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PATRICIO AZOCAR C. for the MASTER OF SCIENCE
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Title: MANAGEMENT FACTORS AFFECTING ESTABLISHMENT OF BIRDSFOOT TREFOIL (LOTUS CORNICULATUS L.)

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William S. McGuire

A field experiment under irrigation was conducted at the Hyslop Agronomy Farm, near Corvallis, Oregon, during the 1967 growing season to evaluate the effect of barley row spacing, nitrogen rate and placement, and weed competition in the year of seeding upon birdsfoot trefoil (*Lotus corniculatus* L.) seedling establishment. The effect of birdsfoot trefoil on barley grain production was also evaluated.

Three herbicides were used to measure the effects of weed competition upon birdsfoot trefoil establishment and barley grain production. These are: Avadex BW 1.25 lb. ai. per acre, 2,4-DB amine 1.50 lb. ai. per acre and DNBP amine 1.50 lb. ai. per acre.

The effects of nitrogen in birdsfoot trefoil establishment and on barley grain production were studied using two systems of placement: 80 lb. N per acre broadcast and 20 lb. N per acre applied in

rows spaced at 7 inches plus 60 lb. N per acre broadcast.

The effects of row spacing on birdsfoot trefoil establishment and barley grain production were determined using five systems of seeding: (1) barley seeded alone in rows spaced at 7 inches, (2) barley seeded alone in rows spaced at 14 inches, (3) barley seeded in rows spaced at 7 inches plus birdsfoot trefoil seeded at the same time in the same row, (4) barley seeded in rows spaced at 14 inches plus birdsfoot trefoil seeded at the same time in the same row and in row between barley, and (5) birdsfoot trefoil seeded in rows spaced at 7 inches.

It was concluded that the use of a barley companion crop to establish birdsfoot trefoil decreases the vigor of the trefoil; however, the number of plants per foot of row was similar to the other treatments. At constant seed rate of barley, an increase in row spacing above 7 inches gave a decrease of grain yield and an increase of dry matter yield of birdsfoot trefoil. Birdsfoot trefoil seeded alone gave the highest dry matter yield in the year of establishment. The trefoil did not affect the yield of barley.

Application of nitrogen as urea reduced the number of plants of birdsfoot trefoil, when this species was seeded alone or together with barley, but the yield of the forage species was not reduced. Nitrogen application of 80 pounds per acre increased barley grain yield when it was applied broadcast, but not when it was split into

20 pounds nitrogen per acre in rows at seven inches and 60 pounds nitrogen per acre broadcast.

An interaction between 2,4-DB application and nitrogen placement was found in barley grain production, but not in birdsfoot trefoil establishment. Also, an interaction between 2,4-DB application and system of seeding was found to affect yield of dry matter of birdsfoot trefoil. 2,4-DB increased birdsfoot trefoil yield and effectively controlled red root pigweed (*Amaranthus retroflexus* L.), common lambsquarter (*Chenopodium album* L.), common groundsel (*Senecio vulgaris* L.), and shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.), but it did not influence barley grain yield and the number of plants of birdsfoot trefoil per foot of row.

DNBP had a detrimental effect on barley yield and was similar to no herbicide on birdsfoot trefoil dry matter yield. It provided good control of common groundsel and shepherdspurse, and gave a poor control of red root pigweed and common lambsquarter.

Avadex BW was applied to control wild oat; however, this weed was not present.

Management Factors Affecting Establishment of Birdsfoot Trefoil (*Lotus corniculatus* L.)

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Professor of Farm Crops
in charge of major

Redacted for Privacy

Head of Farm Crops Department

Redacted for Privacy

Dean of Graduate School

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Typed by Donna Olson for Patricio Azocar C.

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INTRODUCTION

Birdsfoot trefoil (*Lotus corniculatus* L.) is native to the Mediterranean region and northward to the Scandinavian Peninsula. For a hundred years or more it has been used in small plantings in the British Isles and in the countries of continental Europe (65). In the United States, however, the legume is relatively new, and extensive evaluation of its use for forage production has been confined to the last twenty years (21, 22). In this period, birdsfoot trefoil has attracted attention in two widely separated sections of the United States. In eastern New York and in western Oregon, where it first became naturalized, it has spread until now it is found over a comparatively large area (65).

Desirable agronomic qualities of birdsfoot trefoil were summarized by Midgley (67) in 1951. He stated that

> a) it is superior to alfalfa (*Medicago sativa* L.) on poorly drained clay soils, b) it is better than Ladino clover (*Trifolium repens* L.) on drier lands, c) it withstands closer grazing than alfalfa or most clover, and d) it is less exacting in soil fertility or moisture requirements than alfalfa and clover, but, under proper conditions, produces excellent hay, pasture or silage.

The main advantage of birdsfoot trefoil over other legumes is that it does not cause bloat. There has never been a case of bloat reported with animals grazing birdsfoot trefoil pasture (21, 22).

Birdsfoot trefoil is rapidly gaining acceptance as a forage legume and is currently recommended for use in most states of the Northern United States (63, 92). One of the main problems with this legume in all areas where it is being used is that it is slow to establish and is more sensitive to competition than other commonly recommended forage legumes (21). For this reason, Midgley (67) stated that companion crops should be used sparingly if at all. However, it is still a common practice in many parts of the country to make spring seedings of legumes with small grain companion crops (36). The primary reason for this is to get a return from the land while the forage is being established (50). Whether such use of small grain is beneficial or harmful to birdsfoot trefoil seedling establishment is controversial and obviously depends on many factors such as light, nutrients, water, etc.

Hannchen barley is grown extensively in the Willamette Valley and in the Klamath Basin areas of Oregon as a malting barley (37, 51). It is known that nitrogen increases yield of barley (37, 93), but a high nitrogen level may depress nodulation of legumes (15). Some authors have suggested that the relatively slow establishment and seedling failures of birdsfoot trefoil, may be due to inadequate nodulation and a subsequent nitrogen deficiency. The addition of nitrogen to birdsfoot trefoil actually caused a decrease in yield (67), primarily because of excessive barley, and weed growth, and depressed nodulation.

Establishment of birdsfoot trefoil together with small grain can be a good practice in foreign countries where it is difficult from the economic standpoint to seed a pasture. In Chile (7) it is a common practice to establish legumes and grasses with small grains, and it is hard to convince the farmer to seed the pasture without companion crops. Results of experiments made by the author (7) in the south of Chile, under conditions very similar to the Willamette Valley of Oregon, showed that the small grain companion crop did not reduce the stand and yield of a hay-pasture mixture of red clover and ryegrass, or a pasture mixture of subclover and fescue.

The purpose of this investigation was to study under irrigated conditions the effect of barley row spacing, nitrogen placement, and weed competition in the year of seeding upon birdsfoot trefoil seedling establishment under barley, and the effect of birdsfoot trefoil on barley grain production.

LITERATURE REVIEW

Companion Crops and Legume Establishment

Companion crops are often used in pasture establishment for three basic reasons (50, 90, 105): first, they produce a return from the land the year the seed is sown; second, if they are not used, a more harmful companion crop of weeds may replace them; third, on sloping land they help to control erosion while the small-seeded forages become established. Nevertheless, the companion crop is always a competitor of, and usually a detriment to, the young forage seedling.

Weeds may produce a very heavy and rank growth without the use of a companion crop in spring seedings. Thus, the weeds will assume the role of a companion crop. A heavy growth of weeds can be more competitive with the legume seedlings for light and moisture than a grain crop (90).

A companion crop competes with the legume seedlings primarily for light and moisture, but also for soil nutrients when the soil has not been fertilized properly (90).

On fine-textured, fertile soils, especially those high in available nitrogen, shading by the companion crop and by the heavy growth of summer weeds following removal of the companion crop is usually the dominant factor in reducing stands. The most deleterious form of light competition occurs with the lodging of the grain crop, especially when moisture conditions encourage growth of the legume seedlings under the shading of the lodged grain. Competition for moisture may be a dominant competitive factor on fine-textured soils during a dry season (90).

On coarse-textured soils with poor moisture retention, the withdrawal of water by the companion crop is usually the dominant factor in the survival of the seedling (90).

Undersown legumes often fail to establish satisfactorily in adverse seasons. Undersowing has consequently been abandoned in some environments, while in other environments attempts are being made to find ways by which satisfactory growth and yield of both crop and legum can be obtained. The phenomenon involved is clearly one of competition between the companion crop and legume plants. Small grain species in general have larger seeds, faster growth rates, taller shoots and deeper root systems than many legume species, and are therefore better able to exploit the soil. Even when the supply of soil nutrients is sufficient, the companion crops, because of their greater stature, shade the pasture and reduce its growth (84).

Various methods have been adopted to reduce the competition from the companion crop; the most important of them involve consideration of the following factors:

Type of companion crop. Different species of companion crops and, indeed, different varieties of the same crop vary in their competitive ability. The more favorable varieties of small grains to be used as companion crops will a) be stiff-strawed and hence resistant to lodging, b) make a minimum of leaf growth, and c) be early maturing (105). Thatcher *et al.* (90) found that legume establishment with small grains harvested at maturity was best with spring barley, and less successful in turn with early spring oats, late spring oats and winter wheat. The poorest stands were established under winter rye and winter barley. Collister and Kramer (19) found that different varieties of oats used as companion crops affected yield of red clover herbage. Oat height and yield of clover forage were negatively correlated, and they concluded that this was caused by the degree of shade cast, while recognizing that competition for soil moisture and nutrients could also be involved. Nevertheless, differences between varieties are usually not clear-cut; Bula *et al.* (12) found no difference in light intensity beneath five varieties of oats and there was no difference in number of legumes per unit area beneath them. Smith *et al.* (91) studied the establishment of legumes under four varieties of oats (Clinton, Bond, Vicland and Forvic) over a four-year period and with the experimental design used, these oat varieties showed no significant differences on the establishment of the legume stands.

Seed rate of companion crop. Most recommendations on companion cropping suggest sowing the cereal crop at rates lower than normal. Smith (90) stated that the oat companion crop should be sown at two to three bushels per acre on fine soils and at one bushel per acre on coarse or sandy soils. He also stated that reduced rates of sowing oats on fine soils are accompanied by the ingress of weeds. The weeds are often stronger competitors for light, moisture, and nutrients to the legume and grass seedlings than the oats themselves. As a result, there is little practical value to reduce oat sowing rate on fine soils. Smith *et al.* (91) in Wisconsin found the rate of sowing oats to be of considerable importance on sandy soils where moisture was often deficient. Although the legume stands were sometimes significantly thinner on the fine soils with the higher oat sowing rates than with the lower rates, the differences in legume stands were sufficiently small as to be of little practical importance. The reduced rates of sowing oats on the fine soils were accompanied by the encroachment of weeds which tended to even out the differences in oat sowing rates.

Sowing depth. This is another important factor. Small grains are normally drilled at depths of about 1.5 inches and sowing the small-seeded pasture species at the same depths would result in reduced emergence. Stickler and Wasson (94) in Manhattan, Kansas, obtained good emergence of birdsfoot trefoil from the 0.5-inch planting depth, whereas little emergence was found with the 1.0-inch depth, and very little emergence was found at the 1.5-inch depth.

Willard (50) states that on most soils in humid areas, practically all of the small-seeded forage crops are best sown one-fourth to one-half inch deep, or less. Anything deeper than one inch is fatal. Sometimes small seed must be sown deeper than one-fourth to one-half inch in special situations, such as sandy soils, or to reach moist soil, but the hazard is always greater.

Sowing date. Nearly all recommendations on undersowing stress the importance of sowing the crop and the legume at the same time. When a legume is spring sown into a cereal crop sown in the previous fall, competition is severe and the growth of the legume is greatly reduced (84). For instance, Ahlgren (2) obtained successful stands of birdsfoot trefoil from late summer seedings without a companion crop or early spring seedings in oats. Pendleton (74) got better stands of alfalfa when band-sown with winter wheat in fall than when broadcast into the wheat in the following spring. In countries where crops are sown in either fall or spring, simultaneous sowing in the spring appears to be more successful (84), because fall-sown cereals are well established by spring and are therefore the first to take advantage of the factors needed for growth such as light, soil moisture, etc. (57).

Row spacing. Increasing the space between the rows of the companion crop may be expected to reduce competition between the crop and the legume and grass, and to lead to better establishment of the undersown pasture.

The influence of row width on the yield of small grains was reviewed by Holliday (29). At constant seed rate a decrease in row spacing below the standard 7-8 inches has generally given a small increase in yield, while increasing the row-spacing above the standard has usually given some decrease in yield. It should be noted, however, that where it is customary to localize fertilizer along the row, the degree of localization becomes less as row spacing is decreased (29, 55).

Fulkerson (38) found that oats seeded in 7-inch and 14-inch drills and at various seeding rates had a marked effect upon the stand obtained of a hay-pasture mixture. An increase in the oat rate of seeding decreased the stand of all species. Fourteen-inch drills produced more vigorous plants than 7-inch drills. Marked depressions in establishment occurred when the rate of seeding was increased beyond 1.5 bushels per acre in both drill widths.

Results of experiments in the south of Chile under conditions very similar to Willamette Valley, Oregon, showed that wheat drilled in 6 to 7-inch rows produced more than when drilled in 12 to 14-inch rows. The wheat seeded in 6 to 7-inch and 12 to 14-inch drills did not have an adverse effect upon the stand and yield of a hay-pasture mixture of red clover and ryegrass and upon a pasture mixture of subclover and fescue (7).

The effect of planting a small grain crop in rows 7 or 14 inches apart on the growth of legume seedlings and yield of grain has been studied at the Oklahoma Agricultural Experiment Station over a period of 16 years (48). Increasing the distance between rows of small grain from 7 or 8 inches to 14 or 16 inches provided a more favorable opportunity for the survival of legume seedlings during normal drought periods.

Results of cooperative tests in central and eastern Oklahoma show that the effect of row spacing on yield was quite variable. The average production of grain and straw was slightly lower when drill rows were 14 inches apart and only one-half as much seed was planted as compared with a 7-inch spacing (48).

Spring oats planted over a ten-year period at Stillwater, Okla., produced as much grain when drilled in 14-inch rows as when planted in 7-inch rows. Michigan winter barley, planted in 14-inch rows at the rate of 1 bushel per acre, suffered a greater reduction in yield, about 3 bushels net loss, than winter wheat, rye, or spring oats (48).

Harper (48) states that very little advantage in the stand of legume seedlings will be secured from wide row spacing of small grain when summer rainfall is abundant and summer temperatures are below average. During many seasons when summer drought was severe, a good stand of sweet clover was obtained on plots when the small grain was drilled in 14-inch rows, whereas a complete failure occurred on plots where the drill rows were spaced 7 inches apart.

The effect of five different oat row spacing arrangements and broadcast seedings on the growth and yield of oats and a red clover companion crop was determined for three seasons at Urbana (75). In two seasons with normal or above-normal rainfall during May and June, no significant differences in clover stands attributable to row spacing were observed. In 1950, an abnormally dry year in May, the stand, growth and hay yields from the red clover companion crop were proportionately better as the spacing width increased. The 8-inch spacing produced the smallest quantity and poorest quality of hay.

These results suggest that competition is primarily for soil moisture, but evidence that light intensity may be another important factor was given by several workers using corn as a companion crop (84).

Santhirasegaram, basing his arguments on solar radiation and crop characteristics, concluded that at any given latitude there would be an optimum row width and that this would increase with increasing latitude (84).

Row direction. Another way in which the effect of competition can be modified is to vary the direction of the rows, either of one crop relative to the other, or of both crops. Few experiments have been done on this aspect of plant arrangement; perhaps rather surprisingly, they all give the same result despite differences in altitude, season and crop height. All show that yield is greater from a crop with north-south rows than in a crop with east-west rows (29, 84).

The most comprehensive study is that by Pendleton and Dungan (76) in which the two directions were compared at three row spacings of oats for seven years. There was an increase due to north-south rows of 7.7 percent in grain yield at 24-inch spacing, 6.7 percent at 16-inch, but only 2.1 percent at the normal 8-inch spacing. The authors suggested that this was due to differences in the light regime, with superior lighting in north-south rows, as compared with the poor lighting on the north side of east-west rows.

Only a few studies on row direction have been made in connection with undersowing pasture. Kilcher and Heinrichs (54) noted that the establishment of pasture was better when sown at right angles to the rows of cereals than when the two crops were sown in in the same row. Kiselev (84) observed that cross-sowing at 5-inch spacing was better than sowing both crops in the same direction. He considered that cross-sowing would provide a better light micro-climate for the plants, resulting in better utilization of soil moisture and nutrients. Santhirasegaram (84) obtained evidence in favor of north-south rows over east-west in a mediterranean-type climate where the heating effect of the sun on soil moisture during the winter-rainfall season was likely to be of little consequence. The effect of row direction was shown to depend on the amount of direct sunlight received around noon.

Early removal of the companion crop. Since many failures in legume establishment have resulted from using companion crops, these have sometimes been removed before maturity, by either grazing or cutting for hay or silage (84). Krenzin (60) obtained better legume stands and forage yields when the oat companion crop was removed at hay stage of growth rather than at maturity. Klebesadel and Smith (56) removed an oat companion crop at various stages of its growth and found that the later the cover crop was removed, the poorer was the stand of an undersown legume.

Removing the companion crop at the hay stage changes the environment of the legume species drastically and this may be expected to affect their growth (84); however, Pritchett and Nelson

(80) could not find any deleterious effect. Santhirasegaram and Black (84) state that early grazing may reduce the establishment of the legume, but if the companion crop is allowed to remain too long, the growth of the legume is restricted as a result of the severe competition for environmental factors.

Early spring clipping or grazing of the companion crop. Clipping the grain at a level of about three inches when it is five to six inches tall prevents excessive growth and usually eliminates lodging. The same results can be accomplished by grazing when the grain is six to seven inches tall. Heavy stocking is necessary to prevent differential or spotted grazing, and to get the grazing done rapidly. Grazing too long a time and grazing too close should be avoided, and likewise grazing when the soil is not firm. Clipping or grazing will reduce yields, particularly if followed by dry weather, but will help prevent excessive growth and lodging. These practices would benefit the legume and grass seeding particularly on the low-lying, fertile soils high in nitrogen where lodging is of common occurrence (90).

Methods of harvesting the companion crop. The method of harvesting the cereal companion crop influences the performance of the subsequent forage crop. Kilcher and Heinrichs (54) found that cutting the cereal crops at a height of 8 inches or more for grain resulted in better grass-alfalfa stands and yields than was obtained when the cereal crops were mowed at a 2-inch height for hay.

Removal of straw and stubble. It has been found beneficial to the forage seeding if all straw and stubble are removed following combining. For example, Ohio tests (1) show 50 percent more hay the following year when all straw and stubble were removed immediately following combining compared to no removal. The straw apparently favors development of certain diseases, causing loss of forage stand.

Clipping and removing the straw and stubble also give clean hay in the succeeding year. The practice thus saves the stand, increases forage yields, and results in a better-quality hay free of the straw and stubble (1).

Effects of Shading and Plant Competition on Seedling Growth of Birdsfoot Trefoil

In legume seedling establishment, competition may be induced (seeding with a companion crop) or non-induced (ingress of weeds). In either case the growth rate of the companion crop or weeds will exceed that of the legume seedlings and they may be considered as an overstory species.

Clements *et al.* (18) state that

> Competition is purely a physical process. Competition arises from the reaction of one plant upon the physical factors about

> it and the effect of the modified factors upon its competitors. In the exact sense, two plants, no matter how close, do not compete with each other so long as the water content, the nutrient material, the light and the heat are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demands of the plants, competition begins.

The factors for which competition may occur among plants are water, nutrients, light, oxygen, and carbon dioxide; in the reproductive phase, agents of pollination and dispersal must be added. There are other factors affecting growth, such as temperature and humidity, but these are not commodities in finite supply and hence are not subject to competition. Water, nutrients, and light are the factors most commonly deficient, but in rapidly photosynthesizing crops, carbon dioxide may also be depleted by competing plants. Competition for soil oxygen, until recently disregarded, may be of significance in poorly structured soils (29, 83).

Probably the most marked effect of an overstory species upon the micro-environment of an understory species is the reduction of light intensity. Since growth is dependent upon photosynthesis, reduction of light below levels needed for optimum photosynthesis restricts growth. When light is reduced to the point that photosynthesis equals respiration (light compensation point), growth cannot occur. Further reduction will result in a greater loss of substrate by respiration than is being synthesized and death of the seedling may occur (22, 27).

Birdsfoot trefoil is weakly competitive in the seedling stage and slow to establish. The poor seedling vigor of this species has been studied by numerous investigators (22, 23, 24, 33, 34).

Gist and Mott (43, 44) found that root and top growth of birdsfoot trefoil was inhibited by low levels of light intensity in a manner similar to that of alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense*). Total seedling growth, however, was less at all stages of development. Similar results were reported by Cooper (21). He found that shading by companion crops reduced growth of birdsfoot trefoil and alfalfa proportionately. Since birdsfoot trefoil seedlings at a given age are normally smaller than those of alfalfa, the effect of growth reduction from competition may be more critical for birdsfoot trefoil with respect to survival. For example, Cooper and Ferguson (25) found that, at companion crop maturity, birdsfoot trefoil roots had penetrated to a depth of only 8 inches in contrast to a depth of 15 inches for alfalfa. As a result, birdsfoot trefoil would have been more likely to experience drought had surface soils become dry (23). Baylor (9) found that top and root growth of birdsfoot trefoil were severely suppressed by reduced light intensities. Roots were affected more severely than tops.

Bandyopadhyay (8) at Cornell found that the response of alfalfa and birdsfoot trefoil seedlings to light was influenced by soil moisture conditions. Interacting effects of light and moisture were the determining factors for both top and root growth of the legume seedling. Under greenhouse conditions of 1,000-foot-candle light intensity and 40 percent soil moisture, birdsfoot trefoil growth was only 52 percent of that of alfalfa, in part due to its relative intolerance to shading.

Under field conditions of differential shading both alfalfa and birdsfoot trefoil seedling growth was higher under 82 percent daylight. Birdsfoot trefoil under shade of 49 to 24 percent daylight suffered most and did not make significant growth in the second year. Alfalfa varieties needed at least 25 percent daylight while birdsfoot trefoil seedlings needed at least 50 percent daylight at seedling surface during early seedling growth for satisfactory establishment (8).

Rhykerd et al. (82) found that the leaf: steam ratio of birdsfoot trefoil was low at low light intensities but increased with increasing light intensity. In contrast, leaf: stem ratios of alfalfa and red clover were high at low intensity and decreased at high light intensity. McKee (63) found that leaf area per plant of red clover increased under moderate shading, while leaf area of alfalfa and that of birdsfoot trefoil decreased.

Cooper (24) found that relative growth rate of birdsfoot trefoil was greater than that of alfalfa under full sunlight and under 51, 76, and 92 percent of shade intensities due to a greater leaf area ratio. At all light intensities, birdsfoot trefoil had a greater proportion of leaves to stem than alfalfa. He showed that shading reduced yield and plant height proportionately more for alfalfa than for birdsfoot trefoil, and that shading did not affect stands of legumes.

Cooper (23) finally stated that the poorer seedling vigor of birdsfoot trefoil as compared with alfalfa, cannot be attributed to differences in the effect of decreased light intensity upon relative growth rate. Relative growth rate of both species decreased similarly with decreasing light intensity due to decreased net assimilation rate. Leaf area ratio of both species increased with decreasing light intensity.

The generally acknowledged concept that birdsfoot trefoil is less tolerant to shading than other legumes is not apparent from the results reviewed here.

Although shading tolerance of birdsfoot trefoil and alfalfa may be similar, birdsfoot trefoil is more likely to be shaded, both in the seedling stage and later. Seedlings and mature plants of birdsfoot trefoil are smaller than those of alfalfa. In addition, birdsfoot trefoil begins growth later in the spring and recovers more slowly after clipping. These factors increase the likelihood of birdsfoot trefoil becoming shaded by associated species (24).

Effect of a Barley Companion Crop on Birdsfoot Trefoil Establishment and Forage Production

Few experiments have been done on this aspect of competition between barley and birdsfoot trefoil. The most interesting study is that by Cooper (21) in which the effects of a barley companion crop, time of harvest in the first season, and nitrogen and phosphorus fertilization upon stand, survival and subsequent production of alfalfa and birdsfoot trefoil were investigated in Montana. He found that stands of legumes were not affected by fertilization or time of harvest management, but decreased with increasing levels of companion crop competition. Death of seedlings occurred early in the establishment period and the degree of loss was similar for both species. Additional losses of plants did not occur during the establishment year. Losses of birdsfoot trefoil plants established with a companion crop occurred during the first winter following seeding. Stand reduction in the seeding year persisted for the duration of the experiment.

Companion crops inhibited the growth of surviving seedlings. Growth inhibition was less when barley was clipped periodically than when it was matured to grain. In the absence of a companion crop, growth of seedlings was inhibited more by frequent clipping of thin weed stands than by allowing weeds to mature (21).

Yields of weeds were inversely related to density of barley plants. Wild oat plants were more detrimental to seedling growth and were less readily controlled by clipping than red root pigweed (*Amaranthus retroflexus*) or green foxtail (*Setaria viridis*).

Barley markedly reduced the amount of light penetrating to seedlings. It was concluded that shading was the most detrimental effect of barley upon establishment and growth of seedlings. Competition for moisture did not appear to be a factor in establishment. However, shallow root penetration of legume seedlings grown with barley showed that a low moisture content in the surface soil could become most critical to survival and may intensify the effect of shading (25).

Yields of mixtures in years following seeding were reduced as a result of establishment with a companion crop, and to a greater extent and for a longer period of time when barley was allowed to mature. Yield reductions of legumes were compensated in some cases, by increased grass yields.

Cooper (21) concluded that the greatest net return is obtained when legumes are established with barley spaced in 18-inch rows. He recommends that barley be seeded in 18-inch rows at right angles to the forage seedling rows. Seeding the companion crop in 6-inch rows will provide more grain per acre, but the net return from both forage and grain may be less per acre than that obtained from seeding the companion crop in 18-inch rows. Furthermore, the increased competition from a companion crop in 6-inch rows greatly increases the chance of seeding failures.

Effect of Application of Nitrogen Fertilizers on the Yield of Birdsfoot Trefoil and Barley

The effect on the legumes growing among the companion crop of nitrogen applied to the companion crop is not clear. If nitrogen is deficient, it is well known that legumes can furnish nitrogen for the small grain, but where the supply is ample, the legume may act as a competitive crop (62).

The use of nitrogen fertilizers at low rates of application is advisable to aid the establishment of seedling legumes, but if it is used at high rates the legume may be eliminated. This is mainly due to the shading effect of the companion crop, which reduces top and root growth of the legume and causes shedding of nodules (52, 64, 92).

A number of factors should be considered in seeding birdsfoot trefoil under barley companion crop in relationship to nitrogen application. The main factors are as follows:

Effect of nitrogen on barley grain production. Response of barley to nitrogen fertilizer under field condition is affected by various soil and climatic factors including total nitrogen content, organic matter content, content of available forms of N, capacity of soil to release available N, kind and amount of residues, water relations, soil physical properties, precipitation, and temperature (109).

Foote and Batchelder (37) pointed out the benefits derived from application of N on yields of malting barley in the Willamette Valley. Jackson _et al._ (51) found in one experiment at Hyslop Farm, Oregon State University, Oregon, that vegetative response from N was evident on all planting dates. Increases in yield were significant and reached a maximum at 80 pounds of N per acre. Application of 120 pounds of N per acre consistently caused lodging, reduction in yield, reduction in test weight, and increase in percent of thin kernels. They concluded from this experiment and five other experiments established in different localities, that application of nitrogen consistently increased yields.

Effect of nitrogen on legume nodulation. Atmospheric nitrogen is fixed in soils by various free-living and symbiotic bacteria. Of the latter, _Rhizobium_ spp., is one of the most important. The quantities of nitrogen fixed by Rhizobia differ with the rhizobial strain, the host plant, and the environmental conditions under which the two develop. Amounts as high as 500 pounds of nitrogen fixed per acre by clover have been reported from New Zealand. Under the conditions of this work, the climate was extremely favorable for growth the year round. Although this figure is considerably above the average generally reported, much nitrogen is fixed via the legume route in a large part of New Zealand, a country that presently depends almost entirely on this phenomenon for its agricultural nitrogen (99). However, this effect of Rhizobia in legume production may be affected by nitrogenous fertilization of legumes.

Allen and Baldwin (3) stated that the young inoculated leguminous plants require small amounts of available nitrogen for effective nodule development. Apparently much advantage is afforded the plant by eliminating the hunger period that intervenes between exhaustion of the seed nitrogen and the onset of symbiotic nitrogen fixation. However, nitrogen supplied in quantities large enough to support prolonged growth of the plant inhibits or severely depresses nodule formation.

A field study was conducted by Lyons and Earley (61) to determine the possibility of supplementing soil and symbiotically-fixed nitrogen of soybeans with nitrogen fertilizer. In 1947, during a hot dry growing season marked responses were obtained from added nitrogen. The number of nodules per plant decreased 80 to 90 percent, but there were appreciable increases in seed yields. In 1949, with adequate rainfall, moderate temperatures, and 30 to 40 days additional growing season there was little or no response to added nitrogen. The number of nodules per plant on the untreated plots was larger than in 1947, and the application of nitrogen fertilizer (ammonium nitrate) resulted in only a 35 percent decrease in number of nodules. This experiment helps explain some of the variation in response of legumes to nitrogen fertilizers. Rainfall and temperature conditions during the growing season apparently have a direct influence on the sufficiency of symbiotically-fixed nitrogen for maximum yields, thus indirectly influencing the response to added nitrogen.

Koter (59) found that application of nitrogen to inoculated red clover in pots reduced nodulation but accelerated plant growth, except when the source of nitrogen was ammonium nitrate. Weber (104) stated that the amount of symbiotic nitrogen fixation of soybean decreased rapidly with increases in fertilizer nitrogen. Nowotny-Mieczyńska and Ruszkowska (70) showed that nitrate nitrogen affects the growth of legumes and their nodulation specifically.

From the experiments cited above, it may be concluded that there is an inhibitory effect of nitrogenous fertilizers on the development of root nodules in leguminous plants. There is evidence both for an effect of a high total nitrogen content of the plant at all stages of nodule growth (16, 88, 106, 107) and for a local and specific effect of nitrate on the early stages of nodule formation (40, 81, 95, 98, 102). Cartwright (14) in a recent study (1967) suggested that the adverse effect of combined nitrogen on nodulation is due to the accumulation of unsequestered nitrogen compounds and a depletion of carbohydrates generally within the root tissues rather than the local effect of any particular nitrogen compound.

Effect of nitrogen on legume forage production. As reported before, high level of nitrogen inhibits development of root nodules in leguminous plants. However, the effect of high level of nitrogen in legume forage production is not clear.

Blaser *et al.* (10) in Virginia, found that clover population was increased the most on plots which received superphosphate without nitrogen. Cooper (20) in Montana, stated that herbage yields were increased with nitrogen fertilization, in plots with birdsfoot trefoil and ladino clover, at the first harvest date in the year after seeding. The increase was highly correlated with and attributed to, the growth of weeds present. The number of plants per square yard decreased with increasing levels of nitrogen fertilizer.

Ward and Blaser (103) in Virginia, reported that the number of legume plants (alfalfa, red clover, ladino clover, and birdsfoot trefoil) emerging per unit area of soil decreased as the amount of nitrogen applied (0, 20, 40, 80 pounds of nitrogen per acre) increased. The seedling weights of legume taken 28 days after emergence were not influenced by the nitrogen fertilizer. The seedling weights of all legume species taken 56 days after emergence were greatest for the 80-pound rate of nitrogen per acre. The response to 20 or 40 pounds of nitrogen varied for species and years. Yields of the species (weeds inclusive) were not improved by nitrogen fertilizers during the seedling year. The mean yield of the legumes was reduced by 80 pounds of nitrogen, the clovers being reduced more than alfalfa or birdsfoot trefoil. Yields for the season after establishment show that the clovers were depressed by nitrogen. Alfalfa and birdsfoot trefoil yields were unchanged in two of the three years and increased with the 20 pounds of nitrogen per acre during the first year.

Giddens (41) in Georgia, found that nitrogen application of 0, 30, 60 and 90 pounds per acre to new and established stands of alfalfa were too erratic to justify any recommendation.

Mott et al. (69) in Indiana, with an annual application of 120 pounds of nitrogen per acre in addition to lime, phosphorus and potash, obtained an additional increase in beef production per acre of 39 percent. However, this increase in beef production can be attributed to an increase in yield and nutritive value of the forage mixture, or an increase in the yield of the grass of the mixture.

In one experiment in which clover was seeded with a companion crop, and nitrogen applied at different rates, the grain yield was increased with nitrogen, but the hay yield was decreased in the first year but not in the subsequent years.

From the above discussion it may be concluded that the effect of nitrogen at rates recommended for companion crops (60-80 pounds per acre for barley) may not affect the forage production of legumes and particularly of birdsfoot trefoil. The addition of nitrogen to legumes in some cases may decrease their yield through an indirect effect; that is, an increase of companion crop growth or weed growth and, of course, an increase in light competition and a decrease in symbiotic nitrogen fixation (67). Pritchett and Nelson (80) reported that one of the most striking effects of reduced light intensity on alfalfa was the proportional decrease in nodulation. They found that nodulation essentially stops at less than 257 foot candle and stated that this may be a contributing factor to loss of seedlings in the field.

Competition between Barley, Birdsfoot Trefoil and Weeds

A companion crop, like weeds, will compete with seedling plants for light, moisture, and nutrients. Birdsfoot trefoil seedlings grow slowly and furnish little competition to rapidly growing weeds. Too often weeds soon overtop the birdsfoot trefoil seedlings. In order to avoid this, some farmers plant birdsfoot trefoil with companion crops to reduce weed competition. This practice, however, was developed because other effective methods of reducing weed competition were unknown. Today, through the development of selective herbicides for the control of weeds, this is not the major objective. The use of herbicides, companion crops or both in reducing weed competition in legume establishment must depend upon the relative costs, results of residue analysis, and action by the Food and Drug Administration and the U.S. Department of Agriculture (49, 72, 79, 85, 87).

Gilbert (42) found that the effect of the companion crop and weeds, grown separately, reduced birdsfoot trefoil stands and yields, but the effect was not additive when the companion crop and weeds were grown together. The companion crop reduced weed dry matter production by 57 percent in a dry season and 72 percent during a season of above normal rainfall.

Scholl and Brunck (85) studied the competition effects from weed and companion crops as they influenced the establishment and subsequent productivity of birdsfoot trefoil. The use of herbicides such as Dalapon (2,2 dichloropropionic acid) and 4(2,4-DB), gave almost complete control of both grasses and annual broadleaf weeds in birdsfoot trefoil seedings. A companion crop of oats significantly reduced the yield of birdsfoot trefoil in the year of seeding and in the year following.

The influence of companion crops and of various herbicide treatments on stand establishment and yields the year following treatment of birdsfoot trefoil was studied by Scholl and Staniforth (86). They reported excellent control of weeds with a combination of four pounds of Dalapon and 1/2 pound of 4(2,4-DB) per acre. Companion crops reduced stands and yields of birdsfoot trefoil under all managements studied; however, rainfall was a limiting factor in those years in which companion crops were seeded.

The best herbicides for use in cereals under-seeded to legume in Oregon, are recommended by Furtick (39). He states that when the problem is the control of annual broadleafed weeds the following chemicals may be used: MCPA, 2,4-DB or DNBP amine or ammonium salt, and when the problem is the control of wild oats (*Avena fatua*) in spring wheat or barley, Triallate (Avadex BW) for wheat or barley, and Diallate (Avadex) for barley only can be used.

From the above discussion it may be stated that the use of herbicide is a good tool in legume establishment. Some of these compounds, such as Triallate (Avadex BW), DNBP and 2,4-DB, the ones used in this experiment, will be briefly reviewed.

Triallate (Avadex BW). The herbicidal properties of carbamate-type materials were first reported in 1945. Since that time, a number of carbamates, thiolcarbamates and dithiolcarbamates have proven to be excellent herbicides (5). Triallate (2,3,3-trichloroallyl N,N-diisopropyl thiolcarbamate) is used to control wild oats (*Avena fatua*) in spring wheat and barley (39).

In some areas wild oat (*Avena fatua*) ranks as the number one weed problem. Recommended cultural practices which include repeated tillage during early spring, and delayed seeding of the crop, are partially successful in controlling this widespread pest. However, delayed seeding often resulted in substantial crop reduction, which, added to the expense of tillage, made such a program quite costly. Furthermore, in a cold wet spring, delayed seeding is not always effective (11, 47).

Triallate is volatile and must be mixed into the soil immediately after spraying. It may be used on any cereal crop, except oats and rye, without restriction as regard to variety. Spring barley is more resistant than spring wheat (35).

The mode of action of triallate appears to be similar to that of diallate, but with a slightly longer residual period. Its action is most likely attributable to inhibition of cell division. Available evidence suggests that activity of the two products for wild oats control is similar under optimums for moisture and incorporation. Where one of these is deficient, triallate appears to be more effective (6, 68, 89).

Selleck and Hannah (89) reviewed the 1962 field results with diallate and triallate in the United States and Canada. They stated that experiments in North America during 1961 have shown triallate to be significantly more selective in cereal grains than diallate; however, results from experiments in 1962 indicated that triallate was less effective for *Setaria* spp. control than diallate.

Parker (71) found that triallate as compared with diallate has a greater selectivity in barley when the compounds are incorporated deeply; also it has greater selectivity in both wheat and barley when shallowly incorporated after sowing.

Triallate incorporated into a soil at three pounds per hectare before sowing barley gave 90 percent control of wild oats in an average of 86 trials reported by Göpp et al. (45). Also, it increased the yield of grain by 25 percent in the average of 54 trials.

Dodel and Deloraine (28) studied the action of diallate and triallate on forage legumes. They found that birdsfoot trefoil and red clover tolerated 2.4 pounds of triallate per acre. Thus, they stated that there is very little risk of injury to forage legumes undersown in barley. The recommended dosage of triallate on barley is one and one-fourth pounds per acre (39).

Montgomery et al. (68) state that triallate is registered for use on barley and wheat on a no residue basis and that it presents low toxicity to animals.

DNBP. The sodium salt of a dinitro compound was first used to selectively remove broadleaf weeds from small grains in France in about 1933. Since then, different and more effective forms of dinitro have been developed (58).

The selectivity of DNBP (amine salt of 4,6-dinitro-o-sec-butylphenol) is affected by weather conditions. Poor weed control generally occurs when low temperatures prevail after treatments, and excessive crop injury occurs when high temperatures prevail following treatment. Meggitt et al. (66) found that the activity of DNBP increases as temperature after treatment increases from 60° to 96° F; however, the activity is lower under growing temperature of 60° and 90° F prior to treatment than with temperatures of 70° and 80° F prior to the application. Light prior to treatment has no effect whereas light following treatment reduced the apparent activity of DNBP. Plants grown under low light intensities are injured more than those grown under higher light intensities (66).

Humidity also affects the toxicity of DNBP salts. When the plant is dry, absorption takes place very slowly, whereas high humidity moistens both chemical and plant and speeds up the rate of absorption. Observations indicate that plants are more susceptible after periods of cloudy weather. This may be because the plants are more succulent and develop a thin cuticle under such conditions (58). When using salts of DNBP, one factor is especially important: the length of time the salts remain on the plant before a rain. This period varies with temperature, humidity, rate of treatment, and susceptibility of the species. Under favorable conditions at least six hours is required; twenty-four hours usually gives better results (58).

In birdsfoot trefoil seedings, post-emergence applications of DNBP are applied to control many broadleaf weeds. The herbicide appears to be more effective as a post-emergence treatment to the weeds due to the fact that it acts by contact. It should be applied when the legumes are in the two to four true leaf stage of growth. When the legume is seeded under small grain, the application of DNBP should not be made after the cereals are starting into the shoot stage. It must be applied when foliage is dry and the temperature is under 80° F (39).

DNBP may be used at one and one-half pounds active ingredient per acre of either the amine or ammonium salt formulations in 31 or more gallons of water (39). In Wooster, Ohio, post-emergence application of DNBP up to three pounds per acre gave good control of most broadleaf weeds and poor control of grassy weeds with some injury to alfalfa and birdsfoot trefoil. Above three pounds per acre, DNBP severely injured these crops (32). Dowler and Willard (30) reported that DNBP gave good to excellent control of the broadleaf weeds on seedlings of alfalfa, birdsfoot trefoil and red clover, with slight injury to alfalfa at two and three pounds per acre.

Wojtaszer (108) studied the relationship between susceptibility of plants to DNBP and their capacity for ATP generation. He found considerable differences in susceptibility to DNBP between weed species. The species were arranged in four groups in order from low to high sensitivity. The first group, highly resistant, includes mainly the family Gramineae, and representatives of the Amaranthaceae and Leguminosae, while the last group, highly susceptible, contains species of Cruciferae, Chenopodiaceae, Solanaceae and Caryophylaceae. Red root pigweed (Amaranthus retroflexus) appeared to be the most resistant to DNBP. He postulated that the degree of susceptibility between species depends upon the level of ATP in the tissues.

In one experiment conducted at the Schmidt Agronomy Farm, near Corvallis, Oregon, during the 1966 season, Valdes (101) found that DNBP amine applied at 2 lb. ai. per acre when the birdsfoot trefoil and alfalfa were in the two to four leaf stage gave the best broadleaf weed control. It gave good to excellent control of burnet (Sanguisorba spp.), mayweed (Anthemis cotula L.), henbit (Lamium amplexicaule L.), cornflower (Centaurea cyanus L.), and fair control of wild mustard (Brassica kaber (DC.) L.C. Wheeler var. pinnatifida (Stokes) L.C. Wheeler).

Montgomery et al. (68) stated that DNBP has a very appreciable toxicity to animals and to man and it is registered on a no residue basis for post-emergence use on seedling and dormant alfalfa, seedling clovers, many small grains, dormant strawberries, peas and beans.

4-(2,4-dichlorophenoxy) butyric acid (2,4-DB). 2,4-DB, a derivative from the phenoxy family, is used to control many broadleaved weeds in legumes such as peas, alfalfa, red clover, birdsfoot trefoil, alsike clover and ladino clover (58).

In its original molecular state 2,4-DB has only a low toxicity to most plants. Scientists think that many of the legumes convert 2,4-DB into 2,4-D very slowly. In such plants, the concentration of 2,4-D is never sufficient to cause serious plant injury. Most other plants make the conversion to 2,4-D rather rapidly, providing a concentration of 2,4-D high enough to kill the plant. Therefore the legume plants escape injury, and most weeds are killed (58).

Numerous workers have reported the use of 2,4-DB in the establishment of legume forage crops (30, 31, 32, 53, 73, 78, 100). They recommend spraying when legumes have two to more true leaves or when weeds are in the one to three leaf stage. When the legumes are seeded under companion crops the spraying should not be done after the cereals are starting into the boot stage (39).

Furtick (39) recommends applying one to one and one-half pounds of 2,4-DB (butyric acid) in 10 to 20 gallons of water per acre. However, rates of application range from 3/4 to 4 lb. ai. per acre (26, 102).

As a post-emergence application in seedling legumes, the most common treatment reported in dalapon plus 2,4-DB in order to control broadleaf weeds and weedy grasses. Also EPTC as a pre-plant incorporated treatment plus 2,4-DB as a post-emergence application have been reported to give good to excellent weed control (17, 46, 77, 101, 102).

Zemanek _et_ _al_. (110) reported that 2,4-DB killed common lambsquarter (_Chenopodium_ _album_ L.), but its effect on wild radish (_Raphanus_ _raphanistrum_ L.) was slight. They also stated that red clover, white clover, birdsfoot trefoil, black medick and sainfoin were more resistant to 2,4-DB than 2,4-D, MCPA and DNOC. However, 2,4-DB caused leaf deformities in red clover. They obtained few differences in forage yields following herbicidal treatments beyond the first cut. Only where legume stands were seriously infested with weeds did herbicidal treatments result in yield increases.

Montgomery _et_ _al_. (68) stated that when 2,4-DB is applied to a pasture, livestock must not be grazed or fed on treated crops for at least 30 days after treatment.

MATERIALS AND METHODS

Description of Area

The experiment was conducted on the Hyslop Agronomy Farm, near Corvallis, Oregon, during the 1967 growing season.

The climate of Corvallis (13), which is fairly representative of much of the Willamette Valley, may be described as a mild subcoastal type with moist, open winters, a dry harvest period in late summer, and a fairly long growing season. The average frost-free period (217 days) is from April 2 to November 5. Average annual rainfall (1901-1960) is 39.24 inches. The average total rain for the four-month period of June through September is 3.38 inches. A summary of air and soil temperatures and rainfall for the 1967 growing season is shown in the Appendix, Tables 1, 2, and 3.

The soil type at the test site is Woodburn silt loam, typically moderately acid (pH 6.1), and relatively adequate in phosphorus content (68.2 ppm).

The weeds present on June 15 in plots without herbicides consisted mainly of: annual bluegrass (*Poa annua* L.), annual ryegrass, (*Lolium multiflorum* Lam.), red root pigweed (*Amaranthus retroflexus* L.), common lambsquarter (*Chenopodium album* L.), common groundsel (*Senecio vulgaris* L.) and shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.).

Experimental Procedure

The experiment was seeded on April 29 and 30, 1967, to compare the effects of three herbicides, three systems of placement of nitrogen and five systems of seeding on birdsfoot trefoil and barley production seeded together at the same time.

The experimental design was a split-split plot with three replications. Main plots were different herbicides, secondary plots were placement of nitrogen and small plots were systems of seeding.

Phosphorus and potassium were applied to all treatments before seeding. Phosphorus as single superphosphate at the rate of 34.40 pounds per acre (80 pounds P_2O_5) and potassium as potassium chloride at the rate of 99.60 pounds per acre (120 pounds K_2O).

Herbicides. The herbicides, rate in pounds of active ingredient per acre and the dates of application are shown in Table 1.

Avadex BW was applied as a pre-plant treatment, and immediately incorporated with a disc harrow to a depth of three to four inches. 2,4-DB and DNBP were applied as post-emergence treatments when the birdsfoot trefoil was in the two to four leaf-stage of growth; this occurred on June 15. All herbicide applications were made with an experimental plot sprayer, a bicycle-type, with a ten-foot boom. The volume of water used was equivalent to 30 gallons per acre.

Table 1. Herbicides, rate and dates of application.

Treatment	Rate lb. ai. per acre	Date of application
H_1 Check	--	--
H_2 Avadex BW +	1.25	April 29, 1967
2,4-DB amine	1.50	June 15, 1967
H_3 Avadex BW +	1.25	April 29, 1967
DNBP amine	1.50	June 15, 1967

The weather conditions and the stage of growth of weeds, barley and birdsfoot trefoil, during the applications, are shown in Tables 2 and 3.

Table 2. Weather conditions during herbicide applications.

Date	Wind velocity miles/hr.	Air Temp. ^oF	Soil Temp. ^oF	Observations
April 29	0	48	52	Cloudy, slight rainfall
June 15	0	72	74	Clear sunny day

Table 3. Stage of growth of weeds, barley and birdsfoot trefoil on June 15, 1967.

Species	Height in inches	Stage of maturity
Birdsfoot trefoil	2.0	2-4 true leaves
Barley	19.5	tillering to jointing stage
Weeds		
Annual bluegrass	4.6	mature seed
Annual ryegrass	14.0	mature seed
Red root pigweed	8.5	vegetative
Common lambsquarter	11.0	vegetative
Common groundsel	4.5	flowering
Shepherdspurse	12.0	flowering

Nitrogen fertilizer. The nitrogen fertilizer treatments and the system of placement are shown in Table 4.

Table 4. Nitrogen rates, system of placement, and date of application.

Lb. N per acre		System of placement	Date of application
N_1	0	--	--
N_2	80	20 lbs. in rows at 7-inch. + 60 lbs. broadcast	April 29
N_3	80	broadcast	April 29

Nitrogen in row placement was drilled as urea together with barley and inoculated birdsfoot trefoil seeds. Broadcast nitrogen applications were made by hand.

System of seeding. The systems of seeding of birdsfoot trefoil and barley are as follows:

S_1 Barley seeded in 14-inch rows plus birdsfoot trefoil seeded in 7-inch rows.

S_2 Barley seeded in 14-inch rows.

S_3 Barley seeded in 7-inch rows plus birdsfoot trefoil seeded in 7-inch rows.

S_4 Barley seeded in 7-inch rows.

S_5 Birdsfoot trefoil seeded in 7-inch rows.

Barley variety Hannchen (2-row) and birdsfoot trefoil variety Granger were seeded on April 29-30, at the rate of 90 pounds and 6 pounds per acre, respectively. The seed of barley was treated with methylmercury dicyandiamide and the seed of birdsfoot trefoil inoculated with the appropriate strain of rhizobia.

All treatments were seeded with an experimental eight row V-belt seeder on plots 4.5 x 20 feet (90 square feet). The V-belt seeder failed to seed adequately birdsfoot trefoil (too deep), and the germination was poor after fifteen days. For this reason it was seeded again with a Planet Jr. drill on May 17. Plots were irrigated ten times as it is indicated in Table 5, from May 18 to August 21, to obtain better establishment of birdsfoot trefoil and to eliminate moisture as a factor in competition. A fair to good stand was obtained.

Table 5. Irrigation dates and amount of water applied in inches.

Date	Amount of water applied in inches
May 18	0.5
May 19	0.5
May 23	0.5
June 6	1.0
June 13	3.0
June 27	3.0
July 7	3.0
August 9	4.0
August 21	4.0
TOTAL	19.5

Stand Estimation. A stand estimate of weeds was taken from each plot on June 15 before post-emergence herbicide application, and July 24 after post-emergence herbicide application. Also, stand estimate was taken from each plot on July 6.

The stand estimation was based on the following scale:

1 =	0 - 10	%	plants	per	plot
2 =	11 - 20	%	"	"	"
3 =	21 - 30	%	"	"	"
4 =	31 - 40	%	"	"	"
5 =	41 - 50	%	"	"	"
6 =	51 - 60	%	"	"	"
7 =	61 - 70	%	"	"	"
8 =	71 - 80	%	"	"	"
9 =	81 - 90	%	"	"	"
10 =	91 - 100	%	"	"	"

Barley yield. Barley grain was harvested on August 5. The area harvested was two rows 8 feet long for both 7-inch or 14-inch spacing. The yield of each plot was converted to bushels per acre. After the harvest, all plots were clipped with a threshing machine, and the straw left on the plots where barley was grown. In the plots with birdsfoot trefoil alone, the cut straw and weeds from adjacent plots were removed.

Birdsfoot trefoil yield. One clipping of the treatments of birdsfoot trefoil alone was made to control weeds on July 28 using a national mower. Weeds and birdsfoot trefoil were clipped at 2 to 3 inches from the soil, but they were not weighed. Birdsfoot trefoil had about 3 to 4 inches height and weeds about 15 inches; thus, this clipping removed very little birdsfoot trefoil.

Birdsfoot trefoil was harvested on September 11. Yields were estimated by clipping 1 x 2 foot sub-samples with hand shears. Two sub-samples were taken at random from each plot of 4.5 x 20 feet and fresh weights recorded. In the laboratory, the sub-samples were separated into birdsfoot trefoil, red root pigweed and straw plus weeds; then, each species was dried at 160° F for 24 hours and weighed for calculation of percentage of dry weight of each group per plot. From these data the yield in kilograms per acre of birdsfoot trefoil and percentages of each component were calculated.

Stand of birdsfoot trefoil after barley harvest. The number of plants per foot of row was counted on September 18 to 21. Four sub-samples of one-foot long were taken at random from each plot. All plants within sub-sample areas were lifted, counted and observed for effective nodules.

Statistical analysis. The data were subjected to the appropriate analysis of variance and the F-test used to test for significant differences. When F-tests were significant, Duncan's Multiple Range was conducted.

EXPERIMENTAL RESULTS

Yield of Barley in Bushels per Acre

Herbicides. The estimation of the effect of 2,4-DB and DNBP on weed presence is given in Table 6. These data are on stands of weeds on June 15 before herbicide application. They are averages of three replications, three systems of placement of nitrogen and five systems of seeding.

Table 6. Effect of herbicides on weed control.[1/]

Weed	No herbicides		Avadex BW + 2,4-DB		Avadex BW + DNBP	
	Before	After	Before	After	Before	After
Annual bluegrass	3.5	D[2/]	2.6	D	3.0	D
Annual ryegrass	1.3	D	1.2	D	1.3	D
Red root pigweed	4.7	4.4	3.5	1.2	3.5	3.9
Common lambsquarters	1.8	1.7	1.4	1.0	1.5	1.5
Common groundsel	3.6	3.3	3.3	1.3	3.1	1.5
Shepherdspurse	2.0	2.1	2.4	1.0	2.4	1.1

1/ 1 = 0 - 10% weeds species per plot.
10 = 91 - 100% weeds species per plot.

2/ Annual bluegrass and annual ryegrass were dry and they had produced seed.

Avadex BW was used to control wild oats (Avena fatua); however, this weed did not appear in the experiment. For this reason only 2,4-DB and DNBP will be considered.

The main weed in this experiment was red root pigweed, followed by common groundsel, shepherdspurse, annual bluegrass, common lambsquarter and annual ryegrass. 2,4-DB apparently gave good control of red root pigweed, common lambsquarter, common groundsel and shepherdspurse. DNBP did not control red root pigweed and common lambsquarter, but gave fair to good control of common groundsel and shepherdspurse.

The effect of herbicides on yield of barley in bushels per acre is given in Table 7.

Table 7. The effect of herbicides on yield of barley.

Herbicide	Yield of barley Bu. per acre [1/]
2,4-DB	40.32 a
No herbicide	37.39 a
DNBP	31.44 b

[1/] Any two treatments followed by the same letter are not significantly different at 1% probability level.

The chemicals 2,4-DB and DNBP affected barley yield differently; DNBP had a detrimental effect while 2,4-DB had no effect on barley yield.

Nitrogen placement. The effects of nitrogen on yield of barley are given in Table 8.

Table 8. The effects of systems of placement of nitrogen on yield of barley.

System of placement of nitrogen	Yield of barley Bu. per acre 1/
80 pounds N per acre broadcast	40.95 a
20 pounds N per acre in rows at 7-inch. + 60 pounds N per acre broadcast	35.98 b
No nitrogen	32.24 b

1/ Any two treatments followed by the same letter are not significantly different at 1% probability level.

80 pounds nitrogen per acre broadcast increased barley production while 20 pounds nitrogen placed in rows spaced at 7 inches plus 60 pounds nitrogen broadcast did not increase barley yield, when it was compared with the treatment without nitrogen.

Herbicides and nitrogen placement interaction. An interaction between herbicides and nitrogen placement was observed as shown in Table 9.

The best treatments were 2,4-DB plus 80 pounds nitrogen per acre broadcast, 2,4-DB plus 20 pounds nitrogen placed in rows spaced at 7 inches plus 60 pounds nitrogen broadcast, and no herbicide plus 80 pounds nitrogen per acre broadcast. These three treatments were not significantly different. All treatments without nitrogen were significantly inferior.

Table 9. Effects of herbicides and nitrogen on yield of barley.

Herbicides	Nitrogen in pounds per acre		
	80 lb. broadcast	20 lb. in row at 7" + 60 lb. broadcast	No nitrogen
	Bu. per acre 1/	Bu. per acre 1/	Bu. per acre 1/
2, 4-DB	47.36 a	43.16 ab	30.46 c
DNBP	32.46 c	32.39 c	29.46 c
No herbicide	42.97 abc	32.38 c	36.82 bc

1/ Any two treatments followed by the same letter are not significantly different at 5% probability level.

System of Seeding. The effects of birdsfoot trefoil and system of seeding on yield of barly are given in Table 10.

Table 10. The effects of system of seeding on yield of barley.

System of seeding	Yield of barley Bu. per acre 1/
Barley in 7-inch rows + birdsfoot trefoil	44.30 a
Barley in 7-inch rows	41.65 a
Barley in 14-inch rows + birdsfoot trefoil	31.19 b
Barley in 14 inch rows	28.39 b

1/ Any two treatments followed by the same letter are not significantly different at 1% probability level.

The best system of seeding for barley grain production was seeding in rows spaced at 7 inches. This treatment was significantly better than seeding in rows spaced at 14 inches. Birdsfoot trefoil seeded together with barley did not affect barley production.

Yield of Dry Matter of Birdsfoot Trefoil in the Year of Seeding

Herbicides. The effects of 2,4-DB and DNBP on botanical composition are given in Table 11.

Table 11. The effects of herbicides on botanical composition.

Herbicides	Percentage composition 1/		
	Birdsfoot trefoil	Red root pigweed	Straw + weeds
Avadex BW + 2,4-DB	47.62 a	7.21 a	45.17 N.S. 2/
Avadex BW + DNBP	16.39 b	48.20 b	35.41 N.S.
No herbicide	18.57 b	39.64 b	41.79 N.S.

1/ Any two treatments under the same column followed by the same letter are not significantly different at 1% probability level.

2/ Not significantly different at 5% probability level.

2,4-DB increased the percentage of birdsfoot trefoil and decreased the percentage of red root pigweed. DNBP and no herbicide were not significantly different. In both, the percentage of birdsfoot trefoil decreased and the percentage of red root pigweed increased.

The effects of herbicides on yield of birdsfoot trefoil are given in Table 12.

Table 12. The effects of herbicides on yield of birdsfoot trefoil.

Herbicides	Yield of birdsfoot trefoil in kilograms per acre [1/]
2,4-DB	497.11 a
DNBP	146.29 b
No herbicide	163.39 b

[1/] Any two treatments followed by the same letter are not significantly different at 5% probability level.

2,4-DB was significantly different from DNBP and no herbicide treatments, and increased the yield of birdsfoot trefoil. DNBP and no herbicide treatments were not significantly different and gave the least production.

Nitrogen placement. Nitrogen fertilizer and system of placement did not affect yield of birdsfoot trefoil as can be seen in Table 13.

The results obtained indicate that under the conditions of the test, the application of 80 pounds nitrogen per acre, applied broadcast, or 60 pounds nitrogen per acre applied broadcast plus 20 pounds nitrogen per acre applied in a band, gave the same results as no nitrogen application at all.

However, the number of plants per foot of row was affected by nitrogen (Table 14).

Table 13. Analysis of variance. Birdsfoot trefoil dry weight.

Source of variation	df	MS
Replication	2	17,164.38
Herbicides	2	1,056,304.81*
Error a	4	61,851.86
Nitrogen	2	90,831.30
Nitrogen x herbicides	4	70,661.42
Error b	12	45,393.75
System of seeding	2	1,057,792.58**
System of seeding x herbicide	4	673,008.74**
System of seeding x nitrogen	4	20,752.51
System of seeding x herbicide x nitrogen	8	18,941.22
Error c	36	11,224.60

* Significant at 0.05 level of probability.

** Significant at 0.01 level of probability.

Table 14. The effects of systems of placement of nitrogen on number of plants of birdsfoot trefoil.

System of placement of nitrogen	Number of plants of birdsfoot trefoil per foot of row spacing at 7 inches [1/]
80 pounds N per acre broadcast	10.79 a
20 pounds N per acre in rows at 7 inches + 60 pounds N per acre broadcast	8.00 a
No nitrogen	16.39 b

[1/] Any two treatments followed by the same letter are not significantly different at 1% probability level.

The results obtained indicate that the application of 80 pounds nitrogen per acre broadcast, and the application of 60 pounds nitrogen per acre broadcast plus 20 pounds nitrogen per acre applied in rows spaced at 7 inches, gave the same results, but were significantly inferior to no nitrogen application at all. No nitrogen application gave the highest number of plants per foot of row.

Also, botanical composition was affected by nitrogen (Table 15).

The results obtained indicate that there were no effects from system of placement of nitrogen. No nitrogen application at all gave the highest percentage of birdsfoot trefoil and the lower percentage of red root pigweed.

Table 15. The effects of system of placement of nitrogen on botanical composition.

System of placement of nitrogen	Percentage composition 1/		
	Birdsfoot trefoil	Red root pigweed	Straw + weeds
80 pounds N per acre	25.03 a	34.31 a	40.66 N.S. 2/
20 pounds N per acre in rows at 7-inch. + 60 pounds N per acre broadcast	19.52 a	41.33 a	39.15 N.S.
No nitrogen	38.03 b	19.41 b	42.56 N.S.

1/ Any two treatments under the same column followed by the same letter are not significantly different at 5% probability level.

2/ Not significantly different at 5% probability level.

System of seeding. The effects of system of seeding on yield of birdsfoot trefoil are given in Table 16.

Table 16. The effects of system of seeding on yield of birdsfoot trefoil.

System of seeding	Yield of birdsfoot trefoil in kilograms per acre 1/
Birdsfoot trefoil alone	489.31 a
Birdsfoot trefoil + barley in 14-inch rows	211.15 b
Birdsfoot trefoil + barley in 7-inch rows	106.32 c

1/ Any two treatments followed by the same letter are not significantly different at 1% probability level.

The best system of seeding was birdsfoot trefoil seeded without companion crop. Companion crop decreased the yield of birdsfoot trefoil in the year of establishment. When birdsfoot trefoil was seeded with barley as a companion crop, the best treatment was barley seeded in rows spaced at 14 inches. Barley seeded in rows spaced at 7 inches gave the least yield of birdsfoot trefoil.

Botanical composition was influenced by the system of seeding (Table 17).

Table 17. The effects of system of seedings on botanical composition.

System of seeding	Percentage composition 1/		
	Birdsfoot trefoil	Red root pigweed	Straw + weeds
Birdsfoot trefoil alone	41.62 a	49.42 a	8.96 a
Birdsfoot trefoil + barley in 14-inch rows	25.20 b	27.52 b	47.28 b
Birdsfoot trefoil + barley in 7-inch rows	15.76 c	18.11 b	66.13 c

1/ Any two treatments under the same column followed by the same letter are not significantly different at 1% probability.

Birdsfoot trefoil seeded without a barley companion crop gave the highest percentage of birdsfoot trefoil and red root pigweed, but the lowest percentage of weeds other than pigweed plus straw. Birdsfoot trefoil seeded with a barley companion crop in rows spaced at 7 inches gave the lowest percentage of birdsfoot trefoil and pigweed, but the highest percentage of straw plus weeds other than pigweed.

However, the system of seeding did not affect the number of plants of birdsfoot trefoil in the year of seeding (Table 18). The analysis of variance indicated that there were no significant differences among systems of seeding. Birdsfoot trefoil seeded without a companion crop or with the companion crop in rows spaced at 14 inches and 7 inches gave the same number of plants per foot of row.

System of seeding and nitrogen placement interaction. When birdsfoot trefoil was harvested in the year of establishment, there was no interaction between system of seeding and nitrogen placement, as shown in Table 13. However, there was an interaction effect between system of seeding and nitrogen in the number of plants of birdsfoot trefoil per foot of row (Tables 18, 19).

The highest number of plants of birdsfoot trefoil per foot of row were in the treatment without nitrogen. The stand of trefoil seeded alone was not reduced by 80 pounds per acre of broadcast nitrogen.

This treatment was similar to birdsfoot trefoil seeded without companion crop and no nitrogen. The lowest number of plants of

Table 18. Analysis of variance. Number of plants of birdsfoot trefoil per foot of row.

Source of variation	df	MS
Replication	2	31.52
Herbicides	2	41.12
Error a	4	26.84
Nitrogen	2	492.85**
Nitrogen x herbicides	4	41.38
Error b	12	23.62
System of seeding	2	4.65
System of seeding x herbicide	4	14.44
System of seeding x nitrogen	4	34.20*
System of seeding x herbicide x nitrogen	8	20.37
Error c	36	11.91

* Significant at 0.05 level of probability

** Significant at 0.01 level of probability birdsfoot trefoil resulted from systems of seeding in which 60 pounds nitrogen per acre were applied broadcast and 20 pounds nitrogen per acre were applied in rows spaced at 7 inches.

Table 19. Effects of system of placement of nitrogen and system of seeding on number of plants of birdsfoot trefoil (Observations made after barley harvest).

System of seeding	Nitrogen in pounds per acre: 80 lb. broadcast — No. of plants per per foot of row 1/	Nitrogen in pounds per acre: 20 lb. in row at 7" + 60 lb. broadcast — No. of plants per per foot of row 1/	No nitrogen — No. of plants per ft. of row 1/
Birdsfoot trefoil alone	12.31 bc	8.97 cdef	15.28 ab
Birdsfoot trefoil + barley in 14-inch rows	9.89 cde	8.94 cdef	15.30 ab
Birdsfoot trefoil + barley in 7-inch rows	10.17 cd	6.08 f	18.00 a

1/ Any two treatments followed by the same letter are not significantly different at 1% probability level.

System of seeding and herbicide interaction. The interaction of seeding and herbicides on yield of birdsfoot trefoil is given in Table 20.

The best treatment was birdsfoot trefoil seeded without companion crop with post-emergence application of 2,4-DB. DNBP gave the same results as no herbicide application at all, when it was applied to birdsfoot trefoil alone. When 2,4-DB and DNBP were applied to birdsfoot trefoil seeded together with barley in rows spaced at 7 inches, no differences between treatments were found. When 2,4-DB was applied to birdsfoot trefoil seeded together with barley in rows spaced at 14 inches, no difference between treatments was found, but when DNBP in the same system of seeding was used, the yield of birdsfoot trefoil decreased.

Table 20. The effects of system of seeding and herbicides on yield of birdsfoot trefoil.

	Herbicides		No herbicides
	2,4-DB	DNBP	
System of seeding	Kg. per acre 1/	Kg. per acre 1/	Kg. per acre 1/
Birdsfoot trefoil alone	1,078.11 a	197.47 bc	192.39 b
Birdsfoot trefoil + barley in 14-inch rows	303.71 b	157.30 c	172.43 b
Birdsfoot trefoil + barley in 7-inch rows	109.51 c	84.10 c	125.36 c

1/ Any two treatments followed by the same letter are not significantly different at 1% probability level.

The effects of system of seedings and herbicides on botanical composition are given in Table 21.

The results obtained indicate that under the conditions of the test, the seeding of birdsfoot trefoil without companion crop and

Table 21. The effects of system of seedings and herbicides on botanical composition.

System of seeding	Components of vegetation [1]	Percent of each component: Herbicides 2,4-DB	Herbicides DNBP	No herbicides
Birdsfoot trefoil alone	Birdsfoot trefoil	85.56 a	20.09 c	19.20 c
	Red root pigweed	7.56 de	73.66 a	67.04 a
	Straw + weeds [2]	6.88 N.S.	6.25 N.S.	13.76 N.S.
Birdsfoot trefoil + barley in 14-inch rows	Birdsfoot trefoil	37.40 b	17.68 c	20.52 c
	Red root pigweed	10.15 cde	43.48 b	28.92 bc
	Straw + weeds [2]	52.45 N.S.	38.84 N.S.	50.56 N.S.
Birdsfoot trefoil + barley in 7-inch rows	Birdsfoot trefoil	19.90 c	11.40 c	15.99 c
	Red root pigweed	3.91 e	27.46 bc	22.95 cd
	Straw + weeds [2]	76.19 N.S.	61.14 N.S.	61.06 N.S.

[1] Any two treatments under the rows of birdsfoot trefoil or red root pigweed followed by the same letter are not significantly different at 1% probability level.

[2] Not significantly different at 5% probability level.

with post-emergence application of 2,4-DB gave the highest percentage of birdsfoot trefoil, and the lowest percentage of pigweed. The lowest percentage of birdsfoot trefoil was obtained with the seeding of birdsfoot trefoil together with barley in rows spaced at 7 inches. In this case, no difference between herbicide and no herbicide was observed. However, the percentage of red root pigweed was less when 2,4-DB was used. In all treatments, DNBP was ineffective in the control of pigweed.

DISCUSSION

The Effects of Weed Competition in the Year of Seeding upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

From the results of this experiment (Tables 6, 7), apparently weeds did not affect barley grain production and birdsfoot trefoil establishment (Table 18), but they affected birdsfoot trefoil yield during the first year (Tables 11, 12).

Three herbicides were used to reduce weed competition, Avadex BW, 2,4-DB and DNBP. The first one was applied to control wild oat; however, this weed did not appear in this experiment, and for this reason it will not be considered in this discussion. However, this experience indicates the convenience to seed weeds in future experiments, where pre-plant herbicide treatments will be used.

The 2,4-DB gave good control of red root pigweed, common lambsquarter, common groundsel and shepherdspurse, but it did not improve barley grain yield. The competition effect of weeds might have occurred by the time of 2,4-DB application.

The re-seeding of birdsfoot trefoil after 19 days allowed weeds and barley considerable growth before birdsfoot trefoil had the appropriate stage of two to four true leaves to apply the herbicides. At this date possibly weed competition had reduced barley yield in the same way as the treatment without herbicide (58). However, 2,4-DB application provided easier harvesting and avoided reinfestation of the land with weed seeds.

Weeds compete with crop plants for light, soil moisture, soil nutrients and carbon dioxide. Under the condition of this experiment, all these factors were controlled with the exception of light and nitrogen nutrient.

The 2,4-DB reduced weed competition and increased birdsfoot trefoil yield (Tables 11, 12). It did not affect the number of plants of birdsfoot trefoil per foot of row spaced at 7 inches (Table 18), but the plants were more vigorous. There is the possibility that in the next season of growth the yield of birdsfoot trefoil will be similar under herbicides and no herbicides treatments; however, plants under no herbicide and DNBP treatments were weak in the year of seeding and probably would be more susceptible to winter injury.

DNBP had a detrimental effect on barley yield and was similar to no herbicide on birdsfoot trefoil dry matter yield.

The detrimental effect of DNBP on barley could be due to the date of application. Barley was in the tillering to jointing stage. During this last stage the internodes rapidly elongate and plants are susceptible to injury (58). Also, the high temperatures during and after DNBP application (50° to 84° F) (Appendix Table 1) could be the cause of this detrimental effect (66).

The DNBP applications did not injure birdsfoot trefoil, provided good control of common groundsel and shepherdspurse, and gave a poor control of red root pigweed and common lambsquarter (Table 6). These last results are different to those obtained by Valdes (101). He applied DNBP amine at 2 lb. ai. per acre when birdsfoot trefoil was in the two to four true leaf stage of growth and got very good to excellent control of lambsquarter and pigweed. The difference between these results can be explained on the basis of weather conditions that prevailed during and after the herbicide applications and the stage of growth of the plants. The poor results on red root pigweed and lambsquarter was caused by the weeds being beyond the susceptible stage as a result of the reseeding of the birdsfoot trefoil. Red root pigweed and lambsquarter are susceptible only in the two to four leaf stage (Tables 2 and 3).

Weather conditions such as temperature and light affect the toxicity of DNBP salts. Plants grown under low light intensities are injured more than those grown under higher light intensities (66). Plants grown under high temperatures are injured more than those grown under low temperatures (65, 101). Humidity also affects the toxicity of DNBP salts. When the plant is dry, absorption takes place very slowly (58). Variation of these weather conditions can explain in part the differences in results. But the most adequate explanation is the different stage of growth when the herbicide was applied. The application on Valdes experiment (101) was possibly made at a younger stage of growth of red root pigweed than on this experiment, and when it was more susceptible to injury. However, the results of this experiment are in accord with Wojtaszer (108), who studied differences in susceptibility to DNBP between weed species. From all species studied red root pigweed was the most resistant.

The DNBP application gave the same results on birdsfoot trefoil yield as no application of herbicide at all. This is attributed to lack of control of red root pigweed, which was the main weed present in the experiment.

The number of plants of birdsfoot trefoil per foot of row was not affected by DNBP applications as it was with 2,4-DB, but they were weak and possibly they will be affected by the fall and winter weather. Then, the yield of birdsfoot trefoil in the next season will be less than with 2,4-DB applications.

Most weeds present in this experiment were annual and could be controlled by clipping when the legume is grown without companion crop (105).

Two clippings of the plots with no herbicide were made to control weeds; however, 2,4-DB application increased the yield in dry matter of birdsfoot trefoil during the year of establishment by about three times the yield of the treatments with no herbicides and DNBP. Under 2,4-DB treatments, birdsfoot trefoil plants were more vigorous and grew higher than under no herbicide and DNBP. The better establishment should be reflected in more yield of dry matter in the next season of growth, compared with other treatments.

When birdsfoot trefoil is grown with barley companion crop, weeds should be controlled to get good grain production, make harvesting easy, increase crop quality, avoid reinfestation of the land with weed seeds, and get more vigorous plants of the undersown crop. Under the conditions of this experiment, grain production was not increased when weed competition was reduced by 2,4-DB. This was possibly due to the stage of growth of the weeds as was explained before, but the other advantages of the reduction of weed competition, mentioned above, were evident.

The Effects of Nitrogen Placement in the Year of Seeding upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

Under the environmental conditions of this experiment, nitrogen application of 80 pounds per acre increased barley grain production when it was applied broadcast (Table 8), but when it was applied split in 20 pounds per acre in rows at 7 inches and 60 pounds per acre broadcast, no increase in grain barley yield over the no nitrogen treatments was observed.

The source of nitrogen in this experiment was urea. It is known that the rapid hydrolysis of urea is the cause of ammonia injury to seedlings, if large quantities of this material are placed too close to the seed (99). This fact can explain the decrease in yield of barley when fertilizer urea was applied together with seed in the row. Possibly the stand of barley was affected, and then, the yield.

Nitrogen placement did not affect yield of birdsfoot trefoil (Table 13), but did affect the number of plants per foot of row. This was shown by plant counts. No nitrogen application resulted in the highest percentage of birdsfoot trefoil and the lowest percentage of red root pigweed.

These results are similar to those reported by other investigators (10, 41, 67, 103), who found that yields of birdsfoot trefoil (weeds inclusive) were not improved by nitrogen fertilizers during the seedling year.

The decrease of birdsfoot trefoil plants per foot of row did not affect yield of birdsfoot trefoil, because these plants grew and developed more than those with no nitrogen.

Apparently nodulation was not affected by nitrogen treatments. When plants were lifted for stand counts, all plants were classified as effectively nodulated, but number of nodules per plant was not observed. The effectiveness of the nodulation was based on estimation of color. Under field condition, this is difficult and is subject to bias. A laboratory and greenhouse test is advisable to study the effect of nitrogen placement on nodulation.

The Effects of Nitrogen Placement and Herbicide Interaction upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

An interaction between 2,4-DB application and nitrogen placement was found in barley grain production, but not in birdsfoot trefoil establishment (Table 9).

Weeds, as a group, have much the same requirements for growth as crop plants. For every pound of weed growth, the soil produces about one pound less of crops (58). Based on the above consideration we can say that 2,4-DB application influenced the responses of the nitrogen placement treatment, because it decreased weed competition. In birdsfoot trefoil establishment there was not a clear nitrogen response and no nitrogen herbicide interaction.

The Effects of System of Seeding upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

At constant seed rate, an increase in row spacing above 7 inches gave a decrease in yield of barley (Table 10), due possibly to an increase of competition between plants in the row. Rows spaced at 14 inches had twice the seeding rate per row compared with those spaced at 7 inches. No plant counts were made of barley, but either early loss of seedlings in 14-inch rows or intra-specific competition for light is suggested as neither moisture nor nutrients was limiting and inter-specific light competition with birdsfoot trefoil was not apparent (birdsfoot trefoil did not influence barley yield).

The companion crops, because of their greater stature, shade the pasture and reduce its growth (84). To reduce this competition, the space between the rows of the barley companion crop was increased from 7 inches to 14 inches. The increase in the space between the rows of the barley resulted in increase of dry matter yield of birdsfoot trefoil, but it did not affect the number of plants of birdsfoot trefoil per foot of row (Tables 16, 17, 18). Also, birdsfoot trefoil seeded alone gave the highest dry matter yield in the year of establishment, but the number of plants per foot of row was similar to the other treatments. These results are very similar to those obtained in other investigations (7, 21, 29, 38, 48, 55) and indicate a clear problem of competition between barley and birdsfoot trefoil.

In this experiment, the most marked effect of barley upon the micro-environment of birdsfoot trefoil was probably the reduction of light intensity because water and nutrients were under control. Since growth is dependent upon photosynthesis, reduction of light below levels needed for optimum photosynthesis restricts growth.

Under field conditions of differential shading, the number of plants of birdsfoot trefoil was similar. However, the vigor and stage of growth of birdsfoot trefoil plants were higher when seeded alone than when seeded with companion crop. When seeded with companion crop, the highest vigor and growth were obtained with rows of barley spaced at 14 inches.

The Effects of System of Seeding and Nitrogen Placement Interaction upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

No interaction was found in barley grain production and dry matter yield of birdsfoot trefoil. However, the number of plants of birdsfoot trefoil per foot of row presented an interaction effect because nitrogen fertilizer influenced the responses from system of seeding.

Application of nitrogen as urea reduced the number of plants of birdsfoot trefoil in the two systems of placement under the three systems of seeding (Table 19). This could be the result of hydrolysis of urea to ammonia, and the possible injury of seedlings by the ammonia (99). The surviving seedlings could be favored by nitrogen. They grew more than those without nitrogen equalizing the yield of dry matter and for these reasons an interaction was not possible.

The Effects of System of Seeding and Herbicide Interaction upon Barley Grain Production and upon Birdsfoot Trefoil Seedling Establishment

No interaction of system of seeding and herbicides was found in barley grain production due mainly to the apparent lack of weed competition on barley grain production.

The herbicides 2,4-DB and DNBP influenced the responses from system of seeding. 2,4-DB increased the yield of dry matter of birdsfoot trefoil in the three systems of seeding, because it reduced weed competition. Birdsfoot trefoil plants had more light for photosynthesis than under the no herbicide treatments or under DNBP. As was explained before, DNBP did not control red root pigweed, the main weed in this experiment.

SUMMARY AND CONCLUSIONS

A field trial was conducted at the Hyslop Agronomy Farm, near Corvallis, Oregon, during the 1967 growing season. The purpose of this investigation was to study under irrigated conditions the effect of barley row spacing, nitrogen rate and placement, and weed competition in the year of seeding upon birdsfoot trefoil seedling establishment under barley, and the effect of birdsfoot trefoil in barley grain production.

The experimental design was a split-split plot with three replications. Main plots were application of herbicides, secondary plots placement of nitrogen, and small plots system of seeding.

The herbicides used were Avadex BW 1.25 lb. ai. per acre, 2,4-DB amine 1.50 lb. ai. per acre and DNBP amine 1.50 lb. ai. per acre.

Nitrogen as urea was applied broadcast at rate of 80 lb. per acre, and applied 20 lb. per acre in rows spaced at 7 inches and 60 lb. per acre broadcast.

Barley variety Hannchen was seeded at the rate of 90 lb. per acre in rows spaced at 7 inches and 14 inches, together with birdsfoot trefoil, and alone.

Birdsfoot trefoil variety Granger was seeded at the rate of 6 lb. per acre in rows spaced at 7 inches, together with barley, and alone.

On the basis of data from one growing season, the following conclusions are made:

1. At constant seed rate of barley companion crop, an increase in row spacing above 7 inches gave a decrease of grain yield.

2. Birdsfoot trefoil did not affect the yield of barley.

3. The increase in the space between rows of barley resulted in increase of dry matter yield of birdsfoot trefoil in the year of seeding, but it did not affect the number of plants of the legume per foot of row.

4. Birdsfoot trefoil seeded alone gave the highest dry matter yield in the year of establishment, but the number of plants per foot of row was similar to the other treatments.

5. Applications of nitrogen as urea reduced the number of plants of birdsfoot trefoil, when this species was seeded alone or together with barley.

6. Nitrogen at 80 pounds per acre increased barley grain yield when applied broadcast, but not when applied 20 pounds nitrogen per acre in rows at 7 inches and 60 pounds nitrogen per acre broadcast.

7. Nitrogen placement did not affect yield of birdsfoot trefoil, but nitrogen drilled with seed reduced the number of plants per foot of row.

8. An interaction between 2,4-DB application and nitrogen placement was found in barley grain production, but not in birdsfoot trefoil establishment.

9. 2,4-DB gave good control of red root pigweed, common lambsquarter, common groundsel, and shepherdspurse, but it did not influence barley grain yield, probably due to the inadequate date of application of the herbicide.

10. 2,4-DB reduced weed competition and increased birdsfoot trefoil yield, but it did not affect the number of plants of birdsfoot trefoil per foot of row.

11. DNBP had a detrimental effect on barley yield and was similar to no herbicide on birdsfoot trefoil dry matter yield.

12. The DNBP applications did not injure birdsfoot trefoil and provided good control of common groundsel and shepherdspurse, and gave a poor control of red root pigweed and common lambs-quarter.

13. An interaction between 2,4-DB application and system of seeding was found to affect yield of dry matter of birdsfoot trefoil.

In general it can be concluded that the use of a barley companion crop to establish birdsfoot trefoil decreased the vigor of this species, and then the possibility of survival during winter. When birdsfoot trefoil is seeded with barley, the latter should be seeded in rows spaced at 14 inches. If weeds are present, an adequate herbicide should be used to avoid mainly light competition. Under the conditions of this experiment, 2,4-DB was the best. If nitrogen is deficient in the soil, it should be applied broadcast to increase yield of barley.

BIBLIOGRAPHY

1. Ahlgren, G. H. Forage crops. 2d ed. New York, McGraw-Hill, 1956. 536 p.

2. Ahlgren, G. H. et al. Birdsfoot trefoil. New Brunswick, 1955. 15 p. (New Jersey. Agricultural Experiment Station. Bulletin 779)

3. Allen, O. N. and I. L. Baldwin. Rhizobia-legume relationships. Soil Science 78:415-427. 1954.

4. Anttinen, O. Nitrogen fertilization trials on spring cereals and clover leys. Maatalous ya Koetoiminta 18:88-96. 1964. (Abstracted in Herbage Abstracts 35:565. 1965)

5. Appleby, A. P. The influence of soil temperature and soil placement on the phytotoxic properties of EPTC and other carbamate herbicides. Ph.D. thesis. Corvallis, Oregon State University, 1962. 66 numb. leaves.

6. Appleby, A. P., W. R. Furtick and S. C. Fang. Soil placement studies with EPTC and other carbamate herbicides on Avena sativa. Weed Research 5:115-122. 1965.

7. Azocar, P. Establecimiento de praderas con cereales. Santiago, 1966. 138 p. (Chile. Instituto de Investigaciones Agropecuarias. Segunda Memoria Anual)

8. Bandyopadhyay, M. N. Studies on the influence of companion crops on the establishment of alfalfa and birdsfoot trefoil. (Abstracted in Dissertation Abstracts 26:2957-2958. 1965)

9. Baylor, J. E. Establishment and early plant development of birdsfoot trefoil (Lotus corniculatus L.) as affected by several factors of competition. (Abstracted in Dissertation Abstracts 19:10-11. 1958)

10. Blaser, R. E., W. H. Skrdla and T. H. Taylor. Ecological and physiological factors in compounding forage seed mixtures. Advances in Agronomy 4:179-219. 1952.

11. Boxworth Experimental Husbandry Farm, Great Britain. Report of the Boxworth Experimental Husbandry Farm, 1965-

1966. p. 9-12. (Abstracted in Weed Abstracts 16:19. 1967)

12. Bula, R. J., D. Smith and E. E. Miller. Measurements of light beneath a small-grain companion crop as related to legume establishment. Botanical Gazette 115:271-278. 1954.

13. Calhoun, Wheeler. A summary of climate and weather for Corvallis, Oregon, 1889 through 1960. Corvallis, 1961. 12 p. (Oregon. Agricultural Experiment Station. Miscellaneous Paper 105)

14. Cartwright, P. M. The effect of combined nitrogen on the growth and nodulation of excised roots of Phaseolus vulgaris L. Annals of Botany, new ser., 31:309-321. 1967.

15. ________________ The growth and nodulation pattern of leguminous plants as influenced by combined-nitrogen supply, light intensity and day length. In: (Abstract) Proceedings of the Ninth International Botanical Congress, Montreal, Aug., 1959. Vol. 2. Toronto, University of Toronto, 1959. p. 61.

16. Cartwright, P. M. and D. Snow. The influence of foliar application of urea on the nodulation pattern of certain leguminous species. Annals of Botany, new ser., 26:251-259. 1962.

17. Churchill, B. R. Annual weed control in new seedings of birdsfoot trefoil and alfalfa-red clover mixture. Research Report on the Northcentral Weed Control Conference 14:100. 1957.

18. Clements, F. E., J. E. Weaver and H. Hanson. Plant competition; an analysis of community functions. Washington, D. C., Carnegie Institution of Washington, 1929. 340 p.

19. Collister, Earl H. and Herbert Kramer. The effect of oat variety on the stands and development of red clover. Agronomy Journal 44:385. 1952.

20. Cooper, C. S. A comparison of birdsfoot trefoil and ladino clover under varying irrigation and fertility levels. Agronomy Journal 53:180-183. 1961.

21. ________________ The establishment and production of birdsfoot trefoil-grass compared to alfalfa-grass mixtures under several cultural practices. Bozeman, 1966. 22 p. (Montana.

Agricultural Experiment Station. Bulletin 603)

22. Cooper, C. S. Factors affecting establishment, survival, and production of birdsfoot trefoil (Lotus corniculatus L.) and alfalfa (Medicago sativa L.). Ph.D. thesis. Corvallis, Oregon State University, 1964. 101 numb. leaves.

23. __________ Relative growth of alfalfa and birdsfoot trefoil seedlings under low light intensity. Crop Science 7:176-178. 1967.

24. __________ Response of birdsfoot trefoil and alfalfa to various levels of shade. Crop Science 6:63-66. 1966.

25. Cooper, C. S. and H. Ferguson. Influence of a barley companion crop upon root distribution of alfalfa, birdsfoot trefoil and orchardgrass. Agronomy Journal 56:63-66. 1964.

26. Crafts, A. S. and W. W. Robbins. Weed control. 3d ed. New York, McGraw-Hill, 1962. 660 p.

27. Daubenmire, R. F. Plants and environment. A textbook of autoecology. 2d ed. New York, Wiley, 1965. 422 p.

28. Dodel, J. B. and J. Deloraine. The action of diallate and triallate on forage legumes. Paper read at COLUMA/ITCF. Journée d'Études sur l'Utilisation des Herbicides dans les Prairies et Cultures Fourragères, Paris, 1964. p. 13. (Abstracted in Weed Abstracts 13:366. 1964)

29. Donald, C. M. Competition among crop and pasture plants. Advances in Agronomy 15:1-118. 1963.

30. Dowler, C. and C. J. Willard. Herbicides on seedling alfalfa, birdsfoot trefoil and red clover. Research report of the Northcentral Weed Control Conference 14:100-101. 1957.

31. __________ Phenoxybutyric acid compounds on birdsfoot trefoil. Research report of the Northcentral Weed Control Conference 13:110. 1956.

32. __________ Using herbicides on alfalfa and birdsfoot trefoil. Wooster, 1960. 19 p. (Ohio. Agricultural Experiment Station. Research Bulletin 859)

33. Duell, R. W. Fertilizer-seed placement with birdsfoot trefoil and alfalfa. Agronomy Journal 56: 503-505. 1964.

34. ________________ Some factors affecting the establishment of birdsfoot trefoil (Lotus corniculatus L.). (Abstracted in Dissertation Abstracts 17:2753. 1957)

35. Evans, S. A. Wild oats. A problem for cereal growers. Agriculture (London) 73:206-209. 1966.

36. Flanagan, T. R. and J. B. Washko. Spring grain characteristics which influence their value as companion crops. Agronomy Journal 42: 460. 1950.

37. Foote, W. H. and F. C. Batchelder. Effect of different rates and times of application of nitrogen fertilizers on the yield of Hannchen barley. Agronomy Journal 45: 532-535. 1953.

38. Fulkerson, R. S. Effect of a companion crop on seedling establishment in forage crops. In: (Abstract) Proceedings of the Second Meeting of the Canadian Society of Agronomy, Toronto, June, 1956. Toronto, 1956. p. A-3. (Abstracted in Herbage Abstracts 27: 431. 1957)

39. Furtick, W. R. Selective control of weeds in field crops. In: Oregon weed control handbook, by Rex Warren. Corvallis, Oregon State University, 1967. p. 59-60.

40. Gibson, A. H. and P. S. Nutman. Studies on the physiology of nodule formation. 7. A reappraisal of the effect of preplanting. Annals of Botany 24: 420-433. 1960.

41. Giddens, Joel. Nitrogen applications to new and established stands of alfalfa. Agronomy Journal 5: 574. 1959.

42. Gilbert, D. E. The effect of light, moisture and interspecies competition upon the establishment of alfalfa, ladino clover and birdsfoot trefoil. (Abstracted in Dissertation Abstracts 20:2471. 1960)

43. Gist, C. R. and G. O. Mott. Growth of alfalfa, red clover, and birdsfoot trefoil seedlings under various quantities of light. Agronomy Journal 50: 583-585. 1958.

44. Gist, C. R. and G. O. Mott. Some effects of light intensity, temperature, and soil moisture on the growth of alfalfa, red clover, and birdsfoot trefoil seedlings. Agronomy Journal 49:33-36. 1957.

45. Göpp, K., H. Beinhauer and S. Zaake. Three years' trials on the control of wild oats in malting barley, 1962-1964. Monatsschrift für Brauerei 19:225-227. 1966. (Abstracted in Weed Abstracts 16:21. 1967)

46. Gosset, B. J. Forage yields of alfalfa and birdsfoot trefoil following establishment with weed control by herbicides and moving. (Abstracted in Dissertation Abstracts 23:2651. 1963)

47. Hannah, L. H., P. C. Hamm and G. W. Selleck. The performance of 2,3-dichloroallyldiisopropylthiolcarbamate in the wild oat areas of North America. In: Proceedings of the Fifth British Weed Control Conference, Brighton, 1960. Vol. 2. Brighton, 1960. p. 481-485.

48. Harper, H. J. Effect of row spacing on the yield of small grain nurse crops. Journal of the American Society of Agronomy 38:785-794. 1946.

49. Henson, P. R. and H. A. Schoth. The trefoils--adaptation and culture. Washington, D. C., 1962. 16 p. (U.S. Agricultural Research Service. Agriculture Handbook 223)

50. Hughes, H. D., M. E. Heath and D. S. Metcalfe. Forages. 2d ed., rev. Iowa, Iowa State University, 1966. 707 p.

51. Jackson, T. L., W. H. Foote and E. A. Dickason. Effect of fertilizer treatments and planting dates on yield and quality of barley. Corvallis, 1962. 20 p. (Oregon. Agricultural Experiment Station. Technical Bulletin 65)

52. Jones, D. G. and W. E. Davies. The improvement of symbiotic effectiveness in white clover (Trifolium repens L.). In: Proceedings of the Tenth International Grassland Congress, Helsinki, July, 1966. Helsinki, 1966. p. 648-652.

53. Kerking, A. J. and R. A. Peters. Herbicidal effectiveness of 2,4-DB, MCPB, neburo, and other materials as measured by weed control and yields of seedling alfalfa and birdsfoot

trefoil. Proceedings of the Northeastern Weed Control Conference 11:128-138. 1957.

54. Kilcher, M. R. and D. H. Heinrichs. The use of cereal grains as companion crops in dry land forage crop establishment. Canadian Journal of Plant Science 40:81-93. 1960.

55. Kirby, E. J. M. The effect of plant density upon the growth and yield of barley. Journal of Agricultural Science 68:317-324. 1967.

56. Klebesadel, L. J. and Dale Smith. Effects of harvesting an oat companion crop at four stages of maturity on the yield of oats, on light near the soil surface, on soil moisture, and on the establishment of alfalfa. Agronomy Journal 52:627-630. 1960.

57. ________________ Light and soil moisture beneath several companion crops as related to the establishment of alfalfa and red clover. Botanical Gazette 121:39-46. 1959.

58. Klingman, G. C. Weed control: as a science. New York, Wiley, 1966. 421 p.

59. Koter, Z. Nitrogen nutrition of leguminous plants. 1. The effect of different forms of nitrogen on the growth and symbiotic N_2 fixation by red clover and sainfoin plants. 2. The effect of increasing amounts of nitrogen on the yield and N_2 fixation by sainfoin (Onobrychis viciaefolia var. persica). Pamietnik Pulawski 20:3-52. 1965. (Abstracted in Herbage Abstracts 37:404. 1967)

60. Krenzin, R. E. Effects of competition from companion crop and from inter-species associations on forage stand establishment and yield. (Abstracted in Dissertation Abstracts 19:13. 1958)

61. Lyons, J. C. and E. B. Earley. The effect of ammonium nitrate applications to field soils on nodulation, seed, yield, and nitrogen and oil content of soybeans. Proceedings of the Soil Science Society of America 16:259-263. 1952.

62. Mann, H. H. and T. W. Barnes. The competition between barley and certain weeds under controlled conditions. 5. Competition with clover considered as a weed. Annals of Applied Biology 39:111-119. 1952.

63. McKee, G. W. Effects of shading and plant competition on seeding growth and nodulation of birdsfoot trefoil. University Park, 1962. 35 p. (Pennsylvania. Agricultural Experiment Station. Bulletin 689)

64. ________________ Some effects of liming, fertilization, and soil moisture on the seedling growth and nodulation in birdsfoot trefoil. Agronomy Journal 53:237-240. 1961.

65. McKee, Roland and H. A. Schoth. Birdsfoot trefoil and big trefoil. Washington, D. C., 1941. 14 p. (U. S. Department of Agriculture. Circular 625)

66. Meggitt, W. F., R. J. Aldrich and W. C. Shaw. Factors affecting the herbicidal action of aqueous sprays of salts of 4,6-dinitro-ortho-secondary butyl phenol. Weeds 4:131-138. 1956.

67. Midgley, A. R. Birdsfoot trefoil--a promising forage plant. Better Crops with Plant Food 34(4):6-11. 1951.

68. Montgomery, M. L., V. H. Freed and J. M. Witt. Chemicals and properties. In: Oregon weed control handbook, ed. by Rex Warren. Corvallis, Oregon State University, 1967. p. 26-50.

69. Mott, G. O. et al. Grazing trials with beef cattle at Miller Purdue Memorial Farm. Purdue, 1953. 16 p. (Indiana. Agricultural Experiment Station. Bulletin 581)

70. Nowotny-Mieczyńska, A. and M. Ruszkowska. The influence of mineral nitrogen on the growth of inoculated leguminous plants. Acta Microbiologica Polonica 1:205-222. 1952.

71. Parker, C. Factors affecting the selectivity of 2,3-dichloroallyldi-isopropylthiolcarbamate (di-allate) against Avena spp. in wheat and barley. Weed Research 3:259-276. 1963.

72. Parsons, J. L. and R. R. Davis. Establishment and management of birdsfoot trefoil in Ohio. Wooster, 1964. 19 p. (Ohio. Agricultural Experiment Station. Research Bulletin 967)

73. Pearson, J. O. and R. C. Wakefield. Effects of herbicides and soil nitrogen levels on spring seedings of alfalfa.

Proceedings of the Northeastern Weed Control Conference 19: 180-184. 1965.

74. Pendleton, J. W. Fall seed alfalfa with winter wheat. Agronomy Journal 49:567-568. 1957.

75. Pendleton, J. W. and G. H. Dungan. Effect of different oat spacing on growth and yield of oats and red clover. Agronomy Journal 45:442-444. 1953.

76. ________________ Effect of row direction on spring oat yields. Agronomy Journal 50:341-343. 1958.

77. Peters, E. J. Pre-emergence, preplanting and post-emergence herbicides for alfalfa and birdsfoot trefoil. Agronomy Journal 56:415-419. 1964.

78. Peters, E. J. and F. S. Davis. Control of weeds in legume seedings with 4-(2,4-DB), dalapon and TCA. Weeds 8:349-367. 1960.

79. Peters, R. A. Legume establishment as related to the presence or absence of an oat companion crop. Agronomy Journal 53:195-198. 1961.

80. Pritchett, W. L. and L. B. Nelson. The effect of light intensity on the growth characteristics of alfalfa and bromegrass. Agronomy Journal 43:173-177. 1951.

81. Raggio, M. and J. G. Torrey. The interaction of nitrate and carbohydrates in rhizobial root nodule formation. Plant Physiology 40:601-606. 1965.

82. Rhykerd, C. L., R. Langston and G. O. Mott. Influence of light on the foliar growth of alfalfa, red clover, and birdsfoot trefoil. Agronomy Journal 51:199-201. 1959.

83. Rhykerd, C. L., R. Langston and J. B. Peterson. Effect of light treatment on the relative uptake of labeled carbon dioxide by legume seedlings. Agronomy Journal 51:7-9. 1959.

84. Santhirasegaram, K. and J. N. Black. Agronomic practices aimed at reducing competition between cover crops and undersown pasture. Herbage Abstracts 35:221-225. 1965.

85. Scholl, J. M. and R. E. Brunck. Birdsfoot trefoil stand establishment as influenced by control of vegetative competition. Agronomy Journal 54: 142-144. 1962.

86. Scholl, J. M. and D. W. Staniforth. Establishment of birdsfoot trefoil as influenced by competition from weeds and companion crops. Agronomy Journal 49: 432-435. 1957.

87. Schreiber, M. M. Pre-emergence herbicides on alfalfa and birdsfoot trefoil. Weeds 8: 291-299. 1960.

88. Schreven, D. A. van. Effects of added sugar and nitrogen on nodulation of legumes. Plant and Soil 11: 93-112. 1959.

89. Selleck, G. W. and L. H. Hannah. A review of 1962 field results with di-allate and tri-allate in the United States and Canada. In: Proceedings of the Sixth British Weed Control Conference, Brighton, 1962. Vol. 1. Brighton, 1962. p. 361-365.

90. Smith, Dale. Forage management in the north. Dubuque, Iowa, W. M. C. Brown, 1962. 219 p.

91. Smith, Dale et al. Establishment of legumes as influenced by the rate of sowing the oat companion crop. Agronomy Journal 46: 449-451. 1954.

92. Smith, J. H. The influence of environmental factors on the nodulation and yield of birdsfoot trefoil. (Abstracted in Dissertation Abstracts 15: 933-934. 1955)

93. Stanberry, C. O. and M. Lowrey. Barley production under various nitrogen and moisture levels. Agronomy Journal 57: 31-34. 1965.

94. Stickler, F. C. and C. E. Wassom. Emergence and seedling vigor of birdsfoot trefoil as affected by planting depth, seed size, and variety. Agronomy Journal 55: 78. 1963.

95. Tanner, J. W. An external effect of inorganic nitrogen on nodulation. (Abstracted in Dissertation Abstracts 23: 3612. 1963)

96. Tanner, J. W and I. C. Anderson. An external effect of inorganic nitrogen in root nodulation. Nature 198: 303-304. 1963.

97. Thornton, H. G. The action of sodium nitrate upon the infection of lucerne root hairs by nodule bacteria. Proceedings of the Royal Society of London, ser. B, 119:474-492. 1936.

98. Thornton, H. G. and J. Rudorf. The abnormal structure induced in nodules on lucerne (Medicago sativa L.) by the supply of sodium nitrate to the host plant. Proceedings of the Royal Society of London, ser. B, 120:240-252. 1936.

99. Tisdale, S. L. and W. L. Nelson. Soil fertility and fertilizers. 2d ed. New York, McMillan, 1966. 694 p.

100. University of California. Agricultural Experiment Station. Weed control recommendations. Davis, 1966. 41 p.

101. Valdes, L. R. The influence of herbicides, phosphorus fertilization, and mechanical and chemical seedbed preparation on the establishment of alfalfa (Medicago sativa L.) and birdsfoot trefoil (Lotus corniculatus L.). Master's thesis. Corvallis, Oregon State University, 1967. 69 numb. leaves.

102. Wakefield, R. C. and N. Skaland. Effect of seeding rate and chemical weed contrl on establishment and subsequent growth of alfalfa and birdsfoot trefoil. Agronomy Journal 57:547-550. 1965.

103. Ward, C. Y. and R. E. Blaser. Effect of nitrogen fertilizer on emergence and seedling growth of forage plants and subsequent production. Agronomy Journal 53:115-120. 1961.

104. Weber, C. R. Nodulating and non-nodulating soybean isolines. 2. Response to applied nitrogen and modified soil conditions. Agronomy Journal 58:46-49. 1966.

105. Wheeler, W. A. Forage and pasture crops. New York, D. Van Nostrand, 1950. 752 p.

106. Wilson, P. W. The biochemistry of symbiotic nitrogen fixation. Madison, University of Wisconsin, 1940. 302 p.

107. ________________ The carbohydrate-nitrogen relation in symbiotic nitrogen fixation. Madison, 1935. 40 p. (Wisconsin. Agricultural Experiment Station. Research Bulletin 129)

108. Wojtaszer, T. Relationship between susceptibility of plants to DNBP and their capacity for ATP generation. Weeds 14: 125-129. 1966.

109. Young, R. A. *et al*. Yield response of spring wheat and barley to nitrogen fertilizer in relation to soil and climatic factors. Proceedings of the Soil Science Society of America 31:407-410. 1967.

110. Zemanek, J., J. Zvara and A. Suchaneck. The results of field tests with chemical weed killer in forage legumes. [Sbornik Československé Academie Zemědělské] 35:221-240. 1962. (Abstracted in Weed Abstracts 12:947. 1963)

APPENDICES

Appendix Table 1. Daily air temperature from May 1, 1967, to September 30, 1967. Degrees Fahrenheit. Corvallis State College, Oregon.

Date	May		June		July		August		September	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	57	33	64	41	81	51	80	54	90	45
2	62	36	79	43	99	56	86	49	80	52
3	59	35	74	43	96	56	91	49	80	52
4	59	35	77	45	95	51	90	45	86	48
5	61	41	82	52	93	50	87	46	84	47
6	70	44	82	51	83	46	78	52	83	52
7	72	41	69	52	79	48	75	50	80	53
8	76	40	65	53	81	48	78	52	85	45
9	73	43	66	50	75	45	88	55	78	43
10	53	35	65	43	80	50	99	59	81	50
11	56	39	64	45	86	49	85	51	70	55
12	58	41	67	52	90	52	90	57	71	43
13	60	39	74	45	84	48	94	55	75	47
14	65	39	76	46	81	50	96	59	87	57
15	72	48	84	50	83	49	95	54	94	51
16	78	50	87	51	85	47	96	55	98	44
17	85	44	88	51	87	46	96	53	83	47
18	75	51	88	52	79	55	95	52	72	54
19	78	41	91	53	76	48	95	57	74	49
20	80	45	89	55	79	52	97	54	83	49
21	85	42	65	52	81	58	89	51	81	52
22	80	49	69	53	82	52	85	57	84	53
23	74	40	63	43	87	49	91	54	75	51
24	66	44	78	53	85	50	81	49	87	44
25	64	41	85	52	82	52	81	51	89	47
26	73	41	86	50	75	46	95	55	79	47
27	70	39	79	59	77	53	81	59	94	47
28	67	51	80	51	83	50	93	53	92	44
29	64	42	87	59	84	48	98	54	86	45
30	62	44	85	51	87	50	83	49	65	51
31	59	44	--	--	86	56	88	50	--	--
Avg.	68.2	41.8	76.9	49.9	83.9	50.4	88.9	52.9	82.1	48.8

Appendix Table 2. Daily soil temperature taken at 2-in. deep from May 1, 1967, to September 30, 1967. Degrees Fahrenheit. Corvallis State College, Oregon.

Date	May		June		July		August		September	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	62	44	72	53	91	65	92	68	90	65
2	68	44	82	55	97	69	95	67	86	64
3	62	46	82	56	99	72	97	68	86	66
4	61	48	86	55	103	72	98	67	91	65
5	61	47	88	58	102	70	96	66	90	64
6	69	52	88	62	98	68	89	66	88	64
7	72	52	77	63	93	66	83	68	85	65
8	77	53	73	62	93	66	85	67	89	63
9	75	53	73	66	86	64	88	65	87	61
10	58	50	75	59	93	66	97	68	85	60
11	62	55	70	58	96	66	93	69	70	63
12	60	49	78	59	98	67	95	67	75	56
13	65	50	83	60	93	68	96	70	79	55
14	71	50	87	60	95	67	97	72	84	60
15	69	51	92	62	90	61	95	71	88	63
16	76	55	95	65	90	65	100	71	91	62
17	85	56	95	67	96	65	98	71	84	62
18	81	57	96	68	93	65	96	71	74	63
19	85	56	100	68	87	67	95	70	78	58
20	87	56	98	69	89	66	97	71	86	57
21	91	60	74	70	91	68	90	68	83	63
22	89	62	75	61	93	68	94	67	86	62
23	91	57	66	57	95	67	95	69	79	60
24	80	55	82	59	96	68	90	65	82	59
25	78	53	91	63	95	68	87	64	85	58
26	77	53	96	64	83	66	90	65	83	58
27	82	55	92	67	87	65	78	74	85	62
28	76	57	94	67	94	66	94	69	84	60
29	68	55	96	67	93	67	92	68	83	59
30	67	54	92	66	98	67	89	66	65	59
31	67	53	--	--	95	68	93	66	--	--
Avg.	73.3	52.8	84.9	62.2	93.6	66.9	92.7	68.2	83.4	61.2

Appendix Table 3. Daily precipitation in inches from May 1, 1967, to September 30, 1967. Corvallis State College, Oregon.

Day	May	June	July	August	September
1	0.01	-	-	-	-
2	-	0.27	-	-	-
3	-	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	0.37	-	-	-	-
10	0.06	-	-	-	0.03
11	0.05	-	-	-	0.02
12	0.05	-	-	-	0.01
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	0.35
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	0.22	-	-	-
23	-	0.28	-	-	-
24	-	-	-	-	-
25	-	-	-	-	-
26	-	-	-	-	-
27	-	-	-	T*	-
28	0.05	-	-	-	-
29	0.08	-	-	-	-
30	0.07	-	-	-	-
31	0.12	-	-	-	0.43
Total	0.85	0.77	0.0	T*	0.84

* T = Traces

Appendix Table 4. Effects of systems of placement of nitrogen on weed presence. Estimated stands of weeds June 15 and July 24, 1967. Average of three replications, three herbicides and five systems of seeding. [1/]

Weeds	Check		20 lb N/A in rows at 7-inch + 60 lb N/A broadcast		80 lb N/A broadcast	
	June 15	July 24	June 15	July 24	June 15	July 24
Annual bluegrass	3.0	D [2/]	3.2	D [2/]	3.2	D [2/]
Annual ryegrass	1.3	D [2/]	1.3	D [2/]	1.1	D [2/]
Red root pigweed	3.8	2.7	4.1	3.5	3.8	3.2
Common lambsquarter	1.4	1.3	1.7	1.5	1.6	1.4
Common groundsel	3.4	2.3	3.2	2.0	3.2	1.9
Shepherdspurse	2.2	1.5	2.3	1.5	2.3	1.4

[1/] 1 = 0 - 10 % weeds per plot.
10 = 91 - 100 % weeds per plot.

[2/] D = all plants dry.

Appendix Table 5. Effect of system of seeding on weed presence. Estimated stand of weeds June 15 and July 24, 1967. Average of three replications, three herbicides and three systems of placement of nitrogen.[1/]

Weeds	Barley in 14-in. rows + birdsfoot trefoil		Barley 14-inch rows		Barley 7-in. rows + birdsfoot trefoil		Barley 7-inch rows		Birdsfoot trefoil	
	June 15	July 24	June 15	July 24	June 15	July 24	June 15	July 24	June 15	July 24
Annual bluegrass	3.1	D [2/]	3.1	D [2/]	2.7	D [2/]	2.8	D [2/]	3.1	D [2/]
Annual ryegrass	1.2	D [2/]	1.3	D [2/]	1.2	D [2/]	1.2	D [2/]	1.3	D [2/]
Red root pigweed	4.2	3.5	4.0	3.2	3.1	2.4	3.0	2.2	5.2	4.3
Common lambsquarters	1.5	1.4	1.5	1.4	1.4	1.3	1.3	1.3	2.0	1.6
Common groundsel	3.3	2.2	3.6	2.1	2.9	1.9	2.3	1.6	4.0	2.4
Shepherdspurse	2.2	1.4	2.3	1.5	1.8	1.3	2.0	1.2	3.0	1.7

[1/] 1 = 0 - 10 % weed species per plot.
10 = 91 - 100 % weed species per plot.

[2/] D = all plants dry.

Appendix Table 6. Estimated birdsfoot trefoil stand per plot. 1/ Average of three replications. Herbicides x nitrogen x system of seeding. July 6, 1967.

HN / S 2/	H_1			H_2			H_3			Total S
	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	
S_1	6.0	3.7	4.0	6.0	4.3	4.3	5.3	3.7	3.0	4.5
S_3	4.0	1.7	2.3	3.3	1.7	2.0	3.3	2.0	2.0	2.5
S_5	6.0	4.3	5.7	7.7	6.0	6.3	5.7	4.7	4.3	5.6
Total N	5.3	3.2	4.0	5.7	4.0	4.2	4.8	3.4	3.1	4.2
Total H		4.2			4.6			3.8		4.2

1/ 1 = 0 - 10 % plants per plot of birdsfoot trefoil.
10 = 91 - 100 % plants per plot of birdsfoot trefoil.

2/ See experimental procedure.

Appendix Table 7. Yield of barley. Bushel per acre.

S[1] \ HN		H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
S_1	R_1[2]	27.9	23.8	43.4	24.3	35.2	43.8	27.7	27.1	26.9
	R_2	28.4	18.8	29.5	29.4	21.1	44.7	21.9	25.9	18.1
	R_3	34.8	34.1	44.9	26.2	42.8	44.8	32.3	31.2	33.1
S_2	R_1	23.4	23.0	43.1	19.0	38.6	37.5	31.2	15.5	24.9
	R_2	29.7	26.4	20.4	22.1	36.9	36.0	15.1	22.7	18.8
	R_3	37.5	17.9	37.7	22.5	37.4	38.7	28.9	22.0	39.6
S_3	R_1	41.8	42.0	55.3	36.9	47.6	46.5	36.7	39.0	40.7
	R_2	38.2	38.8	43.5	33.2	43.1	47.8	21.7	41.8	42.2
	R_3	56.4	42.7	57.6	45.2	48.7	73.3	50.6	37.7	47.0
S_4	R_1	41.8	31.9	45.7	24.0	54.5	50.6	28.5	43.7	16.5
	R_2	35.2	36.2	37.7	33.0	49.7	46.3	28.9	42.0	35.4
	R_3	46.7	53.0	56.8	49.7	62.2	58.3	30.0	40.1	46.3

[1] See experimental procedure.

[2] Replications.

Appendix Table 8. Birdsfoot trefoil dry weight. Kilograms per acre. Average of two subsamples.

$S^{1/}$ \ HN		H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
S_1	R_1 [2/]	239.58	152.46	304.92	294.03	272.25	283.14	500.94	108.90	65.34
	R_2	261.36	65.34	250.47	283.14	65.34	337.59	381.15	163.35	76.23
	R_3	196.02	16.34	65.34	163.35	588.06	446.49	54.45	21.78	43.56
S_3	R_1	315.81	21.78	206.91	119.79	108.90	76.23	294.03	76.23	32.67
	R_2	239.58	32.67	54.45	196.02	21.78	130.68	141.57	43.56	65.34
	R_3	217.80	6.53	32.67	98.01	201.47	32.67	43.56	16.34	43.56
S_5	R_1	163.35	54.45	337.59	827.64	1,056.33	1,339.47	457.38	163.35	43.56
	R_2	381.15	119.79	141.57	882.09	402.93	1,263.24	370.26	163.35	23.96
	R_3	337.59	65.34	130.68	1,099.89	1,426.59	1,404.81	54.45	108.90	392.04

[1/] See experimental procedure.

[2/] Replications.

Appendix Table 9. Number of birdsfoot trefoil plants per foot of row spacing at 7 inches. Average of four subsamples.

S[1] \ HN		H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
S_1	R_1[2]	21.25	7.75	7.75	18.25	13.00	15.50	20.25	7.75	6.50
	R_2	18.75	10.50	11.75	7.25	1.75	7.75	14.75	9.25	8.00
	R_3	18.00	6.50	12.50	8.50	10.50	10.25	10.75	13.50	9.00
S_3	R_1	22.00	2.25	13.25	11.50	9.50	13.75	32.25	6.50	10.50
	R_2	14.00	5.00	8.75	17.00	3.25	13.75	14.75	10.25	4.00
	R_3	23.75	1.75	13.75	12.75	10.00	6.00	19.25	6.25	7.75
S_5	R_1	13.25	4.75	17.00	20.25	7.75	11.00	14.50	5.25	11.50
	R_2	18.75	9.75	14.00	11.50	5.75	10.25	14.00	9.50	12.50
	R_3	24.50	15.00	17.25	14.75	9.50	7.75	6.00	13.50	9.50

[1] See experimental procedure

[2] Replications.

Appendix Table 10. Percentage of birdsfoot trefoil. Average of two subsamples.

S [1]	HN	H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
	R_1 [2]	31.43	18.18	30.77	56.25	34.72	33.77	48.94	8.62	5.66
S_1	R_2	35.29	6.38	26.74	42.28	6.45	33.51	46.67	21.13	6.42
	R_3	26.47	1.49	7.89	30.61	53.46	45.56	10.00	3.22	8.51
	R_1	45.67	4.00	25.00	33.85	14.70	11.86	34.18	10.45	3.53
S_3	R_2	28.57	4.54	9.43	31.03	6.25	24.00	20.00	4.60	8.45
	R_3	21.79	0.77	4.17	17.31	33.09	6.99	11.76	2.75	6.90
	R_1	22.06	3.65	38.75	95.00	85.84	91.79	58.33	14.85	3.31
S_5	R_2	38.89	9.65	9.42	91.01	44.58	92.65	29.82	12.29	1.49
	R_3	31.31	6.98	12.12	82.11	92.25	94.85	6.06	22.22	32.43

1/ See experimental procedure.

2/ Replications.

Appendix Table 11. Percentage of red root pigweed. Average of two subsamples.

$S^{1/}$	HN	H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
	R_1 [2/]	24.28	32.47	8.79	2.08	6.94	2.60	7.45	54.31	53.77
S_1	R_2	10.29	32.98	51.16	7.32	66.67	1.62	9.33	47.89	81.65
	R_3	14.71	52.74	32.89	2.04	0.99	1.11	34.00	77.42	25.53
	R_1	2.36	20.00	3.95	1.54	13.23	1.69	7.59	31.34	51.76
S_3	R_2	6.49	15.15	35.85	6.90	3.12	4.00	15.38	34.48	36.62
	R_3	1.96	76.33	44.44	1.92	0.72	2.10	2.94	25.69	41.38
	R_1	60.29	89.78	33.75	2.50	3.54	0.75	34.72	78.22	95.04
S_5	R_2	52.22	79.82	83.33	6.74	50.60	0.16	68.42	75.41	98.37
	R_3	50.51	77.91	75.76	1.63	1.41	0.73	88.48	66.67	57.66

[1/] See experimental procedure.

[2/] Replications.

Appendix Table 12. Percentage of straw plus weeds. Average of two subsamples.

S [1] \ HN		H_1			H_2			H_3		
		N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
S_1	R_1 [2]	44.29	49.35	60.44	41.67	58.34	63.63	43.61	37.07	40.57
	R_2	54.42	60.64	22.10	50.40	26.88	64.87	44.00	30.98	11.93
	R_3	58.82	45.77	59.22	67.35	45.55	53.33	56.00	19.36	65.96
S_3	R_1	51.97	76.00	71.05	64.61	72.07	86.45	58.23	58.21	44.71
	R_2	64.94	80.31	54.72	62.07	90.63	72.00	64.62	60.92	54.93
	R_3	76.25	22.90	51.39	80.77	66.19	90.91	85.30	71.56	51.72
S_5	R_1	17.65	6.57	27.50	2.50	10.62	7.46	6.95	6.93	1.65
	R_2	8.89	10.53	7.25	2.25	4.82	7.19	1.76	12.30	0.14
	R_3	18.18	15.11	12.12	16.26	6.34	4.42	5.46	11.11	9.91

[1] See experimental procedure.

[2] Replications.

Appendix Table 13. Analysis of variance. Yield of barley. Bushels per acre.

Source of variation	SS	df	MS	F
Replication	1,785.33	2	892.66	66.12**
Herbicides	1,476.82	2	738.41	54.70**
Error (a)	53.93	4	13.50	
Nitrogen	1,366.09	2	683.04	10.85**
Nitrogen x herbicides	1,240.44	4	310.11	4.92*
Error (b)	755.65	12	62.97	
System of seeding	4,894.19	3	1,631.40	50.57**
System of seeding x herbicides	121.93	6	20.32	0.63
System of seeding x nitrogen	415.14	6	69.19	2.14
System of seeding x herbicides x nitrogen	303.96	12	25.33	0.78
Error (c)	1,742.16	54	32.26	

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Appendix Table 14. Analysis of variance. Yield of birdsfoot trefoil. Dry weight. Kilograms per acre.

Source of variation	SS	df	MS	F
Replication	34,328.77	2	17,164.38	0.277
Herbicides	2,112,609.63	2	1,056,304.81	17.078*
Error (a)	247,407.42	4	61,851.86	
Nitrogen	181,662.61	2	90,831.30	2.001
Nitrogen x herbicides	282,645.67	4	70,661.42	1.557
Error (b)	544.725.04	12	45,393.75	
System of seeding	2,115,585.17	2	1,057,792.58	94.238**
System of seeding x herbicides	2,692,034.96	4	673,008.74	59.958**
System of seeding x nitrogen	83,010.03	4	20,752.51	1.849
System of seeding x herbicides x nitrogen	151,529.78	8	18,941.22	1.687
Error (c)	404,085.57	36	11,294.60	

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Appendix Table 15. Analysis of Variance. Number of plants of birdsfoot trefoil per foot of row spaced at 7 inches.

Source of variation	SS	df	MS	F
Replication	63.04	2	31.52	1.17
Herbicides	82.23	2	41.12	1.53
Error (a)	107.36	4	26.84	
Nitrogen	985.70	2	492.85	20.87**
Nitrogen x herbicides	165.47	4	41.38	1.75
Error (b)	283.49	12	23.62	
System of seeding	9.29	2	4.65	0.39
System of seeding x herbicides	57.74	4	14.44	1.21
System of seeding x nitrogen	136.79	4	34.20	2.87*
System of seeding x herbicides x nitrogen	162.98	8	20.37	1.71
Error (c)	428.74	36	11.91	

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Appendix Table 16. Analysis of variance. Percentage of birdsfoot trefoil.

Source of variation	SS	df	MS	F
Replication	831.90	2	415.95	2.275
Herbicides	16,415.22	2	8,207.61	44.885**
Error (a)	731.44	4	182.86	
Nitrogen	4,873.39	2	2,436.69	5.874*
Nitrogen x herbicides	977.85	4	244.46	0.589
Error (b)	4,977.65	12	414.80	
System of seeding	9,243.47	2	4,621.73	72.532**
System of seeding x herbicides	12,030.66	4	3,007.66	47.201**
System of seeding x nitrogen	172.52	4	43.13	0.677
System of seeding x herbicides x nitrogen	482.42	8	60.30	0.946
Error (c)	2,293.75	36	63.72	

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Appendix Table 17. Analysis of variance. Percentage of red root pigweed.

Source of variation	SS	df	MS	F
Replication	1,226.31	2	613.16	1.7337
Herbicides	25,250.26	4	6,312.56	17.8487**
Error (a)	1,414.69	4	353.67	
Nitrogen	6,764.43	2	3,382.22	5.8967*
Nitrogen x herbicides	2,705.98	4	676.50	1.1794
Error (b)	6,882.92	12	573.58	
System of seeding	13,940.28	2	6,970.14	40.5901**
System of seeding x herbicides	6,441.58	4	1,610.40	9.3781**
System of seeding x nitrogen	662.47	4	165.62	0.9645
System of seeding x herbicides x nitrogen	918.76	8	114.84	0.6688
Error (c)	6,181.88	36	171.72	

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Appendix Table 18. Analysis of variance. Percentage of straw plus weeds.

Source of variation	SS	df	MS	F
Replication	371.29	2	185.64	1.64
Herbicides	1,331.43	4	332.86	2.93
Error (a)	453.72	4	113.43	
Nitrogen	158.05	2	79.02	0.33
Nitrogen x herbicides	635.24	4	158.81	0.66
Error (b)	2,880.66	12	240.05	
System of seeding	45,830.37	2	22,915.18	182.72**
System of seeding x herbicides	1,325.43	4	331.36	2.64
System of seeding x nitrogen	360.12	4	90.03	0.72
System of seeding x herbicides x nitrogen	880.21	8	110.03	0.88
Error (c)	4,514.88	36	125.41	

**Significant at the 0.01 level of probability.