A STUDY OF CERTAIN AGRONOMIC AND MORPHOLOGICAL CHARACTERISTICS OF LOTUS CORNICULATUS L. AND LOTUS ULIGINOSUS SCHK.

by

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A THESIS

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ABSTRACT

Agronomic characteristics and adaptability of L. corniculatus strains were studied by seeding with timothy, in pure stand and with a nurse crop at Macdonald College. Germination tests and root studies were conducted on L. corniculatus. L. corniculatus and L. uliginosus were compared morphologically and for resistance to flooding and 2, 4-D.

The nurse crop retarded birdsfoot establishment but pure stand and birdsfoot-timothy plots yielded substantially during the first season. Hard seeds in birdsfoot samples suggest the use of scarified seed. Extensive root development of young trefoil seedlings is associated with restricted topgrowth. L. corniculatus prostrate types demonstrated superior winter survival and greater desirability than upright strains for this locality. Light applications of 2, 4-D may control weeds during birdsfoot establishment.

L. uliginosus differs from L. corniculatus chiefly by rooting rhizomes, hairy foliage and smaller seed. Flooding experiments indicated adaptability of Bunker and big birdsfoot to moist conditions.

INTRODUCTION

Eastern Canadian agriculture requires a vigorous perennial legume with the ability to grow successfully for hay on land not well suited to alfalfa (*Medicago sativa*). Also, there is demand for a perennial drought-resistant pasture legume making more growth in midsummer than white clover (Trifolium repens). Under present climatic conditions in Eastern Canada, red clover (*T. pratense*) is too short lived for many rotations, and ladino clover (*T. repens*) although high yielding in moist situations, usually will not tolerate severe competition or drought.

For these reasons, considerable interest has developed recently in birdsfoot trefoil (*Lotus corniculatus L.*) a relatively new legume to this area. MacDonald (38), Smith (56) and other writers point out that this species has been common in New York and Vermont States for many years and promises to do much to improve yield and quality of hay and pasture on many farms in the Northeastern States.

The adaptation and limitations of this species are not yet definitely known, but is has been described as primarily a forage crop for land that is not to be plowed often. It is not suggested that birdsfoot trefoil should compete with red clover or alfalfa on the better soils or in short rotations. Instead it is intimated that this plant may be better adapted to the poorer soil types. Reports indicate that the species does well on good soils but continues to grow and persist on moist or shallow droughty areas.

Trefoil belongs to the Lotus family of the botanical order Leguminosae. There are several species, some perennial, others annual. Two perennial types have been dealt with in this study, the true birdsfoot trefoil, L. corniculatus L., and big birdsfoot, L. uliginosus Schk. (L. major Sm) (38). The major portion of the work about to be described has dealt with the first of these two species.

Experiments considered in this report were conducted in the Agronomy Department of Macdonald College during 1949 and 1950. A number of tests involving these species had been laid down previously by the Department. During the years 1911 and 1915 birdsfoot trefoil and big birdsfoot were both seeded in rows at the College, with seed obtained from Sutton and Sons, England. Similar seed was sown during 1935 to establish test plots on two farms in Joilette County, Quebec. These trials with imported seed indicated that the material tested had no economic possibilities and therefore the plots were discarded. By 1947, seed of birdsfoot grown in New York state was available and during that year further tests involving L. corniculatus were successfully established at Macdonald College. Following this, small amounts of seed were distributed to farmers in various parts of Quebec, where trial seedings were made under actual farming conditions. It has proven helpful to refer to some of these seedings during the course of this investigation. Details of such reference shall be pointed out as discussion proceeds.

Purpose of the Investigation.

Nine strains of *L. corniculatus* were seeded at Macdonald College in 1949 in an endeavor to determine the relative performance when grown with and without a nurse crop, in mixture with timothy and on pure stand plots. Yield data, aftermath development, winter killing and re-establishment by volunteer seedlings have been considered with a view towards the possible selection of the most desirable strains for incorporation in regular hay and pasture mixtures.

These lines of investigation have been expanded to include a fertilizer trial, root studies and germination tests on *L. corniculatus*, as well as a study of the morphological characteristics of both *L. corniculatus* and *L. uliginosus*, their resistance to damage from 2,4-D and relative performance under flooding.

Conclusions reached are by no means final but may serve as the basis for future work on Lotus species.

REVIEW OF LITERATURE

The earliest agricultural reports in England concerning L. corniculatus and L. uliginosus according to MacDonald (38) were made by Ellis (1744), Anderson (1777) and Sinclair (1826). MacDonald (38) also refers to Robinson (1934) as saying that by 1810, seed of birdsfoot trefoil was offered for sale by a London seedsman. An article by Hall and Russel (18) concerning experimental plots laid down at Rothamsted in 1856, indicates that birdsfoot trefoil was one of the legumes present on these plots at time of establishment.

Robinson (49) refers to Stebler and Volkart (1911) as stating that the culture of birdsfoot in Switzerland began about 1865 and in Italy according to Lesourd (1928) about 1880. Recently (8), L. corniculatus has been described as being appreciated by sheep in the high regions of the Bergmascan Alps. Culbertson (12) points out that birdsfoot trefoil has been known in Greece since time immemorial. Howell (21), McKee and Scoth (41) all indicate that the species has been cultivated in Europe for well over a century, where its forage value is recognized in France, Italy, Germany, Denmark and other countries. In France credit is given the English by French writers for first recommending the species as having agricultural value. McKee and Scoth (41) continue that in the more northern European countries the chief use of trefoils has been for pastures, while in the south, seed production has been carried on. Recent (45) reports however state that the present European acreage of birdsfoot is relatively small and confined primarily to the highlands of northern Italy and the provincial area of France.

Farmers there today are growing it in rotations with wheat and corn and use it both for hay and pasture. Present seed production is primarily for home consumption.

Robinson (50) and others report that the species, L. uliginosus has received little or no attention in England, but reports of its performance in Western Germany indicate its potential value as a leguminous crop for special circumstances in Britain.

Ditmer (15) has indicated that L. corniculatus occurs throughout the Soviet Union. In hay and pasture mixtures he reports its widespread use in central and southern European Russia and parts of Siberia. This species has similarly been reported by Rodionov (51) to be a promising hay and pasture plant in the non-black soil zone of Russia. Kolar (28) discusses the favorable properties of birdsfoot trefoil indicating that this plant has been bred at Tabor in Russia, where 751 strains were tested in 1936.

Both L. corniculatus and L. uliginosus have been introduced to Australia and New Zealand where they have proven adaptable to certain areas, and Levy (30) reports them as being grown commercially in New Zealand during the past 25 years.

During recent years birdsfoot trefoil has attracted attention in North America especially in New York and Oregon states, but its exact origin or introduction to these areas is not known. MacDonald's (38) explanation of current theories regarding its immigration to America indicates that seed was imported in ballast or livestock feed or in forage seed mixtures from Europe. In this connection Aldrich (1), Hughes and Heath (22) and others agree that the first Lotus seed probably came to America in ship's ballast dumped along the Hudson river in New York or near Portland Oregon, from which points it spread into pastures and meadows or along roadsides. Smith (56) points out that birdsfoot trefoil has been common in parts of New York state for 50 years and he believes it was brought into these areas by Austrian or German farmers from Europe. He also mentions a 30 year old stand of birdsfoot at Orwell, Vermont. Birdsfoot is mentioned by Robinson and Fernald (48) as occurring near Washington, D. C., and on ballast dumps as far north as Nova Scotia. They refer to it as an introduction from Europe.

In America L. uliginosus in the past has not been very important, but Howell (21) recently reported its use as being rapidly accepted along the coast of Oregon and Washington states. Introduced from Europe by the United States Department of Agriculture, it has been tested at the Branch Experimental Station, Astoria, Oregon, for twenty-five years and looks promising as an agricultural plant.

Lotus plants were found growing on Cornell University campus as early as 1885 and Aldrich (1) mentions the species as getting started on farms in Oregon and California between 1920 and 1930. However, it was not until around 1930 that this plant was studied at Cornell Experiment Station. From these beginnings work on the species spread to many other states including Vermont, Oregon, Ohio and Iowa. A recent article by Dodd (16) shows birdsfoot to have been under study in Ohio for the past 10 years, after being introduced in the form of a small sample from the state of Washington over 30 years ago. It spread from the corner of an alfalfa field where it was seeded, to neglected fields, over gullied areas and persisted under grazing on land too poor for alfalfa or clover.

Birdsfoot trefoil has been described by Armstrong (4) as a plant typical of impoverished soils. Dr. Hilgendorf in his "Pasture Plants and Pastures of New Zealand" as reported by Levy (30) recommends the sowing of L. corniculatus on the light soils of Canterbury in an effort to obtain a vigorous and permanent legume on pastures where white clover growth is small and intermittent. An anonymous (3) publication from Australia describes L. corniculatus as blooming all summer with a preference for poor sandy hillsides. The tolerance of L. corniculatus for unfavourable soil conditions is referred to by Ditmer (15), who claims that in Russia this species competes with other legumes and even replaces alfalfa or clover where the latter fail owing to poor soil conditions.

Rodionov (51) claims that L. corniculatus grows well on sandy soils where it has proven useful in land reclamation work. In the dairy farming industry of North Caucasus as pointed out by Zazoev (68), L. corniculatus gains ever increasing importance on the poorer soils. In a recent report, Ward et al (65) have pointed out that farmers in the United States are finding birdsfoot trefoil well suited to poorer fields where clover and alfalfa seedings often fail. McKee and Scoth (41) report from limited observations, the less exacting soil requirements of L. corniculatus compared to L. uliginosus, thus enabeling it to do well under a variety of soil conditions. According to Ditmer (15),

L. uliginosus is superior to L. corniculatus on heavy or wet soils with a moderate pH, both in forage and feeding qualities, although he does say it develops a rather excessive fibre content.

In New Zealand on land wet in winter, L. uliginosus is said by Smallfield (55) to be a very valuable plant. Montgomery (46) substantiates this statement by referring to the same species as being admirably suited to hill country pastures in the high rainfall belt. He has reported it growing over a wide range of soil types, ranging from dry knolls to swamps. It is also evident from Bell's (6) study that L. uliginosus is one of the few perennial legumes adapted to both dry and wet conditions in New Zealand. If soil conditions are unfavorable for white clover, L. uliginosus takes its place, especially where soils are loose and open. Levy (31) mentions big birdsfoot as being particularly vigorous under pioneer conditions on raw peat swamp soils, poorer grasslands and consolidated areas, and as a general legume of permanent pasture mixtures for the lower fertility areas. He also says that L. uliginosus has great value on secondary growth country, since it is able to compete with and reach the light from within clumps of low growing fern or bracken. In his description of regrassing experiments Levy (32) continues that L. uliginosus still persists where soil fertility has fallen and Danthonia species (oatgrass) become dominant. The remarkable feature of these experiments was the success after eight year's trial, of L. uliginosus, Agrostis tenuis (colonial bent grass) and Danthonia species (oatgrass). In a review of the subject Saxley (52) also considers big birdsfoot valuable where secondary growth presents a problem. He points out its usefulness in swampy country where it trails among rushes and other coarse herbs, encouraging stock in their eagerness for the Lotus to graze also the former to some extent. Stapledon (59) favors well managed L. uliginosus as an important ingredient in a sward tending to reduce domination by rushes and other swampy vegetation.

Howell (21) suggests that in America, big birdsfoot be used where other legumes prove unsatisfactory or where Lotus is better adapted. He also suggests that L. uliginosus has shown more promise for reseeding acid timber lands than any other legume. Furthermore, he indicates its growth on a wide range of Oregon soils including heavy clay tidelands with a high water table, and land of low fertility. MacDonald (38) refers to tests made with L. uliginosus at Cornell University, but concludes that it was insufficiently winter hardy for New York state. Limited plantings on alluvial marshy soil were successful, but seedings on uplands with grasses failed to survive.

Birdsfoot trefoil was one of the chief herbaceous colonists found present by Locket (35) in ten year's observations on bare chalk areas in England. Dodd (16) reports trials in which alfalfa, ladino and birdsfoot have been compared, where the latter was the only one to grow on the unlimed and unfertilized portions of the plots.

In the light of results from the United States Regional

Salinity Laboratory reported by Ayers (5), salt tolerance of the narrowleaf strain of L. corniculatus is outstanding. Plots were irrigated to produce three levels of salinity by adding water which contained 2,500, 5,000 and 7,500 p.p.m. of salt respectively. Narrowleaf birdsfoot included in these tests with clover and alfalfa was the only legume to produce an appreciable yield on the high salt plots. All ladino and alsike plants died on the high salt plots with only an occasional survivor on those of medium salt concentration. Red clover died on all the salty plots. During equal growth periods, birdsfoot produced more green material than alfalfa on both the control and salt plots (5,000 p.p.m.).

Data from French sources reported by Robinson (50) show yields of green fodder obtained from birdsfoot areas as high as 15 tons per acre per season on poorer soils. Howell (21) indicates that L. uliginosus and grass mixtures are commonly cut for silage in the coastal section of Oregon, followed by a later crop for hay or seed. Silage cut in May averages 10 tons per acre in yield. According to Montgomery (46), L. uliginosus is slow to begin growth, but once established with grasses it will support reasonable stocking with a minimum of topdressing.

Although birdsfoot trefoil has come into use in areas of low fertility and those more or less deficient in lime, writers today generally agree that proper fertilization is necessary to maintain good stands of this crop. Somerville (58) records great increases in yield of birdsfoot with phosphatic manures in the south of England. Robinson (49) seems firmly convinced that potash and phosphate contribute largely towards the success of this crop in the field. Buckley (9) reports a Mr. Cooke in Albany County, New York, as using one ton of limestone and 300 pounds of 20% superphosphate per acre when seeding birdsfoot. After several years he applies a top dressing of 600 pounds superphosphate per acre. According to his observations, this phosphate makes a big difference both in height and color of the birdsfoot vegetation. Applications of lime to raise the soil pH to the alfalfa level and the addition at seeding time of 500 pounds per acre of 3-12-12 or 0-12-12 are recommended by Dodd (16) as necessary for good birdsfoot response. Smith (56) suggests applying 500 pounds of 0-20-20 fertilizer per acre at seeding time and for top dressing.

Recently in Vermont, Midgley (43) called attention to some seventy-five plantings of birdsfoot made throughout the state in 1941, of which practically all the best stands were on clay soils. He maintains that even though a stand can be produced on soils of low fertility, birdsfoot should in general be fertilized similar to red clover, except during the seedling year. In agreement with Midgley (43), Serviss and MacDonald (53) claim that part of the early difficulty in establishment of birdsfoot stands was due to the complete neglect of fertilization, and add that lime with superphosphate and manure or muriate of potash should be applied regularly.

To support his theory of the need for adequate fertilization, Midgley (43) discusses results of fertility tests with birdsfoot trefoil on heavy and light soils. He declares that the greatest responses were obtained on Panton clay loam from superphosphate. This soil already contained a rather high amount of potash, but an annual application of 60 pounds of P_2O_5 and 15 pounds K_2O produced almost 1.5 tons of extra hay per acre. On lighter soils more deficient in potash, even greater responses were obtained with superphosphate, and where large amounts of lime were used, an application of 50 pounds of borax per acre with manure in the second year proved highly beneficial. For establishment of L. uliginosus on the gumlands of New Zealand, Bell (6) recommends annual dressings of 300 to 400 pounds of superphosphate or slag and 400 pounds of lime per acre. He further indicates that pure stands of this species are not difficult to establish and believes that it should become a valuable constituent of permanent pastures. Montgomery (46) points out that L. uliginosus may be introduced to a sward by adding seed to the fertilizers previous to top dressing, or by broadcasting seed over bare areas. For a quicker and possibly cheaper method on hill country pastures, recommendations are to allow grazing of Lotus plants while seed is still in the pod, thus spreading the seed in the droppings.

By means of hay analysis Damela (14) shows that the percentage of birdsfoot trefoil in meadows and harvested hay does not fluctuate from year to year, as often happens with red clover. He recommends the seeding of Lotus under adverse conditions in mixtures with alfalfa and red clover. As shown by Kuprijanov (29) L. corniculatus sown alone or in mixtures outyields red clover and alfalfa in many regions of Russia. Kolar (28) reports a four year trial at Roznov (1933-36) where an improved strain of birdsfoot produced up to 27.7% more hay than red clover. The same worker (28) previously had recommended the sowing of L. corniculatus in mixtures with red clover and alfalfa under dry conditions. During the years 1932-34 he compared the yields of birdsfoot trefoil with those of T. pratense and found it to surpass the latter each year, both in green and dry matter yields. Zazoev (68) found L. corniculatus to outyield both clover and alfalfa on the poorer soils, and Rodionov (51) mentions it growing in mixtures with clover on sandy areas. Under such conditions the first year's crop is largely clover while birdsfoot comprises the larger portion of the second year's crop.

Dodd (16) reports birdsfoot as producing two tons of hay per acre on fields where both alfalfa and red clover had failed, but admits that the latter species outyield birdsfoot on land to which they are well suited. In Danish experiments reported by Robinson (50), the narrowleaf variety of birdsfoot yielded more hay at four different locations over two harvest years than red clover. The clover yielded heavier during the first year, but considering the total yield for two years, trefoil had a 31% difference in its favor. After two years observation on the grazing behaviour of cows, calves, sheep and other animals, Tiemann and Mueller (61) working in Germany concluded that in continental climates where T. repens does not thrive, L. corniculatus could be used as a partial substitute.

An experiment (50) comparing red clover and birdsfoot trefoil was carried on at Harper Adams College, England, where small areas were sown to mixtures with orchard grass. The initial catch of the birdsfoot plants was much superior to that of red clover in adjacent plots and after a very dry summer the trefoil thickened, creating a marked contrast to the bare thin areas sown to the red clover mixture. Working at Cornell, Culbertson (12) refers to plots of Kentucky bluegrass with birdsfoot, which during the months of July and August produced nearly four times as much dry weight as similar plots of Kentucky bluegrass and white clover mixture. In this connection too, Hughes and Heath (22) state that birdsfoot and bluegrass do well in mixtures.

Dodd (16) shows birdsfoot to have a feeding value similar to alfalfa and clover for hay or pasture. In feeding trials at Cornell University as reported by Loosli (36), birdsfoot hay proved equal to alfalfa for milk production. At corresponding stages of maturity it was fully as palatable as other common legumes.

Birdsfoot silage according to Howell (21) is very palatable with a crude protein content up to 15% calculated on a dry matter basis. Hay from L. uliginosus is said to compare favourably with alfalfa hay in protein content (15-20%) and dry matter per acre, but is sometimes lower in calcium. This is explained by Howell (21) as probably due to the Lotus plant's ability to grow on more acid soils than alfalfa. Referring again to the trials at Cornell (36), the feeding of birdsfoot hay in preliminary tests was observed to eliminate the development of oxidized flavors in milk to a greater extent than any other forage plant studied. Professor Schribaux, School of Agronomy, Paris (3) was reported in 1923 to have stated that no ill effects to stock had been observed from the eating of any part of the Lotus plants. However, he did point out that grazing animals avoided the yellow blossoms, probably due to content of a cyanogenetic glucocide, but he accepted this as an advantage since it helped in reseeding the species. Other writers (21) have supported Professor Schribaux to the effect that birdsfoot trefoil forage does not cause bloat in cattle. Ward et al (65) and Midgley (43) have recently reported that thus far not a single case of bloat has been reported in cattle due to grazing of birdsfoot trefoil. Kolar (27) notes refusal of birdsfoot trefoil by some horses apparently because of a bitter taste. In concluding his article, Ditmer (15) remarks that since the flowers of L. corniculatus contain hydrocyanic glucosides which are absent in L. uliginosus, green forage of the former cut in the flowering stage should not be fed to animals. The hay or silage according to him does not contain these toxic properties. Robinson (49) intimates however, that such a reason given for rejection of flower heads by some animals is probably incorrect, since all parts of the shoot contain the glucoside but are nevertheless eaten.

It is maintained by Damela (13) that dry weather during 1934 proved the importance for permanent meadows of certain legumes including L. corniculatus. In agreement, Klecka (25) states that this species has proven to be one of the most drought resistant meadow plants, and in later work with Fabian (26) again refers to it as a very drought resistant inhabitant of Bohemian meadow swards. Results from Cornell reviewed by Culbertson (12), show birdsfoot to make rank growth during hot dry summers and to provide abundant forage during July and August. McKee and Scoth (4) also found L. corniculatus to withstand droughty conditions. Kuprijanov (29) found it equivalent to alfalfa under dry conditions but also responsive to moisture.

The latter author indicates superiority in longevity for birdsfoot, claiming good yields up to 12 years after seeding. In their discussion, Hughes and Heath (22) indicate that once established, a mixture of birdsfoot and bluegrass can be expected to survive indefinietly. The longevity of birdsfoot over a seven year period was considered on an experimental plot by Kolar (27). During the first four years only 2.9% disappeared, in the fifth year 12.1% died, and in the sixth year 31.1%. By the end of the seventh year only 1.7% remained. Ditmer (15) has stated that under his conditions the life of a birdsfoot sward is for six years or more, with a full yield being produced in the fourth and subsequent years. Ten year old swards of L. uliginosus are discussed by Howell (21) as still improving and competing with natural fescue and bent grasses. A 35 year old stand of birdsfoot in New York state is said to be still yielding more than three tons of hay per acre (65).

Tome and Johnson (62) believe that L. corniculatus has probably undergone natural selection for a long time in nature where it undoubtedly has existed in the tetraploid form. They conclude that the narrowleaf strain is being confused as an agronomic variety of L. corniculatus, when in reality it is a separate species. They describe cytological and morphological studies wherein chromosome numbers of the two have been determined. The narrow leaf type was found to possess six pairs of chromosomes, while the broad leaf type, designated as L. corniculatus has 12 pairs. McKee and Scoth (41) state that information on the introduction of the narrow leaf type to America is lacking and refer to it as a species separate from L. corniculatus.

In a review of fertilization relationships, McKee (40) points out that L. corniculatus shows wide variation in self-fertility, both between and within subspecies. He also refers to L. uliginosus as being highly self-fertile, with self-sterile plants occurring. In experiments conducted by Silow (54), L. uliginosus was found to be self-fertile when artificially self-pollinated while L. corniculatus was highly self-sterile. Tome and Johnson (62) report also on greenhouse studies which showed L. corniculatus to have a high degree of self-sterility. Working with L. corniculatus in the greenhouse, MacDonald (38) obtained similar results. However, when he enclosed bumblebees in cages with individual plants in the field, L. corniculatus proved to be 100% self-fertile.

MATERIALS AND METHODS

Source of Seed.

Seed of the following nine strains of *L. corniculatus* was received from Dr. H. A. MacDonald, Agronomy Department, Cornell University in the spring of 1949.

1. Bunker narrowleaf--origin not indicated.
2. V-103, Hilderberg--origin not indicated.
3. Empire--New York broadleaf.
4. E-491--Northern Italy.
5. E-493--Italy.
6. E-494--Italy.
7. V-102--European.
8. E-492--European.
9. E-495--European.

In May 1950, additional seed of this species was supplied by Dr. MacDonald including ten strains in all, seven of which had been previously received from him in 1949. The three new strains supplied in 1950 were:

1. V-102, Selected--origin not indicated.
2. E-501 --origin not indicated.
3. Goodfellow --origin not indicated.

During the winter of 1949-50 the following seed samples were obtained from the United States Department of Agriculture, Beltsville, Maryland.

1. Oregon narrowleaf -- *L. corniculatus*
2. European upright broadleaf -- *L. corniculatus*

3. New York broadleaf -- L. corniculatus

4. Big birdsfoot trefoil -- L. uliginosus

Mr. Charbonneau, district agronome for Joilette county, Quebec also supplied a small quantity of big birdsfoot seed in the fall of 1949.

Yield Trials

Seed of the original nine strains obtained from Cornell University was used to establish three tests of birdsfoot trefoil on college fields in the spring of 1949. (May 20-21) Each test was arranged in a balanced lattice design with four replications. The tests were as follows:

1. Pure stand of birdsfoot trefoil. (Range 1, East Field)
2. Mixture of birdsfoot with timothy (Phleum pratense) Drummond variety. (Range 32, East Field).
3. Pure stand of birdsfoot with a nurse crop of barley (Hordeum vulgare) Montcalm variety. (Range 2, Avenue Field)

After the areas had been prepared and marked, seeding was done in seven row plots by means of a hand propelled Planet Junior seeder. Birdsfoot trefoil was seeded on all plots at the rate of four pounds per acre. Timothy was sown at eight pounds per acre on the mixture plots, Range 32. All Lotus seed was inoculated with the special nodule forming bacteria supplied with the seed. This was accomplished by thoroughly mixing a teaspoonful of inoculant with each half-pint of seed as it was placed in the hopper. The nurse crop area was seeded to barley with an ordinary horse drawn seeder at the rate of two bushels per acre a few days previous to the birdsfoot seeding operation. Individual plots of each strain were rectangular in shape, 51 X 7 links in area, running at right angles to the length of their respective ranges. Germination tests of each birdsfoot strain were conducted in the laboratory at seeding time.

All plots were kept under observation throughout the growing season, with plant heights, blooms, seed set, seed dehised and other characteristics recorded at regular intervals.

The pure stand seeding and the mixture with timothy seeding were harvested as hay in late July with a Gravely mower. Immediately prior to this operation, borders and alleys were removed, thus reducing the area harvested per plot to 40 X 5 links or five rows per strain. Yields of green material in grams were obtained by weighing the entire amount of topgrowth removed from individual plots. Percent dry matter per strain was determined by placing 1000 gram samples of green material in the drier at 200° F until constant weight was attained. Finally all yield data from the two seedings was converted to pounds of dry matter per acre. An analysis of variance was carried out on this data with necessary differences being calculated for comparable means. Observations regarding recovery and aftermath production on the two harvested areas were recorded regularly until snowfall in November. None of this aftermath was removed in an attempt to increase winter hardiness of plants.

The nurse crop of Montcalm barley was removed from the third seeding during the month of August, but no harvest or yields of birdsfoot were taken.

Winter Survival of Birdsfoot Trefoil.

Winter survival was considered in the spring of 1950. During May the inclined point quadrat was used to make stand counts of vegetation on the birdsfoot plots of Ranges 1 and 32, East Field. Percentages of overwintered birdsfoot, birdsfoot seedlings, timothy, other plants and bare ground were calculated from these counts according to the method described by Levy (33). No counts were made on the nurse crop seeding at this time, but observations and notes were taken, after which these plots were discarded. Pure stand plots on Range 1, East Field were also discarded following quadrat counts and observations. Those of the mixture on Range 32 were kept for further study throughout the summer. Top growth was removed from this area in July but no yields were determined. Further quadrat counts were made on Range 32 seeding in the fall of 1950 to determine any alterations in percentage of different species present.

Fertility Trial

In the spring of 1949 five fertility plots including a check were established on a strip of birdsfoot trefoil and timothy at North Hatley, Quebec. This test was not replicated but four rates of 2-12-10 fertilizer were applied, 100,200,400 and 800 pounds per acre. The area had been seeded in 1947. Individual plots were 12 X 12 feet in area, each one lying adjacent to the next in a row, so that the total area involved was a 12 X 60 foot rectangle. Inclined point quadrat counts were made on all plots both in the spring and fall of 1949 and 1950. Percentage of each species present was calculated for each set of readings.

<u>Birdsfoot Seedings During 1950</u>

A birdsfoot nursery was seeded in late May 1950 on Range 10, Agronomy East Field. Plants were not individually spaced but the Planet Junior seeder used in the seeding operation was calibrated to give the lowest possible rate of seeding, with the result that plants emerged in the rows with a minimum of crowding. Fifteen rows were seeded to each of the nine following types.

1. Empire.
2. V-103.
3. Big birdsfoot.
4. V-102.
5. E-491.
6. E-492.
7. E-493.
8. E-494.
9. E-495.

The nursery area was cultivated and kept free of weeds throughout the summer but no topgrowth or plants were removed. Thirty plants of V-102 strain selected from 1949 seedings on Ranges 1 and 32 were introduced as individual spaced plants to another row beside the nursery. These plants were selected because they appeared to survive the winter very well in plots where there was a high percentage of winter killing.

Also in May 1950, a seeding was made on sandy loam soil, Range 11E Northwest Field, including the nine strains of <u>L. corn-</u>

iculatus on which work was done the previous year. This seeding was laid out as a balanced lattice design with four replications, adjacant to an area devoted to root studies, seeded in 1949. After light cultivation and a period of dry weather this seeding was discarded and disked up in early summer, because of poor birdsfoot emergence and a vigorous weed population. However, the area was kept free by frequent disking for a dates of seeding experiment, involving two strains of birdsfoot, Bunker and Empire. The first seeding of this test took place in mid-August and the last at the end of September. It consisted of four seeding dates each two weeks apart, with four replications in a randomized block design.

Seed supplied by Dr. MacDonald in the spring of 1950 was used for another seeding of birdsfoot and timothy on Range 34, East Field. It consisted of four replications in a randomized block design. Size of individual plots was 51 X 7 links and rate of seeding for birdsfoot was four pounds per acre. Drummond timothy was seeded on all plots in a separate operation at eight pounds per acre. This seeding was cultivated thoroughly early in July with a wheel hoe. Following a period of rainy weather during late July, weeds increased to the point where it was impossible to remove them satisfactorily without serious damage to the small birdsfoot seedlings. It was, therefore, decided to conduct a 2, 4-D weed control experiment on this area.

Effect of 2, 4-D on Birdsfoot

(a) Seedlings Sprayed in Field

The seeding of birdsfoot and timothy on Range 34 East Field, selected for a weed control test had been originally designed as a replicated randomized block. The 2, 4-D experiment was designed in a similar manner with four replications, and was superimposed over the previous plan with plots at right angles to those of the vegetation. The chemical was applied at rates of two, eight and 16 ounces per acre in two gallons of water per plot, during the month of August. Check plots were also established and a visual estimate made of the percentage cover contributed by various species at time of spraying. Observations and notes were made regularly on the area until it was discarded and plowed up in October. Prior to discarding, a second visual estimate was made of the species comprising the sward.

(b) Seedlings Sprayed in Greenhouse.

In an effort to obtain further information regarding the effect of 2, 4-D on birdsfoot seedlings, a small experiment was carried on in the greenhouse during the fall of 1950, which involved the spraying of seedlings at four different age groups. Plants studied included two strains of L. corniculatus, Bunker and Empire, L. uliginosus, and Dollard red clover. Sixty-four six inch porous pots were filled with a sandy loam soil to make up four replications. Seeds were sown without pre-germination and one month later each pot was thinned to contain 10 plants. The first application of 2, 4-D in water with a spreader was applied to foliage at the third true leaf stage by means of a small hand fly-sprayer. (16 ounces per 50 gallons of water) Plants were sprayed until foliage dripped. Subsequent applications took place at nine day intervals. Notes and observations were made after each spraying and throughout the experiment. Since results were mainly observational, no analysis was carried out, but a detailed report was prepared concerning effects of spray on the plants.

Silage Experiment

Silage was made in early July 1950 from two sources, a pure stand of *L. corniculatus* and a mixture of *L. corniculatus* with about 20% timothy. The foliage was chopped into one inch lengths immediately after cutting and placed in burlap bags overnight. The next morning 500 gram portions of this green material were packed tightly into quart sealers, using a short section of broom handle for packing. One series of jars received no preservative, one received 5% molasses by weight, while the third group received 4% by weight of a 10% solution of P_2O_5. These preservatives were poured into the sealers on top of the packed material. The sealers were immediately closed tightly with rubber rings for 24 hours, then the tops were loosened for several days. Finally they were sealed again, but allowances were made in adjusting the covers for a small amount of gas to escape when sufficient pressure built up inside. Sealers were opened in January 1951 and silage judged for quality. Dry matter content and pH values were also determined and recorded.

Flooding Experiments

(a) Flooding Previous to Emergence

A split plot flooding experiment with four replications was set up in the greenhouse including the species *L. uliginosus*, and three strains of *L. corniculatus*, namely Bunker, Empire and E-495. Lengths of flooding were considered as main plots and strains or variety as sub-plots. A total of 80 glazed earthen crocks, each one gallon in volume were involved. These were filled to within two inches of the top with a loamy soil mixture and all except the check treatment plugged with corks in the bottoms. One hundred seeds were sown in each crock and covered with one eighth inch of sand. Sufficient water to fill the crocks was immediately added and maintained at this depth until the end of each flooding period, one, two, three and four weeks respectively. In each case water was removed at the appropriate time by removing corks from the bottoms of crocks. Germination tests were carried out on seed used in this experiment. At the conclusion of the experiment, three months after seeding, final stand percentages were determined and the date analyzed for significant differences.

(b) Flooding After Emergence

A second split plot flooding experiment with four replications was carried on in the greenhouse during the summer of 1950. Lengths of flooding periods were again considered the main plots with strains as sub plots. Earthen crocks similar to those used in the previous test were again employed. This second experiment involved the flooding after emergence of Bunker, Empire, big birdsfoot and Dollard red clover seedlings for periods of one, two, three and four weeks. All crocks were filled with soil to within two inches of the top and all except the checks were plugged. Thirty-five to 40 pre-germinated or swollen seeds of the plants involved were placed in their respective crocks, covered to about one eighth inch with sand and watered. In the latter process, care was constantly exercised during establishment of seedlings in order to prevent waterlogging of soil in the plugged crocks. Since seeds of big birdsfoot were slower to germinate they were not transferred to the crocks until a day later. A second seeding of this species was made two weeks later since emergence in some crocks was very poor.

Immediately prior to flooding, crocks containing more than 25 seedlings were thinned to this number and in those containing fewer plants, the actual number present was counted and recorded.

Floodings were applied three weeks after first emergence. Crocks were drained at the end of their respective flooding periods by removing corks from bottoms. Plants were allowed to recover and grow for a period of approximately one month beyond removal of the last flooding. At the end of this time all plants were harvested, final stand counts made and percentage survival calculated. When percentages had been transformed to degrees an analysis of variance was carried out on the data. Means and L. S. D. values were calculated.

Root Studies.

Individual spaced plants of two prostrate strains of L. corniculatus, Empire broadleaf and Bunker narrowleaf were grown on two soil types in the Agronomy fields during the summer of 1949. In October of the same year, typical plants of each strain and from each soil type were chosen and removed to the greenhouse where all soil was removed from the roots. Volumes of roots and tops of these plants were determined.

A similar procedure was followed in regard to solid seedings of these two strains in rows, both in pure stand and in mixture with timothy. Plants from the latter two seedings were also removed and washed out during October 1950, to give data for two successive years.

In the summer of 1950 two boxes with glass fronts were constructed and filled with soil in the greenhouse. Individual plants of Bunker and Empire were established in each box for the purpose of recording the rate of root growth of the two strains. Due to circumstances beyond control, the Bunker plant had to be discarded when about two months of age. At 14 weeks of age the Empire plant was washed from the soil, volume of roots and tops determined and each portion photographed.

Morphological Studies.

The nine strains of L. corniculatus supplied by Dr. MacDonald from Cornell University were studied in a detailed manner for characteristic morphological features which might be useful for identification purposes. This study was carried out on field plots of Ranges 1 and 32 as well as in the laboratory. A considerable number of plant characters were studied and several measured, including length and width of terminal and lateral leaflets, length of internode, footstalk, peduncle , and florets. A total of fifty measurements were made for each of these characters.

Fifty gram samples of aftermath foliage from each of the nine L. corniculatus strains seeded were collected from plots of Range 1, East Field in the summer of 1949. Individual strain samples were separated into leaves, stems and flowering parts in an endeavour to compare relative percentages of these elements in the nine strains. The separated portions were dried to constant weight in the drier. Percentages were calculated and recorded from this dry weight data for each individual strain considered.

In continuing the morphological study, rates of establishment of two birdsfoot species, L. corniculatus and L. uliginosus and a variety of alfalfa were considered. One dozen plants of each strain and species involved were seeded separately in six inch porous pots in the greenhouse. Detailed observations and notes were made on individual plants beginning with date of emergence and extending to maturity.

Germination Tests.

In August 1949, a two year old stand of birdsfoot trefoil was cut for seed. (Avenue Field). To reduce loss of seed by shattering of pods, top growth was removed with a sickle in early morning while still damp with dew, and immediately placed in large burlap bags. These were transported to the barn, where the foliage was spread out on a concrete floor to dry. In about three weeks time the material was threshed by means of a hand flail, and seed collected for cleaning and storage. Seed was again harvested in a similar manner from the identical area in August, 1950. Seed samples from these two sources were chosen for germination tests in the laboratory.

Each sample consisted of 200 seeds which were spread on blotting paper in small porous trays. The trays were placed in water in the germinator and the water level controlled so that the blotting paper was kept moist but not flooded. Germination of individual samples was checked and recorded regularly.

RESULTS AND DISCUSSION

Yield Trials

The two seedings without a nurse crop established themselves rapidly in the spring of 1949. Plant counts per random yard lengths of row made on all strains one month after seeding indicated a consistently higher number of emerged seedlings for Bunker than for any other strain. When the two seedings referred to above were harvested for hay at eight weeks of age, foliage had already reached an average height of 15 inches, with an abundance of blooms and pods present. Observations on flowering previous to this time showed that the upright strains V-102, E-491, E-492, E-493, E-494 and E-495 produced blooms and pods approximately one week earlier than either of the three prostrate types, Bunker, Empire or V-103. Among the latter three strains there was no appreciable difference in date of flowering.

The summer months of 1949 were very dry and the birdsfoot plots of pure stand and the mixture with timothy compared favorably with those of spring seeded red clover and alfalfa in the immediate vicinity. Response of birdsfoot was striking because the thick green foliage and abundant yellow blossoms showed up for long distances in the field.

Average yields of dry matter in pounds per acre obtained from the two seedings harvested are reported in Table 1. A more detailed record of this data may be found in Appendix Tables I and II with corresponding analysis of variance in Appendix Tables III and IV. Percent dry matter of birdsfoot strains determined from the 1000 gram samples of harvested green forage are presented in Appendix Table V.

Table I-Average Yields in Pounds of Dry Matter per Acre

Birdsfoot Alone		Birdsfoot With Timothy	
Strain	Yield (lbs./acre)	Strain	Yield (lbs/acre)
E-495	1191.3	E-495	1037.9
E-492	1115.2	Bunker	984.9
V-102	861.2	E-491	900.9
E-494	702.6	E-494	883.0
Empire	696.3	E-493	816.8
E-493	690.3	E-492	749.6
Bunker	646.0	Empire	728.9
E-491	618.5	V-102	555.4
V-103	331.2	V-103	519.7

L.S.D.-5% point = 300.3 L.S.D.-5% point = 407.3

L.S.D.-1% point = 408.2 L.S.D.-1% point = 553.6

Mean for upright strains in pure stand = 863.2

Mean for prostrate strains in pure stand = 557.8

In pure stand, upright strain E-495 yielded significantly more dry matter per acre than V-102 and highly significantly more than strains E-494, Empire, E-493, Bunker, E-491 and V-103. Strain E-492 yielded highly significantly more than strains E-494, Empire, E-493, Bunker, E-491 and V-103. Comparing upright and prostrate strains in pure stand the former strains yielded significantly more than the latter, Empire, Bunker, and V-103. Comparing the three prostrate strains in pure stand, Bunker and Empire both produced significantly more dry matter per acre than V-103. Considering the mixed stand, strain E-495 and timothy together produced the largest amount of dry matter per acre, significantly more than strains V-102 and V-103 in mixture with timothy. Of the three prostrate strains Bunker and timothy mixture produced a significantly higher yield than V-103 with timothy. There was no significant difference between upright and prostrate strains in mixture with timothy.

Observations during the summer of 1949 on the nurse crop seeding of barley with birdsfoot showed poor establishment of trefoil plants, apparently because of the vigorous growth and competition of the barley. When the nurse crop was removed, growth of birdsfoot was found to be insufficient for harvesting, and therefore no yields of the legume were taken.

Aftermath Development

Four weeks following harvest of the pure and mixed seedings, prostrate strains Bunker, Empire and V-103 had recovered to average heights of three to five inches, with numerous blooms and pods. Aftermath production from these strains consisted of a thick spreading mat of succulent vegetation, completely covering the plots. The remaining upright strains during the same period had attained average heights of from six to eight inches with few blooms and pods. Growth was erect but bushy enough for tops to meet between rows, as seen in Figure A. On closer examination this new foliage in all strains was observed to be growing up about equally from two sources; half from the original crown at the soil surface and the remaining half from the

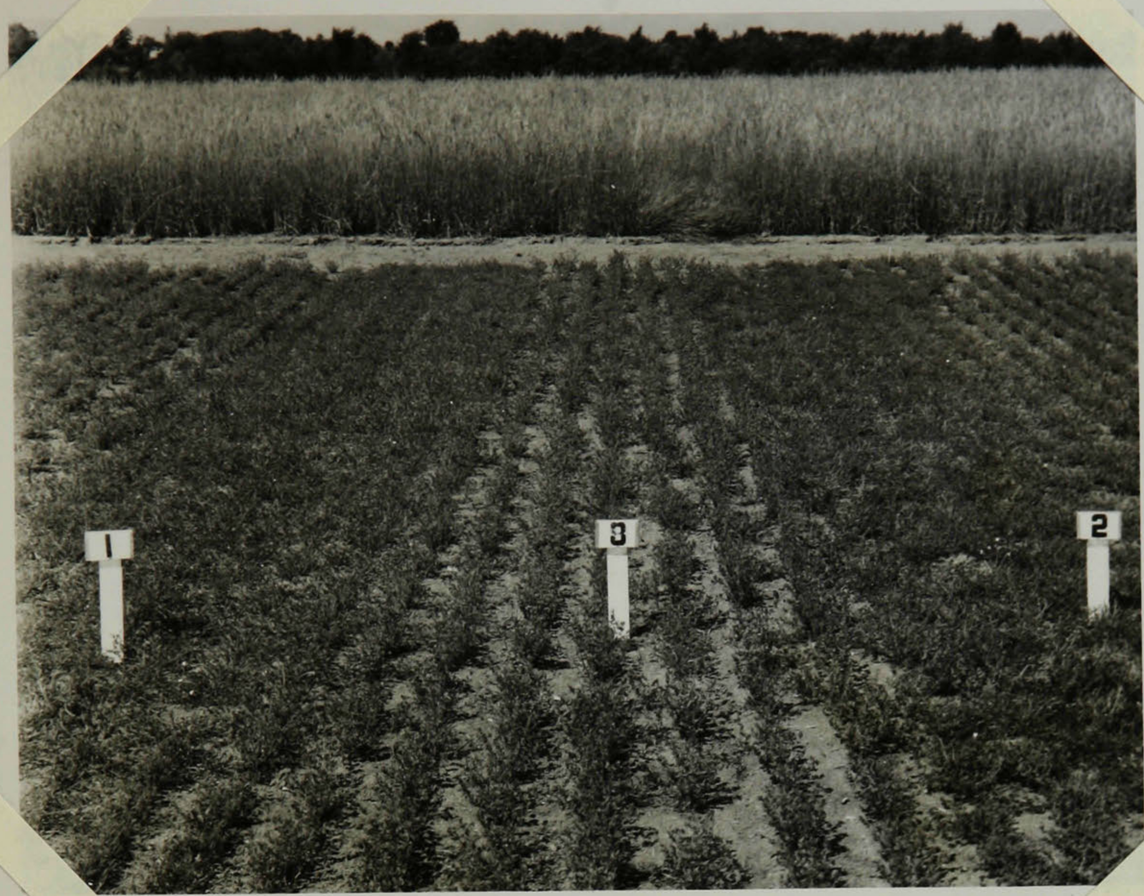

Figure A - Birdsfoot Trefoil Types Two Weeks Following Harvest. (1) Bunker prostrate (8) E-495, upright (2) Empire prostrate. Note how the prostrate strains have covered the ground more completely than the upright strains.

stubble or uncut stems left by the mower. After a rainy period in mid-September, all strains showed a marked increase in aftermath production of a lighter green color. This was especially noticeable with Empire where the amount of lighter colored foliage in proportion to older darker growth was greater than on other strains. This late foliage covered many seed pods. It tended to keep the pods damp, thereby reducing loss of seed from dehising. Pods opened and examined at this time revealed many swollen seeds and frequent germination.

Observations near the end of October showed that blooming had ceased with about 50% of all seed dehised. Many green pods remained attached to the plants. Rooting at nodes and internodes was observed in Bunker, Empire, V-102, E-494 and E-495 strains while V-102, E-492, E-494 and V-103 strains gave indications of rooting at wounds or points of injury. Plots on both ranges (1 and 32, East Field) remained green and growing until cold weather, and on November 19 were covered with snow. The three prostrate strains by this time had attained heights up to eight inches while upright averaged from six to nine inches tall.

During aftermath production in late summer and fall of 1949 occasional plants were observed on Ranges 1 and 32 which appeared slightly different from their companions. These plants were characteristically tall and upright in growth habit with light colored foliage. Leaves were generally narrower than those of other plants in the same plots. Most of these off-type plants appeared on plots of the upright strain V-102, although a few showed up scattered among other upright strains.

Winter Killing and Re-establishment by Volunteer Seedlings.

Of the nine birdsfoot strains seeded in pure stand and in mixture with timothy during 1949, only the three prostrates, Bunker, Empire and V-103 gave evidence of good winter survival. This is clearly shown by percentages in Table 2 which were calculated from point quadrat counts made on the two areas in the spring of 1950, according to the method outlined by Levy (33).

Table 2 - Percentages Calculated from Point Quadrat Counts of Vegetation on Plots in East Field, May 1950.

Percentage Ground Covered by Each Species.
Birdsfoot and Timothy Mixture - Range 32, East Field.

Strain	Timothy	Birdsfoot Overwintered Plants	Birdsfoot New Seedlings	Other Plants	Bare Ground
Bunker	62.4	8.4	2.4	10.8	25.2
Empire	26.4	31.2	4.8	9.6	34.8
V-102	43.2	20.4	6.0	4.8	34.8
E-491	40.8	6.0	3.6	3.6	44.4
E-492	30.0	T	1.2	8.4	58.8
E-493	31.2	1.2	7.2	10.8	49.2
E-494	38.4	12.0	1.2	10.8	45.6
E-495	44.4	15.6	3.6	6.0	32.4
V-103	36.0	34.8	6.0	9.6	30.0
		Birdsfoot Pure Stand - Range 1. East Field			
Bunker	--	25.2	15.6	36.0	33.6
Empire	--	50.4	9.6	33.6	21.6
V-102	--	9.6	8.4	78.0	9.6
E-491	--	T	12.0	79.2	13.2
E-492	--	7.2	15.6	75.6	13.2
E-493	--	T	18.0	80.4	6.0
E-494	--	T	13.2	76.8	13.2
E-495	--	T	12.0	68.4	22.8
V-103	--	34.0	18.0	58.8	9.6

T-- trace of vegetation

Superior survival of the three prostrate strains is especially evident on pure stand plots of Range 1, and to a lesser extent on Range 32, where timothy was grown in mixture with the birdsfoot.

Seedings of Empire birdsfoot in mixtures with various grasses and legumes on college fields have shown good winter survival since establishment during 1947. Similar seedings of Empire on dry acid upland near Mansonville, Quebec and on meadow land at Shawville, Quebec have lived through successive winters and shown a continued tendency towards thickened stands of hay. In this regard, Chiasson (10) writing from Fredericton, New Brunswick has reported birdsfoot seedings persisting over the period from 1931-37. Similarly, Truscott (63) states that <u>L. corniculatus</u> appears winterhardy under conditions at Brandon,Manitoba, where an observational nursery plot of the species persisted for two years under winter snowfall cover.

Figure B shows differential winter killing of 1949 seeded birdsfoot pure stand plots which occurred during the winter of 1949-50 at Macdonald College. Winter survival of these Lotus seedings was disappointing but it has indicated that in this vicinity, further immediate study of the species should be concentrated on prostrate strains. Superiority of prostrate types may be true for the present but there is always the possibility of selection from within the upright types which would be adaptable to our soil and climatic conditions. In this connection it is well to note that the off-type plants of upright strain V-102 observed in 1949 appeared to survive the winter of 1949-50

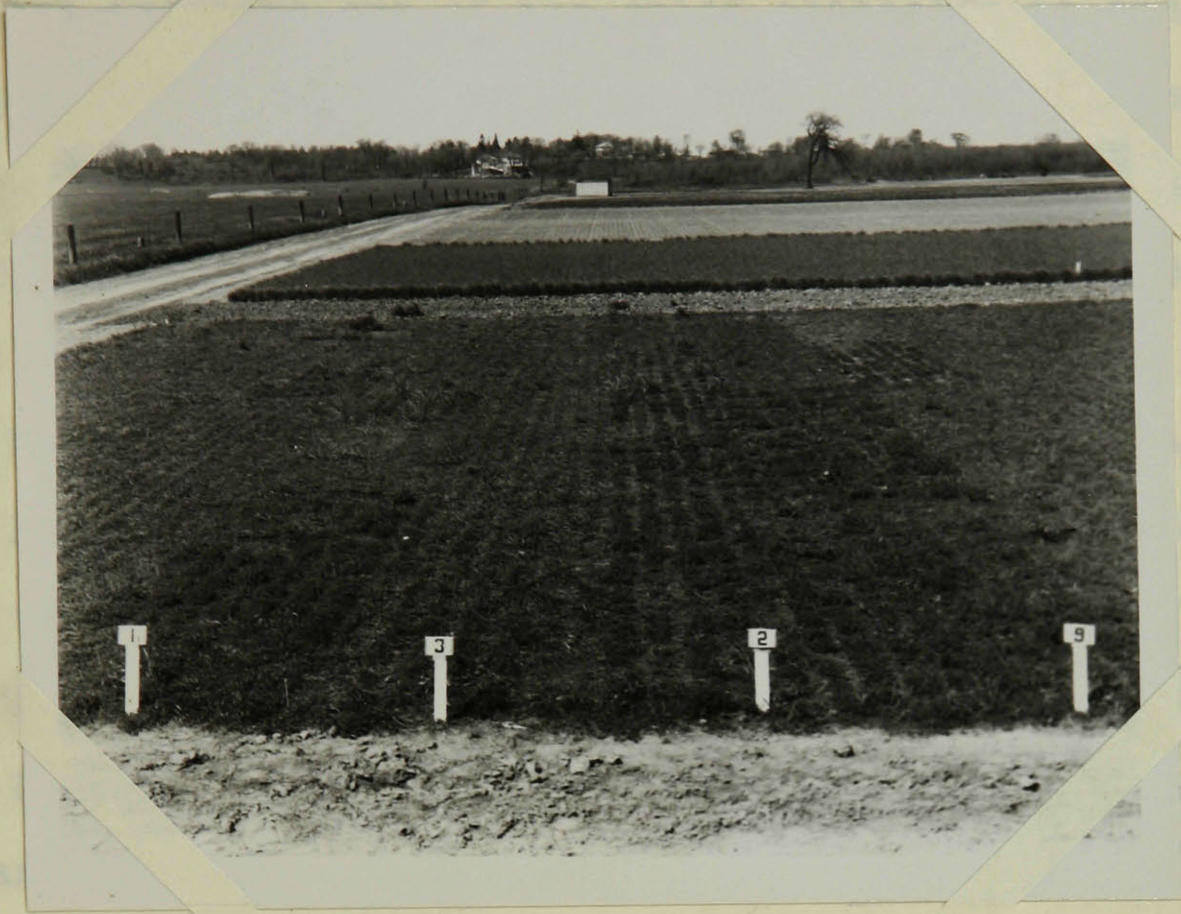

Figure B - Differential Winter Killing of Birdsfoot Trefoil, Photographed May, 1950. (1) Bunker narrow-leaf prostrate (2) Empire broadleaf prostrate (3) V-102 broadleaf upright (9) V-103, broadleaf prostrate. Also Upright Strains in Background and on Either Side. Note Lack of New Growth on the Upright Plots.

in good condition. They were easily detected in the spring of 1950 because of their vigorous early growth. By mid-May these plants had already reached heights of seven to eight inches high. As stated earlier (page 18), Dr. MacDonald supplied seed of a birdsfoot strain in the spring of 1950, which he referred to as V-102, Selected. The question immediately arises whether "V-102, Selected" is similar to those few plants of V-102 strain observed on the 1949 seedings in this investigation. It is important to remember that these latter plants proved winter hardy at Macdonald College during the winter of 1949-50.

Although tested for only the one year, it is possible that they may have overcome one of the chief obstacles to the general use of upright birdsfoot strains in this locality. Therefore, one might conclude from these observations that the selection within upright strains for plant types adapted to our conditions shows considerable promise.

The winter of 1949-50 was a severe one for all new seedings in this locality because of light snow cover during periods of low temperature. Many seedings of normally well adapted red clover strains were observed to winterkill during this time both at Macdonald College and on neighbouring farms. Red clover normally overwinters in this vicinity without any great difficulty. Therefore, one might conclude that the birdsfoot trefoil seedings considered here received a severe trial as far as winter hardiness was concerned. Similarly we might also say that the three prostrate strains, Bunker, Empire and V-103 showed excellent waterhardiness under conditions of this experiment.

Spring observations on the nurse crop seeding showed very few living birdsfoot plants. Maximum cover of individual plots was estimated at 50% with a minimum of half a dozen plants on some plots. Dead crowns of birdsfoot were present and these could usually be lifted freely from the soil. Occasionally however, new topgrowth was observed arising from apparently lifeless crowns, with small roots developing below the soil surface. In regard to the poor establishment of birdsfoot with the nurse crop of barley, it is felt that the rate of seeding of barley (2 bu. per acre) with trefoil was too heavy, since the cereal plants competed strongly with the legumes for available moisture and nutrients. Therefore, it appears that a lower than normal rate of seeding of the nurse crop would be desirable. Similar observations have been reported elsewhere, and MacDonald (38) at Cornell University also found that the use of a cereal companion crop retarded the seedling establishment of birdsfoot trefoil.

Upright strains of birdsfoot in pure stand and in mixture with timothy showed fair survival on parts of a few plots, but they were largely winterkilled especially on low areas where ice sheets had formed during the winter. Such a statement is supported by again referring to Table 2 where the percentages of overwintered birdsfoot plants are presented. These figures were calculated from inclined point quadrat counts of vegetation made on the two seedings (Ranges 1 and 32) in May, 1950.

On the mixed seeding (Range 32) a narrow strip of good survival including all birdsfoot strains stretched across the block corresponding to the position of an old under drainage ditch. One might expect from this observation that all nine strains tested would show good winter survival on very well drained soil, if seeded under conditions similar to those of this experiment. Various workers have pointed out good survival of birdsfoot on high ridges or sloping hillsides. Dodd (16) reports two tons of hay per acre from birdsfoot growing on thin droughty uplands. Reports from Nappan experimental station, Nova Scotia (60), refer to seedings of birdsfoot made on the sides and bottom of a slight valley. In the bottom of the valley, winter-killing was practically 100%, while on the higher well drained land, spring stand was almost equal to that of the preceeding fall.

Continued observations in the spring of 1950 on the two 1949 seedings without a nurse crop revealed many new birdsfoot seedlings present on all plots. They apparently developed from seeds produced and scattered in the fall of 1949 by mature birdsfoot plants. Such seedlings were most numerous on plots of the pure stand as shown in Table 2. When point quadrat readings were made on these areas in the spring of 1950, birdsfoot seedlings were recorded separately from the overwintered plants, and percentages included in the above mentioned table were calculated from these counts.

The percentage of weeds on pure stand plots of Range 1 was considered too great for the new seedlings to survive. Therefore, these plots were discarded immediately after point quadrat counts were made. However, the mixture of birdsfoot and timothy on Range 32 was relatively free of weeds and these plots were retained for further observation and study.

Plots of Empire and V-103 prostrate strains on this area improved in appearance during the growing season of 1950, and by September had produced vegetation six to 12 inches high. Both strains contained an abundance of blooms and pods. Quadrat counts made on the birdsfoot and timothy seeding in the autumn of 1950 were converted to percentages and are compared with similar data from the spring quadrat counts in Table 3.

Table 3 - Comparison of Percentage Species Determined in Spring and Autumn of 1950, on 1949 Seeded Birdsfoot and Timothy Mixture.

Percentage of Each Species in Sward

Strain	Birdsfoot		Timothy		Other Plants	
	Spring	Autumn	Spring	Autumn	Spring	Autumn
Bunker	12.9	51.5	74.3	44.1	12.8	4.4
Empire	50.0	50.0	36.7	46.0	13.3	4.0
V-102	35.5	39.1	58.1	56.5	6.4	4.4
E-491	17.8	34.9	75.5	57.1	6.7	8.0
E-492	3.0	40.8	75.6	55.1	21.2	4.1
E-493	16.7	45.2	61.9	45.2	21.4	9.6
E-494	21.2	44.9	61.6	37.9	17.3	17.2
E-495	27.6	54.7	63.8	41.5	8.6	3.8
V-103	47.1	37.8	41.8	62.2	11.1	Trace

Percentage of Bunker birdsfoot in sward at autumn time (1950) showed an increase of four times over that of the spring but similar values for timothy on Bunker plots had decreased to a greater extent than on most other strain plots during the summer. This may be explained by the fact that more of the timothy plants on Bunker plots developed heads than those of other strain plots. On the latter, a large proportion of timothy plants remained in the vegetative stage. Therefore, when foliage was mown off the timothy vegetation on Bunker plots was largely removed, whereas on the remaining strain plots a greater proportion of short vegetative timothy leaves remained behind. In the production of aftermath previous to point quadrat readings being made, the latter plots would naturally have a greater cover of timothy leaves than plots of Bunker.

Upright strains of birdsfoot on Range 32 formed few flower heads during the 1950 season and reached heights of eight to 10 inches. Timothy growth with upright strains was sparse and irregular.

Percentage of sward devoted to other plants, chiefly weeds, can be observed in most plots to have decreased during the growing season. This is a favorable factor since it indicates the ability of a birdsfoot-timothy mixture to compete successfully with a weed population during the second year of establishment.

Differential Stimulation of Timothy by Birdsfoot Strains

Observations on the root study plots of Range 32, East Field in June 1950, indicated a denser and taller growth of timothy with Bunker than with Empire birdsfoot on an adjoining plot. Growth of Empire itself was satisfactory but the timothy plants were sparsely distributed, short, (8-15 inches), not headed out and light green in color. In comparison, timothy plants growing in association with Bunker birdsfoot were taller (20-28 inches), about 75% headed out, with foliage of a dark green color. Foliage of Bunker birdsfoot was also a darker green than that of Empire strain.

These latter observations were more clearly demonstrated on the mixture plots of Range 32, as can be seen in Figure C.

Figure C - Bunker Birdsfoot and Drummond Timothy Growing in Association (Plot to left of center as indicated).

By standing at any spot on the block, one could point without difficulty to the exact location of all four plots of Bunker and timothy mixture. This was possible because in every instance, timothy plants growing with Bunker were taller and more mature with a larger percentage of heads than those on other strain plots. Foliage of both timothy and Bunker birdsfoot was also several shades darker in color than that of surrounding plots. Timothy plants with Bunker ranged from 18 to 26 inches in height, while on other strain plots, average heights ran from eight to 22 inches.

Further observations during September substantiated the above statements to the effect that timothy growth on Bunker plots was much greater than on any others. By this time timothy foliage reached a height of thirty inches and was practically all headed out. When present on other strain plots, timothy had seldom progressed beyond the vegetative stage.

Such outstanding growth of timothy when grown in mixture with Bunker birdsfoot is very interesting. Literature refers to the beneficial effect of certain leguminous species on an accompanying grass species. Evans (17) found a greater increase in growth and more green leaves of timothy, redtop, and bluegrass when grown with red clover than when grown alone. Similarly, Karraker (24) noted bluegrass growth on bluegrass-legume plots to be three times that of plots with bluegrass alone. He also observed the grass on legume plots to possess a much darker green color than that grown on non-legume plots. The observations of these workers appear similar to those made on the Bunker and timothy mixture plot under discussion. Lipman (34) and Lyon and Bizzell (37) called attention to the fact that a legume growing in association with a non legume caused an increase in the percentage nitrogen of the non-legume plant. A stimulating effect of <u>L. uliginosus</u> on grasses grown with it is reported by Howell (21). However, no literature was found which reported a differential response of grasses when grown in association with different strains of any legume.

Plants of Bunker birdsfoot dug up and examined did not show any excessive nodulation over that of other strains. From these observational results two assumptions might be made. The first is that the darker foliage of the Bunker plant itself and its apparent stimulation on timothy are two definite characteristics possessed by the Bunker narrowleaf strain. A second explanation might be that some local strain of nodule bacteria already present in the soil is playing a role. If such a strain of bacteria is present, then it must be more specifically adapted to the Lotus strain Bunker than to any of the other trefoils tested. Similarly it must be more suited to Bunker birdsfoot strain than was the legume inoculant actually used at seeding time. These observations were discussed with the Bacteriology Department of Macdonald College, but no definite explanation other than that already presented was received from this source.

Fertility Trial

Reports in the literature (43) indicate that birdsfoot trefoil is adapted to soils lower in fertility than that required for other legumes, or that it does not persist in competition with other plants when they are stimulated by fertilizer applications. In an endeavour to test such a hypothesis, fertility plots were established on a farm in May 1949. These plots were laid out on a two year old sward of a birdsfoot and timothy mixture. Four rates of 2-12-10 fertilizer were applied, namely 100,200, 400 and 800 pounds per acre. A check plot was included to make a total of five plots. The area was inadvertently top-dressed by the co-operating farmer during the fall of 1949 with manure at the rate of 10 tons per acre. Inclined point quadrat counts were made on all plots at time of establishment, again in October 1949, and also in the spring and fall of 1950. Percentage of each species in the sward calculated from each of these quadrat counts are included in Table 4.

Table 4 - Changes in Percentage of Each Species in Sward of Fertility Plots Over Two Year Period, 1949-50.

Treatment	Date	Birdsfoot	Timothy	Other Plants
	May 1949	21.4	77.7	0.9
Check	Oct 1949	42.0	58.0	T
	May 1950	79.2	17.0	3.8
	Oct 1950	32.8	65.7	1.6
	May 1949	21.4	77.7	0.9
100 lbs.	Oct 1949	35.5	59.7	4.8
2-12-10	May 1950	75.0	20.5	4.5
	Oct 1950	32.2	55.9	11.9
	May 1949	21.4	77.7	0.9
200 lbs.	Oct 1949	36.5	61.5	2.0
2-12-10	May 1950	66.7	26.3	7.0
	Oct 1950	33.3	63.0	3.7
	May 1949	21.4	77.7	0.9
400 lbs.	Oct 1949	46.0	52.4	1.6
2-12-10	May 1950	78.4	19.6	2.0
	Oct 1950	32.1	62.3	5.6
	May 1949	21.4	77.7	0.9
800 lbs	Oct 1949	43.3	53.4	3.3
2-12-12	May 1950	78.3	17.4	4.3
	Oct 1950	33.3	61.7	5.0

At time of establishing the fertility test both timothy and Lotus plants were well distributed, forming a good mixed sward. The farmer was of the opinion that the trefoil had thickened since the year of seeding (1947). He also reported that birdsfoot plants had competed well with timothy during the previous year, the latter tending to support the birdsfoot in a more or less erect position during growth. Good yields of mixed hay and aftermath were produced on the area. Other plants including weeds and unseeded species were scarce.

Observations on these plots in mid-June 1949, indicated that the area was doing very well. The plot which received 2-12-10 at the rate of 800 pounds per acre was showing greatest response at this time in regard to height of foliage. By early October 1949, treated plots appeared more vigorous than the check and the strip of trefoil with timothy was very conspicuous in the field, especially from a distance. It showed up clearly because of its brighter green foliage than the remainder of the field.

Point quadrat readings showed that percentage of birdsfoot in the sward had increased while that of timothy had decreased during the growing season of 1949 (Table 4). Close inspection of fertilized plots at this time revealed a considerable amount of undissolved fertilizer still lying in granules on the soil surface. This was apparently due to the dry weather of 1949 and may partly explain why the check plot during that season showed an increase in birdsfoot equivalent to that of the highest fertility plot. That is, only a small amount of the fertilizer applied became actually available to the plants.

Point quadrat counts on the fertility plots in the spring of 1950 showed good winter survival of both birdsfoot and timothy. Many new seedlings of the legume were becoming established. During the month of October 1950, the birdsfoot and timothy appeared very satisfactory with a vigorous mixed sward of legume and grass. Calculations of percent cover made from quadrat counts did not show any appreciable difference between the rates of fertilization, or even between fertilized plots and the check. However, they did indicate a substantial decrease in birdsfoot and an increase in timothy over those of the 1950 spring readings.

Other workers refer to experiments where fertilization has caused a decrease in birdsfoot associated with an increase in grass species. Midgley (43) reports a decreased yield of birdsfoot following a nitrogen application, apparently due to stimulation of competing grasses. As previously pointed out, Hall and Russell (18) at Rothamsted found birdsfoot trefoil to be the most prominent legume on unfertilized plots sixty years after establishment. Under nitrogenous dressings, the species disappeared. Smith (56) and Midgley (43) both suggest that manure be used sparingly on birdsfoot seedings because it stimulates grasses and weeds to the extent of crowding out the trefoil.

By referring to Table 4 it may be seen that all plots except those of the check and the 200 pound per acre application showed an increase in percentage of other plants which were chiefly weeds, during the season of 1950. In conclusion then, the increase of weeds and timothy associated with a decrease of birdsfoot as observed on the fertility plots during the 1950 season, appears to have been the result of stimulation similar to that reported above, due to the topdressing of manure applied in the autumn of 1949

Effect of 2, 4-D on Birdsfoot.

(a) Seedlings Sprayed in Field.

Experiments concerning the effect of 2, 4-D on birdsfoot trefoil were carried out to determine whether the species possessed any degree of resistance to applications of this material. If sufficiently resistant to damage from 2, 4-D, the spraying of new birdsfoot seedings with such a chemical might offer a practical solution to the weed problem during early establishment of trefoil seedlings.

Individual plots of the weed control experiment were approximately 375 square feet in area, and were sprayed August 22, with a commercial 2, 4-D preparation, "Herbate". This is a water soluble 2, 4-D compound of the plant growth regulant class, manufactured by Canadian Industries Limited under the Registration Number 583. Rates of two, four and 16 ounces per acre in two gallons of water were applied per plot.

Observations made daily for a week immediately after spraying showed damage to pigweed (Amaranthus retroflexus L.) and lamb's quarters (Chenopodium album L.) but purslane (Portulaca oleracea L.) appeared unharmed. Birdsfoot plants showed slight twisting of growing tips, but generally gave little evidence of serious damage.

Continual observation of sprayed plots for a month following application of 2, 4-D showed distinct differences between the damage done to birdsfoot plants on the two ounce per acre plots and those of heavier application. On the eight and 16 ounce per acre plots many birdsfoot plants were killed completely, with leaves brown and crisp. Some plants showed such damage on the uppermost leaves, while near the base foliage remained green and alive. Damage to birdsfoot seedlings was not extensive on the two ounce per acre plots. This rate of application caused birdsfoot foliage to turn a reddish color but there was little death of tissue and plants remained growing. Trefoil plants on such plots produced a substantial increase to the sward during the month subsequent to 2, 4-D application. Timothy foliage increased on all sprayed plots, as did that of wild grasses present.

Purslane was seriously injured on all plots and from 85-90% killed. Pigweed and occasional plants of alsike clover (T. hybridum) present were also killed. Lamb's quarters and other broad leaved weeds were severely injured or killed. Little difference could be discerned in injury to the weeds between low and high rates of 2, 4-D application.

The slight injury to birdsfoot seedlings on the two ounce per acre plots, points to the possibility of controlling weeds profitably on new stands of this species, through the use of light applications of 2, 4-D. One of the major problems in successful establishment of birdsfoot is the control of weeds, since weeds have a tendency to crowd out the young birdsfoot seedlings during early stages of growth. The latter statement has been well demonstrated through the course of this investigation and other workers (65) have reported similar problems elsewhere.

(b) Seedlings Sprayed in Greenhouse.

Seedlings of Bunker narrowleaf, Empire broadleaf, big birdsfoot trefoil and Dollard red clover (T. pratense) were sprayed with 2, 4-D in the greenhouse during the fall of 1950. The commercial 2, 4-D "Herbate" preparation used in the field experiment was again employed, at the rate of 16 ounces per 50 gallons of water. Each pot was sprayed until the foliage dripped. Stages of growth at which the four sprays were applied are given in Table 5. Pots were observed closely throughout the experiment and for a period of one month after the last application of 2,4-D.

Table - 5 - Stages of Seedling Growth When 2,4-D Applied

Plants Sprayed	Number of True Leaves at Spraying Dates			
	Nov. 14.	Nov. 23.	Dec. 2.	Dec. 11.
Bunker birdsfoot	3	4	5	6
Empire birdsfoot	3	4	5	6
Big birdsfoot	3	4	6	7
Red clover	3	4	5	7

The immediate observation in all sprayings was the more rapid susceptibility of red clover seedlings to visual injury than those of birdsfoot trefoil. At all stages of growth indicated in Table 5, red clover showed twisting of stems within 12 hours of 2, 4-D application. By the end of 48 hours severe twisting had occurred. Badly wilted leaves and dead plants of red clover were common four days after each application. Petioles of red clover leaflets showed characteristic twisting, bending backward sharply to fold the leaves together, while the main stem of many plants turned downward to give the impression of burying their folded leaves in the soil. Crowns of red clover plants became more open than normal and roots decayed, enabeling the plant to be lifted freely from the soil. Close inspection of these red clover roots revealed that the decaying process started at the growing tips and gradually moved towards the soil surface. All red clover plants of the first spraying date were dead one month after application of 2, 4-D. Results from later sprayings were similar to the first, except that occasional plants maintained a single green leaf for several weeks. These plants finally proceeded to produce new shoots from the crown, but leaves were crinkled and dwarfed in appearance.

Empire birdsfoot plants showed no damage or twisting within 48 hours of spraying and many appeared normal for 72 hours after application of 2, 4-D. When twisting did occur it was relatively slight compared to that of red clover. The most conspicuous early damage to Empire seedlings was a folding back of leaves and thickening of stems into club like structures. Subsequent symptoms included a drying out of terminal leaves, and yellowing of foliage generally followed by death. The most severely damaged Empire plants were those of the first spraying date. One month after spraying all of this group were dead. When sprayed at more mature stages of growth Empire gave evidence of greater resistance to 2,4-D. Twisting of stems was less and more serious damage was longer appearing. Occasional plants appeared perfectly healthy except for stunting and a few yellowed leaves. Thickened stems however were found in all pots of Empire, and plants which died were seen to have decayed roots similar to those of red clover. Several Empire plants in the later sprayings survived, and proceeded to develop normally by sending up new growth from the crown.

Injury to big birdsfoot seedlings was very severe especially in the first spraying group. Plants of this species remained normal for 48 hours after spraying with no sign of injury. Twisting began suddenly on the third day and within three more days entire plants had died. All big birdsfoot plants in the first spraying group were dead at the end of two weeks. Seedlings involved in the second spraying showed more resistance. Twisting of stems began shortly after spraying followed by leaf curling and yellowing of foliage. Big birdsfoot pots of the second spraying group contained living plants up to six weeks after application of 2,4-D. In the remaining two spray groups occasional big birdsfoot plants showed slight twisting in 12 hours, coalescing dead spots appearing on the foliage within a week following spray application. This condition was not observed on other species or strains studied. Leaves finally became yellowish in color with very noticeable thickening of young lateral branches and stems. Several large swollen lesions appeared on the stems. An occasional plant of big birdsfoot remained alive and growing at the conclusion of the spraying experiment.

Comparing the strains and species tested, Bunker narrowleaf birdsfoot presented the most resistance to damage from 2, 4-D, under conditions of this spraying experiment. Although resembling Empire with folded dessicated leaves and development of club like stems, resistance of Bunker to further damage appeared greater. Immediately after spraying, seedlings remained upright with only slight twisting and edges of leaves damaged. About a week after spraying, stunting of plants was observed. Dwarfed leaves developed on club like tillers with shortened internodes. Occasional plants developed small lesions on the stems. Pots of the first spraying maintained living green plants until six weeks after application of 2, 4-D. This was an additional two weeks survival beyond that of corresponding Empire pots. Observations at the end of the experiment indicated about 20% survival of Bunker plants in the last two spraying groups. These consisted mainly of damaged or deformed plants which were sending up normal foliage from the crown.

One factor appearing to cause the greater susceptibility of red clover to 2, 4-D injury was its open crown structure. Such a crown tends to collect and hold the spray materials with one of two results. The crown either dies very shortly itself due to effects of the 2, 4-D, or failing that, each new leaf coming up from the crown contacts the 2, 4-D resulting in deformity or early death. Crowns of birdsfoot compared to those of red clover are smooth, so that any excess spray material simply runs off. New birdsfoot tillers growing up from the crown are therefore, less subject to damage by a residue of 2,4-D material than are those of red clover plants.

The dense hairiness of red clover stems and leaves collects and retains more of the spray than a hairless surface, resulting in greater damage from the 2,4-D than that suffered by foliage of the latter type. This factor probably accounts in part for the severe injury suffered by big birdsfoot from 2,4-D applications. Big birdsfoot plants are very hairy but the remaining strains tested (Bunker and Empire) are free from hairs. Therefore, foliage of the latter birdsfoot types would shed a greater proportion of the spray applied to them and consequently receive less damage.

The bending of leaf petioles backward and stems downward as well as lesion formation are all characteristic effects of 2,4-D application, as pointed out by MacLean (39) in his discussion of the subject.

There is no doubt that under field conditions, less 2,4-D would contact the birdsfoot plants than in the greenhouse from an application of similar strength, because surrounding foliage of weeds would collect a large proportion of the spray materials. Therefore, damage to birdsfoot foliage should be less than in this experiment. Trials reported here concerning effects of 2,4-D on birdsfoot have been limited. A problem of this nature requires more extensive research under a greater variety of conditions. However, from response of Bunker seedlings in this greenhouse test one might propose that light experimental applications of 2, 4-D to weedy seedings of Bunker birdsfoot be carried out under field conditions. The importance of weed control during establishment of birdsfoot seedings cannot be over emphasized and a practical solution to this problem is of definite importance.

Silage Experiment

The quart sealer experimental silos were stored at room temperature for six and a half months, then opened and judged for quality by the Professors of the Agronomy Department. When opened at this time (January) sealers of the check treatment exerted the greatest pressure on the covers, but all discharged a sharp smelling gas when the covers were loosened.

Duplicate samples of silage were taken for the purpose of measuring the pH. To accomplish this, a representative 50 gram sample of the ensiled material was placed in a 250 millilitre beaker and 150 c.c. of distilled water added. After thorough and intermittent stirring the samples were left standing overnight. The next morning they were stirred and agitated further to form a thick slurry. pH readings were taken on this material by means of a pH meter in the Chemistry Department. Dry matter content of the various treatments was determined by taking 100 gram duplicate samples of each and drying in the oven at 100° C until a constant weight was reached. Percent dry matter and pH readings of silage are presented in Table 6.

Table 6 - Percent Dry Matter and pH Values of Birdsfoot and Birdsfoot-Timothy Silage

Treatment	pH	Percent Dry Matter
Pure Stand Birdsfoot		
No preservative	4.4	21.5
5% molasses	4.0	23.8
4% P_2O_5 (10% solution)	3.8	19.5
Birdsfoot and Timothy Mixture		
No preservative	4.0	25.8
5% molasses	4.2	27.0
4% P_2O_5 (10% solution)	3.7	24.0

Results presented in Table 7 were obtained by Woodward and Shepherd (67) in experiments involving different methods of making silage from alfalfa.

Table -7 - Percent Dry Matter, pH Values and Quality Ratings of Alfalfa Silage Made by Woodward and Shepherd.

Treatment	pH	Percent Dry Matter	Quality
No preservative	5.3	25.6	Good
3% molasses	4.9	26.1	Good
10% 2N HCl--H_2SO_4	3.5	25.8	Good

The apparent quality of such silage was rated as good. Comparing the pH and dry matter values of this table with those obtained from the birdsfoot silage in the trial under discussion, one can see that there is not a great deal of deviation. Therefore a reasonable conclusion would be that the birdsfoot and birdsfoot-timothy mixture made good silage under conditions of this experiment. This statement is supported further by those who examined the silage at time of opening. They felt that it was all of good quality and maintained that dairy cattle should find it very palatable as a constituent in their diet.

Flooding Experiments.

(a) Flooding Previous to Emergence.

In flooding of forage crop seeds before emergence MacKenzie et al (42) found alsike and alfalfa to emerge fairly well after three weeks flooding. Results obtained by Bolton and McKenzie (7) indicate a definite upper limit of tolerance to flooding for forage crops and also show that there are great differences in ability of crops to withstand early spring flooding.

An endeavor was made in this investigation to determine the performance of birdsfoot under flooded conditions in the greenhouse. Seeded pots of *L. uliginosus* and three strains of *L. corniculatus* (Bunker, Empire and E-495) were subjected to flooding before emergence for periods of one, two, three and four weeks. Observations were made on relative emergence after flooding but the objective was extended to also consider final percentage stand of the plant types involved.

Heinricks and McKenzie (20) found that reed canary grass seed would not emerge under flooded soil conditions, but following removal of water emergence began in about two weeks. Observations on the flooded birdsfoot pots in this experiment however, indicated slight germination three days after application of water. By the end of five days emergence had occurred in all flooded pots. One week from seeding time emergence was observed in all check pots except those of L. uliginosus. The latter required 10 days to emerge.

Occasional seeds were dislodged from the soil when water was applied and these produced young seedlings which floated on the water with cotyledons above the surface and roots below. Few of these seedlings actually rooted while flooded, but those of the one and two week flooding periods did produce normal plants after removal of water. In the pots flooded for three and four weeks most of these floating plants died before the water was drained off, although a few of Bunker strain were observed rooted. Measurements made on a number of these plants after floodings were removed showed them to possess roots extending above the soil surface for distances of two to three inches. Bunker was the only strain observed to demonstrate such a tendency.

Within 10 days of flooding, small bubbles were observed on the water surface of several pots. These were apparently the beginnings of algae colonies because from that time on the water surface of most flooded pots was covered with a vigorous green growth. This hampered observations and increased seedling casualities. Efforts to control the algae met with little success, but it was removed at frequent intervals and immediately prior to each draining. However, it invariably formed a slight greenish crust over the soil surface and leaves and appeared to cause unthriftiness among the seedlings. Other seeds continued to germinate in spite of this, with no apparent differential response among the plant types studied.

At termination of all floodings, plants were allowed to recover and grow normally for a period of nine weeks, with stand counts and observations being made regularly. At the end of this time foliage was harvested and final stand counts made. Final percentage stand of birdsfoot plants per pot was calculated by means of the following formula;

$$\text{Final percentage stand per pot} = \frac{\text{Final stand in pot}}{\text{Percent germination of seed}} \times 100\%$$

Germination percentages were calculated from seed samples placed in the germinator at the beginning of the experiment. Averages of the final percentages per pot are presented in Appendix Table VI. Since some of the percentages obtained were very high and others were very low, the data was transformed to degrees prior to analysis, according to the method described by Hayes and Immer (19). Appendix Table VII presents average final percentages per pot expressed in terms of degrees. Flooding and strain means also in degrees and L. S. D. values determined in an analysis of the transformed data are listed in Table 8. A more detailed analysis of variance table is presented in Appendix Table VIII.

Table 8 - Flooding and Strain Means Expressed as Transformed Data. (Degrees)

Flooding	Means	Strain (Species)	Means
0 weeks	45.00	Bunker	42.12
1 week	32.45	E-495	26.05
2 weeks	30.41	Empire	25.82
3 weeks	24.76	Big birdsfoot	24.76
4 weeks	15.81		

L. S. D.- 5% - 8.95 L. S. D. - 5% - 8.18

L. S. D.- 1% -12.45 L. S. D. - 1% -10.89

The check pots of zero flooding gave a highly significant final percentage stand over those of all floodings. One and two weeks of flooding both resulted in highly significant final percentage stands over the four weeks flooding treatment. Difference in final percentage stand between the three and four weeks of flooding reached significance in favour of the three weeks treatment.

Considering strains and species tested Bunker narrowleaf birdsfoot produced a final percentage stand of high significance over that of all others. There was no significant difference in final percentage stand between big birdsfoot, Empire and E-495 under the conditions of this experiment.

According to Hughes and Heath (22), narrowleaf strains of birdsfoot are best adapted to moist soils. MacDonald (38) also reports that the narrowleaf strain of birdsfoot trefoil is more suited to moist situations than the broadleaf types. Such statements lend support to the findings on the performance of Bunker narrowleaf strain in this test. Results from this flooding before emergence experiment indicate that further experimental trials involving Bunker strain might be profitably conducted on spring flooded areas. Such tests may lead to successful establishment of narrowleaf birdsfoot strains on land too wet for most long lived legumes.

(b) Flooding After Emergence.

To supplement the previous flooding experiment a second one was carried out, also in the greenhouse. Its objective was the determination and comparison of resistance in young birdsfoot and red clover seedlings to different lengths of flooding after emergence. Two prostrate strains of *L. corniculatus*, namely Bunker narrowleaf, and Empire broadleaf were included, as well as seedlings of big birdsfoot and Dollard red clover.

Pre-seeding germination of seed was carried out to overcome the hard seed problem of birdsfoot seed samples. A definite number of seedlings were desired with which to start the experiment. Therefore by avoiding the planting of any hard seeds, it was felt there would be no danger of additional plants emerging at the conclusion of the flooding periods.

Observations after seeding showed that seedlings of all species emerged within forty-eight hours. Emergence of big birdsfoot was poorer than the others so that a second seeding of this species was necessary. Three weeks beyond seeding and immediately prior to flooding, L. corniculatus plants as well as a number of big birdsfoot had reached the five-leaflet stage. Plants from the re-seeding of L. uliginosus were well emerged by this time but had not reached the stage of growth referred to above.

General observations were made on the performance of plants during the experiment and up to time of harvesting. When the water was removed all birdsfoot pots of the one week's flooding appeared considerably poorer than corresponding checks. Differences between trefoils in the check pots at this time were practically nil.

Observations made on pots ten days after termination of floodings indicated that Bunker narrowleaf plants possessed more foliage than other Lotus strains. Plants of Bunker were also characterized by a darker green color than the others. This strain continued to recover rapidly and at the termination of the experiment possessed the largest number of living plants. For this reason growth in the Bunker pots appeared more restricted in comparison to other trefoils. Check pots contained a few yellowed leaves near the soil surface but all uppermost foliage possessed a deep green color. An abundance of new tillers were springing up from the crowns of plants, and pots of three and four weeks flooding were noticeably more succulent in growth habit than those of the check.

Early observations on Empire pots shortly after removal of floodings showed this strain to be almost as vigorous as Bunker. In all four replications of Empire new stems were observed growing up where top growth had previously died. Death of this tissue had occurred at the end of the two week flooding period. About 50% of the Empire stand was seen to recover in this manner. Empire check pots were superior in all replications because of a greater number of plants and consequently more foliage than flooded pots. Plants grew very close to the soil surface forming a dense mat, and thus differed from Bunker which developed a more erect growth habit under greenhouse conditions. Periods of least flooding in Empire strain produced more foliage than the three and four week floodings. All plants showed excellent color but of a lighter green than Bunker strain.

An estimated 75% of big birdsfoot plants sent up new topgrowth after flooding in a manner similar to Empire strain. Occasionally, new green foliage and dry withered leaves appeared on a plant at the same time. On others, new topgrowth was separated from the main root by a short length of shrivelled brown stem tissue. In general, plants of big birdsfoot appeared to suffer more from the actual flooding than those of Bunker and Empire strains. Foliage was of a lighter green color than that of <u>L. corniculatus</u> plants, and in some pots only a small percentage of seedlings had survived the treatments. During the month preceeding harvest however, big birdsfoot pots made a surprising recovery. In many individual pots of this species, the amount of final foliage produced exceeded the strains of <u>L. corniculatus.</u> Leaves were broad and much larger than those of Empire, the other broadleaf type considered. Individual leaf areas of big birdsfoot plants were three to four times greater than those of Empire. Rhizomes were abundant in the pots with tiny roots growing out all along their length. In a few pots of the two, three and four week floodings, roots were visible at the soil surface. Foliage of big birdsfoot remained a light green color, that of the four week floodings being almost yellowish green.

Red clover pots of one week's flooding looked superior to corresponding checks when water was removed, in that leaves were larger, plants were taller and incidence of mildew was less. From 75-80% of foliage in the check pots contained mildew, while those flooded for a week showed only 25-50% infection. In addition plants of red clover check pots showed a marked tendency to wilt while all others including Lotus stood erect. Foliage on checks was readily discernable because of a characteristic darker green color than remaining pots. Similar observations on red clover pots throughout the following month and immediately preceeding harvest indicated little difference in outward appearance between the five treatments. Check pots contained dead foliage around crowns of plants with smaller and less succulent leaves than those flooded. During the recovery period following removal of water, red clover foliage turned a darker green, with that of the longer floodings being progressively lighter in color and least infected with mildew. Fine rootlets appeared at the soil surface of red clover pots during the last week of flooding, apparently in an attempt to secure more oxygen. These roots remained at the surface after removal of water with their tips growing back into the soil. Some were several inches in length with small nodules attached. Such roots were not present in any of the remaining red clover pots.

At termination of experiment one month following removal of the last flooding, foliage in all pots was harvested and final stand counts made. Percentage survival per pot was calculated by reference to the original number of plants present when floodings were applied. This percentage data covered a wide range and was therefore transformed to degrees, similar to the percentage data obtained in the flooding previous to emergence test. Appendix Table IX presents average final percentage stand per pot and these averages expressed in degrees are presented in Appendix Table X. Flooding means in degrees, and L. S. D. values calculated in an analysis of variance of the transformed data may be found in Table 9. A complete analysis of variance table is presented in Appendix Table XI.

Table 9 - Flooding Means Expressed as Transformed Data. (Degrees)

Flooding	Means
0 weeks	84.73
1 week	77.63
2 weeks	66.62
3 weeks	60.87
4 weeks	55.71
L. S. D. - 5% -	13.39
L. S. D. - 1% -	18.63

Check pots produced a significantly greater final stand than those flooded for two weeks and a highly significantly greater final stand than those of the three and four weeks flooding. There was no significant difference in the final stand produced between the two, three and four weeks of flooding. Similarly, there was no significant difference between strains or species tested in regard to the final stand of plants under conditions of this experiment.

When the two flooding experiments were designed it was expected that L. uliginosus (big birdsfoot) would demonstrate superior recovery and survival over all others included. Such a belief was based on numerous reports in the literature. From Oregon, Howell (21) reports instances of L. uliginosus being flooded during the winter season for three or more months without apparent damage to the stand. Robinson (49) indicates that L. uliginosus is a typical plant of moist situations useful for colonizing marshy or peaty land. An anonymous (2) publication from New Zealand as early as 1916 made reference to big birdsfoot as doing best on damp soil. Montgomery (46) has also found it persisting on drained and semi-drained swamps of New Zealand.

It must be understood that care should be exercised in drawing conclusions from greenhouse experiments on the assumption that field conditions have been simulated. The failure of big birdsfoot to emerge well after the first seeding may have been due to the depth of seeding. All seeds were covered to approximately the same depth when seeded, but big birdsfoot may be more sensitive than L. corniculatus to depth of seeding since it is smaller seeded. The majority of big birdsfoot pots were not as far advanced as those of L. corniculatus or red clover when floodings were applied. Plants of the former were thus subjected to a disadvantage which probably contributed to the lower final survival of the species. Many big birdsfoot plants were still in the first or second true leaf stage when flooded and were covered completely by the water. Naturally such plants would have less chance of survival than the larger ones of L. corniculatus and red clover, which in many cases reached well above the water. However, since both the latter species were developing rapidly, flooding could not be further delayed. Such action would have defeated the primary objective of the experiment, that of testing the resistance of young seedlings of these species to different lengths of flooding.

The possible merits of big birdsfoot should not be discounted on the basis of this greenhouse trial. There is the observational evidence of a somewhat outstanding recovery after removal of water in pots of this species. Such performance indicates that big birdsfoot trefoil must possess certain inherent characteristics, favorable to or resistant to prolonged periods of excessive soil moisture. Considering final stands of L. corniculatus obtained in these preliminary greenhouse flooding tests, one might conclude that short periods of spring flooding should not prevent the establishment of birdsfoot seedings. However, further investigations of birdsfoot resistance to soil flooding under actual field conditions are necessary before definite recommendations can be made in this direction.

Root Studies

Individual plants of L. corniculatus spaced 4 X 4 links apart and staggered in rows 51 links in length were grown in the Agronomy fields on two soil types, one of sandy loam (Range 11E, Northwest Field) and one of medium loam (Range 32, East Field). Plants of Bunker and Empire birdsfoot were seeded for this study. The objective was to compare these two strains in regard to growth of roots and tops, when growing free from competition.

When the plants had reached 12 weeks of age, soil surface areas covered by their individual spreading tops were measured. Thirty six plants of Bunker and 36 of Empire were measured in this manner on each of the two soils. Table 10 includes average areas of soil surface covered by the two strains.

Table 10 - Comparison of Average Areas Covered by Topgrowth of Individual Bunker and Empire Plants Determined from 36 Measurements of Each.

Soil Type	Average Area Covered per Plant (sq. cm)	
	Bunker	Empire
Medium loam	4402.7	2547.9
Sandy loam	810.4	486.8

For comparison of strains on medium loam soil, "t" = 5.6014.

For comparison of strains on sandy loam soil, "t" = 5.3083.

At 1% level of significance in each instance "t" = 2.5758.

Statistical analysis of data represented in Table 10 was carried out using the "t" test as outlined by Paterson (47). This analysis indicated that when both strains were grown free from competition, the vigorous topgrowth of individual narrowleaf Bunker plants covered a highly significantly greater area than corresponding broadleaf Empire plants on both soil types. The much greater growth of both strains on medium loam compared to sandy loam soil is immediately apparent from the data.

At 19 weeks of age, typical individual plants of Bunker and Empire on each soil type were selected for root measurement. For this purpose, a one cubic foot wooden box was constructed with an open bottom, a partially open top and one screened side. A trench, 18 inches in depth was dug around each selected plant leaving a cubic foot of soil containing the plant in the center. The box was then fitted down smugly over the intact portion of soil, removed from the excavation and transported to the greenhouse. Here the larger portion of soil was washed from the roots by applying water from an adjustable hose nozzle through the screened side of the box. Finer soil particles adhering to the roots were later removed by hand under a water tap in the sink. A total of four individual plants, one from each strain involved on the two soil types were removed and washed out in this manner. Relative volumes of tops and roots were determined by displacement of water in a large graduated cylinder, after which plants were preserved in formaldehyde solution for future reference. Results of these measurements are found in Table 11.

Table 11 - Relative Root and Top Volumes of Individual Bunker and Empire Plants, Grown on Two Soil Types.

Plant Part	Medium Loam		Sandy Loam	
	Bunker	Empire	Bunker	Empire
	c.c.	c.c.	c.c.	c.c.
Root	265	150	55	55
Top	740	810	105	128

By reference to Table 11 it can be seen that the development of roots and tops in both strains was considerably less on sandy than on medium loam soil. It would therefore appear that under conditions of this experiment, Bunker and Empire strains are better adapted to medium loam than to sandy loam soils. A similar conclusion may be drawn by reference to the areas covered by tops of these strains in Table 10.

Bunker and Empire strains were also studied in a somewhat similar manner to determine differences in volume of roots and tops on sandy and medium loam soils when grown in pure stand compared to growing in mixture with Drummond timothy. These plants were not grown individually but were seeded in row plots each 51 X 7 links in area, immediately adjacent to the plots containing individually spaced plants. Eight of these seeded plots were established, including a pure stand and a mixture with Drummond timothy of both Empire and Bunker strains on each of the two soil types.

At the end of the growing season, one cubic foot of soil containing plants was selected at random from each plot and removed to the greenhouse in the manner described for individual plants. Washing procedure was also similar to that described above. Relative root and top volumes were determined again by displacement of water. Vegetation and roots removed from soil were photographed and preserved in sealers for future reference. A similar procedure was repeated in the fall of 1950 and included plants which had overwintered as well as numerous birdsfoot seedlings which had grown up during the summer.

Relative volumes of roots and tops of Bunker, Empire and timothy plants removed from the soil during 1949-50 are presented in Appendix Table XII. The two year's volumes of Bunker and Empire plants determined in this study are included in Table 12.

Table 12 - Volumes of Bunker and Empire Plants From One Cubic Foot of Soil Grown on Medium and Sandy Loam in Mixture with Drummond Timothy and in Pure Stand, During 1949 and 1950.

Type of Seeding	Volumes of Birdsfoot Trefoil.							
	Medium loam				Sandy loam			
	Roots		Tops		Roots		Tops	
	1949 c.c	1950 c.c	1949 c.c	1950 c.c	1949 c.c	1950 c.c	1949 c.c	1950 c.c
Bunker and timothy	192	140	385	210	110	105	160	145
Empire and timothy	155	90	190	110	140	125	138	170
Bunker pure stand	190	120	265	205	156	185	215	280
Empire pure stand	140	185	355	305	100	195	115	200

No consistent difference was evident in growth of seeded plants on the two soil types compared to striking differences when individual plants were grown on the same areas (Table 11).

As already stated, both the 1949 and 1950 figures in Table 12 were obtained from plants on identical plots seeded in the spring of 1949. Therefore one would expect the root volumes at least of birdsfoot strains to be larger in the second year. However, such an increase occurred only on the pure stand plots of Empire during the second year. All other plots of Empire and Bunker, either in pure stand or mixture show an actual decrease in plant root volumes during 1950. The explanation for this seems to be that some of the 1949 plants were winterkilled, with the result that many of those dug up and measured in 1950 were actually new seedlings. Such an explanation appears logical, especially when one observes in Figure D the number of seedling plants present among those washed from Bunker pure stand plots during 1950.

Due to the difficulty of accurately determining the speed and depth of root growth of birdsfoot in an ordinary pot or in the field, two wooden boxes were constructed in the spring of 1950 for a preliminary trial in the greenhouse. These boxes measured 24 X 18 X 9 inches in volume and were fitted with a removable glass front and an open top. A removable covering of heavy insul board was fitted over the glass. Each box was filled with a loamy clay and sand mixture and a single plant established near the glass front, so that the roots could be observed in their downward growth. A Bunker plant was established in one box and

Figure D - Bunker Pure Stand Plants Washed From One Cubic Foot of Sandy Loam Soil, October 1950. Plants With Smaller, Shorter Roots are 1950 Seedlings. Area Seeded, May 1949.

an Empire plant in the remaining box, but the former was discarded at a later date because of glass breakage.

Root growth of the Empire plant was checked daily. For about a week after germination, root growth was very slow, but by ten days after emergence, downward rate of growth had increased to approximately one inch per twenty-four hours as shown in Figure E. This continued until the bottom of the box was reached (24 in.) six weeks from seeding time. A slender tap root first grew straight down with very little branching. During the same period top growth had only amounted to six inches of semi-prostrate foliage.

Immediately on attaining this depth the root system began to spread out and numerous branches were observed near the glass front. When this happened top growth became very rapid and a large bushy plant quickly developed at the soil surface.

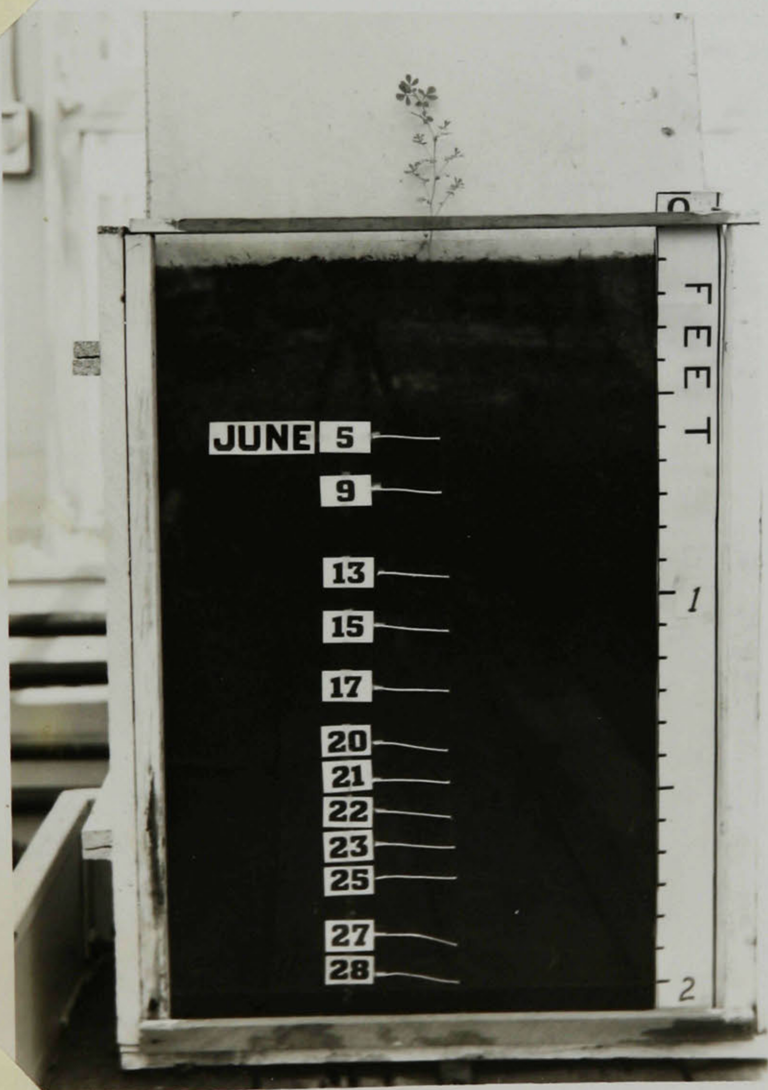

Figure E - Root Development of Six Weeks Old Empire Birdsfoot Plant in Glass Fronted Box in Greenhouse.

Fourteen weeks after emergence the entire plant was washed from the soil by means of a garden hose equipped with an adjustable nozzle. Volume of roots and top were determined by displacement of water in a graduated cylinder. Length of roots and top when stretched out was also measured. These may be noted in Table 13.

Table 13 - Root and Top Measurements of a Fourteen Weeks Old Empire Plant Grown in Box With Glass Front.

	Volume	Length
	c.c.	in.
Roots	35	35.5
Top	260	29.0

Top growth of the plant was removed, photographed, and placed in a press, while the root itself was mounted on a black background with shellac and also photographed. These portions of the plant may be seen in Figures F and G respectively.

Although it is realized that a normal compact soil profile was not used in this greenhouse box, it is felt that the behavior observed closely parallels what actually happens in the field. Early top growth of birdsfoot seedlings is always slow, as was observed in all field trials conducted here. This fact is recognized as one of the disadvantages of the Lotus species. Slow development of tops in early stages of growth is apparently

Figure F - Topgrowth From Fourteen Weeks Old Empire Plant Grown in Glass Fronted Box in Greenhouse.

due to extensive root development going on below the soil surface at that time.

Single plants of the original nine strains of L. corniculatus supplied by Dr. MacDonald were started in the greenhouse in eight inch glazed earthen crocks. These were buried in the field to soil level when emergence was complete. Starting when eight weeks of age, these plants were washed from the soil at regular intervals of four weeks throughout the summer, and relative root and top volumes of progressively older plants

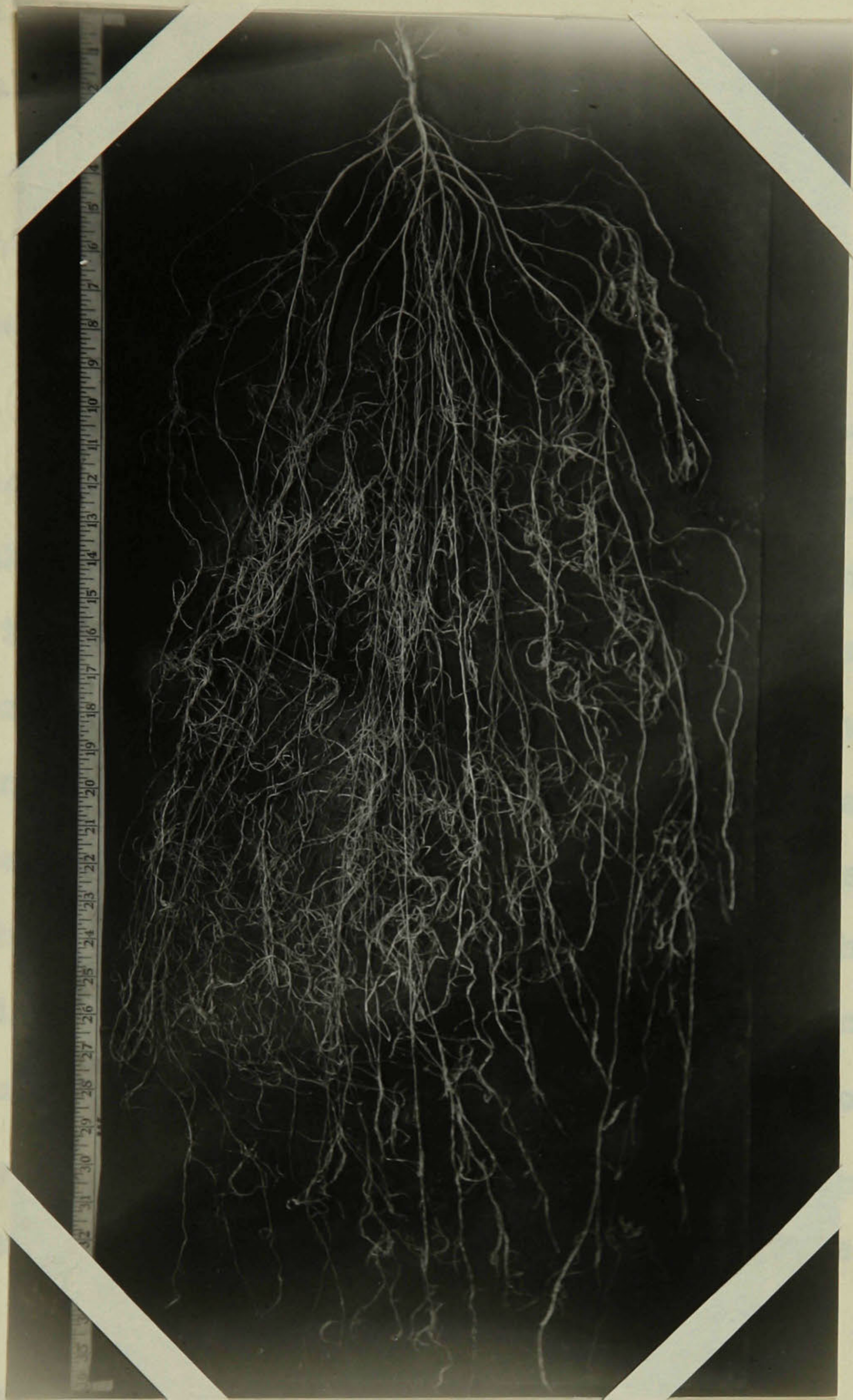

Figure G - Root of Fourteen Week Old Empire Plant Grown in Glass Fronted Box in Greenhouse.

determined by displacement of water. Root and top lengths of the 16 and 20 week old plants were also measured.

Due to certain casualties of plants a complete record of each strain was impossible to obtain. However, available data from the above described measurements and determinations is presented in Appendix Table XIII.

Because of the preliminary nature of this test, sufficient data was not obtainable to allow proper statistical analysis. Therefore, discussion must necessarily be limited to observations and notes made during the period it was carried on. At twelve weeks of growth, root volumes of all prostrate strains were less than those of the uprights, but as plants grew older this difference disappeared, until among the 20 week old series, roots of one prostrate strain, V-103, were equivalent to the best of the uprights. In washing out these roots they were observed to have proceeded down to the bottom of the crocks almost immediately, where they continued to grow in a circular manner around the inside. With plants 12 weeks old and older, the greatest concentration of roots was at this point, with fine rootlets emerging from drainage holes in the crocks. Such restricted root development resulted in poor and irregular topgrowth as evident in the table of data.

In conclusion then it might be stated that strains grown in crocks and buried in the field did not have a reasonable chance to express any inherent differences which they might possess. The apparently normal habit of birdsfoot roots to grow straight downward for a considerable distance prior to development of side branches was impossible. Therefore, no definite conclusions with respect to strain differences should be drawn from results of this test. Such a technique however, would probably prove useful for determining such differences in very young plants or during early stages of growth.

Vegetative Propogation

Two sets of stem cuttings taken from potted Bunker plants were established in sand in the greenhouse. One set was treated with a commercial rooting preparation containing the plant auxins indole butyric acid and alpha napthyl acetic acid, the other set received no treatment. One month later all cuttings were washed free of sand, percentage of rooting calculated and a few selected for photographing. Of the treated stem cuttings 88.7% had developed roots at the end of this period and of those untreated, 85.0% were rooted. Blooms were observed on several plants. Beyond a slight increase in the number of roots developed per cutting under treatment, there was little difference between the two sets. The most interesting point in this trial was the presence of numerous nodules on practically all new roots developed in the sand as seen in Figure H. Such a phenomenon suggests that nodule bacteria suitable for narrowleaf Bunker birdsfoot strain were already present in the sand when the stem cuttings were first placed there.

Root cuttings from potted plants of Bunker, Empire and big birdsfoot were made by splitting larger roots longitudinally into smaller segments, and placing in flats of moist sand.

Figure H - Rooted Stem Cuttings of Narrowleaf Bunker Strain. (1) Untreated Cuttings (2) Treated With Rooting Preparation.

None of these were treated but two types of cuttings were made; (1) those including a portion of the crown on each segment, and (2) those made solely from the true root with no crown tissue present. Big birdsfoot root segments included in all cases a portion of the crown, since the only available plants were young with very short and shallow roots. At the end of one month, all cuttings were washed from the sand and percentage of those rooted calculated. Table 14 presents the percentage of Bunker, Empire and big birdsfoot root cuttings alive at the time of washing from the sand.

Table 14 - Percentage of Living Birdsfoot Root Cuttings After One Month in Sand.

Strain	Root and Crown	Root Only
	%	%
Empire	33.7	7.5
Bunker	42.5	0
Big Birdsfoot	41.9	No cuttings available

Midgley and Gershoy (44) experienced excellent results in vegetative propogation tests with crownless segments of birdsfoot trefoil roots. Results from the above described preliminary trial of this nature carried on in the greenhouse were not very successful. All Bunker crownless segments failed to survive, while of Empire only 7.5% produced new plants. This does indicate promise for the narrowleaf strain however, since immature plants were used, whereas the above workers had mature plants with long tapering tap-roots at their disposal.

In connection with vegetative propogation an interesting observation was made in the fall of 1949 on the root study plot of medium loam soil. An individual spaced plant of Bunker was observed to have a branch partially torn away from the main stem, which became rooted at the point of injury. Further observations in the spring and summer of 1950 showed the original mother plant to have been winterkilled, while the rooted branch survived the winter and produced abundant top growth throughout the growing season. This plant was photographed and is shown in

Figure I. These observations as well as those of the seedings on Ranges 1 and 32 East Field regarding the rooting of birdsfoot plants at points of injury, suggest the possibility that occasional disking or heaving might thicken up old established stands of birdsfoot trefoil.

Figure I - Rooted Branch of 1949 Bunker Plant Photographed in May 1950. (Lower left corner) Remaining Bushy Vegetation Consists of Many New Seedlings Seeded by the 1949 Plant.

Morphological Studies

A detailed morphological study was carried out on the nine original strains of L. corniculatus in an endeavor to determine certain characteristics which would be useful in identifying or separating one strain from another. This was accomplished in two ways. Observations were made first on the general growth habits of each strain under normal field conditions. Later, foliage from each strain was removed to the laboratory where differences in plant characters were observed and actually measured wherever possible.

As far as growth habits are concerned one may consider that there exists three types of L. corniculatus.

(1) Narrowleaf type, with prostrate habits of growth as represented by Bunker strain.

(2) Broadleaf type with prostrate habits of growth as found in Empire and V-103.

(3) Broadleaf type with erect growth habits, characteristic of strains V-102, E-491, E-492, E-493, E-494, E-495.

Type (1) When seeded in a mixture, stems of the prostrate narrowleaf type are supported in an erect position by other plants, but if sown alone where there is plenty of space these plants display their prostrate habit of growth. Under these circumstances many of them form a dense circular mat of foliage lying close to the soil surface as shown in Figure J. In others the greater part of the stem is prostrate but tips grow erect. There is a great variety in number and length of stems,

Figure J - Individual Spaced Plant of Bunker Birdsfoot, Narrowleaf Prostrate Type.

number of flower heads and so forth, but leaflets are always narrow in relation to their length. The long internodal length of this type is also evident, especially in the early seedling stage, and is a characteristic often useful in identification.

Type (2). The prostrate broadleaf type has growth habits similar to those of the narrowleaf, but individual leaflets of the former are broader in relation to their length. This gives the plants a denser appearance as seen in Figure K. Empire strain appears outstanding in respect to its broad leaves, but in strain V-103 for example, all sorts of gradations and intermediate stages may be observed.

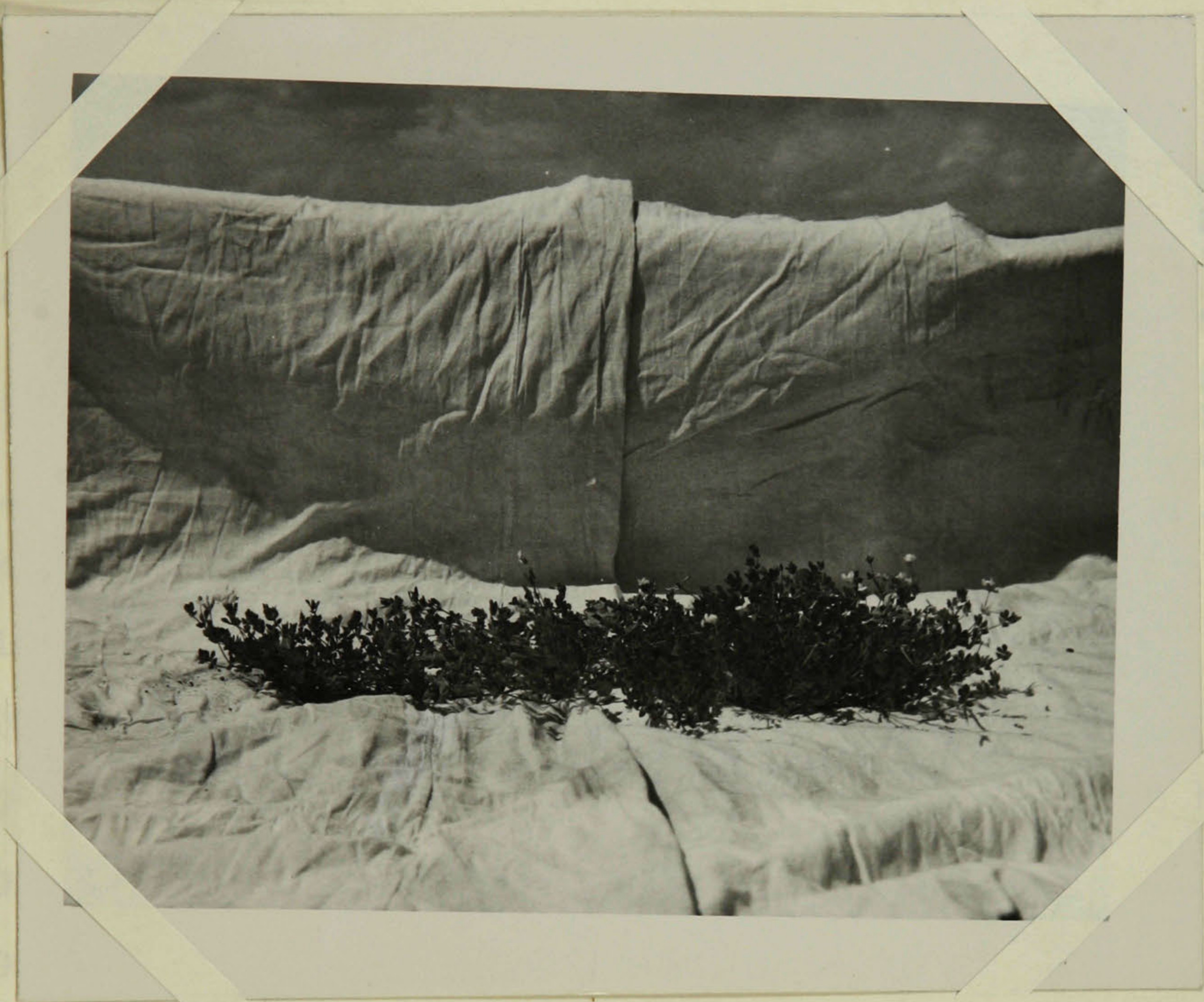

Figure K - Individual Spaced Plant of Empire Birdsfoot, Broadleaf Prostrate Type.

Type (3). Erect broadleaf types of birdsfoot have the characteristic leaflets, broader in relation to their length than the narrow forms. Stems grow erect even when sown in pure stand, and for this reason appear from a distance to be producing a greater amount of foliage. Crowns of these erect plants branch freely and tops meet between the rows to give a dense cover. Soil surface remains free of stems and when mown or grazed off, only the crown and stubble show evidence of new growth. Numerical results of the laboratory study on ten randomly selected plants from each of the nine birdsfoot strains are presented in Table 15. Five measurements per plant were made of each character listed.

Table 15 - Relative Size of Various Morphological Structures in Birdsfoot Strains Determined from Actual Laboratory Measurements.

Strain	Length-width Ratio Terminal Leaflet	Length-width Ratio Lateral Leaflet	Length of Footstalk	Length of Internode	Inflorescence Length of Peduncle	Inflorescence Length of Floret
			m.m.	c.m.	m.m.	m.m.
Bunker	3.90	5.07	3.96	2.53	57.4	10.0
Empire	1.90	2.31	6.21	2.10	46.0	11.6
V-102	2.18	2.37	6.16	2.36	59.3	11.2
E-491	1.79	2.09	6.23	2.47	59.7	11.1
E-492	2.08	2.36	6.38	2.16	57.2	11.1
E-493	2.18	2.43	6.38	2.31	54.4	11.4
E-494	2.13	2.37	5.95	2.17	58.3	11.1
E-495	2.37	2.61	5.93	1.99	54.5	11.7
V-103	2.13	2.51	7.75	2.14	44.1	11.8

L.S.D. for terminal leaflets at 5% point 0.44; 1% point 0.58

L.S.D. for lateral leaflets at 5% point 0.44; 1% point 0.58

L.S.D. for footstalk length at 5% point 1.19; 1% point 1.58

Analysis of variance as outlined by Snedecor (57) was carried out on all data included in Table 15 except that for length of florets. Bunker was found to possess the largest terminal leaflet length-width ratio which was highly significantly greater than that of all other strains. Terminal leaflet length-width ratio of strain E-495 was significantly greater than that of strains E-491 and Empire. Bunker strain lateral leaflet length-width ratio was also greater than that of all other strains to a highly significant degree. Length-width ratio of lateral leaflets in strain E-495 was significantly greater than that of strain E-491. Footstalk length of strain V-103 was highly significant in length over that of strains V-102, E-494, E-495 and Bunker, and significantly longer than that of strains E-492, E-493, E-491 and Empire. Bunker footstalk length was shorter than that of all other strains to a highly significant degree.

Results of analysis of variance indicated that differences in peduncle and internodal length approached but did not attain significance.

Analysis of variance tables for length-width ratio of terminal leaflets, lateral leaflets and length of footstalk may be found in Appendix Tables XIV, XV and XVI respectively.

To determine the relative proportions of leaves, stems and flower parts in the nine strains of birdsfoot, 50 gram samples of each strain were collected at random from the aftermath production of four replications seeded in the field (Range 1). Each 50 gram sample of green foliage was separated into leaves, stems and flower parts respectively, and dried in separate paper bags at 200° F until constant weight was reached. Samples were weighed and data converted to relative percentages of leaves, stems and flower parts for the nine strains, as seen in Table 16.

Table 16 - Relative Percentages in Dry Matter of Leaves, Stems and Flower Parts of Nine Strains of *L. corniculatus*.

Strain	Leaves	Stems	Flower Parts
	%	%	%
Bunker	26.0	39.2	34.8
Empire	48.8	41.5	9.7
V-102	61.5	30.8	7.7
E-491	61.1	31.5	7.4
E-492	58.2	29.1	12.7
E-493	59.6	31.9	8.5
E-494	60.0	31.1	8.9
E-495	60.0	31.1	8.9
V-103	35.0	35.0	30.0

The larger proportion of flowering parts in strains Bunker and V-103 is immediately evident with corresponding smaller proportions of leaves. Observations under field conditions support the above data, since Bunker and V-103 strains exceed the others in production of blooms and pods.

The small percentage of leaves on Bunker serves to illustrate further its narrowleaf character. Terminal and lateral leaflets of Bunker strain were found by measurement to have average areas of 57.7 and 35.6 sq.mm.respectively. Corresponding areas of the remaining eight strains ranged from 81.9 to 113.2 sq. mm. for terminal leaflet and from 53.3 to 89.1 sq. mm. for lateral leaflets. Average terminal and lateral leaflet areas of strain V-103 were 81.9 and 61.0 sq. mm., also less than most of the other strains.

Leaves are alternate in Lotus species, possessing very short stalks and indistinct veins. Each leaf consists of five leaflets, a terminal one, two laterals at the apex of a common footstalk, and a pair of opposite leaflets at the base of the latter structure. The latter pair are often referred to as stipules.

Since detailed descriptions of L. corniculatus plant types have already been included, it is sufficient to review here a few characters common to the species. Stems of L. corniculatus are solid at the base but more or less hollow and filled with pith in the upper parts. Plants are free from hairs or nearly so. The basal part of the stem may be covered with soil for a few inches and it then becomes whitish in color, but it remains slender and does not generally produce roots at its nodes or internodes.

Flower heads of this species are borne at the top of a long peduncle usually from 4.5 -7.0 cm. in length. Flowers are horizontal, each being borne on a separate short curved petiole. From one to six florets usually comprise a flower head, which is yellow or orange in color but sometimes tinted with red. Pods are narrow cylindrical structures from 2.0-3.0 cm. in length. They extend outward at an angle from the top of the peduncle and when inverted resemble a bird's foot. From this characteristic the plant gets its name. Pods dehise by splitting longitudinally and scatter numerous olive brown or speckled seeds in the vicinity of the parent plant. In shape, seeds of L. corniculatus are almost spherical, resembling a short stumpy seed of red clover. Individual seeds range from 1.5-1.9 mm. long, 0.8-1.4 mm. wide and about 1.0 mm. thick.

L. uliginosus plants closely resemble those of L. corniculatus but may be readily distinguished by several characteristics. Stems and tillers of big birdsfoot which develop shortly after emergence have a tendency to bend downward after leaving the crown, to either lie prostrate on the surface or bury themselves in the soil. In later stages, fleshy underground runners or rhizomes spring from the crown of the plant as shown in Figure L.

Figure L - Seedlings of L. uliginosus From Greenhouse Pots Showing Early Rhizome Development.

They may grow several inches in length, rooting at nodes and sending up numerous stems to the surface. Leaves and stems of L. uliginosus are usually very hairy but smooth types do occur. Stems are long and somewhat trailing. Leaves are broad and larger than those of L. corniculatus with very conspicuous veins, especially on the underside.

The flower head of L. uliginosus compared to that of L. corniculatus also presents certain striking differences. In the latter, sepals lie along or parallel to the unopened bud, but with big birdsfoot the five sepals bend out at right angles from the body of the bud. When observed from a top view, each individual flower bud of L. uliginosus has a star shape. This gives the unopened raceme a bushy appearance. Flower heads of L. uliginisos contain more florets than L. corniculatus, sometimes as many as 12 or 15, while the latter species seldom if ever exceeds six florets per flower head. L. uliginosus individual florets are also smaller in size. Pods of big birdsfoot are narrower with smaller seeds than those of the true birdsfoot, ranging from yellowish green to reddish brown in color. Seeds are globular or heart shaped, 1.0-1.5 mm. long, 0.6-1.1 mm. wide and approximately 0.6 mm. in thickness.

A rate of establishment study was conducted in the greenhouse on three legume species, L. corniculatus, L. uliginosus and Medicago sativa. L. corniculatus strains involved were Bunker, Empire and E-495. The alfalfa variety included was North Sweden. The objective was to compare speed of development in the three species from time of emergence to maturity, with special reference to differences between the two species of Lotus. Detailed observations were made on these plants from day to day.

Specific data collected in the rate of establishment study is summarized in Table 17. The first true leaf and others referred to are those developing first and following in consecutive order, after emergence of the cotyledons. The number of days recorded for any given stage to develop has been measured from the time the plants emerged.

Table 17. - Comparison of L. corniculatus, L. uliginosus, and M. sativa, Regarding Rates of Establishment and Development Under Greenhouse Conditions.

Growth Stages Studied	Bunker	Empire	E-495	Big Birdsfoot	Alfalfa
	Days	Days	Days	Days	Days
Emergence	11	11	10	16	10
First true leaf	21	20	20	19	12
Number of leaflets	3	3	3	3	1
Second true leaf	25	24	25	23	21
Number of leaflets	3	3	3	5	3
Third true leaf	30	30	31	30	26
Number of leaflets	3	3	3	5	3
Fourth true leaf	36	35	35	34	29
Number of leaflets	5	5	5	5	3
First pair tillers	25	23	25	20	29
Second pair tillers	30	33	30	26	32
Third pair tillers	42	45	44	39	33
Blooms	95	100	96	98	75
Pods	105	110	108	109	86

There was little difference between strains or species of birdsfoot as far as rate of establishment was concerned. Alfalfa developed leaves more quickly than birdsfoot, especially in the early stages. Under conditions of this test alfalfa required a longer period than Lotus for tillering to begin, but once started it proceeded faster and produced blooms and seed about three weeks earlier than the latter species. The first true leaf of alfalfa differed from that of Lotus, in that it consisted of a single leaflet.

Another species difference was observed between L. uliginosus and L. corniculatus. In the former the second true leaf at time of unfolding consisted of the five leaflets which is characteristic of the genus. However on the strains of L. corniculatus considered, this familiar "five-leaflet" stage did not appear until the fourth true leaf had developed. L. uliginosus seedlings required considerably more time to emerge than did L. corniculatus or M. sativa. However, big birdsfoot was observed to develop its first tillers earlier than either alfalfa or the true birdsfoot plants.

A distinct difference was observed in a comparison of alfalfa and birdsfoot florets. The keel of the floret in Lotus species studied was found to differ from that of alfalfa by a fusing together at the front and back. In alfalfa and other common legumes such as Trifolium and Melilotus species, this fusion is confined to the back. Consequently, insects are able to trip the flowers, thus releasing both style and stamens from the keel. In birdsfoot however, the only opening in the keel is a small hole at the tip through which pollen is shed. When insects exert pressure on the upper portion of the keel, anthers and filaments are forced into the tip, and pollen is liberated through the small keel opening. The stigma may also be forced out, thus enabling the process of cross pollination to occur.

Germination Tests

Percentage germination obtained in tests conducted on the nine original strains of birdsfoot trefoil at seeding time 1949 are presented in Appendix Table XVII. Results indicate a relatively high content of hard seeds in many strains. The percentage germination for strain E-491 was only 16%, while the seed of several other strains contained up to 40 and 50% hard seed. Hard seeds are described as those remaining dormant at the end of a test period under optimum germination conditions, after all others have sprouted or decayed. MacDonald (38) reports birdsfoot germination of from four to 90% in New York state, with averages from 50 to 60%. He also states that commercial birdsfoot seed has an average germination of approximately 50%. It would therefore be desirable to know when the stage of maximum germination is reached and the effect if any of storage on percent germination of birdsfoot seed.

With this in mind, seed was harvested in late August 1949 from a two year old stand of birdsfoot trefoil at Macdonald College. A sample from this material consisting of 200 seeds each was placed in the germinator at the beginning of each month following harvest, until the spring of 1951. A similar procedure was followed in regard to monthly samples from 1950 harvested seed grown on the same area. Here, the first sample of 200 seeds was placed in the germinator in September, 1950. All seed was stored at room temperature throughout the experiment. Records were kept of the week to week germination of individual samples. Appendix Table XVIII includes the accumulated germination percentages of these samples from month to month. Figure M presents the same data in graphical form.

All seed samples remained in the germinator continually where a very small percentage germinated each month. A few seeds decayed but the great majority not germinated remained hard and apparently impervious to moisture. At the termination of the study, the first two samples (September and October) of 1949 harvested seed, in the germinator for 18 and 17 months respectively, were far ahead of the remaining 1949 samples in percent germination. The first sample of 1950 seed, placed in the germinator in September of that year had more seeds germinated in four months than either of the 1949 samples. Later samples of 1950 seed harvested at the same time showed much slower monthly germination. A second series of 1949 seed samples placed in the germinator month by month beginning August 1, 1950, gave consistently higher germination than similar samples had during the corresponding period of 1949. Monthly germination of this second series was also higher than that of the newly harvested 1950 seed, except for the first sample of the latter as indicated above.

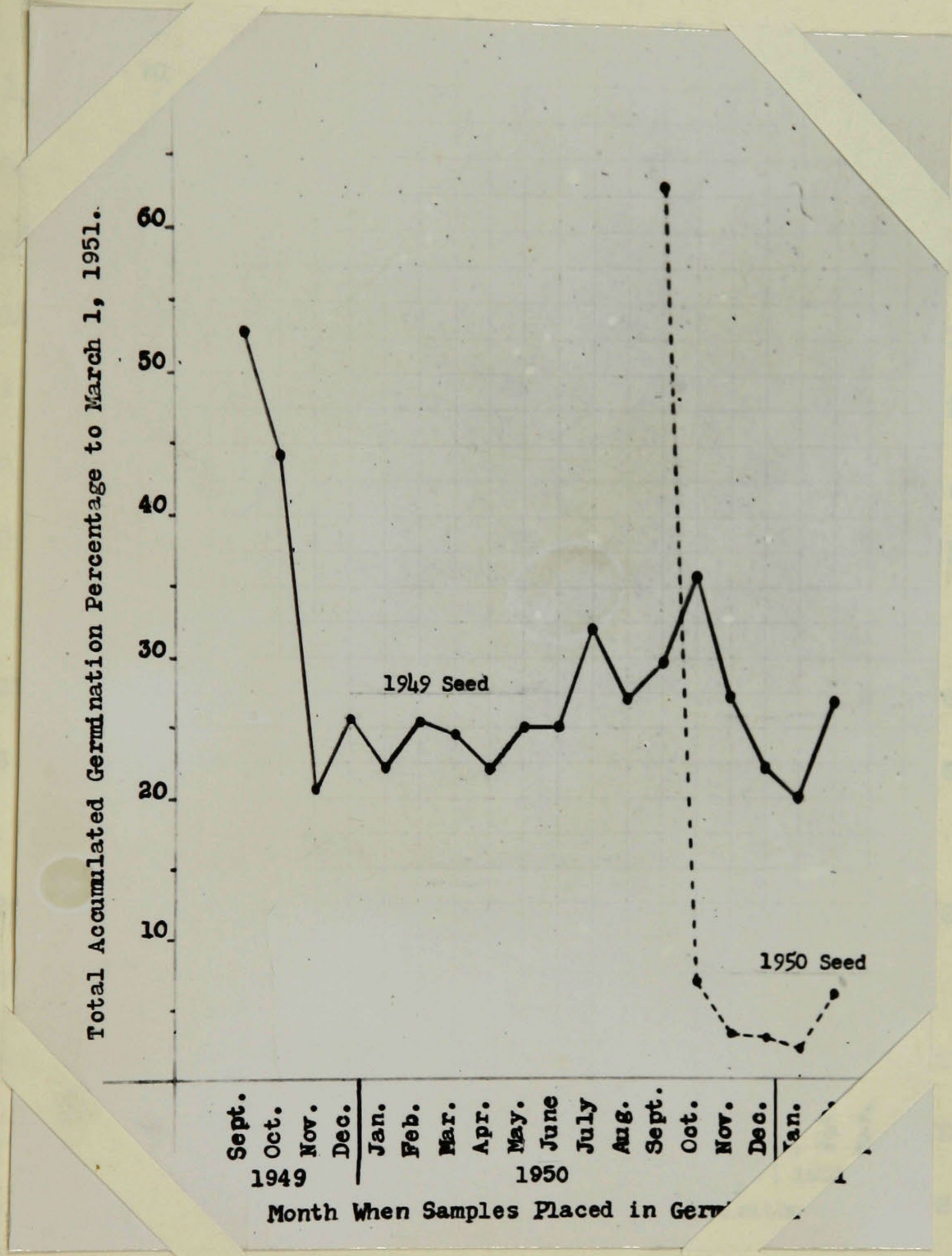

Figure M - Comparison of Accumulated Percent Germination of Freshly Harvested Birdsfoot Seed Versus Similar Seed Stored at Room Temperature for Varying Periods.

Higher germination immediately after seed harvest and an increase in hard or impermeable seeds with storage, give one the impression that maximum germination of birdsfoot would be obtained by seeding immediately after threshing in late summer or early autumn. Stebler and Volkart (1911) as reported by MacDonald (38) obtained a decrease in percentage germination of L. corniculatus and L. uliginosus seed with increasing age. Somewhat similar results were obtained by Jones (23) working at Cornell with vetch (Vicia villasa) seed. He reported an absence of hard seed in green seed samples of this species, but also indicates that such seed stored in the laboratory subsequently showed a considerable proportion of hard seed. He also found that low humidities increased the number of hard seed in stored samples of vetch while high humidities produced the reverse effect.

Reduced germination after a few months storage as was apparent in this test, points to the initiation of some physiological or morphological process shortly after harvest. If such a process occurs it must either induce embryonic dormancy or lead to the development of a hard seed coat more or less impermeable to water. Comparing the coats of permeable and impermeable sweet clover seed (Melilotus spp.), Coe and Martin (11) found the latter to differ by a greater amount of thickening in the cell walls of the Malpighian layer. This layer is comprised of palisade cells making up the modified epidermal layer of the ovule, commonly referred to as the outer layer of the seed coat.

In an attempt to determine whether embryonic dormancy had occurred in the birdsfoot seed used, scarification of seed coats was carried out on samples of 100 seeds before placing them in the germinator. Scarification was accomplished by two methods; (1) the use of sandpaper and (2) immersion in concentrated sulphuric acid. For the first, two circular disks were cut from medium grade sandpaper to fit down into a glass petri dish. One disk was glued to the inside bottom of the dish, sand side up and seeds added. The second disk of sandpaper with rough side down was used to cover the seeds, and then slowly rotated with slight pressure from the fingers for about 30 seconds. Seeds were then removed, counted and placed in the germinator.

When scarifying with H_2SO_4, birdsfoot seeds were first placed in the bottom of a large beaker and sufficient acid added to cover the seeds. The mass was stirred slowly with a glass rod and when the required time had elapsed, a large volume of water was quickly added to halt the scarification process. Seeds were immediately removed by pouring the contents of the beaker into another container through a filter paper funnel. Seeds remained on the filter paper where they were thoroughly washed with water and allowed to dry before placing in the germinator. Samples were scarified by this method for five, 10, 15 and 20 minutes respectively.

A total of six seed samples were included in this test, four treated with H_2SO_4, one with sandpaper and a check or zero treatment. Germination counts were made and recorded on all samples for a period of 90 days, results of which are included in Table 18 below.

Table 18 - Percentage Germination of Check and Scarified Birdsfoot Seed Samples Over a 90 Day Period.

Time in Germinator	Check	Sandpaper 30 sec.	Acid 5 min.	Acid 10 min.	Acid 15 min.	Acid 20 min.
24 hours	3	17	10	18	37	9
48 hours	6	66	28	40	60	49
3 days	11	79	28	44	61	62
4 days	11	85	33	48	67	64
5 days	11	89	41	54	68	65
6 days	12	90	45	55	69	68
30 days	15	91	64	64	74	75
60 days	16	92	70	65	75	78
90 days	17	92	71	65	76	79

Number of decayed seeds in either of these treatments was very small. Seeds scarified with sandpaper for 30 seconds gave the most complete germination, the final 92% being greater than any of the other treatments. Germination of the 15 minute H_2SO_4 treated sample corresponded closely with that of the sandpaper sample during the first three days in the germinator, but final results of the former were considerably less. Check treatment gave a very low germination of only 17% in 90 days.

The high germinations obtained in this scarification test indicate that embryos of birdsfoot seed used did not enter a dormant stage. Rupturing of seed coats to allow ready absorbtion of water by the seed overcame the problem of hard seeds in the samples studied. Therefore, it seems reasonable to conclude that the low germination of similar samples held in storage, as observed in this study, was due to an alteration of the seed coat rendering a large proportion of the seeds impermeable to moisture.

Hard seeds might conceivably play an important part in grassland agriculture by providing a source of new plants for several months or even years to come. Turner (64) reports seed of _L. uliginosus_ remaining viable in storage for 81 years. In presenting the characteristics of birdsfoot trefoil, Dodd (16) describes it as establishing itself without reseeding from hard seeds in the soil, which gradually become permeable to water and germinate through time. Dodd indicates further that the hard seed content of birdsfoot requires the use of scarified seed or at least seeding at a heavier rate than normally. There seems to be some question in the minds of workers (66) regarding the ability of scarified seed to produce viable seedlings. No attempt was made in this laboratory study to determine the accuracy of such a statement. However, two birdsfoot seed samples scarified with sulphuric acid and sandpaper respectively, were both observed to produce vigorous seedlings under actual field conditions during the month of July, 1950.

SUMMARY AND CONCLUSIONS

Experiments considered in this thesis were conducted on birdsfoot trefoil in the Agronomy Department of Macdonald College from 1949-51. Two species were involved, the true birdsfoot trefoil (L. corniculatus) and big birdsfoot (L. uliginosus), although the bulk of the work was done on the former. Strains of L. corniculatus studied included a narrowleaf prostrate type, Bunker, two broadleaf prostrate types, Empire and V-103, and six broadleaf uprights, V-102, E-491, E-492, E-493, E-494 and E-495. These nine strains were seeded with and without a nurse crop, in mixture with timothy and in pure stand. Yield data, aftermath development, winter killing and re-establishment by volunteer seedlings were considered on the seeded plots. Root studies, germination tests and a fertility trial were also carried out on L. corniculatus strains.

Morphological differences of L. corniculatus and L. uliginosus were considered and the relative performance of these two species under flooding and 2,4-D applications was investigated.

1. From observations throughout this investigation the prostrate types of L. corniculatus with their spreading growth habit appear more desirable for pasture purposes, while upright strains show greater promise for hay production.

2. The cultivation of birdsfoot trefoil with a grass is recommended since the grass plants assist in supporting the comparatively weak stems of the legume, and also keep down weeds which are encouraged by the slow growth of trefoil seedlings.

3. The three prostrate strains, Bunker, Empire and V-103, survived the winter of 1949-50 in a satisfactory manner at Macdonald College, while the remaining six upright strains were practically all winter killed. Older seedings of Empire at the college and at several other locations in Quebec have demonstrated good winter survival.

4. Winter survival of L. corniculatus seedings at Macdonald College during 1949-50, indicates that in this locality further study of the species should be concentrated on prostrate types or on the selection of more winter hardy types from available upright strains.

5. Of the three prostrate strains studied (Bunker, Empire and V-103), Bunker narrowleaf yielded the greatest amount of dry matter per acre when in mixture with timothy, but in pure stand Empire yielded the greatest amount of the three. Yield of Bunker was significantly greater than that of V-103 strain both in pure stand and in mixture with timothy. Yield of Empire was significantly greater than that of V-103 in pure stand only. There was no significant difference in yielding ability of Bunker and Empire strains either in pure stand or in mixture.

6. Fertilization of birdsfoot and timothy sward with four rates of 2-12-10 fertilizer showed an increase in birdsfoot trefoil during the first season, but during the second year after being topdressed in the fall with manure, a marked decrease in percentage of trefoil was evident. This decrease of birdsfoot

was associated with an increase of timothy and other plants in the sward, and is similar to results reported by other workers, indicating that birdsfoot trefoil does not always compete well with grasses under fertilization.

7. Root studies indicate that initial root development of *L. corniculatus* consists of a slender main root growing straight downward for several weeks, followed by rapid initiation of fibrous side branches. The latter process is then followed by tillering and spreading of the top which previous to this time is generally restricted in growth.

8. Germination tests on *L. corniculatus* seed resulted in substantially higher germination immediately after seed harvest than that obtained from similar seed stored for varying periods at room temperature. Rupturing of seed coats by scarification produced very high germination, thus overcoming the problem of hard seeds in the samples studied. These results indicate that the low germination of birdsfoot seeds in storage is due to an alteration or maturation of the seed coat, rendering a large proportion of the seeds impermeable to moisture. Such a characteristic of *L. corniculatus* seed samples suggests seeding at a heavier rate than would be normal or the use of scarified seed for maximum germination and establishment.

9. Application of 2,4-D at the rate of two ounces per acre to a weedy stand of birdsfoot trefoil caused only slight damage to the legume foliage. A supplementary 2,4-D spraying experiment in the greenhouse involving Bunker, Empire, big birdsfoot and red

clover plants, gave observational results where Bunker narrowleaf birdsfoot presented up to 25% survival when sprayed at the fifth and sixth true leaf stage. Therefore, it may be possible to control broad leaved weeds on new seedings of birdsfoot by the use of very light applications of 2,4-D.

10. When flooded prior to emergence, Bunker birdsfoot strain produced a final stand of high significance over Empire, E-495 and big birdsfoot. In flooding after emergence there was no significant difference in final survival between Bunker, Empire, big birdsfoot and red clover. Recovery of L. uliginosus after removal of floodings, indicates that the species may possess some inherent characteristics enabling it to do well under conditions of excessive soil moisture.

11. Morphological studies showed that of the nine strains of L. corniculatus dealt with, Bunker narrowleaf strain possessed the largest terminal leaflet length-width ratio, which was highly significantly greater than that of all other strains studied. Bunker strain lateral leaflet length-width ratio was also found to be greater than that of all other strains to a highly significant degree. Footstalk length of strain V-103 was highly significant in length over that of strains V-102, E-494, E-495 and Bunker, and significantly longer than that of strains E-492, E-493, E-491 and Empire. Bunker footstalk length was shorter than that of all other strains to a highly significant degree.

12. The species *L. uliginosus* differs from *L. corniculatus* by the development of rooting rhizomes, larger leaves, hairy foliage, more florets per flower head and the bending out of calyx teeth to give a bushy appearance to the raceme.

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A P P E N D I X

Appendix Table I - Yields of Birdsfoot in Pure Stand, Range 1, East Field. (Pounds dry matter per acre).

Strain	Rep. I	Rep. II	Rep. III	Rep. IV	Strain Totals
Bunker	251.4	645.7	975.4	711.5	2584.0
Empire	594.0	707.6	899.5	584.2	2785.3
V-102	841.3	359.3	1155.2	1089.0	3444.8
E-491	418.7	368.5	803.7	883.1	2474.0
E-492	781.7	937.8	1429.5	1311.8	4460.8
E-493	601.9	486.4	754.0	921.8	2764.1
E-494	779.8	617.7	788.6	624.3	2810.4
E-495	1260.3	1335.2	1334.7	835.2	4765.4
V-103	507.7	187.2	350.7	279.2	1325.1
Rep. Totals	6036.8	5645.4	8491.3	7240.4	27413.9

Appendix Table II - Yields of Birdsfoot in Mixture With Timothy, Range 32, East Field. (Pounds dry matter per acre).

Strain	Rep. I	Rep. II	Rep. III	Rep. IV	Strain Totals
Bunker	775.6	1141.8	743.6	1278.8	3939.8
Empire	417.5	1235.4	618.0	644.7	2915.6
V-102	455.2	681.7	607.1	477.7	2221.7
E-491	516.8	1407.1	859.8	820.0	3603.7
E-492	462.7	1274.6	518.8	742.5	2998.6
E-493	313.9	406.7	1127.0	1419.7	3267.3
E-494	599.7	1127.3	633.5	1171.5	3532.0
E-495	851.6	1458.6	484.0	1357.6	4151.8
V-103	605.0	679.9	288.3	505.6	2078.8
Rep. Totals	4998.0	9413.1	5880.1	8418.1	28709.3

Appendix Table III - Analysis of Variance Table for Pure Stand Yields, Range 1, East Field.

Source	D.F.	S.S.	Variance	F	F 5%	F 1%
Total	35	3777481.2				
Replications	3	550953.9	183651.3	4.31	3.01	4.72
Strains	8	2205525.2	275690.6	6.48	2.36	3.36
Narrow vs. broadleaf	1	60028.2	60028.2	1.41	4.26	7.82
Upright vs. prostrate	1	732953.9	732953.9	17.23	4.26	7.82
Error	24	1021002.1	42541.8			

"t" at 5% point for 24 D.F. - 2.06
"t" at 1% point for 24 D.F. - 2.80

L.S.D. at 5% point for strain means $= \sqrt{\frac{42541.8 \times 2}{4}} \times 2.06 = 300.3$

L.S.D. at 1% point for strain means $= \sqrt{\frac{42541.8 \times 2}{4}} \times 2.80 = 408.2$

Appendix Table IV - Analysis of Variance Table for Mixed Stand Yields, Range 32, East Field.

Source	D.F.	S.S.	Variance	F	F 5%	F 1%
Total	35	4333923.06				
Replications	3	1441162.51	480387.5	6.14	3.01	4.72
Strains	8	1016411.46	127051.4	1.62	2.36	3.36
Narrow vs. broadleaf	1	158151.60	158151.6	5.49	4.26	7.82
Upright vs. prostrate	1	239190.60	239190.6	3.05	4.26	7.82
Error	24	1876349.09	78181.2			

"t" at 5% point for 24 D.F. - 2.06
"t" at 1% point for 24 D.F. - 2.80

L.S.D. at 5% point for strain means $= \sqrt{\frac{78181.2 \times 2}{4}} \times 2.06 = 407.3$

L.S.D. at 1% point for strain means $= \sqrt{\frac{78181.2 \times 2}{4}} \times 2.80 = 553.6$

Appendix Table V - Percent Dry Matter of Vegetation From Birdsfoot Pure Stand and Birdsfoot-Timothy Mixture. (Ranges 1 and 32 East Field).

Strain	Pure Stand	Mixture With Timothy
	%	%
Bunker	18.6	20.1
Empire	20.2	20.7
V-102	21.5	22.6
E-491	20.9	22.9
E-492	22.2	21.9
E-493	21.1	22.9
E-494	21.1	22.1
E-495	21.3	21.6
V-103	19.5	20.3

Appendix Table VI - Average Final Percent Survival of Birdsfoot per Pot in Flooding Prior to Emergence Experiment.

Weeks Flooded	Empire	Bunker	Big Birdsfoot	E-495
	%	%	%	%
0	45.9	78.8	36.3	37.8
1	27.6	54.5	18.3	18.2
2	17.0	30.3	29.5	26.5
3	10.9	43.4	8.2	14.0
4	3.8	19.1	4.3	6.0

Appendix Table VII - Average Final Percentages per Pot Transformed to Degrees.

Weeks Flooded	Empire	Bunker	Big Birdsfoot	E-495
0	42.6	62.6	37.0	37.9
1	31.7	47.6	25.3	25.3
2	24.4	33.4	32.9	31.0
3	19.3	41.2	16.6	22.0
4	11.2	25.9	12.0	14.2

Appendix Table VIII - Analysis of Variance Table of Transformed Percentages of Flooding Prior to Emergence Experiment.

Source	D.F.	S.S.	Variance	F	F 5%	F 1%
Total	79	18846.6				
Floodings	4	7353.6	1838.4	13.83	3.26	5.41
Replications	3	835.1				
Error "a" Flood. X reps.	12	1594.2	132.8			
Varieties	3	4142.4	1380.8	8.41	2.82	4.26
Var. X flood.	12	1165.3	97.1			
Error "b" Var. X reps. Var. X reps. X flood	45	7385.1	164.1			

"t" at 5% point for 12 D.F. - 2.20
"t" at 1% point for 12 D.F. - 3.06

L.S.D. at 5% point for flooding means $= \sqrt{\frac{132.8}{16} \times 2} \times 2.20 = 8.95$

L.S.D. at 1% point for flooding means $= \sqrt{\frac{132.8}{16} \times 2} \times 3.06 = 12.45$

L.S.D. at 5% point for variety means $= \sqrt{\frac{164.1}{20} \times 2} \times 2.02 = 8.18$

L.S.D. at 1% point for variety means $= \sqrt{\frac{164.1}{20} \times 2} \times 2.69 = 10.89$

"t" at 5% point for 45 D.F. - 2.06
"t" at 1% point for 45 D.F. - 2.69

Appendix Table IX - Average Final Percent Survival of Plants per Pot in Flooding After Emergence Experiment.

Weeks Flooded	Empire	Bunker	Big Birdsfoot	Red Clover
	%	%	%	%
0	98.9	99.7	97.4	99.7
1	95.1	99.7	94.1	89.1
2	72.0	99.7	82.3	69.1
3	91.8	86.8	45.9	73.1
4	61.3	90.0	50.7	66.1

Appendix Table X - Average Final Percentages per Pot Transformed to Degrees.

Weeks Flooded	Empire	Bunker	Big Birdsfoot	Red Clover
0	84.1	87.1	80.8	87.1
1	77.2	86.8	75.9	70.7
2	58.1	87.1	65.1	56.2
3	73.4	68.7	42.6	58.8
4	51.5	71.6	45.4	54.4

Appendix Table XI - Analysis of Variance Table of Transformed Percentages of Flooding After Emergence Experiment.

Source	D.F.	S.S.	Variance	F	F 5%	F 1%
Total	79	39428.8				
Floodings	4	9126.7	2281.6	7.67	3.26	5.41
Replications	3	811.8				
Error "a"						
Flood X reps.	12	3565.4	297.1			
Varieties	3	3795.4	1265.1	1.96	2.82	4.26
Var. X flood.	12	3015.1				
Error "b"						
Var. X reps. Var. X reps. X flood	45	28900.4	642.2			

"t" at 5% point for 12 D.F. - 2.20
"t" at 1% point for 12 D.F. - 3.06

L.S.D. at 5% point for flooding means $= \sqrt{\frac{297.1 \times 2}{16}} \times 2.20 = 13.39$

L.S.D. at 1% point for flooding means $= \sqrt{\frac{297.1 \times 2}{16}} \times 3.06 = 18.63$

Appendix Table XII - Relative Volumes of Roots and Tops of Birdsfoot and Timothy Plants Removed From One Cubic Foot of Soil. (Ranges 11E, Northwest Field and 32, East Field).

Seeding (1949)	Range 32 Medium Loam				Range 11E Sandy Loam			
	Birdsfoot		Timothy		Birdsfoot		Timothy	
	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
Bunker and timothy	192	385	21	22	110	160	45	52
Empire and timothy	155	190	20	16	140	138	25	20
Bunker alone	190	265	--	--	156	215	--	--
Empire alone	140	355	--	--	100	115	--	--
Seeding (1950)								
Bunker and timothy	140	210	60	190	105	145	80	160
Empire and timothy	90	110	75	180	125	170	60	130
Bunker alone	120	205	--	---	185	280	--	---
Empire alone	185	305	--	---	195	200	--	---

Appendix Table XIII - Relative Root and Top Volumes and Lengths of Birdsfoot Plants Grown in Crocks and Buried in Soil.

Strain		8 weeks		12 weeks		16 weeks		20 weeks	
		Vol.	Len.	Vol.	Len.	Vol.	Len.	Vol.	Len.
		c.c.	ins.	c.c.	ins.	c.c.	ins.	c.c.	ins.
Bunker	Roots	0.3	10.5	5.7	19.5	10.0	26.0	45.0	22.0
	Tops	----	----	----	----	22.0	10.5	52.0	12.0
Empire	Roots	1.0	12.0	12.5	20.0	17.5	31.5	----	----
	Tops	----	----	----	----	98.5	14.0	----	----
V-102	Roots	0.7	13.5	18.5	14.5	12.0	18.0	68.0	20.0
	Tops	---	----	----	----	24.0	10.0	122.0	12.0
E-494	Roots	---	----	17.0	17.0	16.0	19.5	18.0	24.0
	Tops	---	----	----	----	29.8	8.0	26.0	8.0
E-495	Roots	3.0	9.5	16.0	23.0	10.5	20.0	12.0	30.0
	Tops	---	---	----	----	32.5	11.5	14.0	7.5
V-103	Roots	3.9	15.5	3.0	19.0	3.5	26.0	64.0	24.0
	Tops	---	----	---	----	3.3	7.5	115.0	12.0

Appendix Table XIV - Analysis of Variance Table for Terminal Leaflet Length-Width Ratios.

Source	D.F.	S.S.	Variance	F	F (5%)	F (1%)
Total	89	50.40	0.57			
Between strains	8	31.20	3.90	16.25	2.06	2.74
Within strains	81	19.20	0.24			

"t" at 5% point for 81 D.F. - 1.99
"t" at 1% point for 81 D.F. - 2.64

L.S.D. at 5% point for strain means $= \sqrt{\frac{0.24}{10} \times 2} \times 1.99 = 0.44$

L.S.D. at 1% point for strain means $= \sqrt{\frac{0.24}{10} \times 2} \times 2.64 = 0.58$

Appendix Table XV - Analysis of Variance Table for Lateral Leaflet Length-Width Ratios.

Source	D.F.	S.S.	Variance	F	F (5%)	F (1%)
Total	89	85.51				
Between Strains	8	65.88	8.24	34.33	2.06	2.74
Within Strains	81	19.63	0.24			

"t" at 5% point for 81 D.F. - 1.99
"t" at 1% point for 81 D.F. - 2.64

L.S.D. at 5% point for strain means $= \sqrt{\frac{0.24}{10} \times 2} \times 1.99 = 0.44$

L.S.D. at 1% point for strain means $= \sqrt{\frac{0.24}{10} \times 2} \times 2.64 = 0.58$

Appendix Table XVI - Analysis of Variance Table for Footstalk Length in Birdsfoot Strains.

Source	D.F.	S.S.	Variance	F	F (5%)	F (1%)
Total	89	225.55				
Between Strains	8	75.42	9.43	5.09	2.06	2.74
Within Strains	81	150.13	1.85			

"t" at 5% point for 81 D.F. - 1.99
"t" at 1% point for 81 D.F. - 2.64

L.S.D. at 5% point for strain means $= \sqrt{\frac{1.85 \times 2}{10}} \times 1.99 = 1.19$

L.S.D. at 1% point for strain means $= \sqrt{\frac{1.85 \times 2}{10}} \times 2.64 = 1.58$

Appendix Table XVII - Percentage Germination and Hard Seed of the Nine Strains of Birdsfoot Trefoil at Time of Seeding, May, 1949.

Strain	Growth Type	Germination	Hard Seed
		%	%
Bunker	Narrowleaf prostrate	75	21
Empire	N.Y. broadleaf prostrate	81	16
V-102	Broadleaf upright	55	29
E-491	Broadleaf upright	16	24
E-492	Broadleaf upright	64	35
E-493	Broadleaf upright	52	43
E-494	Broadleaf upright	55	32
E-495	Broadleaf upright	59	25
V-103	Broadleaf prostrate	60	21

Appendix Table XVIII - Comparison of Total Accumulated Percentage Germination to March 1, 1951, of Birdsfoot Seed Samples Held in Storage at Room Temperature for Varying Periods of Time.

Month Placed in Germinator	Accumulated Germination Percentage (March 1, 1951) 1949 seed	1950 seed
	%	%
September	53	--
October	44	--
November	21	--
December	26	--
January	22	--
February	26	--
March	24	--
April	22	--
May	25	--
June	25	--
July	32	--
August	27	--
September	29	63
October	36	7
November	27	3
December	22	3
January	20	2
February	27	6