar and Hilderbrand, 1975; Tesar, 1978).

Frans and Sprague (1953) reported what they regarded as four essential criteria for a chemical to be acceptable for use in pasture renovation:

1. Must kill the entire plant.

2. Should have a short period of toxicity.

3. Must be harmless to livestock.

4. The chemical must be economically feasible to use from the point of eliminating or minimizing tillage.

All four criteria have not been considered essential in areas where existing pastures have been rejuvenated with legumes, as suppression rather than eradication has been the goal. However, in Michigan and Wisconsin where there are millions of acres infested with quackgrass *(Agropyron repens)* adherance to Frans and Sprague's four criteria are of the utmost importance. Tesar (1975a) reported glyphosate to be extremely effective in killing quackgrass and claimed it would be an excellent herbicide for pasture renovation when cleared for use in the USA. Moshier and Penner (1978) showed glyphosate to have a relatively short toxicity period of less than three days, although conflicting evidence has been reported from Australia (Campbell, 1976a). In research trials this herbicide has given promising results and appears to fulfill the four requirements of an acceptable chemical for pasture renovation.

MATERIALS AND METHODS

Investigations were carried out in 1977, 1978, and 1979 at three field locations at East Lansing and one field location at Lake City. Two locations utilized existing sods of quackgrass *(Agropyron repens L.)* for the renovation trials while the other two locations were on sods of preplanted grasses.

Experiment 1: East Lansing, sod seeded birdsfoot trefoil, pH 7.2, three herbicide rates fall applied on five grasses, two seeding methods and dates, three years: 1977, 1978, and 1979.

Experiment 1 was established in 1977 on the Michigan State University experimental farm area at East Lansing. The soil was a Capac loam, a member of the fine-loamy, mixed, mesic family of Aeric Ochraqualfs with a 2% slope. Soil tests indicated a pH of 7.2, 109 kg of Phosphorus, 224 kg of Potassium, and 3467 kg of calcium per hectare.

Five grasses were established in the fall of 1973 in plots 2.44 by 18.29 m. These grasses and planting rates per hectare were as follows:

1. Lincoln bromegrass *(Bromus inermis L.)* at 26.90 kg
2. Pennlate orchardgrass *(Dactylis glomerata L.)* at 17.94 kg
3. Commercial tall fescue *(Festuca arundinacea L.)* at 26.90 kg
4. Commercial reed canarygrass *(Phlaris arundinacea L.)* at 26.90 kg
5. Park Kentucky bluegrass *(Poa pratensis L.)* at 17.94 kg

The experiment was designed as a split plot, randomized, complete block with three replications and plots 2.44 by 6.10 m in size. Main plot variables consisted of the grasses listed above. The herbicide *3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide* (Pronamide) was applied to each grass sod on November 15, 1976, at rates of 0.56, 1.12, and 1.68 kg^{ai}/ha.

Mackinaw birdsfoot trefoil *(Lotus corniculatus L.)* was seeded into the sprayed grass sods in the following spring. Prior to planting, the seed was inoculated with *Rhizobium* bacteria using the Pelinoc-Pelgel method. This is a proprietary system (Nitragin Co., Milwaukee, Wisconsin) which consists of mixing the seeds with a sticker supplement called Pelgel, and then covering the moistened seeds with a peat-base inoculum called Pelinoc. The trefoil seed was planted at 11.21 kg/ha using a modified John Deere grain-fertilizer-legume drill with eleven disk openers spaced 17.78 cm apart (Fig. 1). Modifications included the ability to drill the seed into the sod or braodcast it from the same seed-box on the machine. Birdsfoot trefoil was seeded by the following methods and dates (split plots):

1. Broadcast on sods on 31 March
2. Broadcast on sods on 15 April
3. Drilled into sods in slits 1 cm deep on 15 April (Fig. 2)

Nine weeks after seeding, visual estimations were made of the percentage trefoil present in each plot. All plots were fertilized on 22 June with 110 kg of P_2O_5 and 330 kg of K_2O per hectare. Similar applications were made in the spring of 1978 and 1979.

Stand density was determined ten weeks after seeding by counting trefoil plants in two directed samplings from each plot. A

Fig. 1. Modified John Deere grain-fertilizer-legume drill sod seeding into a herbicide treated sod.

Fig. 2. Slit in the sod formed by a disk opener when sod seeding with the modified grain-fertilizer-legume drill.

quadrat of 35.56 cm was the size of each sampled area.

In the year of seeding (1977), the plots were harvested on 3 October. Three harvests were made in 1978: 22 June, 31 July, and 15 November. Two harvests were made in 1979: 13 July, and 13 September. Before each harvest visual estimations were made of the percentage of birdsfoot trefoil present in each plot. These percentages were used to calculate yields of birdsfoot trefoil. Yields were determined by cutting an area 0.91 by 4.32 m using a Carter self-propelled harvester. A 1,000 g green weight sample was taken from each plot, forced air dried at 65°C for 48 hours, and weighed to determine percentage dry matter. These dry matter yields were then used in calculations for yields of hay at 12% moisture.

Experiment 2: East Lansing, alfalfa and birdsfoot trefoil, pH 7.4, two herbicides fall applied on three grasses, three seeding methods and dates, two years: 1978, and 1979.

Experiment 2 was established in 1978 on the Michigan State University experimental farm area at East Lansing. The soil was a Capac loam, a member of the fine-loamy, mixed, mesic family of Aeric Ochraqualfs with a 2% slope. Soil tests indicated a pH of 7.4, organic matter content of 3.14%, 151 kg of phosphorus, 179 kg of potassium, and 5045 kg of calcium per hectare.

The experiment was designed as a split-split, randomized, complete block with four replications. The statistical analysis was made by considering each legume as a separate experiment. Three grasses constituting the split plots were established in June 1977 in plots 1.83 by 9.14 m. These grasses were as follows:

1. Lincoln bromegrass
2. Pennlate orchardgrass
3. Park Kentucky bluegrass

In order to suppress or kill these grasses, *N-(phosphonomethyl) glycine* (glyphosate) was applied on 14 October 1977 at 1.68 kg^{ai}/ha to ten designated treatment blocks, which included all three grasses in each block. On 17 November, pronamide at 1.68 kg^{ai}/ha was applied to two treatment blocks.

Prior to planting, the seed was inoculated with the appropriate species *Rhizobium* bacteria using the moist slurry method. This was done by making a water slurry of the peat-based carrier of the *Rhizobia*, mixing the slurry with the seed which was then allowed to dry before planting. Twice the recommended amount of inoculum was added to the birdsfoot trefoil seed. Alfalfa *(Medicago sativa L.)* was seeded at 13.45 kg and birdsfoot trefoil at 9.97 kg per hectare using the same machinery as described in experiment 1.

In the spring of 1978 Iroquois alfalfa and Viking birdsfoot trefoil were seeded into these grass sods on three dates and by three seeding methods which are tabulated below as main plots.

1. April 24, legume broadcast onto sods with no previous herbicide treatment.
2. April 24, legume drilled 1 cm deep into sods with no previous herbicide treatment.
3. April 24, legume broadcast onto sods that were fall treated with glyphosate.
4. April 24, legume drilled 1 cm deep into sods that were fall treated with glyphosate.
5. April 24, legume broadcast onto sods that were fall treated with pronamide.

6. May 1, legume band seeded into a tilled seedbed after sods fall treated with glyphosate were plowed under.

7. May 22, legume broadcast onto sods that were fall treated with glyphosate.

8. May 22, legume drilled 1 cm deep into sods that were fall treated with glyphosate. Press wheels used to compact soil around the seed.

When the seed was drilled into the sod it was placed in contact with 62 kg/ha of P_2O_5 fertilizer, in a slit 1 cm deep that was made by the spring-loaded disk openers of the drill. When the seed was broadcast the disks were raised to prevent cutting of the sod and the fertilizer was broadcast with the seed onto the sod. The band seeding method was used only on plots with a tilled seedbed. Plowing followed by disking and several harrow-drag cultivations constituted a tilled seedbed. Band seeding placed the fertilizer in a band 5 cm below the band of seed that was dropped on the surface and compacted into the soil with press wheels.

Visual estimations of percentage legume present in each plot were made 3 and 12 months after seeding. Broadleaved weeds were controlled by an application of 1.12 kg^{ai}/ha of *4-(2,4-dichlorophenoxy) butanoic acid* (2,4-DB) six weeks after seeding. Insecticide was used at appropriate intervals to control weevils and leafhoppers. In the spring of 1979, 470 kg/ha of K_2O fertilizer was applied to all plots.

Stand density was determined ten weeks after seeding by counting legume seedlings in four directed quadrat samplings of 35.56 cm from each plot. Quadrats were placed 1.83 m apart with rows two and three of the eleven-row drill plot being included in sample one, rows four and five in sample two, rows six and seven in sample three, rows eight and nine in sample four.

The plots were harvested in the year of seeding on 8 August, and 31 October. Three harvests were made in 1979: 21 June, 6 August, and 23 October. Visual estimations were made of the percentage of legume present in each plot before each harvest. Yields were determined by cutting an area of 0.91 by 8.23 m using machinery and procedures as described in experiment 1.

Experiment 3: East Lansing, alfalfa on quackgrass, pH 6.6, four herbicides fall applied at various rates, two seeding methods and surfaces, two years: 1978, and 1979.

Experiment 3 was established in 1978 on a stand of almost pure quackgrass on Michigan State University experimental farm area at East Lansing. The soil was a Marlette fine sandy loam, a member of the fine-loamy, mixed, mesic family of Glossoboric Hapludalfs with slopes of 2 to 6%. Soil tests indicated a pH of 6.6, organic matter content of 1.95%, 28 kg of phosphorus, and 152 kg of potassium per hectare. Prior to establishing the experiment, 1.12 kg^{ai}/ha of *(2,4-dichlorphenoxy)acetic acid* (2,4-D ester) was sprayed over the entire area on August 1977 to ensure that red clover *(Trifolium pratense L.)* and other legumes were eradicated as completely as possible.

The experiment was designed as a split plot, randomized, complete block with three replications and plots 2.13 by 7.62 m in size. Replicates were divided into two blocks: one was sod seeded and the other was plowed, tilled, and planted by the band seeding method. Four herbicides, to suppress or kill the quackgrass, were applied to the plots and are listed below. Rates were in active ingredient per hectare.

1. Control with no herbicide
2. *1,1'-dimethyl-4,4'-bipyridinium ion* (Paraquat) applied on 25 April at 0.56 kg
3. Pronamide applied on 17 November at 0.56, 1.12, and 1.68 kg
4. Glyphosate applied on 14 October at 0.56, 1.12, and 1.68 kg
5. *3(5-(1,1-dimethylethyl0-1,3,4-thiadiazol)-2-yl)-4-hydroxy-1-methyl-2-imidazolidinone* (Buthidazole) applied on 14 October at 0.56, 1.12, and 1,68 kg

Iroquois alfalfa was seeded on 1 May at 13.45 kg/ha using the same procedures, equipment, fertilizer and rate, and method of *Rhizobia* inoculation as in experiment 2. Control of broadleaved weeds and insects, subsequent fertilizer applications, stand density determinations, and visual estimations of percentage of legume present in each plot were the same as in experiment 2.

The plots were harvested in the year of seeding on 2 October. Three harvests, 17 June, 26 July, and 11 September, were made in 1979. Harvests were from an area of 0.91 by 7.00 m and yields obtained by the same procedure as described in experiment 1.

The monthly precipitation data for 1977, 1978, and 1979 at East Lansing are presented in Table 1.

Table 1. Precipitation (mm) with deviations from normal for three years at the Michigan State University experimental farm. East Lansing, 1977-79.

Month	1977		1978		1979	
	Precipitation	Deviation	Precipitation	Deviation	Precipitation	Deviation
Jan.	23.6	- 70.3	67.6	+ 26.7	47.8	+ 6.9
Feb.	15.8	- 18.5	9.7	- 24.6	10.7	- 23.6
Mar.	67.3	+ 12.5	55.1	+ 0.3	35.8	- 19.1
Apr.	94.0	+ 24.6	37.3	- 32.0	72.1	+ 2.8
May	10.2	- 79.0	58.9	- 30.2	53.9	- 35.3
June	93.5	- 3.1	57.4	- 39.1	108.0	+ 11.4
July	86.6	+ 13.5	38.4	- 34.8	42.4	- 30.7
Aug.	52.3	- 30.7	71.4	- 11.7	111.0	+ 27.9
Sept.	133.9	+ 70.9	96.3	+ 33.3	0.0	- 63.0
Oct.	36.8	- 23.6	56.1	- 4.3	65.5	+ 5.1
Nov.	46.2	- 10.4	48.5	+ 4.8	83.1	+ 26.4
Dec.	59.2	+ 15.5	47.8	+ 4.1	68.8	+ 25.1
Annual	719.3	- 45.7	644.4	-120.7	699.0	- 66.0

Experiment 4: Lake City, alfalfa on quackgrass, pH 6.3, three herbicides fall applied at three rates, two seeding methods and surfaces, two years: 1978, and 1979.

Experiment 4 was established in 1978 on a stand of almost pure quackgrass on Michigan State University experimental farm area at Lake City. The soil was an Iosca sandy loam, a member of the sandy over loamy, mixed, frigid family of Alfic Haplaquads with a 2% slope. Soil tests indicated a pH of 6.3, organic matter content of 1.69%, 580 kg of phosphorus, and 202 kg of potassium per hectare. Prior to establishing the experiment 1.12 kg^{ai}/ha of *(2,4,5-trichlorophenoxy)acetic acid* (2,4,5-T) herbicide was sprayed over the entire area in August 1977, to ensure that existing alfalfa plants were eradicated as completely as possible.

The experiment was designed as a split plot, randomized, complete block with four replications, and plots 1.83 by 7.62 m in size. The statistical analysis was made by considering each seeding method as a separate experiment. Replicates were divided into two blocks: one was sod seeded and the other was plowed, tilled, and planted by the band seeding method. Three herbicides, to suppress or kill the quackgrass, were applied to the plots. Rates were in active ingredient per hectare.

1. Control with no herbicide
2. Pronamide applied on 14 November at 0.70, 1.40, and 2.10 kg
3. Glyphosate applied on 13 October at 0.70, 1.40, and 2.10 kg
4. Buthidazole applied on 14 October at 0.70, 1.40, and 2.10 kg

Iroquois alfalfa was seeded on 17 April at 13.45 kg/ha using the same planting procedures, equipment, fertilizer and rate, and

method of *Rhizobia* inoculation as in experiment 2. Stand density was determined 12 weeks after seeding by the directed sampling procedure used in experiment 2. Visual estimations of percentage alfalfa in each plot were made 3 and 14 months after seeding. Broadleaved weeds and insects were controlled as in experiment 2. In the spring of 1979, 78 kg of P_2O_5, 235 kg of K_2O, and 1.4 kg of boron per hectare was applied to all plots.

The one harvest in the year of seeding was made on 31 August. Three harvests, 25 June, 14 August, and 7 October, were made in 1979. Harvests were from an area of 0.91 by 7.00 m and yields obtained by the same procedure as described in experiment 1. The monthly precipitation data for 1978, and 1979 at Lake City are presented in Table 2.

Table 2. Precipitation (mm) with deviations from normal for two years, at the Lake City experimental farm. Lake City, 1978 and 1979.

Month	1978		1979	
	Precipitation	Deviation	Precipitation	Deviation
Jan.	56.4	+ 25.4	40.1	+ 9.1
Feb.	56.4	- 7.9	14.7	- 12.5
Mar.	20.8	- 17.8	84.8	+ 46.2
Apr.	33.5	- 36.3	123.2	+ 53.3
May	56.4	- 17.8	41.4	- 32.8
June	50.8	- 37.3	84.6	- 3.6
July	32.0	- 57.9	38.9	- 51.1
Aug.	85.1	+ 21.6	86.6	+ 23.1
Sept.	193.6	+108.2	2.8	- 82.6
Oct.	70.6	+ 4.3	105.7	+ 39.4
Nov.	30.2	- 34.0	75.7	+ 11.4
Dec.	32.5	- 2.5	58.7	+ 23.6
Annual	681.2	- 52.1	757.2	+ 23.9

RESULTS AND DISCUSSION

Experiment 1: East Lansing, sod seeded birdsfoot trefoil, pH 7.2, three herbicide rates fall applied on five grasses, two seeding methods and dates, three years: 1977, 1978, and 1979.

Stand Density

Seeding year (1977): All methods of seeding produced stands of trefoil which were judged adequate for good forage production. The April drilled seeding (205 plants/m^2) produced a better stand than both the March and April broadcast seedings (Table 3). The April broadcast method (152 plants/m^2) was intermediate in stand density while the March seeding (132 plants/m^2) was the poorest. This was possibly a result of frost damage to germinated seed in the earlier seeding. The significant increase in seedlings in the April drilled method over both broadcast methods shows the importance of placing the seed in the soil in contact with a reliable supply of moisture. Differences in stand density were also obtained between the grasses and the herbicide rates.

Trefoil density increased only in bromegrass and tall fescue sods as the rate of herbicide was increased. The lack of response by orchardgrass to different levels of pronamide applications substantiates its known resistance to this herbicide (Triplett et al., 1977). The stand of trefoil was best in reed canarygrass which indicated the

Table 3. Stand density (plants/m^2) of Mackinaw birdsfoot trefoil three months after seeding (1977) in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding Date	Seeding Methods	Pronamide 0.56 kg^{ai}/ha	Pronamide 1.12 kg^{ai}/ha	Pronamide 1.68 kg^{ai}/ha	Average
			Bromegrass		
31 March	broadcast	$_{a}^{ab}$ 94 $_{a}^{a}$	$_{a}^{ab}$ 136 $_{a}^{a}$	$_{a}^{a}$ 141 $_{a}^{a}$	$_{a}^{b}$ 124 $_{a}^{a}$
15 April	broadcast	$_{a}^{a}$ 92 $_{a}^{a}$	$_{a}^{ab}$ 133 $_{a}^{a}$	$_{b}^{b}$ 177 $_{b}^{a}$	$_{ab}^{b}$ 134 $_{a}^{a}$
15 April	drilled	$_{a}^{bc}$ 187 $_{a}^{b}$	$_{c}^{c}$ 330 $_{c}^{c}$	$_{b}^{b}$ 260 $_{b}^{b}$	$_{b}^{d}$ 259 $_{b}^{c}$
	average	$_{a}^{a}$ 124 $_{a}^{a}$	$_{b}^{b}$ 199 $_{b}^{b}$	$_{b}^{bc}$ 192 $_{b}^{a}$	$_{b}^{bc}$ 172 $_{b}^{b}$
			Orchardgrass		
31 March	broadcast	$_{a}^{a}$ 75 $_{a}^{a}$	$_{a}^{a}$ 75 $_{a}^{a}$	$_{a}^{a}$ 96 $_{a}^{a}$	$_{a}^{a}$ 82 $_{a}^{a}$
15 April	broadcast	$_{a}^{a}$ 78 $_{a}^{a}$	$_{a}^{a}$ 79 $_{a}^{a}$	$_{a}^{a}$ 105 $_{a}^{a}$	$_{a}^{a}$ 87 $_{a}^{a}$
15 April	drilled	$_{a}^{a}$ 108 $_{a}^{a}$	$_{a}^{a}$ 141 $_{a}^{b}$	$_{a}^{a}$ 152 $_{a}^{a}$	$_{a}^{a}$ 134 $_{a}^{b}$
	average	$_{a}^{a}$ 87 $_{a}^{a}$	$_{a}^{a}$ 98 $_{a}^{ab}$	$_{a}^{a}$ 118 $_{a}^{a}$	$_{a}^{a}$ 101 $_{a}^{a}$
			Tall fescue		
31 March	broadcast	$_{a}^{a}$ 86 $_{a}^{a}$	$_{a}^{ab}$ 120 $_{a}^{a}$	$_{a}^{a}$ 138 $_{a}^{a}$	$_{a}^{ab}$ 115 $_{a}^{a}$
15 April	broadcast	$_{a}^{ab}$ 133 $_{a}^{a}$	$_{ab}^{bc}$ 157 $_{a}^{a}$	$_{b}^{b}$ 199 $_{b}^{a}$	$_{ab}^{bc}$ 163 $_{ab}^{b}$
15 April	drilled	$_{a}^{ab}$ 145 $_{a}^{a}$	$_{b}^{b}$ 241 $_{b}^{b}$	$_{ab}^{a}$ 166 $_{ab}^{a}$	$_{ab}^{b}$ 184 $_{ab}^{b}$
	average	$_{a}^{a}$ 121 $_{a}^{a}$	$_{b}^{b}$ 173 $_{b}^{a}$	$_{b}^{b}$ 168 $_{b}^{a}$	$_{ab}^{b}$ 154 $_{ab}^{b}$
			Reed canarygrass		
31 March	broadcast	$_{a}^{b}$ 158 $_{a}^{a}$	$_{b}^{c}$ 223 $_{b}^{a}$	$_{b}^{b}$ 227 $_{b}^{a}$	$_{ab}^{c}$ 203 $_{ab}^{ab}$
15 April	broadcast	$_{a}^{b}$ 189 $_{a}^{ab}$	$_{a}^{bc}$ 185 $_{a}^{a}$	$_{a}^{b}$ 185 $_{a}^{a}$	$_{a}^{c}$ 186 $_{a}^{a}$
15 April	drilled	$_{a}^{c}$ 237 $_{a}^{b}$	$_{b}^{b}$ 228 $_{a}^{a}$	$_{a}^{b}$ 244 $_{a}^{a}$	$_{a}^{cd}$ 236 $_{a}^{b}$
	average	$_{a}^{b}$ 195 $_{a}^{ab}$	$_{b}^{b}$ 212 $_{a}^{a}$	$_{a}^{c}$ 218 $_{a}^{a}$	$_{a}^{d}$ 208 $_{a}^{ab}$
			Kentucky bluegrass		
31 March	broadcast	$_{a}^{ab}$ 111 $_{a}^{a}$	$_{a}^{b}$ 157 $_{a}^{a}$	$_{a}^{a}$ 144 $_{a}^{a}$	$_{a}^{b}$ 137 $_{a}^{a}$
15 April	broadcast	$_{a}^{b}$ 177 $_{a}^{b}$	$_{a}^{c}$ 211 $_{a}^{a}$	$_{a}^{b}$ 183 $_{a}^{ab}$	$_{a}^{c}$ 190 $_{a}^{b}$
15 April	drilled	$_{a}^{bc}$ 206 $_{a}^{b}$	$_{a}^{ab}$ 208 $_{a}^{a}$	$_{a}^{ab}$ 220 $_{a}^{b}$	$_{a}^{bc}$ 211 $_{a}^{b}$
	average	$_{a}^{b}$ 164 $_{a}^{ab}$	$_{b}^{b}$ 192 $_{a}^{a}$	$_{a}^{bc}$ 182 $_{a}^{ab}$	$_{a}^{c}$ 179 $_{a}^{b}$
			Averages		
31 March	broadcast	105 $_{a}^{a}$	142 $_{bc}^{a}$	149 $_{c}^{a}$	132 $_{b}^{a}$
15 April	broadcast	134 $_{a}^{b}$	153 $_{b}^{ab}$	170 $_{c}^{a}$	152 $_{b}^{b}$
15 April	drilled	177 $_{a}^{c}$	230 $_{c}^{c}$	208 $_{b}^{b}$	205 $_{b}^{c}$
	average	138 $_{a}^{b}$	175 $_{b}^{b}$	176 $_{b}^{a}$	163 $_{b}^{b}$

Means followed by the same letter within columns and grasses are not significantly different at the 5% level using Duncan's Multiple Range Test.

Means preceded by the same letter within columns, and seeding date and method, are not significantly different at the 5% level using Duncan's Multiple Range Test.

Means underscored by the same letter within rows are not significantly different at the 5% level using Duncan's Multiple Range Test.

greater susceptibility of this grass to pronamide. Trefoil stands in bromegrass, tall fescue, and Kentucky bluegrass were intermediate.

Stand Estimations

Visual estimations of the percentage of trefoil present in each grass sod were made ten weeks after seeding (Table 4). The grasses were ranked as follows, with the greatest to the least of percentage trefoil present: Kentucky bluegrass, reed canarygrass, bromegrass, tall fescue, and orchardgrass. Estimations made one year after seeding (Table 5) indicated the same ranking except for a change in positions between reed canarygrass and tall fescue. In third-year estimations (Table 6), the same ranking was maintained except that reed canarygrass equalled orchardgrass with the least amount of trefoil present in the sods.

Although visual estimations are a somewhat subjective evaluation, a clear pattern is shown by the three-year response of these grasses to pronamide. Orchardgrass demonstrated the greatest resistance to the chemical, and, since it is a vigorous grass, it remained consistently the least affected by competition from the trefoil. Kentucky bluegrass was the most susceptible grass to pronamide. Reed canarygrass displayed the greatest initial susceptibility to the herbicide but was the most vigorous grass in re-establishing itself. Bromegrass and reed canarygrass were the only two grasses that showed a consistent three-year decline of percent trefoil in the sward.

Table 4. Percentage estimations ten weeks after seeding (1977) of Mackinaw birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Expt. 1, East Lansing.

Seeding		Pronamide kg^{ai}/ha			
Date	Methods	0.56	1.12	1.68	Average
		Bromegrass			
31 March	broadcast	59	79	91	76
15 April	broadcast	54	70	92	72
15 April	drilled	74	91	92	86
	average	62	80	92	78
		Orchardgrass			
31 March	broadcast	44	35	44	41
15 April	broadcast	34	43	51	43
15 April	drilled	24	35	44	34
	average	34	38	46	39
		Tall fescue			
31 March	broadcast	65	73	82	73
15 April	broadcast	57	71	88	72
15 April	drilled	65	77	84	75
	average	62	72	85	74
		Reed canarygrass			
31 March	broadcast	76	86	94	85
15 April	broadcast	66	73	93	77
15 April	drilled	68	85	91	81
	average	70	81	93	81
		Kentucky bluegrass			
31 March	broadcast	74	86	97	86
15 April	broadcast	90	91	96	92
15 April	drilled	93	99	99	97
	average	86	92	97	92
		Averages			
31 March	broadcast	64	72	82	73
15 April	broadcast	60	70	84	71
15 April	drilled	65	77	82	75
	average	63	73	83	73

Table 5. Percentage estimations one year (1978) after seeding of Mackinaw birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding		Pronamide kg[ai]/ha				Percent Change
Date	Methods	0.56	1.12	1.68	Average	Over 1 Year[†]
			Bromegrass			
31 March	broadcast	63	72	73	69	- 7
15 April	broadcast	58	68	82	69	- 3
15 April	drilled	67	73	83	74	- 12
	average	63	71	79	71	- 7
			Orchardgrass			
31 March	broadcast	57	72	70	66	+ 25
15 April	broadcast	62	68	72	67	+ 24
15 April	drilled	57	65	68	63	+ 29
	average	59	68	70	65	+ 26
			Tall fescue			
31 March	broadcast	73	72	75	73	0
15 April	broadcast	78	80	82	80	+ 8
15 April	drilled	78	85	85	83	+ 8
	average	76	79	81	79	+ 5
			Reed canarygrass			
31 March	broadcast	70	73	80	74	- 11
15 April	broadcast	53	63	73	63	- 14
15 April	drilled	60	68	78	69	- 12
	average	61	68	77	69	- 12
			Kentucky bluegrass			
31 March	broadcast	80	85	88	84	- 2
15 April	broadcast	92	93	97	94	+ 2
15 April	drilled	92	96	98	95	- 2
	average	88	91	94	91	- 1
			Averages			
31 March	broadcast	69	75	77	73	0
15 April	broadcast	69	74	81	75	+ 4
15 April	drilled	71	77	82	77	+ 2
	average	70	75	80	75	+ 2

[†]Average difference from Table 4.

Table 6. Percentage estimations two years (1979) after seeding of Mackinaw birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding Date	Seeding Methods	Pronamide kg[ai]/ha 0.56	1.12	1.68	Average	Percent Change In Second Year[†]
			Bromegrass			
31 March	broadcast	68	68	70	69	- 0
15 April	broadcast	58	60	63	60	- 9
15 April	drilled	63	65	72	67	- 7
	average	63	64	68	65	- 6
			Orchardgrass			
31 March	broadcast	60	60	65	62	- 4
15 April	broadcast	52	60	60	57	- 10
15 April	drilled	50	50	50	50	- 13
	average	54	57	58	56	- 9
			Tall fescue			
31 March	broadcast	77	78	78	78	+ 5
15 April	broadcast	82	85	85	84	+ 4
15 April	drilled	83	85	87	85	+ 2
	average	81	83	83	82	+ 3
			Reed canarygrass			
31 March	broadcast	50	50	57	52	- 22
15 April	broadcast	53	53	57	54	- 9
15 April	drilled	60	60	67	62	- 7
	average	54	54	60	56	- 13
			Kentucky bluegrass			
31 March	broadcast	88	92	87	89	+ 5
15 April	broadcast	83	83	85	84	- 10
15 April	drilled	87	85	88	87	- 8
	average	86	87	87	87	- 4
			Averages			
31 March	broadcast	67	70	71	69	- 4
15 April	broadcast	66	68	70	68	- 7
15 April	drilled	69	69	73	70	- 7
	average	67	69	71	69	- 6

[†]Average difference from Table 5.

Yields

Seeding year (1977): Total average yields of the one harvest made in the seeding year were 3.75 mt/ha (Table 7). No differences in yields were obtained between seeding methods even though stand density as shown in Table 3 indicated a variation of 132 to 205 plants/m^2. There were significant differences in yields between grasses and herbicide rates. The differences between grasses was most likely a result due to reporting total grass and legume yields, instead of pure trefoil yields.

First year after seeding (1978): Total yields of pure trefoil from three harvests were good, averaging 7.86 mt/ha (Table 8). There were no differences in yields between seeding methods measured over all grasses and levels of herbicide. The best yields of trefoil were from the tall fescue sods (8.73 mt/ha) with significantly lower yields from the orchardgrass (7.36 mt/ha) and Kentucky bluegrass (7.44 mt/ha) interseedings. This trend in yield differences was the same from the harvest in the year of seeding. Trefoil in the reed canarygrass and bromegrass sods was slightly lower in yield than that in the tall fescue sods. There were no significant yield differences between the rates of herbicide applied to the grasses which indicated that the low rate was adequate to suppress the grass competition during seedling establishment.

These yield differences in the first year after seeding are not explained by the variation in stand density. High yields have been obtained from established stands of alfalfa in Michigan State

Table 7. Yields (mt/ha of 12% moisture) from one harvest in the year of seeding (1977) birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding		Pronamide kg^{ai}/ha			
Date	Methods	0.56	1.12	1.68	Average
		Bromegrass			
31 March	broadcast	3.24	3.68	3.62	3.51
15 April	broadcast	2.30	3.07	3.95	3.11
15 April	drilled	2.74	3.40	3.48	3.21
	average	2.76	3.39	3.68	3.28
		Orchardgrass			
31 March	broadcast	3.01	3.34	3.19	3.18
15 April	broadcast	3.25	3.37	3.95	3.52
15 April	drilled	2.88	3.23	3.53	3.21
	average	3.05	3.31	3.56	3.31
		Tall Fescue			
31 March	broadcast	4.38	4.02	4.61	4.34
15 April	broadcast	4.72	4.33	5.33	4.79
15 April	drilled	4.29	4.69	5.18	4.72
	average	4.46	4.35	5.04	4.62
		Reed canarygrass			
31 March	broadcast	4.39	4.15	4.21	4.25
15 April	broadcast	4.48	3.90	4.35	4.24
15 April	drilled	3.83	4.36	4.62	4.27
	average	4.23	4.14	4.39	4.25
		Kentucky bluegrass			
31 March	broadcast	3.45	3.31	3.18	3.31
15 April	broadcast	2.93	3.39	2.71	3.01
15 April	drilled	2.99	3.53	4.06	3.53
	average	3.12	3.41	3.31	3.28
L.S.D. (0.05)^{a}					NS
L.S.D. (0.05)^{b}					1.23
		Averages			
31 March	broadcast	3.69	3.70	3.76	3.72
15 April	broadcast	3.54	3.61	4.06	3.74
15 April	drilled	3.35	3.84	4.17	3.79
	average	3.52	3.72	4.00	3.74

[a]Between seeding methods within the same grass.

[b]Between grasses within the same seeding method.

Table 8. Yields (mt/ha of 12% moisture) of pure trefoil from three harvests[†] in the first year (1978) after seeding birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding Date	Seeding Methods	Pronamide kg[ai]/ha 0.56 Cut 1	0.56 Cut 2	0.56 Cut 3	0.56 Total	1.12 Cut 1	1.12 Cut 2	1.12 Cut 3	1.12 Total	1.68 Cut 1	1.68 Cut 2	1.68 Cut 3	1.68 Total	Average Total
							Bromegrass							
31 March	broadcast	6.99	0.15	0.96	8.10	6.86	0.19	0.72	7.78	7.27	0.11	0.90	8.29	8.06
15 April	broadcast	6.55	0.32	1.25	8.12	6.58	0.27	1.14	7.99	7.00	0.31	1.09	8.39	8.17
15 April	drilled	6.61	0.07	0.85	7.54	7.26	0.14	0.87	8.27	6.97	0.10	0.73	7.81	7.87
	average	6.72	0.18	1.02	7.92	6.90	0.20	0.91	8.01	7.08	0.17	0.91	8.16	8.03
							Orchardgrass							
31 March	broadcast	6.52	0.78	0.71	8.00	5.81	0.75	0.77	7.32	5.92	0.71	0.72	7.35	7.56
15 April	broadcast	6.00	0.75	0.99	7.75	6.06	0.73	1.11	7.90	6.50	0.76	0.86	8.12	7.92
15 April	drilled	5.36	0.40	0.58	6.33	5.28	0.49	0.58	6.37	6.03	0.51	0.54	7.08	6.59
	average	5.96	0.65	0.76	7.36	5.72	0.66	0.82	7.20	6.15	0.66	0.70	7.52	7.36
							Tall fescue							
31 March	broadcast	7.33	0.73	0.93	8.99	6.37	0.58	0.84	7.79	7.05	0.49	0.93	8.47	8.42
15 April	broadcast	7.28	0.62	1.01	8.91	7.85	0.82	1.20	9.86	6.45	0.63	0.96	8.03	8.93
15 April	drilled	6.51	0.53	1.15	8.19	7.71	0.44	1.15	9.30	7.38	0.62	1.03	9.03	8.84
	average	7.04	0.64	1.03	8.70	7.31	0.62	1.06	8.99	6.96	0.58	0.97	8.51	8.73
							Reed canarygrass							
31 March	broadcast	6.63	0.22	1.08	7.93	6.14	0.25	0.85	7.24	6.53	0.18	0.81	7.53	7.57
15 April	broadcast	6.88	0.30	0.81	7.98	6.82	0.43	0.77	8.02	6.63	0.25	0.90	7.77	7.92
15 April	drilled	6.53	0.19	1.06	7.79	6.24	0.29	1.04	7.58	6.40	0.26	0.96	7.62	7.66
	average	6.68	0.24	0.98	7.90	6.40	0.32	0.89	7.61	6.52	0.23	0.89	7.64	7.72
							Kentucky bluegrass							
31 March	broadcast	6.12	0.43	0.78	7.33	5.14	0.39	0.67	6.20	6.02	0.35	0.68	7.05	6.86
15 April	broadcast	6.10	0.23	1.17	7.50	6.32	0.24	1.15	7.71	5.61	0.16	1.14	6.92	7.38
15 April	drilled	6.71	0.28	1.15	8.14	6.72	0.20	0.91	7.83	7.02	0.20	1.02	8.25	8.07
	average	6.31	0.31	1.03	7.66	6.06	0.28	0.91	7.25	6.22	0.24	0.95	7.41	7.44
L.S.D. (0.05)[a]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L.S.D. (0.05)[b]		1.65	0.36	0.44	1.83	1.65	0.36	0.44	1.83	1.65	0.36	0.44	1.83	1.06
							Averages							
31 March	broadcast	6.72	0.46	0.89	8.07	6.06	0.43	0.77	7.27	6.56	0.37	0.81	7.74	7.69
15 April	broadcast	6.56	0.45	1.05	8.05	6.73	0.50	1.07	8.30	6.44	0.42	0.99	7.85	8.07
15 April	drilled	6.34	0.29	0.96	7.60	6.64	0.31	0.91	7.87	6.76	0.34	0.86	7.96	7.81
	average	6.54	0.40	0.97	7.91	6.48	0.41	0.92	7.81	6.59	0.38	0.89	7.85	7.86

[†]Cut 1 June 22; Cut 2 July 31; Cut 3 Nov. 1.

[a]Between seeding methods within the same grass.

[b]Between grasses within the same seeding method.

University trials from as few as 25 plants/m^2; whereas stand densities of trefoil reported here are in excess of 100/m^2 (Tesar, 1979b). As grass suppression increased, trefoil stand density increased and competition for moisture, light, and nutrients, was likely greater in those grasses that were least affected by the herbicide.

Second year after seeding (1979): Total yields of pure trefoil from two harvests were high, averaging 9.78 mt/ha (Table 9). Even though only two harvests were made versus three in the previous year, this was a 24% increase in trefoil yield, due mainly to a more mature and productive stand. There were no significant differences in yields between seeding methods measured over all grasses and levels of herbicide. Trefoil in Kentucky bluegrass and tall fescue sods produced the best yields. There were significant differences among grass sods which are ranked below in descending order of trefoil yields: tall fescue, bromegrass, orchardgrass, and reed canarygrass.

In this third year of growth, these trefoil yield differences were most indicative of the vigor, and ability of each grass to withstand interplant competition. Reed canarygrass was initially suppressed the most by pronamide but the intense vigor of this grass was demonstrated in the declining yields and percentage estimations of trefoil in the sward. Yields of trefoil from Kentucky bluegrass sods did not entirely corroborate the estimations that showed this grass to be consistently the least resistant to pronamide. This may be due in part to estimator error or bias, and the short growth height of the species in comparison to the other grasses of the trial.

Table 9. Yields (mt/ha of 12% moisture) of pure trefoil from two harvests[†] in the second year (1979) after seeding birdsfoot trefoil in five grass sods treated with three rates of herbicide. Two seeding dates and methods. Exp. 1, East Lansing.

Seeding Date	Seeding Methods	Pronamide kg[ai]/ha 0.56 Cut 1	0.56 Cut 2	0.56 Total	1.12 Cut 1	1.12 Cut 2	1.12 Total	1.68 Cut 1	1.68 Cut 2	1.68 Total	Average Total
					Bromegrass						
31 March	broadcast	5.63	4.48	10.11	5.07	5.06	10.13	4.98	5.01	9.98	10.07
15 April	broadcast	4.93	5.15	10.08	4.78	5.63	10.42	4.60	4.86	9.46	9.99
15 April	drilled	4.31	4.02	8.33	4.74	5.53	10.27	5.16	4.92	10.07	9.56
	average	4.95	4.55	9.51	4.86	5.41	10.27	4.91	4.93	9.83	9.87
					Orchardgrass						
31 March	broadcast	5.72	4.78	10.50	4.60	4.66	9.26	4.28	4.84	9.12	9.63
15 April	broadcast	5.30	4.68	9.98	4.98	4.60	9.57	4.38	4.88	9.26	9.60
15 April	drilled	3.40	4.28	7.68	3.71	4.39	8.11	3.09	4.57	7.67	7.82
	average	4.81	4.58	9.39	4.43	4.55	8.98	3.92	4.77	8.68	9.02
					Tall fescue						
31 March	broadcast	5.09	5.55	10.64	4.85	5.49	10.34	4.21	5.61	9.82	10.27
15 April	broadcast	5.59	4.83	10.42	6.16	5.90	12.05	5.22	5.09	10.31	10.93
15 April	drilled	6.42	5.10	11.52	6.29	5.56	11.85	6.06	5.64	11.70	11.69
	average	5.70	5.16	10.86	5.77	5.65	11.42	5.16	5.45	10.61	10.96
					Reed canarygrass						
31 March	broadcast	3.64	3.90	7.54	3.59	4.37	7.96	3.91	4.74	8.65	8.05
15 April	broadcast	3.93	3.22	7.15	3.85	3.70	7.55	3.33	3.77	7.10	7.27
15 April	drilled	4.40	3.87	8.27	3.46	3.85	7.31	4.46	4.89	9.35	8.31
	average	3.99	3.66	7.66	3.63	3.97	7.61	3.90	4.46	8.37	7.88
					Kentucky bluegrass						
31 March	broadcast	4.83	4.11	8.94	5.55	5.45	10.99	5.07	5.91	10.99	10.31
15 April	broadcast	5.51	5.11	10.62	5.67	6.58	12.23	5.28	7.01	12.29	11.05
15 April	drilled	6.46	4.86	11.31	5.46	5.29	10.75	5.87	6.43	12.29	11.45
	average	5.60	4.69	10.29	5.55	5.77	11.32	5.41	6.45	11.86	11.16
L.S.D. (0.05)[a]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L.S.D. (0.05)[b]		1.53	0.97	1.91	1.53	0.97	1.91	1.53	0.97	1.91	1.10
					Averages						
31 March	broadcast	4.98	4.56	9.55	4.73	5.01	9.74	4.49	5.22	9.71	9.67
15 April	broadcast	5.05	4.60	9.65	5.08	5.28	10.35	4.56	5.12	9.68	9.89
15 April	drilled	5.00	4.43	9.42	4.73	4.92	9.66	4.93	5.29	10.22	9.77
	average	5.01	4.53	9.54	4.85	5.07	9.92	4.66	5.21	9.87	9.78

[†]Cut 1 July 3; Cut 2 Sept. 13.

[a]Between seeding methods within the same grass.

[b]Between grasses within the same seeding method.

Experiment 2: East Lansing, alfalfa and birdsfoot trefoil, pH 7.4, two herbicides fall applied on three grasses, three seeding methods and dates, two years: 1978, and 1979.

Stand Density

Seeding year (1978): Alfalfa--Seedings made on herbicide-suppressed sods on 24 April by the broadcast and drilled methods had high seedling counts and were considered satisfactory for good future yields (Table 10). These stands (286 to 329 plants/m^2) were similar to those made on 1 May by the accepted method of band seeding in a well tilled seedbed (333 plants/m^2). Seedings made on 24 April by broadcasting or drilling the seed into a grass sod not treated by a herbicide, however, were too poor for satisfactory future yields, particularly when the seed was broadcast (Fig. 3). Seedings made on 22 May on herbicide-treated sods were similar to those made in April on untreated sods (treatments 7 and 8). The broadcast seeding made on 22 May was a near failure with only 32 plants/m^2 (Fig. 4).

Good stands of alfalfa were obtained on all grasses treated with either herbicide when the seedings were made early by either method on 24 April. Stands were generally better on bromegrass and orchardgrass sods than on the bluegrass sods except in treatments 2 and 8 where the alfalfa was drilled into the sward. There appears to be no good explanation why the stand of alfalfa was better on the bluegrass sod in these two cases.

Seeding year (1978): Birdsfoot trefoil--Seedling counts of trefoil were lower than those for alfalfa (Table 10) even though the

Table 10. Stand density (plants/m^2) of Iroquois alfalfa and Viking birdsfoot trefoil three months after seeding (1978) in three grass sods treated with two herbicides. Three seeding dates and methods. Exp. 2, East Lansing.

Treatment Number	Seeding Date	Seeding Method	Seeding Surface	Herbicide kg^{ai}/ha		Brome-grass	Orchard-grass	Kentucky bluegrass	Average
				Alfalfa					
1	April 24	broadcast	sod	Control	0.00	*a* 54 *a*	*a* 42 *ab*	*a* 69 *b*	55 *a*
2	April 24	drilled	sod	Control	0.00	*a* 111 *b*	*a* 84 *b*	*b* 210 *cd*	135 *b*
3	April 24	broadcast	sod	Glyphosate	1.68	*a* 286 *c*	*a* 300 *d*	*a* 290 *e*	292 *c*
4	April 24	drilled	sod	Glyphosate	1.68	*b* 330 *d*	*b* 300 *d*	*a* 229 *d*	286 *c*
5	April 24	broadcast	sod	Pronamide	1.68	*a* 345 *d*	*a* 335 *d*	*a* 307 *e*	329 *d*
6	May 1	band	tilled	Glyphosate	1.68	*b* 360 *d*	*ab* 332 *d*	*a* 307 *e*	333 *d*
7	May 22	broadcast	sod	Glyphosate	1.68	*a* 34 *a*	*a* 38 *a*	*a* 25 *a*	32 *a*
8	May 22	drilled press wheels	sod	Glyphosate	1.68	*a* 129 *b*	*ab* 150 *c*	*b* 170 *c*	150 *b*
				Birdsfoot trefoil					
3	April 24	broadcast	sod	Glyphosate	1.68	*b* 164 *d*	*b* 159 *d*	*a* 130 *d*	151 *d*
4	April 24	drilled	sod	Glyphosate	1.68	*b* 130 *c*	*ab* 116 *c*	*a* 100 *c*	115 *c*
5	April 24	broadcast	sod	Pronamide	1.68	*a* 170 *d*	*a* 150 *d*	*a* 165 *e*	162 *d*
6	May 1	band	tilled	Glyphosate	1.68	*a* 113 *c*	*a* 123 *c*	*a* 114 *cd*	117 *c*
7	May 22	broadcast	sod	Glyphosate	1.68	*a* 19 *a*	*a* 15 *a*	*a* 17 *a*	17 *a*
8	May 22	drilled press wheels	sod	Glyphosate	1.68	*a* 78 *b*	*a* 65 *b*	*a* 75 *b*	73 *b*

Means followed by the same letter within columns and legume are not significantly different at the 5% level using Duncan's multiple range test.

Means preceded by the same letter within rows are not significantly different at the 5% level using Duncan's multiple range test.

Fig. 3. Alfalfa broadcast on untreated Kentucky bluegrass sod (left) produced a negligible stand in comparison to seeding by the same method after pronamide suppression of the grass sward (right).

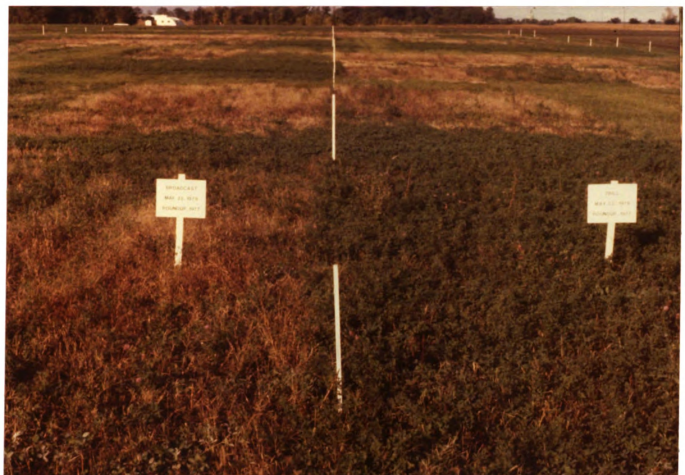

Fig. 4. Alfalfa seeded on 22 May on glyphosate-suppressed grass swards produced a poor stand when broadcast (left) and a good stand when drilled into the sod (right).

seeding rate for each legume was similar. This was due to the known lower vigor and greater problem of seeding establishment of trefoil than of alfalfa. The best stands (151 to 162 plants/m^2) were obtained when the seed was broadcast on, rather than drilled into, the herbicide treated sod on 24 April (treatments 3 and 5). These stands were adequate for high subsequent yields but this was the reverse of expected results. It is possible that the trefoil seed may have been planted too deeply in the sod, resulting in poorer stands from drilling than with broadcasting. However, it is more likely that there was some fertilizer injury from the 62 kg/ha of P_2O_5 placed in contact with the trefoil seed, as noted by Tesar in unpublished research. It was expected that the best stand would be from the recommended procedure of band seeding in a tilled seedbed (treatment 6) but this treatment was not as good as when the seed was broadcast on 24 April on herbicide-treated sods (treatments 3 and 5).

No trefoil seedings were made without a grass-suppressing herbicide as earlier work done in Michigan had clearly shown the necessity of reducing competition before sod seeding this legume (Tesar, 1976). The poorest stand, as expected, was from broadcasting the seed on the late seeding date in May when drier conditions prevailed. The stand was considerably better when drilled into the sod compared to broadcasting on the surface (73 versus 17 plants/m^2) but both treatments were much poorer than earlier seedings made in April when moisture conditions were more favorable.

Seedings of trefoil were equally good on the three grasses when seeded by the accepted method of band seeding in a prepared seedbed (treatment 6), broadcast on 24 April (treatment 5) and by

either seeding method in late May (treatments 7 and 8). Stands were considerably better in bromegrass and orchardgrass sods that were glyphosate-treated and seeded in April by both methods than in Kentucky bluegrass which had a much denser sward. The thickness of the bluegrass sward may have prevented broadcast seeds from reaching the soil but it is not known why the drilled method produced a lower stand than in the other grasses.

Contrary to expectations, the trefoil stand on pronamide-treated orchardgrass sods was as good as on the glyphosate-treated sods. In experiment 1 stands of trefoil were significantly poorer on pronamide-treated orchardgrass swards because of the greater resistance of orchardgrass than the other grasses to this herbicide. Possibly the grasses were not established for a long enough period before the herbicide application for orchardgrass to display any noticeable resistance.

Estimations

Percentage estimations of the two legumes established in the grass swards were made 3 and 12 months after seeding (Table 11). In the first year, broadcasting alfalfa and trefoil on 24 April on a pronamide-treated sod produced the highest percentage of legumes which was equal to the seedings on a tilled seedbed. Seedings made on 24 April on glyphosate-treated sods had less trefoil than on pronamide-treated sods but were considerably better than when seeded in late May or on unsuppressed sods.

All treatments had an increase in percent legume from the

Table 11. Percentage estimations of Iroquois alfalfa and Viking birdsfoot trefoil three and twelve months after seeding (1978) in three grass sods treated with two herbicides. Three seeding dates and methods. Exp. 2, East Lansing.

Treatment Number	Seeding			Herbicide		1978				1979				Percent Increase Over 9 Months
	Date	Method	Surface	kg[ai]/ha		Brome-grass	Orchard-grass	Kentucky bluegrass	Average	Brome-grass	Orchard-grass	Kentucky bluegrass	Average	
								Alfalfa						
1	April 24	broadcast	sod	Control	0.00	1	1	1	1	18	16	65	33	32
2	April 24	drilled	sod	Control	0.00	2	2	2	2	31	31	78	47	45
3	April 24	broadcast	sod	Glyphosate	1.68	64	61	64	65	98	96	99	98	33
4	April 24	drilled	sod	Glyphosate	1.68	59	60	59	59	99	97	99	98	39
5	April 24	broadcast	sod	Pronamide	1.68	86	74	88	87	98	94	99	97	10
6	May 1	band	tilled	Glyphosate	1.68	84	81	84	83	99	99	98	99	16
7	May 22	broadcast	sod	Glyphosate	1.68	1	1	1	1	98	94	99	97	96
8	May 22	drilled press wheels	sod	Glyphosate	1.68	19	23	20	21	98	95	99	97	76
L.S.D. (0.05)									16				15	
								Birdsfoot trefoil						
3	April 24	broadcast	sod	Glyphosate	1.68	15	19	18	17	97	97	98	97	80
4	April 24	drilled	sod	Glyphosate	1.68	15	16	16	16	97	94	97	96	80
5	April 24	broadcast	sod	Pronamide	1.68	70	60	73	69	96	87	99	94	25
6	May 1	band	tilled	Glyphosate	1.68	70	64	60	65	98	98	97	98	33
7	May 22	broadcast	sod	Glyphosate	1.68	1	1	1	1	23	24	19	22	21
8	May 22	drilled press wheels	sod	Glyphosate	1.68	6	5	5	5	90	85	90	88	83
L.S.D. (0.05)									14				7	

first to the second year with a greater increase obtained in the trefoil than in the alfalfa seedings. A dramatic increase in percent alfalfa was observed in the year after seeding estimations of treatment 7. Seedling counts and first year estimations of this late May broadcast method (treatment 7) were similar to those of the 24 April broadcast seeding onto unsuppressed grass swards, but in the second year, percentage alfalfa of the two treatments was greatly different. This increase in the percentage of alfalfa in treatment 7 cannot be attributed to the later seeding date being more favorable, but appears to be a more direct result of the lack of competition from the grass sward. Increases in percent legume in every treatment and each grass sward over the duration of this experiment may be due to the short period of time the grasses were established before spraying and interseeding took place.

Yields

Seeding year (1978): Alfalfa--Total average yields of pure alfalfa from two harvests from herbicide treated sods were 3.29 mt/ha (Table 12). The best yields were from the 24 April broadcast seedings on a pronamide-treated sod (5.01 mt/ha), which were comparable to the band seeding treatment (5.08 mt/ha) on a tilled seedbed. The higher yields from the April broadcast method (5.01 mt/ha, treatment 3) than those of the April drilled seedings (3.66 mt/ha, treatment 4) were most likely a result of the greater stand density in the broadcast treatment. The lowest yields, as expected, were from both seeding methods on sods not suppressed by a herbicide and the late May

Table 12. Yields (mt/ha of 12% moisture) from two harvests of alfalfa and birdsfoot trefoil in the year (1978) of seeding in three grass sods treated with two herbicides. Three seeding dates and methods. Exp. 2, East Lansing.

Tmt No.	Seeding Date	Seeding Method	Seeding Surface	Herbicide kg[a]/ha		Bromegrass Cut 1	Bromegrass Cut 2	Bromegrass Total	Orchardgrass Cut 1	Orchardgrass Cut 2	Orchardgrass Total	Kentucky bluegrass Cut 1	Kentucky bluegrass Cut 2	Kentucky bluegrass Total	Average Total
									Alfalfa						
1	Apr. 24	broadcast	sod	Control	0.00	0.03	0.03	0.06	0.03	0.02	0.05	0.03	0.02	0.05	0.05
2	Apr. 24	drilled	sod	Control	0.00	0.03	0.11	0.14	0.03	0.03	0.06	0.03	0.10	0.13	0.11
3	Apr. 24	broadcast	sod	Glyphosate	1.68	2.33	1.83	4.15	1.77	2.17	3.95	2.03	2.34	4.37	4.16
4	Apr. 24	drilled	sod	Glyphosate	1.68	1.83	1.84	3.68	1.91	1.79	3.69	1.73	1.88	3.62	3.66
5	Apr. 24	broadcast	sod	Pronamide	1.68	2.71	2.28	4.99	2.69	2.43	5.12	2.63	2.29	4.93	5.01
6	May 1	band	tilled	Glyphosate	1.68	2.70	2.48	5.18	2.78	2.23	5.01	2.70	2.35	5.05	5.08
7	May 22	broadcast	sod	Glyphosate	1.68	0.03	0.07	0.10	0.02	0.20	0.22	0.03	0.12	0.15	0.16
8	May 22	drilled press wheels	sod	Glyphosate	1.68	0.23	1.57	1.80	0.26	1.36	1.61	0.26	1.26	1.52	1.64
L.S.D. (0.05)						0.70	0.40	0.84	0.70	0.40	0.84	0.70	0.40	0.84	0.49
									Birdsfoot trefoil						
3	Apr. 24	broadcast	sod	Glyphosate	1.68	0.21	1.23	1.44	0.32	1.78	2.10	0.28	1.38	1.66	1.73
4	Apr. 24	drilled	sod	Glyphosate	1.68	0.34	0.91	1.25	0.38	1.46	1.84	0.31	1.64	1.94	1.68
5	Apr. 24	broadcast	sod	Pronamide	1.68	1.63	2.02	3.65	1.56	2.48	4.05	1.43	2.61	4.05	3.92
6	May 1	band	tilled	Glyphosate	1.68	1.05	1.56	2.62	0.86	2.10	2.97	1.19	1.60	2.79	2.79
7	May 22	broadcast	sod	Glyphosate	1.68	0.02	0.02	0.04	0.02	0.02	0.04	0.02	0.02	0.04	0.04
8	May 22	drilled press wheels	sod	Glyphosate	1.68	0.12	0.14	0.26	0.10	0.08	0.18	0.12	0.03	0.15	0.20
L.S.D. (0.05)						0.60	1.11	1.58	0.60	1.11	1.58	0.60	1.11	1.58	0.91

[+]Cut 1 Aug. 8; Cut 2 Oct. 31.

seedings. In the seeding year these low yields were most likely a reflection of the low stand density.

Treatments 3 and 5 were April broadcast seedings and differed only in the herbicide applied to the grass sods. The pronamide-treated sods (treatment 5) yielded more alfalfa (5.01 mt/ha) than the glyphosate-treated sods (4.16 mt/ha, treatment 3), and stand density and seeding year estimations were also different in favor of the pronamide treatment. It is not known why the pronamide application to these grasses was more successful than glyphosate in suppressing the swards. Temperature and weather conditions at the time of herbicide application, as well as the short period of grass establishment before initiating the experiment are possible factors in the differences.

Seeding year (1978): Birdsfoot trefoil--Total average yields of pure trefoil from two harvests from herbicide-treated sods were 1.73 mt/ha which was 53% as high as those from alfalfa (Table 12). The 24 April broadcast seeding (treatment 5) on pronamide-treated swards was the best yielding treatment (3.92 mt/ha). There is no good explanation why the 1 May band seeding on a tilled seedbed yielded less than this April broadcast treatment. The yields from the seedings on 24 April on glyphosate-treated grasses were the same for each method but considerably better than yields from the late May seedings.

First year after seeding (1979): Alfalfa--Total average yields of pure alfalfa from three harvests from herbicide-treated sods

were excellent at 13.74 mt/ha (Table 13). The 24 April seedings of both methods on herbicide-treated sods produced the highest yield, equal to the late May drilled method. None of these treatments, however, was as good as the band seeding in a tilled seedbed (treatment 6). The late May broadcast seeding produced very satisfactory yields (11.44 mt/ha) even though stand density was low. The extremely poor yields (2.85 and 5.47 mt/ha) from the April seedings on grasses that were not suppressed with herbicides were expected as earlier work has shown the necessity of suppressing the grass before seeding (Tesar, 1976).

First year after seeding (1979): Birdsfoot trefoil--Total average yields of pure trefoil from three harvests from herbicide-treated sods were excellent at 9.90 mt/ha which was 72% as high as those from alfalfa (Table 13). The glyphosate-treated sods seeded by both methods on 24 April were the highest yielding (11.24 and 11.99 mt/ha) equal to the band seeding in a prepared seedbed (11.66 mt/ha). The pronamide-treated swards (treatment 5) were similar in trefoil yield (10.69 mt/ha) to the late May drilled seedings (10.29 mt/ha). The reason for this reversal in yields of treatment 5 from those of the seeding year may be due in part to the vigor of orchardgrass and the shorter suppressing effect on this grass by pronamide than glyphosate. The 22 May broadcast seeding produced the lowest yields of 3.52 mt/ha. This was expected since the stand of trefoil (17 plants/m^2) was considered extremely low (Table 10).

Alfalfa and trefoil: It is evident by the low yields and

Table 13. Yields (mt/ha of 12% moisture) from three harvests of alfalfa and birdsfoot trefoil in the first year (1979) after seeding in three grass sods treated with two herbicides. Three seeding dates and methods. Exp. 2, East Lansing.

Tmt No.	Seeding Date	Seeding Method	Surface	Herbicide	kg[a1]/ha	Bromegrass Cut 1	Bromegrass Cut 2	Bromegrass Cut 3	Bromegrass Total	Orchardgrass Cut 1	Orchardgrass Cut 2	Orchardgrass Cut 3	Orchardgrass Total	Kentucky bluegrass Cut 1	Kentucky bluegrass Cut 2	Kentucky bluegrass Cut 3	Kentucky bluegrass Total	Average Total
									Alfalfa									
1	Apr. 24	broadcast	sod	Control	0.00	0.90	1.61	0.79	3.30	0.44	0.36	0.45	1.25	1.31	1.86	0.84	4.00	2.85
2	Apr. 24	drilled	sod	Control	0.00	2.23	2.39	1.01	5.63	0.92	1.87	0.67	3.46	2.97	3.12	1.22	7.31	5.47
3	Apr. 24	broadcast	sod	Glyphosate	1.68	8.26	4.16	1.64	14.06	7.24	4.61	1.75	13.60	7.64	4.43	1.73	13.79	13.82
4	Apr. 24	drilled	sod	Glyphosate	1.68	6.97	4.53	1.60	13.09	6.41	4.75	1.73	12.89	7.36	4.84	1.51	13.72	13.23
5	Apr. 24	broadcast	sod	Pronamide	1.68	7.95	5.16	1.64	14.75	7.35	5.07	1.71	14.13	7.16	5.23	1.67	14.06	14.31
6	May 1	band	tilled	Glyphosate	1.68	8.77	5.68	1.97	16.42	7.79	6.27	1.86	15.92	8.55	5.66	1.67	15.88	16.07
7	May 22	broadcast	sod	Glyphosate	1.68	5.68	3.55	1.35	10.58	6.52	4.33	1.52	12.38	6.18	3.77	1.42	11.36	11.44
8	May 22	drilled press wheels	sod	Glyphosate	1.68	6.72	4.86	1.51	13.09	7.26	4.38	1.68	13.33	7.87	4.79	1.57	14.23	13.55
L.S.D. (0.05)						1.33	1.12	0.45	2.27	1.33	1.12	0.45	2.27	1.33	1.12	0.45	2.27	1.31
									Birdsfoot trefoil									
3	Apr. 24	broadcast	sod	Glyphosate	1.68	8.23	3.44	1.06	12.72	7.48	2.97	1.24	11.70	7.86	2.81	0.89	11.56	11.99
4	Apr. 24	drilled	sod	Glyphosate	1.68	7.13	3.42	0.99	11.54	7.34	3.08	0.99	11.40	6.84	2.82	1.10	10.77	11.24
5	Apr. 24	broadcast	sod	Pronamide	1.68	6.78	2.60	0.89	10.27	6.23	2.79	0.85	9.86	8.02	2.84	1.08	11.93	10.69
6	May 1	band	tilled	Glyphosate	1.68	6.90	2.84	1.14	10.88	7.30	3.99	0.93	12.22	7.62	3.35	0.91	11.87	11.66
7	May 22	broadcast	sod	Glyphosate	1.68	6.39	1.71	1.29	3.64	0.87	1.87	1.26	4.01	0.49	1.55	0.85	2.89	3.51
8	May 22	drilled press wheels	sod	Glyphosate	1.68	5.90	4.01	0.76	10.67	5.51	3.31	0.68	9.49	6.31	3.48	0.94	10.72	10.29
L.S.D. (0.05)						1.40	0.58	0.36	1.73	1.40	0.58	0.36	1.73	1.40	0.58	0.36	1.73	1.00

[+]Cut 1 June 21; Cut 2 Aug. 6; Cut 3 Oct. 23.

poor stand establishment that seeding a legume into a grass without first suppressing the sward (treatments 1 and 2) is not satisfactory. Seedling counts were similar on the seedings made on 24 April in grasses not suppressed, to those made on 22 May when the swards were chemically suppressed; yields in the year of seeding were similar but differed greatly in the second year. The increase in yields from herbicide treated sods (11.44 and 13.55 mt/ha) over the alfalfa yields from the unsuppressed grass swards (2.85 and 5.47 mt/ha) is directly attributable to interplant competition. These late May seedings (treatments 7 and 8) were poor in seedling counts and yields, especially in the first year. Three to four tons more alfalfa per hectare were harvested in the seeding year from treatments utilizing a herbicide and earlier seeding date. Trefoil tonnage differences were not as great between early and late seeding dates, except in the late broadcast seeding, which clearly indicated the advantages of early seeding. Late seeding in May by the broadcast method was shown to be much less satisfactory than the drilled seeding on the same date. The method of seeding appeared to be less important when a herbicide was used to suppress the grasses and the seeding date was in April. The later the seeding date, the more important it was to drill the seed into the sod.

Experiment 3: East Lansing, alfalfa on quackgrass, pH 6.6, four herbicides fall applied at various rates, two seeding methods and surfaces, two years: 1978, and 1979.

Stand Density

Seeding year (1978): Band seedings in a tilled seedbed measured over all herbicide treatments produced significantly better stands of alfalfa than seedings drilled into the sod (Table 14). Alfalfa after the high rate of glyphosate in the band seeding method produced the best stand (161 plants/m^2). Alfalfa after other rates and herbicides produced intermediate stands (120 to 140 plants/m^2) except after the low rate of pronamide which was the poorest (98 plants/m^2).

Stands in the sod seeding method were best when established after the three rates of glyphosate (107 to 139 plants/m^2). Stand density was considerably lower after the two rates of pronamide (76 and 57 plants/m^2) and at the one rate of paraquat (69 plants/m^2) but both of these treatments were much higher than when alfalfa was seeded in an untreated sod (23 plants/m^2). This stand of 23 plants/m^2 was considered too low for good future yields. Less initial quackgrass competition probably was the major factor in the increase in stand density of alfalfa in the tilled areas when compared to the stands produced in the sods.

Table 14. Stand density (plants/m^2) of alfalfa ten weeks after seeding (1978) in a quackgrass sod treated with three herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	Rate kg[a1]/ha	Seeding Method and Surface: Drilled Sod	Band Tilled	Average
Control	0.00	*a* 23 *a*	*b* 122 *ab*	73 *a*
Paraquat	0.56	69 *bc*	-	-
Pronamide	0.56	-	98 *a*	-
	1.12	*a* 76 *bc*	*b* 140 *ab*	108 *ab*
	1.68	*a* 57 *ab*	*b* 132 *ab*	95 *ab*
Glyphosate	0.56	*a* 107 *cd*	*a* 123 *ab*	115 *abc*
	1.12	*a* 135 *d*	*a* 120 *ab*	127 *bc*
	1.68	*a* 139 *d*	*a* 161 *b*	150 *c*
Average	0.56	-	*b* 111	-
	1.12	*a* 106	*b* 129	118
	1.68	*a* 98	*b* 147	122

Means followed by the same letter within columns, or preceded by the same letter within rows, are not significantly different at the 5% level using Duncan's multiple range test.

Estimations

Visual estimations of the percentage of alfalfa present in the quackgrass infested sods were made 3 and 13 months after seeding (Table 15). In the seeding year estimations, alfalfa seeded in sods treated with the medium and high rates of glyphosate showed a significantly higher percentage present than all other treatments of the sod seeding method. Within the same seeding method, pronamide, paraquat, and the low rate of glyphosate treatments were intermediate in percentage alfalfa present, with the unsuppressed quackgrass sods the poorest. No differences were obtained between herbicide treatments in the band seeding method during the year of seeding. Percentage estimations made in the seeding year indicated almost 50% more alfalfa was established by the band seeding method when compared to drilling the seed into the suppressed quackgrass sods.

Year after seeding (1979): These estimations showed in both seeding methods an increase in percent alfalfa from all glyphosate rates and a decrease or status quo from all pronamide treatments. Percentage alfalfa was not higher in the second year in the band seedings but showed a slightly increased stand when sod seeded. This increase comes entirely from the glyphosate treatments on the quackgrass as the other herbicide treatments showed a decline in the percentage of alfalfa present.

Glyphosate displayed a longer, more pronounced period of quackgrass suppression than pronamide. The paraquat-treated sods did not have a significantly higher percentage of alfalfa than the

Table 15. Percentage estimations of alfalfa present 3 and 13 months after seeding (1978) in a quackgrass sod treated with three herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	kg[a1]/ha	1978			1979			Percent Change Over 10 Months	
		Drilled Sod	Band Tilled	Average	Drilled Sod	Band Tilled	Average	Drilled Sod	Band Tilled
Control	0.00	3	67	35	5	75	40	+ 2	+ 8
Paraquat	0.56	23	-	-	23	-	-	0	-
Pronamide	0.56	-	80	-	-	53	-	-	- 27
	1.12	38	80	59	30	80	55	- 8	0
	1.68	42	80	61	30	81	55	- 12	+ 1
Glyphosate	0.56	37	80	58	68	86	78	+ 31	+ 6
	1.12	68	77	73	89	87	88	+ 21	+ 10
	1.68	73	87	80	85	92	88	+ 12	+ 5
L.S.D. (0.05)		24	NS	17	23	23	16		
Average	0.56	-	80	-	-	70	-	-	- 10
	1.12	53	79	66	60	84	72	+ 7	+ 5
	1.68	58	84	71	58	87	73	0	+ 3

control treatment of no herbicide application. The quackgrass was too vigorous in growth to be suppressed adequately by paraquat which retarded only the top growth for about six weeks and then permitted regrowth.

Yields

Seeding year (1978): Total average yields of pure alfalfa from the one harvest were 0.51 mt/ha (Table 16). There were significant differences in yields between seeding methods but none among herbicide treatments. Alfalfa band seeded on a tilled seedbed yielded almost three times as much as the alfalfa from the sod seeded method. Broadleaved weeds were a problem in stand establishment and the below normal precipitation (Table 1) from seeding to late summer contributed to the poor yields.

Year after seeding (1979): Total yields of pure alfalfa from three harvests were very good, averaging 9.49 mt/ha (Table 17). When the alfalfa was drilled in the sod the average yields were 8.33 mt/ha but the tilled seedbed yields were almost 25% more at 10.64 mt/ha. There were significant differences in yields between seeding methods and herbicide treatments. Alfalfa after the treatments of the medium and high rates of glyphosate produced the best yields in the sod seeding method (10.80 to 12.47 mt/ha). Alfalfa yields after the low rate of glyphosate and all pronamide treatments were intermediate (6.48 to 8.88 mt/ha). After paraquat at the low rate the alfalfa yields were the poorest (4.67 mt/ha) from those sods treated with a

Table 16. Yields (mt/ha of 12% moisture) from one harvest[†] of alfalfa in the year of seeding (1978) in a quackgrass sod treated with three herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	Rate kg[ai]/ha	Seeding Method and Surface: Drilled Sod	Seeding Method and Surface: Band Tilled	Average
Control	0.00	0.02	0.87	0.45
Paraquat	0.56	0.21	-	-
Pronamide	0.56	-	0.86	-
	1.12	0.14	0.72	0.43
	1.68	0.33	0.59	0.46
Glyphosate	0.56	0.19	0.69	0.44
	1.12	0.34	0.68	0.51
	1.68	0.43	0.80	0.62
L.S.D. (0.05)		NS	NS	NS
Average	0.56	-	0.78	-
	1.12	0.24	0.70	0.47
	1.68	0.38	0.75	0.57

[†]Cut on Oct. 2.

Table 17. Yields (mt/ha of 12% moisture) from three harvests[†] of alfalfa in the first year (1979) after seeding in a quackgrass sod treated with three herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	kg[ai]/ha	Drilled in Sod				Band Seeded in Tilled Surface				Average
		Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Total
Control	0.00	0.28	0.31	0.11	0.70	4.40	3.27	2.72	10.39	5.55
Paraquat	0.56	1.40	1.53	1.74	4.67	-	-	-	-	-
Pronamide	0.56	-	-	-	-	3.62	2.59	2.56	8.78	-
	1.12	2.00	2.26	2.21	6.48	4.54	2.47	2.65	9.66	8.07
	1.68	1.95	1.89	2.82	6.67	5.03	2.91	3.39	11.33	9.00
Glyphosate	0.56	4.02	2.26	2.59	8.88	4.48	2.59	3.52	10.60	9.74
	1.12	5.25	2.71	2.84	10.80	5.38	2.71	3.15	11.24	11.02
	1.68	5.19	3.56	3.72	12.47	5.55	3.42	3.27	12.23	12.35
L.S.D. (0.05)		1.58	0.95	0.83	2.63	1.58	0.95	0.83	2.63	1.52
Average	0.56	-	-	-	-	4.05	2.59	3.04	9.69	-
	1.12	3.63	2.49	2.53	8.64	4.96	2.59	2.90	10.45	9.55
	1.68	3.57	2.73	3.27	9.57	5.29	3.17	3.33	11.78	10.68

[†]Cut 1 June 17; Cut 2 July 26; Cut 3 Sept. 11.

herbicide (Fig. 5). Almost negligible yields were obtained when alfalfa was seeded in the quackgrass sods that were not suppressed in any way (0.70 mt/ha).

Alfalfa yields were very similar when seeded by either method in the medium and high rates of glyphosate-treated sods, but at the low rate, band seeding in a tilled seedbed was better than when sod seeded. After pronamide treatments there was over 50% greater yields when alfalfa was seeded in a tilled seedbed than when sod seeded. Band seeding alfalfa in a tilled seedbed after all rates of glyphosate and the high level of pronamide treatments produced the highest yields. Yields from seedings in a tilled seedbed were slightly better when no herbicide was applied to the quackgrass than when the low and medium rates of pronamide were used. Chemical toxity to the alfalfa was not a likely explanation as this effect was displayed only in the lower rates. Sufficient quackgrass suppression may have been achieved with only the one cultivation so that herbicide rates were possibly of little consequence.

Glyphosate successfully suppressed the quackgrass to give a good stand establishment (Table 12) and the best alfalfa yields (Tables 16 and 17). Pronamide over all rates did not control the quackgrass as consistently or as well as glyphosate, with resulting erratic stand establishment, estimations, and yields. Paraquat did not suppress quackgrass sufficiently to enable a reasonable stand of alfalfa to be established.

Included in the trials reported here was a fourth chemical called buthidazole. Applied at the same rates and conditions as the

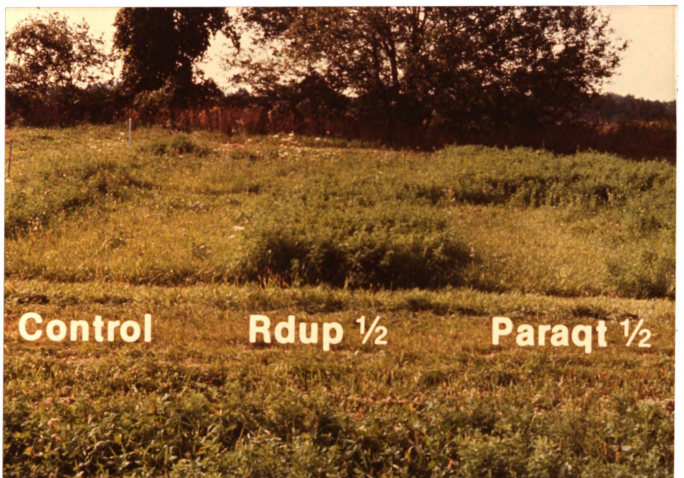

Fig. 5. Alfalfa drilled in a quackgrass sod produced good yields after glyphosate application to the quackgrass (center--Rdup ½), poor yields after paraquat application (right--Paraqt ½), and negligible yields without a herbicide application (left--Control).

other herbicides it demonstrated a very severe destruction of all vegetation, including the seedings of alfalfa with resulting poor stands. The characteristics of this herbicide were similar to that of a mild soil sterilant and it was considered to be of little value as a herbicide in suppressing quackgrass prior to alfalfa establishment (see Appendix Tables 21, 22, 23, and 24).

Experiment 4: Lake City, alfalfa on quackgrass, pH 6.3, three herbicides fall applied at three rates, two seeding methods and surfaces, two years: 1978, and 1979.

Stand Density

Seeding year (1978): There were significant differences in stand establishment between seeding methods and treatments (Table 18). Alfalfa band seeded in the tilled seedbed after all herbicide treatments produced almost 300% more plants than when drilled into the quackgrass sod. This may have been accentuated by the extremely sandy nature of the soil in this trial and favorable precipitation after seeding which favored the tilled area seedings. There were no differences in stand density between herbicides in either seeding method. The seedings without chemical suppression of the quackgrass were the poorest in each method.

Estimations

Visual estimations of the percentage of alfalfa present in the tilled quackgrass sods were made 3 and 14 months after seeding

Table 18. Stand density (plants/m^2) of alfalfa three months after seeding (1978) in a quackgrass sod treated with two herbicides applied at various rates. Two seeding methods and surfaces. Exp. 4, Lake City.

Herbicide	Rate kg^{ai}/ha	Seeding Method and Surface: Drilled Sod	Band Tilled	Average
Control	0.00	*a* 15 *a*	*b* 263 *a*	*a* 139 *a*
Pronamide	0.70	-	376 *b*	-
	1.40	*a* 107 *b*	*b* 424 *b*	*b* 265 *b*
	2.10	*a* 140 *b*	*b* 417 *b*	*b* 278 *b*
Glyphosate	0.70	*a* 148 *b*	*b* 429 *b*	*b* 289 *b*
	1.40	*a* 161 *b*	*b* 378 *b*	*b* 270 *b*
	2.10	*a* 120 *b*	*b* 415 *b*	*b* 268 *b*
Average	0.70	-	403	-
	1.40	134	401	268
	2.10	130	416	273

Means followed by the same letter within columns, or preceded by the same letter within rows, are not significantly different at the 5% level using Duncan's multiple range test.

(Table 19). There was little difference in percent alfalfa in both years between herbicide treatments except after the low rate of pronamide where alfalfa percentage was the lowest. Glyphosate treated sods produced almost no change in percent alfalfa between the first and second year while pronamide-treated sods over the same period decreased in percent alfalfa in all but the high rate.

There was a heavy infestation of volunteer alfalfa in the sod seeded areas of the trial. Estimations and yields with this volunteer alfalfa included would not have been accurate so results presented are only for the band seedings in a tilled seedbed.

Yields

Seeding year (1978): Total average yields of pure alfalfa from the one harvest were 1.98 mt/ha (Table 20). Yields of alfalfa were the same from all herbicide treatments with the untreated sods yielding the least.

Year after seeding (1979): Total yields of pure alfalfa from three harvests were good on the drouthy soil, averaging 7.9 mt/ha (Table 20). There were significant differences in yields between herbicide treatments with alfalfa after all rates of pronamide and glyphosate yielding equally as well (7.06 to 7.43 mt/ha) except after the low pronamide rate which was considerably lower (5.81 mt/ha). Alfalfa in the unsuppressed quackgrass sods produced the poorest yield of 3.39 mt/ha.

There were no significant differences in the response of

Table 19. Percentage estimations of alfalfa 3 and 14 months after band seeding in a tilled quackgrass sod treated with two herbicides applied at three rates. Exp. 4, Lake City, 1978 and 1979.

Herbicide	Rate kg[ai]/ha	1978	1979	Percent Change Over 11 Months
Control	0.00	23	30	+ 7
Pronamide	0.70	60	50	- 10
	1.40	86	78	- 8
	2.10	86	89	+ 3
Glyphosate	0.70	85	86	+ 1
	1.40	85	85	0
	2.10	89	90	+ 1
Average	0.70	73	68	- 5
	1.40	86	82	- 4
	2.10	88	90	+ 2
	average	82	80	- 2

Table 20. Yields (mt/ha of 12% moisture) of alfalfa from one harvest[†] in the year of seeding (1978) and three harvests[††] in the first year (1979) after band seeding in a tilled quackgrass sod treated with two herbicides applied at three rates. Exp. 4, Lake City.

Herbicide	Rate kg[ai]/ha	1978	1979			
		Cut 1	Cut 1	Cut 2	Cut 3	Total
Control	0.00	0.25	1.14	1.39	0.85	3.39
Pronamide	0.70	2.01	2.31	2.30	1.19	5.81
	1.40	2.00	3.09	2.90	1.44	7.43
	2.10	2.01	3.49	2.42	1.16	7.06
Glyphosate	0.70	2.07	3.39	2.70	1.26	7.34
	1.40	1.86	3.18	2.66	1.33	7.17
	2.10	1.93	3.47	2.40	1.32	7.21
L.S.D. (0.05)		0.52	0.84	0.55	0.24	1.18
Average	0.70	2.04	2.85	2.50	1.23	6.58
	1.40	1.93	3.14	2.78	1.39	7.30
	2.10	1.97	3.48	2.41	1.24	7.14
	average	1.98	3.16	2.56	1.29	7.01

[†] Cut on Aug. 31.

[††] Cut 1 June 25; Cut 2 Aug. 14; Cut 3 Oct. 7.

quackgrass to the herbicides pronamide and glyphosate, in contrast to the differences favoring glyphosate in the heavier soil of experiment 3.

Stand density and estimations, were not significantly different between the herbicides, or the various rates at which they were applied and alfalfa yields only differed in one herbicide rate. Factors such as the sandy nature of the soil, and the slightly higher herbicide rates in this trial, than used in experiment 3, may have influenced the lack of differences among treatments.

Buthidazole was also tested in this experiment under the same conditions and rates as the other chemicals. Because of the very severe destruction of all vegetation and new seedlings this chemical was considered to be of little value as a herbicide in suppressing quackgrass prior to alfalfa establishment (see Appendix Tables 25, 26, and 27).

SUMMARY AND CONCLUSIONS

Legumes Seeded Into Grass Sods

Excellent stands of alfalfa and birdsfoot trefoil were established in bromegrass, orchardgrass, reed canarygrass, tall fescue, and Kentucky bluegrass sods in a fine textured soil when the grasses were suppressed by a herbicide and seedings were made in early spring by drilling the seed 1 cm deep in the sod, or broadcasting the seed on the sod. The method of seeding was less important than grass suppression and early seeding. For satisfactory stand establishment, the seeding method became more crucial when the date of seeding was in late May when precipitation and ground moisture were less abundant. Drilling the seed 1 cm deep produced good stands in late May but broadcasting the legumes was completely unsatisfactory at this late date.

When a herbicide was used to suppress the grasses, broadcasting or drilling the seed into the sod in April produced good stands of either legume, equal to stands obtained by band seeding in a tilled seedbed. Stand densities, percent legume in the stand, and yields all clearly indicated the absolute necessity of suppressing the grasses before interseeding a legume into the swards. Negligible alfalfa stands and yields were obtained when no herbicide was used to suppress the grasses. Previous work had shown suppression of the existing

sward to be so important, especially with trefoil seedings, that trials without herbicide applications were tested only on alfalfa. Stand densities of alfalfa were poorest when the seed was broadcast on untreated sods and subsequent yields from either seeding method were unacceptable.

Alfalfa Seeded into Quackgrass Sods

Herbicide suppression of quackgrass on untilled sandy loam sods was shown to be essential for good alfalfa establishment. Better than expected stands and yields of alfalfa were obtained when the quackgrass was plowed under in late April without first being treated with a herbicide, and the sod prepared for immediate seeding without frequent tillage to suppress or kill the quackgrass. The good stands and high yields of alfalfa from the untreated, tilled sods were more pronounced in the trials on the sandy loam soil at East Lansing than on the similar soil at Lake City.

Lower rates of herbicide were more successful in obtaining good stands and yields of alfalfa after tilling and band seeding than when alfalfa was seeded on an undisturbed herbicide-treated sod. Glyphosate applications were successful and consistent in suppressing quackgrass: pronamide was less effective. Paraquat did not suppress quackgrass adequately for successful sod seeding of alfalfa.

APPENDIX

Table 21. Stand density (plants/m^2) of alfalfa ten weeks after seeding (1978) in a quackgrass sod treated with four herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	Rate kg^{ai}/ha	Seeding Method and Surface: Drilled Sod	Seeding Method and Surface: Band Tilled	Average
Control	0.00	*a* 23 *a*	*b* 122 *ab*	73 *a*
Paraquat	0.56	69 *bc*	-	-
Pronamide	0.56	-	98 *a*	-
	1.12	*a* 76 *bc*	*b* 140 *bc*	108 *bc*
	1.68	*a* 57 *ab*	*b* 132 *abc*	95 *ab*
Glyphosate	0.56	*a* 107 *cd*	*a* 123 *ab*	115 *bc*
	1.12	*a* 135 *d*	*a* 118 *ab*	126 *cd*
	1.68	*a* 139 *d*	*a* 161 *c*	150 *d*
Buthidazole	0.56	*a* 55 *ab*	*b* 99 *a*	77 *a*
	1.12	*a* 93 *bc*	*b* 128 *abc*	110 *bc*
	1.68	*a* 67 *b*	*b* 111 *ab*	89 *ab*
Average	0.56	-	*b* 107	-
	1.12	*a* 101	*b* 129	115
	1.68	*a* 88	*b* 135	112

Means followed by the same letter within columns, or preceded by the same letter within rows, are not significantly different at the 5% level using Duncan's multiple range test.

Table 22. Percentage estimations of alfalfa 3 and 13 months after seeding (1978) in a quackgrass sod treated with four herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	kg[a1]/ha	1978 Drilled Sod	1978 Band Tilled	1978 Average	1979 Drilled Sod	1979 Band Tilled	1979 Average	Percent Change Over 10 Months Drilled Sod	Percent Change Over 10 Months Band Tilled
Control	0.00	3	67	35	5	75	40	+ 2	+ 8
Paraquat	0.56	23	-	-	23	-	-	0	-
Pronamide	0.56	-	80	-	-	53	-	-	- 27
	1.12	38	80	59	30	80	55	- 8	0
	1.68	42	80	61	30	81	55	- 12	+ 1
Glyphosate	0.56	37	80	58	68	86	78	+ 31	+ 6
	1.12	68	77	73	89	87	88	+ 21	+ 10
	1.68	73	87	80	85	92	88	+ 12	+ 5
Buthidazole	0.56	32	83	57	20	77	48	- 12	- 6
	1.12	48	73	61	35	82	58	- 13	+ 9
	1.68	62	63	63	65	95	80	+ 3	+ 32
L.S.D. (0.05)		29	NS	20	23	23	17		
Average	0.56	-	81	-	-	72	-	-	- 9
	1.12	51	77	64	51	83	67	0	+ 6
	1.68	59	77	68	60	89	75	+ 1	+ 12

Table 23. Yields (mt/ha of 12% moisture) from one harvest[†] of alfalfa in the year of seeding (1978) in a quackgrass sod treated with four herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	Rate kg[ai]/ha	Seeding Method and Surface: Drilled Sod	Seeding Method and Surface: Band Tilled	Average
Control	0.00	0.02	0.87	0.45
Paraquat	0.56	0.21	-	-
Pronamide	0.56	-	0.86	-
	1.12	0.14	0.72	0.43
	1.68	0.33	0.59	0.46
Glyphosate	0.56	0.19	0.69	0.44
	1.12	0.34	0.68	0.51
	1.68	0.43	0.80	0.62
Buthidazole	0.56	0.40	0.88	0.64
	1.12	0.43	0.83	0.63
	1.68	0.70	0.93	0.82
L.S.D. (0.05)		0.30	NS	NS
Average	0.56	-	0.81	-
	1.12	0.30	0.74	0.52
	1.68	0.49	0.77	0.63

[†]Cut on Oct. 2.

Table 24. Yields (mt/ha of 12% moisture) from three harvests[†] of alfalfa in the first year (1979) after seeding in a quackgrass sod treated with four herbicides applied at various rates. Two seeding methods and surfaces. Exp. 3, East Lansing.

Herbicide	kg[ai]/ha	Drilled in Sod				Band Seeded in Tilled Surface				Average
		Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Total
Control	0.00	0.28	0.31	0.11	0.70	4.40	3.27	2.72	10.39	5.55
Paraquat	0.56	1.40	1.53	1.74	4.67	-	-	-	-	-
Pronamide	0.56	-	-	-	-	3.62	2.59	2.56	8.78	-
	1.12	2.00	2.26	2.21	6.48	4.54	2.47	2.65	9.66	8.07
	1.68	1.95	1.89	2.82	6.67	5.03	2.91	3.39	11.33	9.00
Glyphosate	0.56	4.02	2.26	2.59	8.88	4.48	2.59	3.52	10.60	9.74
	1.12	5.25	2.71	2.84	10.80	5.38	2.71	3.15	11.24	11.02
	1.68	5.19	3.56	3.72	12.47	5.55	3.42	3.27	12.23	12.35
Buthidazole	0.56	1.38	1.23	1.66	4.27	4.64	2.62	2.98	10.24	7.26
	1.12	2.31	2.03	2.41	6.76	4.85	3.12	3.19	11.16	8.96
	1.68	4.66	2.65	2.51	9.82	6.12	3.42	2.84	12.38	11.10
L.S.D. (0.05)		1.60	1.10	0.97	2.87	1.60	1.10	0.97	2.87	1.66
Average	0.56	-	-	-	-	4.25	2.60	3.02	9.87	-
	1.12	3.19	2.33	2.49	8.01	4.92	2.77	3.00	10.69	9.35
	1.68	3.93	2.70	3.02	9.65	5.57	3.25	3.17	11.98	10.82

[†]Cut 1 June 17; Cut 2 July 26; Cut 3 Sept. 11.

Table 25. Stand density (plants/m^2) of alfalfa three months after seeding (1978) in a quackgrass sod treated with three herbicides applied at various rates. Two seeding methods and surfaces. Exp. 4, Lake City.

Herbicide	Rate kg^{ai}/ha	Seeding Method and Surface: Drilled Sod	Band Tilled	Average
Control	0.00	*a* 15 *a*	*b* 263 *c*	139 *c*
Pronamide	0.70	-	376 *d*	-
	1.40	*a* 107 *b*	*b* 424 *e*	265 *d*
	2.10	*a* 140 *bc*	*b* 417 *de*	278 *d*
Glyphosate	0.70	*a* 148 *bc*	*b* 429 *e*	289 *d*
	1.40	*a* 161 *c*	*b* 378 *d*	270 *d*
	2.10	*a* 120 *bc*	*b* 415 *de*	268 *d*
Buthidazole	0.70	*a* 15 *a*	*b* 194 *b*	105 *b*
	1.40	*a* 13 *a*	*a* 51 *a*	32 *a*
	2.10	*a* 12 *a*	*b* 67 *a*	40 *a*
Average	0.70		333	
	1.40	94	284	189
	2.10	91	300	196
	average		306	

Means followed by the same letter within columns, or preceded by the same letter within rows, are not significantly different at the 5% level using Duncan's multiple range test.

Table 26. Percentage estimations of alfalfa 3 and 14 months after band seeding in a tilled quackgrass sod treated with three herbicides applied at various rates. Exp. 4, Lake City, 1978 and 1979.

Herbicide	Rate kg^{ai}/ha	1978	1979	Percent Change Over 11 Months
Control	0.00	23	30	+ 7
Pronamide	0.70	60	50	- 10
	1.40	86	78	- 8
	2.10	86	89	+ 3
Glyphosate	0.70	85	86	+ 1
	1.40	85	85	0
	2.10	89	90	+ 1
Buthidazole	0.70	30	23	- 7
	1.40	30	18	- 12
	2.10	31	30	- 1
Average	0.70	58	53	- 5
	1.40	67	60	- 7
	2.10	69	70	+ 1
	average	65	61	- 4

Table 27. Yields (mt/ha of 12% moisture) of alfalfa from one harvest† in the year of seeding (1978) and three harvests†† in the first year (1979) after band seeding in a tilled quackgrass sod treated with three herbicides applied at three rates. Exp. 4, Lake City.

Herbicide	Rate kg[ai]/ha	1978	1979			
		Cut 1	Cut 1	Cut 2	Cut 3	Total
Control	0.00	0.25	1.14	1.39	0.85	3.39
Pronamide	0.70	2.01	2.31	2.30	1.19	5.81
	1.40	2.00	3.09	2.90	1.44	7.43
	2.10	2.01	3.49	2.42	1.16	7.06
Glyphosate	0.70	2.07	3.39	2.70	1.26	7.34
	1.40	1.86	3.18	2.66	1.33	7.17
	2.10	1.93	3.47	2.40	1.32	7.21
Buthidazole	0.70	0.81	1.01	2.02	0.99	4.02
	1.40	0.94	1.08	1.69	0.72	3.49
	2.10	1.45	1.71	1.65	0.62	3.98
L.S.D. (0.05)		0.55	0.77	0.62	0.26	1.25
Average	0.70	1.63	2.24	2.34	1.15	5.72
	1.40	1.60	2.45	2.42	1.16	6.03
	2.10	1.80	2.89	2.16	1.03	6.08
	average	1.68	2.53	2.31	1.11	5.94

† Cut on Aug. 31.

†† Cut 1 June 25; Cut 2 Aug. 14; Cut 3 Oct. 7.

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