ESTABLISHMENT, PRODUCTION, CHEMICAL COMPOSITION AND DIGESTIBILITY OF FORAGE CROPS IN THE MANITOBA INTERLAKE AREA

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ABSTRACT

The purpose of this study was to evaluate the effects of fertilization on native vegetation in the Interlake area, and secondly, to substitute agronomic forage crops for the existing sward. Four Interlake soil series, with various fertilizer treatments, were used in field and greenhouse experiments. Fertilizer rates of application were 0, 225 lbs., and 450 lbs. 27-14-0 per acre on the meadow site.

Fertilization of native meadow vegetation increased dry matter yield, *in vitro* digestibility, crude protein, phosphorus and potassium concentrations. Calcium, magnesium and sodium concentrations as well as four trace elements, Mn, B , Cu and Mo, increased with fertilization. Although molybdenum contents in meadow hay increased markedly with fertilization, its concentrations remained below the toxicity level for livestock. Unfertilized meadow vegetation was marginal in copper content and inadequate in crude protein and phosphorus content for livestock production; furthermore, native vegetation yielded only about one-half ton per acre.

While concentrations of calcium, magnesium and boron increased throughout the season, dry matter yield, *in vitro* digestibility, crude protein, phosphorus and potassium concentrations decreased with advancing maturity. From the data it appears that meadow vegetation should be harvested between late June and mid-July.

With fertilization a marked change occurred in the botanical composition of meadow vegetation; *Sonchus arvensis* L. and *Ambrosia psilostachya* DC. responded markedly to fertilization. Native meadow hay was distinctly inferior to brome-alfalfa or birdsfoot trefoil.

Severe weed competition was encountered in establishing forage crops on the meadow soil. Due to droughty conditions, most of the grasses tested failed to establish satisfactorily on the meadow soil. Meadow fescue and reed canary grass indicate potential for the area. Alfalfa outyielded all other species in field and greenhouse experiments.

Nitrogen and phosphorus are deficient on Interlake soils and their application is required for forage establishment. On upland soils no particular problems were encountered in establishing forage crops, however, further work will be required to resolve the establishment problems on Interlake meadow soils.

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I. INTRODUCTION

The Interlake area of Manitoba can be broadly defined as the area of land situated between Lake Winnipeg and Lake Manitoba. A considerable portion of the soils in this area have been developed on the Interlake Till Plain which is very high in lime carbonate content and in many instances is also very stony.

Tree-covered land which has not been cleared is used for grazing, and the carrying capacity is very low. Extensive meadow areas are used mostly for hay production, however, the hay is of poor nutritive value and is low in productivity. Improved land utilization in this area would benefit livestock producers economically.

Livestock production is the major enterprise in the district. Most of the livestock are overwintered on a ration composed mainly of native hay. Major nutritional problems in livestock often appear in late winter or early spring. Malnutrition may be manifested by depraved appetite, slow growth, and in some instances, by death. The depraved appetite is recognized as an early symptom of phosphorus deficiency. Phosphorus has long been recognized as being deficient in the native hay of the Interlake, and phosphorus supplementation with bone meal has been made, however, not with entire success.

The purpose of this study was to evaluate the productivity, botanical composition, digestibility, and chemical composition of the native hay under various levels of soil fertility; and secondly, to ascertain the ecological adaptibility and potential growth of cultivated forage crops on several representative Interlake soil series.

II. LITERATURE REVIEW

Forage production on rangelands can primarily be increased by (a) adjusting the rate, time and distribution of grazing to encourage natural improvement, (b) by fertilizing the indigenous species, and (c) by introducing more productive species of greater nutritional value. The latter two approaches have been taken in this present study. Very little previous work has been done in the Interlake area to improve the productivity and nutritional value of native meadows, however, considerable work has been done elsewhere.

A. Fertilization of Native Grasslands

Since native grasslands are in equilibrium with their environment, any shift in the environment will tend to favour certain species and at the same time, depress other species. This plastic characteristic of the sward - the tendency to develop an equilibrium with the environment - is the most important principle of grassland management (Klapp, 45). Changing the soil nutrient status by applying fertilizer will change the species equilibrium of the forage stand. Changing the climax vegetation, (Love and Williams, 46) should be considered to attain new production horizons, just as in other phases of agricultural production. The addition of fertilizer will improve rangelands which are unsuitable for cultivation because of stoniness, topography or other adverse soil characteristics.

The growth of grasses is limited more often by a deficiency of nitrogen than by any other nutrient. Most of the native grasslands contain a very small percentage of legumes; nitrogen must therefore be obtained mainly from the mineralization of organic matter. The rate of mineralization is influenced by the C/N ratio, the soil organic matter, soil pH, and climatic conditions. Nonsymbiotic nitrogen-fixing organisms and rainfall generally contribute very little to the soil nitrogen supply.

Rumburg, Wallace and Raleigh (58) studied the effects of various levels of nitrogen on seasonal production and nitrogen accumulation in meadow vegetation in Oregon. Nitrogen in the form of NH_4NO_3 was applied at the rates of 0, 80, 160, 240, 320, and 400 lbs. per acre with subplots corresponding to six harvesting dates. The investigators reported that total dry matter production increased with time and with increasing levels of applied nitrogen up to 240 lbs. N/acre. Nitrogen application also extended the period of production later into the season. The nitrogen content of the herbage increased with increasing levels of nitrogen fertilizer early in the season, but as maturity advanced, some of the fertilized plots were actually lower in nitrogen content than the unfertilized plots.

Many investigators (9, 34, 53, 63) have reported an increase in the nitrogen content of grass following nitrogen application over the nitrogen concentration of non-fertilized grass. Thomas (63) reported that the increase in percentage of nitrogen in forage with additions of nitrogen fertilizer was modified with increasing amount of seasonal precipitation. Forty pounds of nitrogen in a dry year increased the nitrogen percentage from 1.31 to 2.34 per cent; whereas, in a year with more precipitation than in a dry year, 40 pounds of nitrogen changed the nitrogen content of grass from 1.58 to 1.70 per cent. The lower percentage of nitrogen values obtained at a given fertilizer rate with high seasonal rainfall was due to the enhanced crop growth.

The results obtained in experiments with nitrogen fertilization of meadows or rangeland is often evaluated according to the increase in hay or dry-matter yields. This criterion is not entirely satisfactory unless it also considers the quality of the forage. The ultimate evaluation of nitrogen fertilization is in terms of animal production per acre. The per cent dry-matter content generally decreases in nitrogen fertilized swards, but there is a simultaneous and significant increase in crude protein content (Regal, 54). He also reported that the content of lignified tissues was less in herbage intensively fertilized with nitrogen, resulting in a higher coefficient of digestibility. Walker (66) states that grasses are exceptionally efficient at recovering applied nitrogen, often utilizing up to 60%. Grable, Willhite and McCuistion (32) studying nitrogen fertilizer utilization on well-drained sites found nitrogen recovery rates of 55, 39 and 34% at elevations of 6200, 7700 and 9700 feet, respectively, in Colorado. Efficiency of nitrogen recovery was calculated as follows:

$$\frac{\text{Yield of N} - \text{Yield of N from check}}{\text{N Applied}} \quad \text{X } 100$$

Using the same formula, Thomas (63) in South Dakota, obtained 31.1 and 40.4 per cent recovery of 40 and 160 pounds nitrogen additions in two cropping seasons. Continued cropping increased the percentage of recovery slightly.

Regal (54) evaluated nitrogen recovery on the basis of the increase in protein yield, compared with control plots. He noted that in meadows treated with 100 kg N/ha 62.2% of the nitrogen in the fertilizer was recovered, and at 200 kg N/ha, 55%. It is further pointed out by Regal that possibly the C:N ratio in poor meadow soils is favourably adjusted by applying nitrogen, supporting the mineralization of organic nitrogen from which further nitrogen may be utilized by the stand. Not only will different species respond differently to applied nitrogen, but nitrogen recovery of individual species will vary considerably under various levels of initial soil fertility.

Yield increases of native grasses to nitrogen fertilizer have also been recorded by numerous other workers (23, 44, 39). Pringle and Van Ryswyk (53) studied the response of native hay in interior B.C. to a single heavy application of fertilizer over a period of five seasons. Nitrogen alone was not beneficial, but applications of NP and NPK both gave significant increases in yield each year after application. Color and height differences between treatments were most noticeable during the first cutting season. Nutrients supplied gave increases in percentage nitrogen and phosphorus in the forages during the first year only. Fertilizer applications, however, failed to affect digestibility. Kilcher _et al_. (44) investigating fertilizer response of native grassland in Western Canada obtained total yield increases of 335 to 615 lbs/acre over a 3- or 4-year period from 60 lbs. N per acre. Residual response to nitrogen accounted for a large part of the yield increases. Weeds, mainly _Artemisia frigida_, where present, showed a marked response to nitrogen fertilizer. Residual weed yield increases were not sustained to the same extent as were the grass yield increases. Weed response was mainly during the first and second year after fertilization. Similarly, Hubbard and Mason (39) at Kamloops, B.C. noted that applications of fertilizers to range areas not only stimulated the production of desirable forage species, but also weeds.

Johnston, Smoliak and Lutwick (43) studied the recovery of Mixed Prairie vegetation in fair condition when fertilized with various rates of nitrogen and phosphorus. They reported that Agropyron species and Artemisia frigida Willd. increased while some short grasses and Stipa comata Trin. and Rupr. decreased. Fertilized plots were invaded by Descurainia sophia (L.) Webb, Chenopodium leptophyllum Nutt., and Hordeum jubatum L. Fertilizer applications increased rangeland production by about 300% at low rates (10-185 kg/ha N, 10-155 kg/ha P) and about 900% at high rates (870-1095 kg/ha N, 680-820 kg/ha P); the latter were accompanied by major vegetation changes.

Some botanical composition changes upon nitrogen fertilization are favourable, Hall and Altona (34) report that upon using heavy rates of nitrogen, the climax grasses in the veld of South Africa eventually died out and were replaced by more desirable grasses, mainly lovegrasses (Eragrostis spp.) and some Bermuda grass (Cynodon spp.). This transition could be accomplished more quickly by higher levels of nitrogen. Many unpalatable grasses were replaced by more desirable species and the fertilized sward also remained palatable for a longer period in fall.

Improvement of a grassland sward under a system of rotational grazing and application of inorganic nitrogen was studied in the Netherlands by Ennik (27). In rotational grazing Lolium perenne and Poa trivialis were favoured by high nitrogen application (140 kg N/ha), however, Trifolium repens showed a preference for low nitrogen. Continuous grazing, at the same nitrogen rate, favoured the less valuable forage species, eg. Holcus lanatus. Grazing systems, according to Ennik, have a greater effect on botanical composition than differences in nitrogen application, indicating that careful management is essential to regulate the changes that occur in botanical composition upon fertilization.

Clarke and Tisdale (21) studying the chemical composition of native forage plants on the Canadian Prairies reported that in general, the species studied appeared to supply the requirements of range livestock reasonably well except phosphorus. The calcium-phosphorus ratio was quite low at the earlier growth stages, but was fairly high in the cured forage which tended to intensify the effects of the low percentage of phosphorus. Reports of phosphorus deficiencies in feeds have been widespread, particularly in semi-arid or arid regions. The phosphorus content was significantly increased by applications of phosphate fertilizers. The lack of phosphorus in the native forage could be remedied either by fertilization or by adding a mineral supplement directly to the diet of livestock. The investigators noted that the percentage of protein, ether extract and phosphorus dropped sharply from the leaf to the flowering stage and then declined more gradually until curing occurred. Crude fibre increased throughout growth development. There was a positive correlation between protein and phosphorus and a negative association between each of these constituents with crude fibre.

Bezeau, Lutwick, Smith and Johnston (9) studying rough fescue (*Festuca scabrella*) in Alberta noted that while percentage of protein generally increased with increasing rate of fertilizer, silica content decreased. A protein content of at least 16% was required to keep the silica content below 2% and thus prevent formation of silica uroliths.

Most of the broad-leaved forage species were significantly superior to grasses in phosphorus content (21). Clarke and Tisdale found meadow grasses to be slightly lower in protein content and slightly higher in fibre than in the main shortgrass species, but the phosphorus contents were about the same.

Herriott (38) noted that phosphate applications were important in establishing forage species in Great Britain because of greater vigour and for providing better opportunity for increased final establishment. It is generally accepted that legumes require more phosphorus for development then do cereals or grasses. Legumes also require boron and molybdenum for successful nodulation (47).

B. Trace Elements

Copper. An intermediate range for copper in alfalfa tops has been defined as 5.1-9.6 ppm and in wheat straw 9-18 ppm (16). Whitehead (72) reports that copper content in herbage species is generally within the range of 2-15 ppm; white clover was found to have consistently higher copper contents than grasses. According to Gilbert (31) soils high in organic matter, especially newly cultivated peat soils, are most likely to be deficient, but very sandy soils with a low humus content may require copper as well.

The copper content of timothy reportedly decreased with maturity (7). Whitehead (72) found some grasses decreasing in copper content with maturity, while red and white clover showed no significant decrease. According to the Agricultural Research Council (A.R.C.) London (2) 10 ppm of copper per dry-weight diet are required for a dairy cow weighing 500 kg. and yielding 10 kg. milk.

Manganese. Mulder and Gerretsen (49) reported that there was little agreement in the literature as to the critical amount of manganese in plants below which deficiency symptoms may be found. Rye, ryegrass, and a tolerant barley variety were found to be healthy when containing only 10 to 11 ppm manganese on a dry weight basis. Wheat and barley were slightly deficient at concentrations of 14 and 12 ppm of manganese, respectively. According to Allaway (3) 15-100 ppm is the normal concentration in plants and 10-40 ppm are the critical levels in animal diets.

Beeson and MacDonald (7) found that the manganese content of timothy and birdsfoot trefoil increased with maturity.

Plant uptake of manganese is particularly influenced by pH and drainage. Deficiencies of manganese may occur on well-drained calcareous soils, while manganese toxicity may occur in plants on very acid soils (72,6).

Zinc. Zinc deficiencies of cereals and herbaceous plants appears to be related to soil reaction rather than to total zinc concentration in the soil (6). The zinc content in grasses and legumes is generally in the range 15-60 ppm. Allaway (3) reports that a concentration of 8-15 ppm is required for plants, while values of over 200 ppm are toxic to the plant. Gerloff et al. (30) found that a certain species contained 300-700 ppm zinc while comparison species contained less than 50 ppm, suggesting selective uptake by certain plants.

Ruminant requirements were 50 ppm according to A.R.C. (2), and 30 ppm according to Underwood (64). Whitehead (72) states that zinc deficiencies are not common in grazing animals.

Iron. Iron deficiency typically shows up as a chlorosis, particularly on calcareous soils, but crops differ markedly in their susceptibility to this trouble (72). Fruit trees and vegetable crops, particularly beans and soyabeans, are very sensitive to lime-induced chlorosis. A survey of the iron content of several corn varieties in New Jersey indicated a range of 113-318 ppm (35). Compilations of data by Woodward (73) show that leguminous plants average over 16 ppm of iron and wheat about 30 ppm.

The minimum level of uptake suggested by A.R.C. (1) is 30 ppm for ruminants. Like zinc, iron generally is not a problem with grazing livestock.

Molybdenum. Molybdenum content in pasture species varied from 0.01 to more than 200 ppm, but the usual range is 0.1 to 4 ppm (72). Barshad (4) found that legumes tend to absorb considerably larger amounts of molybdenum than nonlegumes, particularly when grown on soils with high soluble molybdenum content. The molybdenum content in plant material is determined mainly by the molybdenum status of the soil and its pH. In contrast to other trace elements, molybdenum is generally more available to plants growing on alkaline soils than in acid soils. Legumes are unable to fix nitrogen in the absence of an adequate molybdenum supply. Every nitrogen-fixing organism so far recognized requires molybdenum for this process (60).

Much of the research on the role of molybdenum in animal nutrition has been concerned with effects due to excess molybdenum. Dick (25) reports that toxic effects have been observed in cattle if concentrations of pasture ranged from 15-300 ppm on a dry weight basis. Bear (6) considers 5 ppm molybdenum as being the upper tolerance limit in animals and indicates an interaction with copper may occur. Molybdenum-induced copper deficiency occurs at higher levels of molybdenum and is also related to the copper content and sulphate concentrations in the diet. Although molybdenum is listed as one of the elements required by animals, the required levels have been considered to be less than 1.0 ppm of the dry diet for many species (3).

Boron. Underwood (64) states that the essentiality of boron in animal diets has not been established. Berger (8) reports that alfalfa is deficient if boron content is less than 10 ppm on a dry weight basis. Dicotyledonous plants require about four times as much boron as moncotyledonous plants. An intermediate range for boron in oats is 15-50 ppm (16).

The uptake of trace elements could be affected by a change in pH of the root zone from the application of nitrogen and phosphorus. Furthermore, these macro-nutrients could also change the physiological processes of plants. Using N-depleted wheat seedlings grown in nutrient solution, Jackson and Williams (41) found that these seedlings were only poorly able to transport cations to the shoots, but in the presence of nitrate the transport processes were increased substantially. Supplying nitrate to N-depleted seedlings stimulated the uptake of both divalent (Sr, Mn, and Mg) and monovalent (Cs, Na, and K) cations.

C. Stage of Cutting

Forages change markedly in chemical composition as they mature and thereby influence the nutritive value of the forage for livestock. As reviewed above, per cent crude protein decreases while the per cent dry matter, crude fibre and lignin increase. Extensive reports have been published with regard to digestibility as affected by the stage of harvesting, however, only a brief outline of this subject can be presented here.

Digestibility of forage dry matter, crude protein, crude fibre and nitrogen-free extract declines as the forage matures. The result is a lower energy or total digestible nutrient content (65). Johnston and Bezeau (42) state that carotene content of range forages also decreased with advancing maturity. Seasonal declines in percentages of crude protein and phosphorus were closely paralleled by a decline in liveweight gains of cattle.

D. Changing the Botanical Composition by Introducing More Productive Species

Preliminary range seeding trials have been conducted by the Manitoba Dept. of Agric., Soils and Crops Branch in Manitoba. Breakey (12) compared the effectiveness of (a) direct sod seeding, (b) rotovation and seeding, and (c) two cultivations plus harrowing before seeding in a demonstration trial near Eriksdale, Man. In the first treatment competition from native grasses was severe. Treatments two and three resulted in some native grass competition, but as a whole, forage quality and yields were improved.

Considerable research has been conducted in New Zealand and in the British Isles to introduce more desirable species in land that is unsuitable for reseeding by conventional methods. Surface sowing has been attempted with the use of aircraft, with special machinery for overdrilling, and in conjunction with the use of herbicide applications (17).

For successful resowing the following conditions must be met: (a) the correction of soil nutrient deficiencies, (b) the elimination of the old sward, (c) getting the seed into contact with the soil, and (d) suitable management during and after establishment. These points were mentioned by Charles (17) who reviewed the subject of surface-overdrilling methods quite comprehensively.

It is of great importance to select the proper species that will compete with the native vegetation and persist successfully. Species capable of spreading rapidly by tillering or by their creeping habit are desired. While persistency is important, there may be a place for the quick-growing, short-lived species which would serve as cover crops for the more persistent species.

Heinrichs (37) working in Western Canada reported that natural regrassing of abandoned farms required 20-30 years and yielded poorly. Abandoned farmlands following the period of 1928 - 1937 were successfully reseeded by drilling the seed into the ground without any previous cultivation. The changeover from annual weeds to grass required approximately one or two years. Crested wheatgrass was a successful competitor with most weeds and native grasses. In arid and semi-arid regions of Western United States, Pechanec (50) found introduced wheatgrasses to do well, but removal or reduction of plant competition was essential for successful seeding.

In Great Britain the pasture varieties of Lolium perenne are very useful for their quick initial growth. Copeman and Roberts (22) found Dactylis glomerata to establish easily on drier sites in Northern Scotland and Phleum pratense adaptable to the wetter sites. The latter species, however, tended to be grazed out because of their high palatability and poor competitive ability. In a heather-dominant plant community (Calluna vulgaris) nitrogen applications resulted in adverse competition to seedlings. More efficient utilization of nitrogen was obtained when applications were delayed sufficiently to utilize the applied nitrogen (56).

Trifolium repens has been reported to establish by surface sowing without the use of herbicides (17). Birdsfoot trefoil provided a 2.7-fold increase in beef production over unimproved pastures in Southern Iowa (70). The unimproved pasture contained Kentucky bluegrass and white clover. Birdsfoot trefoil has proven to be a valuable legume for renovating pastures in Southern Ontario (71). This species was established following destruction of the sod by dalapon or paraquat.

Blackmore (10) in New Zealand, sprayed paraquat in narrow bands of pasture directly in the paths of the coulters of a drill. The sprayed band suppressed the plants growing within the band and permitted the overdrilling species to establish without direct competition from the existing sward. By seeding clover they obtained a virtual domination of clovers within the bands.

The use of paraquat in improving pastures in Manitoba was studied by Bowes and Friesen (11). Spring applications of paraquat at 1 lb. per acre were effective in suppressing the existing grasses and forbs, thereby enhancing alfalfa establishment. Woody perennials, however, were a problem.

Various equipment has been used in sod-seeding. On dense swards, in the absence of chemical pre-treatments, it appeared necessary to remove a small ribbon of turf exposing an open furrow for the seed. A skim-disc coulter was developed for this purpose and was used by Warboys and Johnson (68). These investigators found significant differences of emergence in timothy, with the pasture strains germinating considerably better than the hay strains. Fertilizer had no effect upon germination nor on the subsequent plant numbers in fall. Herbicidal pre-treatment had no significant effect upon seedling emergence, but seedlings on the sprayed plots appeared to be larger and stronger than those on unsprayed treatments. Failure of improved grasses and white clover to establish was thought to be due to various factors, particularly competition from vigorous lowland swards.

In another experiment, Warboys (67) studied the establishment of pasture plants by oversowing techniques, using paraquat to eliminate competition. The herbicidal treatment was followed by rotary cultivation which gave better establishment than any other oversowing technique, but did not always reduce the more persistent weed grasses.

III. MATERIALS AND METHODS

The study of native and cultivated forage crop production in the Interlake was conducted in three field experiments and one greenhouse study. The field experiments were located approximately ten miles west of Lundar, Manitoba.

A. Native Forages Study

A native vegetation study was conducted on an area immediately adjacent to the cultivated forages study on Clarkleigh-Marsh soil complex in NE 16-20-6W (site 1). The plot area of 150 feet by 450 feet was divided into three strips, each fifty feet in width. Three fertilizer treatments, randomly assigned to the three strips, were applied broadcast on June 14, 1966. The rates applied were 0, 225 lbs., and 450 lbs. 27-14-0 per acre, (1 lb/acre = 1.121 kg/ha), which will henceforth be referred to as levels 0, 1, and 2, respectively. Level 1 approximated the rate (80 lbs. N-acre and 45 lbs. P_2O_5/acre) recommended by Manitoba Soil Testing Laboratory, University of Manitoba, for establishing grasses. Originally, it was planned to apply 300 lbs./acre and 600 lbs./acre for levels 1 and 2, but from calculations of the amount applied, it was realized that these rates were not achieved.

Sampling of forages in the study area was conducted at bi-weekly intervals in 1966 from June 15 until September 20. The plant material was cut approximately two inches above ground level. The sampling area at each harvest date consisted of five square yards per plot which were obtained by random throwings of a square yard quadrat.

The forage samples were stored at below freezing temperatures after which percentage dry matter and total dry weight were determined. The samples were ground in a Wiley mill and analysed for crude protein (nitrogen), P, and K according to procedures outlined below. Minor elements were analysed with a direct-reading Jarrell-Ash Atomocounter by Ohio State University. Lithium was used as the internal standard. *In vitro*. digestibility was determined by the Animal Science Dept., University of Manitoba; according to methods by Clark and Ingalls (19).

Samples were also taken at bi-weekly intervals from an area of land adjacent to the cultivated species experiment on an Inwood soil in NE 22-20-6 (site 2). Samples were taken in 1966 from June 15 to August 9, at which time the grass reached maturity due to droughty conditions.

Vegetation consisting mainly of *Scholocloa festucacea* (Wild), spangle-top, was sampled on June 15, 1966 from an area approximately 200 yards west of site 1.

On May 9, 1967 fertilizer treatments consisting of 0, 240 lbs. 33.5-0-0 per acre, 85 lbs. 11-48-0 per acre, and 300 lbs. 27-14-0 per acre were superimposed in triplicate, on the levels of 0, 1 and 2 established in 1966. These original levels were regarded as main plots in a split-plot experimental design. The fertilizer was applied with a Gandy fertilizer broadcaster. The 1967 treatments were chosen to test for responses to N and P alone, and to combined NP treatments. In the phosphorus only treatment, however, 9 1/3 lbs. of N were included. The rates were selected so that the NP treatment corresponded to level 1 in 1966 and the single element applications approximated the amount of nitrogen and phosphorus in the 300 lb. 27-14-0 per acre rate.

Sampling of forages were made in a similar manner as described above, on June 13 and July 26, 1967. These dates represented the early to late range in harvesting. The samples were used for determination of total dry weight only.

In order to control an infestation of sow thistle and other weeds the entire plot area was sprayed on June 14, 1967 with 10 oz. of 2,4-D amine (active ingredient) in 5 gallons of water per acre.

B. Cultivated Forages Study

Three field experiments with nine forage species and three soil fertility levels were established on two different soil series. Two field experiments, sites 3 and 4, were sown on June 14 and 15, 1966. Site 3 was immediately adjacent to the previously described Clarkleigh-Lundar soil (site 1) and, similarly, site 4 on the Inwood soil was in close proximity to site 2, described in part A. Another experiment, site 5, was sown on May 24 and 25, 1967, on a newly-cleared area on Inwood soil in section NW 22-20-6W.1. The species and varieties sown were as follows:

Species	Variety	Seeding Rate (lbs./acre)
White Clover	Ladino	6
Birdsfoot Trefoil	Leo	6
Alfalfa	Vernal	6
Alsike Clover	Aurora	3
Reed Canary grass	Frontier	3
Timothy	Champ	3
Brome grass	Lincoln	6
Blue grass	Kentucky	20
Meadow Fescue	Ensign	7

Seeding on Sites 3 and 4 was accomplished with a 12 foot - 12 run drill owned by the co-operator, and Site 5 was seeded with a John Deere 8 foot drill.

Soil samples were taken from each field before seeding and samples were also taken from Site 3 in the spring of 1967.

Site 4 was a cultivated field requiring no special seed bed preparation; Site 3 was prepared for seeding by disking and rototilling the native sod; Site 5 had been recently broken and was prepared by clearing stumps and branches within the test area, followed by disking and harrowing.

The experimental area for Sites 3 and 4 were 150 ft. by 450 ft. and for Site 5 the area was 288 ft. by 88 ft. The individual plots were equal to 50 ft. by 12 ft. on sites 3 and 4, and 8 feet by 24 feet on Site 5. A split-plot experimental design was used on all three sites with each treatment being replicated four times.

Fertilizer treatments were applied by broadcast application with a John Deere fertilizer spreader prior to seeding on sites 3 and 4; fertilizer was drilled in at site 5. All fertilizer applications were made within the above-mentioned dates for seeding. Fertilizer treatments were identical to those applied on the native vegetation experiment in 1966 and are also designated as levels 0, 1 and 2. Additional fertilizer was applied on site 3, May 9, 1967 on treatments 1 and 2 at 150 lbs. and 300 lbs. respectively, of 27-14-0 per acre with a Gandy fertilizer spreader.

The fertilizer treatments for site 5 were: Check, no fertilizer; 215 lbs., and 430 lbs. 11-48-0 per acre. The second rate approximated the phosphorus requirements of legumes according to Manitoba Soil Testing Laboratory.

Observations and notes were made on establishment and vigor of all plots throughout the growing season. Forage samples were taken on June 13 and July 26, 1967 from site 3 on treatments where the cultivated species had become fairly well established.

For purposes of comparing yield, nutrient content and dry matter digestibility, forage samples were taken from the Plant Science Department plot of birdsfoot trefoil near Eriksdale, Manitoba, and from a brome-alfalfa field on the co-operator's farm. The sampling dates for the latter field were on June 15, July 11, July 26 and August 9, 1966. The birdsfoot trefoil plot was sampled on July 11 and August 9, 1966. Site 5 was harvested on August 7, 1967.

Percent ground cover was determined by the point quadrat method described by Clarke, Campbell and Campbell (20). Forty counts per sub-plot on site 3 were taken on June 28, 1967. A hit was recorded whenever a leaf touched the pin from the ground level to one inch above ground.

Site 3 was sprayed with 24 oz. MCPB in 20 gal. of water per acre on July 29, 1966, to control a severe weed infestation.

C. Greenhouse Study

A factorial experiment with three soils, three soil fertility levels, and six species, with a completely randomized block design, replicated three times, was conducted in a greenhouse during the winter of 1966-67. Soil for the study was taken from three Interlake soil series, Garson, Inwood and Clarkleigh from the 0-6 inch surface layer. The soil was air-dried and ground to pass through a 1/2 inch screen. Surface samples were sent to Manitoba Soil Testing Laboratory for routine analysis. Field capacity was determined by the moisture retained at 1/3 atmospheric pressure by the pressure plate extractor method.

A total of 162 plastic pots were prepared. Each pot contained 2 kg. air-dried soil. The fertilizer treatments were as follows:

(a_o) check, no fertilizer

(a_1) 45 ppm Nitrogen + 20 ppm Phosphorus + 45 ppm K

(a_2) 90 ppm Nitrogen + 40 ppm Phosphorus + 90 ppm K

These rates can be converted to lbs./acre by multiplying ppm by two.

The carriers for nitrogen and phosphorus were NH_4NO_3, and K_2HPO_4, respectively. The fertilizers were dissolved in water and applied in the solution form, one inch below the seed.

The forage species used were those used in the field experiments but alsike clover, white clover, and blue grass were omitted. White clover and blue grass were grown on the Garson soil only and were not included in statistical analysis.

Seeding was completed on Dec. 21, 1966. Ten seeds per pot were sown 1/2 inch below the surface and thinned down to four plants per pot on February 16 and 17, 1967. Optimum moisture conditions were provided by adding water daily to bring the moisture level to field capacity. Notes were made on emergence up to January 12, 1967.

The first harvest date was March 9 and 10 and the second harvest was on April 13 and 14. Notes as to stage of maturity were taken at harvest dates. Height measurements were made on March 16, 23, and 31. Photographs of reed canary grass were taken on April 13. The plants were cut off directly above the surface, oven dried, weighed and stored for possible future analysis.

Statistical analyses were made according to procedures outlined by Steel and Torrie (62).

D. Chemical Analyses

A representative sample of the ground forage material was ashed as outlined by Jackson (40) and the total phosphorus content determined colorimetrically as outlined by Barton (5). The nitrogen content of the plant material was determined by the Kjeldahl methods (13). The crude protein content was obtained by multiplying the total N by 6.25 (36). The latter determination was made by the Plant Science Dept., University of Manitoba. Potassium, extracted with NaOAc, was determined by the flame photometric method, using lithium as an internal standard (69).

IV. RESULTS AND DISCUSSION

A. Description of the Study Area

The soils in the study area have developed on highly calcareous glacial till and occur in the physiographic area known as the Interlake Till Plain (51). According to Pratt et al. (51) the Interlake Till Plain is a gently undulating area of ground morraine consisting of mainly limestone materials. All the soils are very stony.

The land has a distinctive low ridge and swale topography with a general north-west to south-east linear pattern. The ridges provide a damming effect on drainage.

The soil series in this study were Garson, Inwood, Clarkleigh, and Lundar. The latter two soil series were mapped as a complex at sites 1 and 3. These soils occupy an extensive area in the Interlake. Soil samples were taken from each of the plot areas and the analyses are shown in Table 1.

The results indicate that available phosphorus and nitrate-nitrogen were very low at the two experimental sites, while exchangeable potassium was high (Table 1). The conductivity of the subsoil in the Clarkleigh-Lundar Complex was less than four mmhos/cm. and therefore cannot be classified as saline. These areas, according to Pratt et al. (51) bordering Lake Manitoba are natural grasslands because soil salinity has prevented tree growth. The modal Clarkleigh soil profile described by Pratt et al. was saline in the Ahsg horizon and in the parent material. While soil sampling did not indicate a salinity problem, it was suspected nevertheless. The saline soils along the east shore of Lake Manitoba are generally high in both sulphates and chlorides, with appreciable amounts of soluble calcium, magnesium

TABLE 1

SOME SURFACE SOIL CHARACTERISTICS

		Inwood (Site 2)	Clarkleigh-Lundar Complex (Site 1)		
			Low	Intermediate	Ridge
Profile		Gleyed dark gray	Carbonated rego humic gleysol	Gleyed carbonated rego black	Gleyed carbonated rego black
Texture		CL	CL	CL	CL
Soil Reaction		8.1	8.2	9.0	8.8
Conductivity (mmhos/cm)	0-6"	0.3	2.4	0.6	0.5
	6-12"	0.2	2.1	3.1	1.0
	12-24"	-	-	3.0	-
Phosphorus - $NaHCO_3$ extractable (ppm)		0.5	1.5	2.5	1.5
Potassium - exchangeable (ppm)		165	120	150	180
Nitrate - N (ppm)	0-6"	0.8	1.6	0.4	0.8
	6-12"	0.4	1.5	1.5	1.2
	12-24"	-	-	0.9	-

and sodium (52).

Conductivity did not appear to be affected by cultivation (Table 2). Phosphorus was very low, even after high rates of fertilizer applications. Nitrogen content of the surface was increased slightly by fertilizer application. Some nitrification may have occurred on the unfertilized cultivated site, and accumulated because of negligible forage growth.

Analysis of the three soils used in the greenhouse study indicate that they were all very low in available phosphorus and nitrate-nitrogen, (Table 3). The moisture retained by the Clarkleigh-Lundar soil at 1/3 atmosphere was considerably greater than the other two soils, possibly because of a higher organic matter content.

B. Evaluation of Native Vegetation

1. Effect of fertilization on yield and per cent dry matter.

Dry matter yields on unfertilized meadow vegetation are very low (Table 4), approximately half a ton per acre in 1966. At the August 23 harvest date increases of 230% and 280% were obtained from the recommended and double rates, respectively. Forage yields on all plots declined after August 23. Percent dry matter increased throughout the growing season for all treatments, but at the final harvest date the percent dry matter for fertilizer level #2 was still less than that of unfertilized vegetation on June 15. The higher moisture content of fertilized vegetation was partly accounted for by succulent weed growth.

Forage yields of unfertilized native vegetation on Inwood soil (Table 5) were slightly lower than yields of unfertilized meadow vegetation. The percent dry matter of Inwood native hay, brome-alfalfa, and birdsfoot trefoil increased with advancing maturity. No further harvests were taken

TABLE 2

SOME SURFACE SOIL (CLARKLEIGH-LUNDAR COMPLEX) CHARACTERISTICS ONE YEAR AFTER APPLICATION OF VARIOUS TREATMENTS

	Fertilizer Treatments		
	Check	Level 1	Level 2
Native Vegetation Experiment			
Soil Reaction	7.6	7.6	7.6
Conductivity (mmhos/cm)	1.9	1.4	2.0
Phosphorus NaHCO$_3$ extractable (ppm)	3.9	8.4	11.9
Potassium, exchangeable (ppm)	275	312	279
Nitrate - N (ppm)	2.0	12.4	20.8
Cultivated Forages Experiment			
Soil Reaction	7.5	7.6	7.5
Conductivity (mmhos/cm)	2.3	1.9	1.0
Phosphorus NaHCO$_3$ extractable (ppm)	5.7	6.6	10.9
Potassium, exchangeable (ppm)	282	262	252
Nitrate - N (ppm)	12.0	17.9	30.5

TABLE 3

CHARACTERISTICS OF SOILS
FOR GREENHOUSE STUDY

	Soil Series		
	Garson	Inwood	Cl.-Lundar
Texture	CL	CL	CL
Soil Reaction	7.8	7.0	7.7
Conductivity (mmhos/cm)	0.6	0.7	1.2
Phosphorus, $NaHCO_3$ extractable (ppm)	6.6	6.2	7.0
Potassium, exchangeable (ppm)	343	350	439
Nitrate - N (ppm)	1.9	7.5	13.4
Field Capacity (%)	31.1	33.9	47.8

TABLE 4

PERCENT DRY MATTER AND PRODUCTION OF NATIVE FORAGES ON CLARKLEIGH-LUNDAR SOIL AS AFFECTED BY THREE SOIL FERTILITY LEVELS

Harvest	Per cent Dry Matter			Dry Matter Yield		
Dates	Check	Level 1	Level 2	Check	Level 1	Level 2
1966				(lbs/A)	(lbs/A)	(lbs/A)
June 15	43.6	-	-	418	-	-
July 11	43.5	31.0	22.5	1128	2159	2142
July 26	43.7	31.4	27.5	1002	2287	2389
August 9	47.4	37.0	33.8	1106	2172	3202
August 23	47.8	37.2	31.2	1129	2610	3165
September 6	51.3	42.4	38.8	929	2111	2905
September 20	54.5	48.0	41.8	838	1454	2604

TABLE 5

PERCENT DRY MATTER AND PRODUCTION OF VARIOUS INTERLAKE FORAGE CROPS AT SEVERAL HARVESTING DATES

Harvest Dates	Percent Dry Matter			Dry Matter Yield		
	I. Native Hay	Brome-alfalfa	B. Trefoil	I. Native hay	Brome-alfalfa	B. Trefoil
1966				(lbs/A)	(lbs/A)	(lbs/A)
June 15	28.4	24.1	17.3	252	1959	1895
July 11	41.6	26.1*	21.1	977	985*	2025
July 26	44.3	31.0	**	803	1258	**
August 9	52.8	36.7	31.7	537	1279	763

* following first cut

** no regrowth recorded after first cut on particular harvest date after August 9 because growth of Inwood native vegetation had ceased and the second cut had been taken from brome-alfalfa and birdsfoot trefoil. These latter two crops made rapid growth in early spring compared to native vegetation. Yield of brome-alfalfa was slightly more than one and one-half tons per acre (1959 lbs. for first cut and 1279 for last cut), while birdsfoot trefoil yielded slightly less (2025 lbs. for first cut and 763 lbs. for last cut). These yields are very favourable compared to unfertilized native vegetation and might have been considerably higher if moisture conditions had been optimum.

2. Effect of fertilization on macro- and micro-nutrient concentrations in plant materials.

Phosphorus Content. The phosphorus content of the native vegetation receiving the high fertilizer rate increased markedly within four weeks after application (Figure 1). The increase in phosphorus content was not so marked for the level 1 fertilizer treatment. After early July, all fertilized vegetation declined in phosphorus content, except for a slight increase in late August. This increase could have been due to fresh growth following rain after a droughty period. Unfertilized vegetation decreased rapidly after the first harvest date and continued to generally decrease in phosphorus content throughout the growing season. The phosphorus content of fertilized vegetation remained higher than the phosphorus content of unfertilized vegetation on all harvest dates. The vegetation fertilized with the high rate was considerably higher in phosphorus content than the medium (level 1) treatment throughout the entire season.

The phosphorus contents of unfertilized Inwood native hay and brome-alfalfa also decreased with time (Table 6). Generally, the phosphorus content

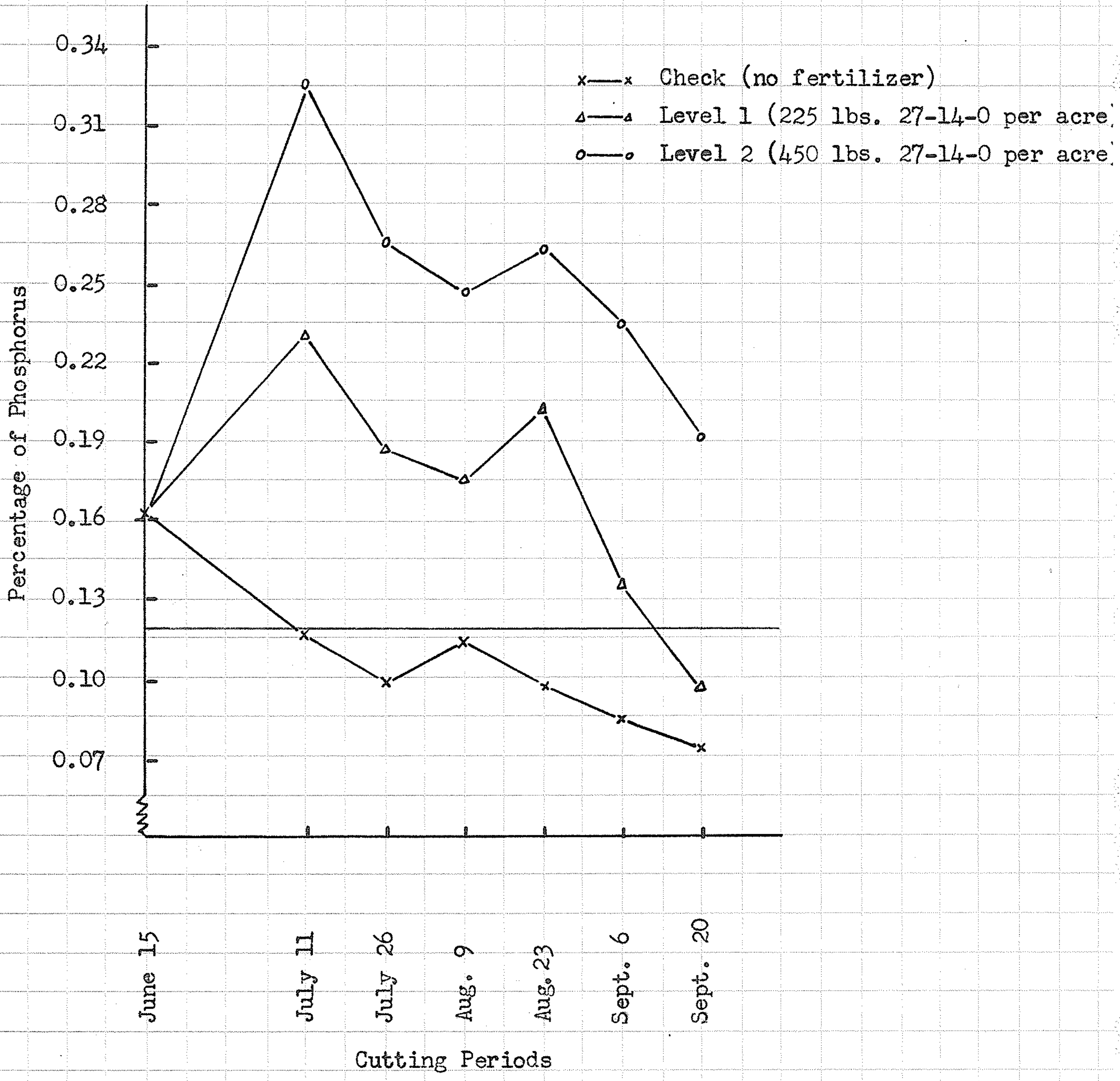

Figure 1. Effect of fertilizer treatments and season on the phosphorus content of native meadow forages. Horizontal line at 0.12 per cent indicates phosphorus to be low for range livestock.

of brome-alfalfa was considerably higher than that of Inwood native vegetation. In early August brome-alfalfa and birdsfoot trefoil had a higher phosphorus content than either Inwood or unfertilized meadow vegetation. The low phosphorus values in Interlake native vegetation concurred with the observations of Grieve (33), and Ellis and Caldwell (26).

Potassium Content. The potassium content of native meadow vegetation also generally decreased after late July (Figure 2). The fertilized meadow vegetation absorbed more potassium than unfertilized vegetation. In the latter part of September the forage treated with the highest fertilizer rate had a greater potassium content than all other treatments. Brome-alfalfa (Table 6) had a higher potassium concentration than either fertilized or unfertilized meadow vegetation. The potassium concentrations of brome-alfalfa were generally considerably above 2% which is considered the critical level for alfalfa to overwinter successfully (18). The critical potassium level (that concentration at which growth first begins to be retarded, compared with plants above the critical concentration) for barley is 1% K in dry matter and for alfalfa 1.25% (16). Higher critical potassium concentrations have, however, been cited by other investigators. In August the potassium concentration of unfertilized meadow hay was below 1%, however, this cannot be interpreteted as a deficiency since potassium is leached from the leaves as the season progresses.

Crude Protein Content. The crude protein content of native meadow vegetation increased considerably upon fertilization, but generally decreased after early July (Figure 3). The second increase in protein content in late August could be due to new growth following rain. The unfertilized meadow vegetation decreased rapidly in crude protein content after the middle of June to 5.7% in late September. If harvested later than mid-July, unfertilized

TABLE 6

SEASONAL PHOSPHORUS AND POTASSIUM CONCENTRATIONS OF VARIOUS INTERLAKE FORAGE CROPS

Harvest	Phosphorus			Potassium		
Dates	I. Native	Brome-Alfalfa	B. Trefoil	I. Native	Brome-Alfalfa	B. Trefoil
1966	(%)	(%)	(%)	(%)	(%)	(%)
June 15	0.230	0.220	-	2.07	2.70	-
July 11	0.163	0.308	0.212	1.47	2.50	2.13
July 26	0.133	0.198	-	1.31	2.21	-
August 9	0.129	0.156	0.179	1.04	1.86	1.67

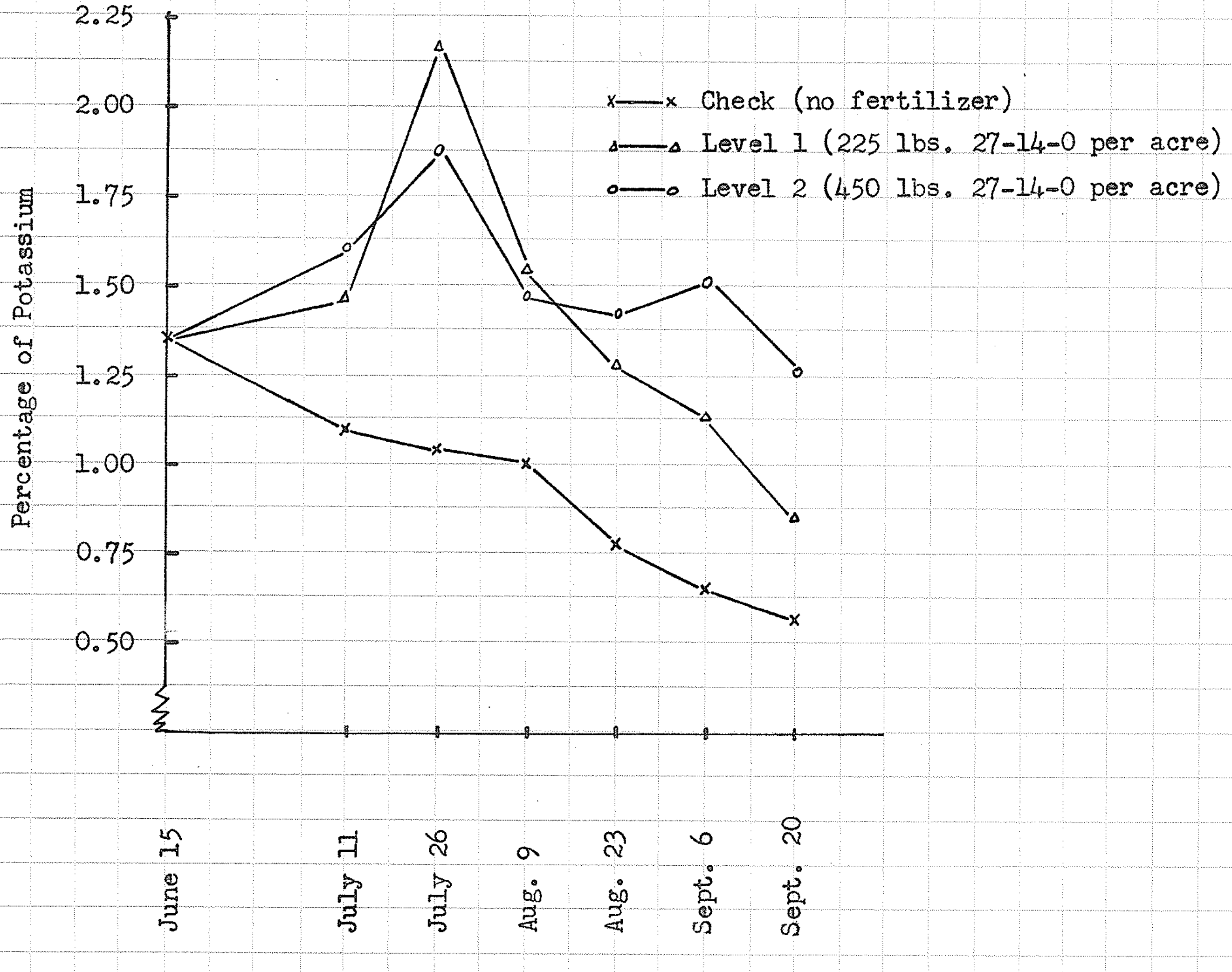

Figure 2. Effect of fertilizer treatments and season on the potassium content of native meadow forages.

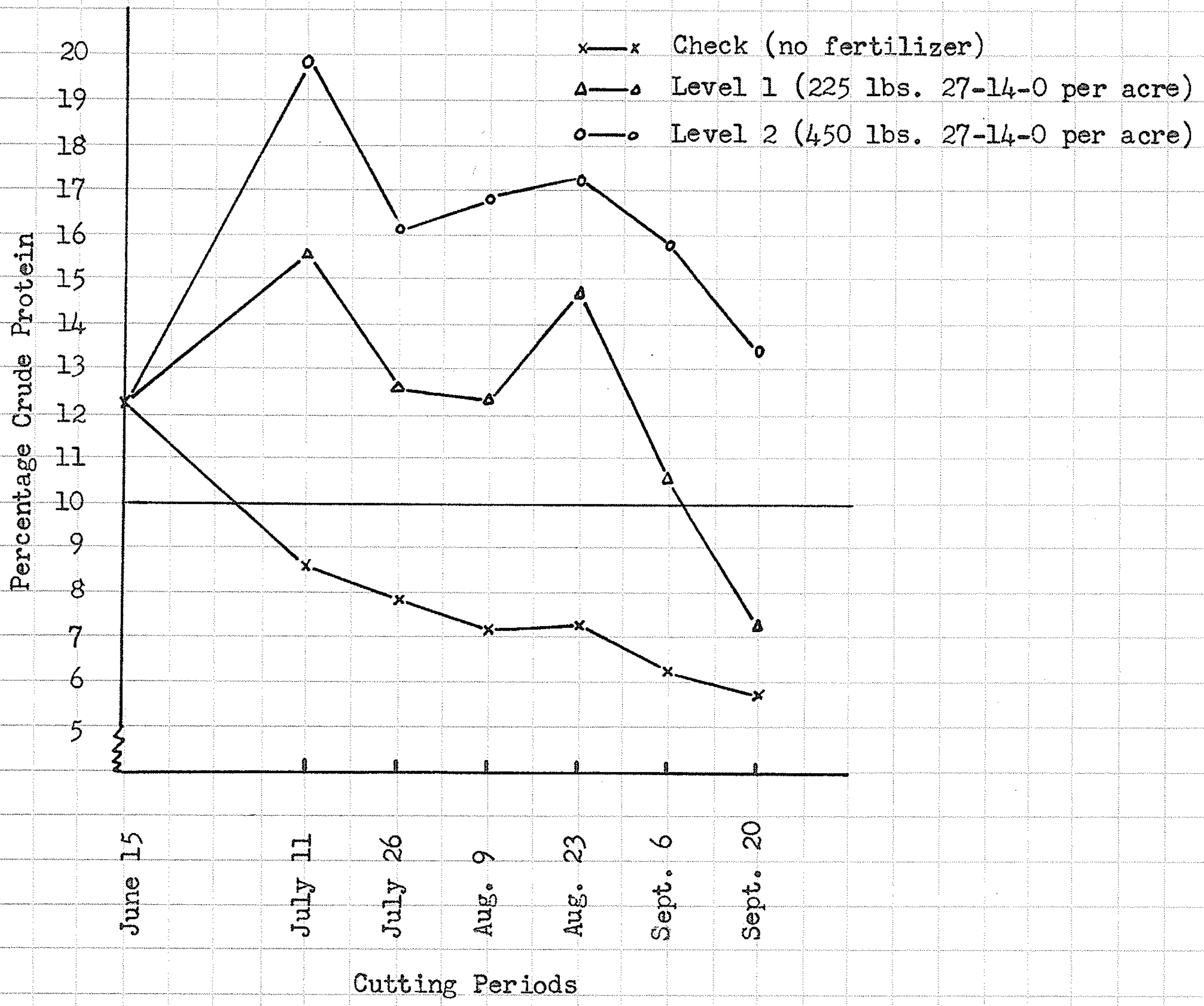

Figure 3. Effect of fertilization and season on percentage crude protein of native meadow forages. Horizontal line at ten per cent indicates that crude protein content is inadequate as feed for growing young cattle and brood cows.

meadow vegetation has an inadequate supply of crude protein for growing young cattle and brood cows (Figure 3). Brome-alfalfa (Table 7) contained a considerably greater amount of crude protein than fertilized native meadow vegetation and upland native hay. Following the first cut, most of the regrowth was from alfalfa, resulting in an increase in crude protein content on the July 11 harvest date. Data of yield, crude protein, phosphorus, and potassium all indicate that brome-alfalfa is a much superior forage to either native upland or meadow vegetation. The general seasonal decreases in crude protein and potassium are in agreement with the findings of other investigators.

Calcium, Magnesium and Sodium. Concentration of calcium and magnesium in native meadow hay generally increased with fertilization and advancing maturity (Tables 8, 9 and 10). The increase in calcium content corresponds to results obtained by Johnston and Bezeau (42) who also noted that crude fibre increased with advancing maturity. The ratio of calcium to magnesium seemed to decrease with fertilization.

Fertilized vegetation in early July had the desired Ca:P ratio of 1:2 to 2:1 (Table 11). The ratios of fertilized vegetation at level 1 were slightly improved over the non-fertilized vegetation. A significant improvement in the Ca:P ratio occurred with the high fertilization rate (level 2).

Calcium content of alfalfa was considerably higher than all native vegetation, fertilized or unfertilized, and was slightly higher than in birdsfoot trefoil (Tables 12 and 13). Ca:P ratios of 9.1, 4.9, 11.1 and 13.3 were obtained for the four successive harvest dates of brome-alfalfa, respectively, from the data in Tables 6 and 12. Native upland vegetation had 2.3, 2.4, 4.7 and 5.0 parts of calcium to one part of phosphorus at the four respective harvest dates (calculated from the data in Tables 6 and 14).

TABLE 7

CRUDE PROTEIN CONTENT OF VARIOUS INTERLAKE FORAGE CROPS AT SEVERAL HARVEST DATES

Harvest Dates 1966	Crude Protein		
	I. Native (%)	Brome-Alfalfa (%)	B. Trefoil (%)
June 15	11.5	19.8	-
July 11	10.7	21.1	14.2
July 26	8.9	18.5	-
August 9	8.8	18.1	15.7

TABLE 8

SEASONAL CONCENTRATIONS OF NINE ELEMENTS IN UNFERTILIZED NATIVE MEADOW VEGETATION

Harvest Dates	Elements								
	Ca	Mg	Na	Mn	Fe	B	Cu	Zn	Mo
1966	(%)	(%)	(%)	ppm	ppm	ppm	ppm	ppm	ppm
June 15	0.41	0.22	0.05	31	133	11	10	39	1.10
July 11	0.54	0.28	0.03	27	114	14	7	35	2.07
July 26	0.64	0.32	0.10	36	102	15	8	35	1.69
August 9	0.70	0.37	0.10	29	112	21	15	41	1.75
August 23	0.84	0.37	0.12	39	145	22	14	44	1.97
September 6	0.77	0.39	0.05	23	84	23	14	38	2.41
September 20	0.84	0.38	0.05	24	123	27	17	46	2.97

TABLE 9

SEASONAL CONCENTRATIONS OF NINE ELEMENTS IN NATIVE MEADOW VEGETATION FERTILIZED AT LEVEL ONE

Harvest Dates	Elements								
	Ca	Mg	Na	Mn	Fe	B	Cu	Zn	Mo
1966	(%)	(%)	(%)	ppm	ppm	ppm	ppm	ppm	ppm
July 11	0.47	0.36	0.16	34	193	14	8	37	1.58
July 26	0.91	0.58	0.26	37	124	27	11	46	3.11
August 9	0.88	0.64	0.23	34	117	24	17	42	4.16
August 23	1.02	0.61	0.32	47	187	28	16	39	3.23
September 6	1.14	0.68	0.25	37	103	32	18	45	4.31
September 20	1.08	0.56	0.21	32	95	34	17	42	3.23

TABLE 10

SEASONAL CONCENTRATIONS OF NINE ELEMENTS IN NATIVE MEADOW VEGETATION FERTILIZED AT LEVEL TWO

Harvest Dates	Elements								
	Ca	Mg	Na	Mn	Fe	B	Cu	Zn	Mo
	(%)	(%)	(%)	ppm	ppm	ppm	ppm	ppm	ppm
July 11	0.66	0.48	0.23	48	143	19	10	37	3.15
July 26	0.74	0.67	0.41	52	118	24	13	44	4.87
August 9	0.92	0.67	0.34	42	115	27	17	37	4.55
August 23	0.91	0.67	0.24	46	188	31	19	38	4.26
September 6	1.17	0.85	0.36	54	131	36	20	39	6.64
September 20	1.04	0.72	0.33	47	124	35	20	34	4.31

TABLE 11

SEASONAL RATIOS OF CALCIUM TO PHOSPHORUS IN NATIVE MEADOW VEGETATION AT THREE SOIL FERTILITY LEVELS

Harvest Dates	Ratios of Calcium to Phosphorus at Three Soil Fertility Levels		
	Check	Level 1	Level 2
June 15	2.5	-	-
July 11	4.6	2.0	2.0
July 26	6.5	4.9	2.8
August 9	6.2	5.0	3.7
August 23	9.3	4.8	3.5
September 6	9.6	8.2	5.0
September 20	12.0	11.5	5.4

TABLE 12

SEASONAL NUTRIENT CONCENTRATIONS IN BROME-ALFALFA

Element	Harvest Dates (1966)			
	June 15	July 11	July 26	August 9
Calcium (%)	2.00	1.50	2.20	2.08
Magnesium (%)	0.34	0.32	0.39	0.34
Sodium (%)	<0.01	<0.01	<0.01	<0.01
Manganese (ppm)	31	27	25	23
Iron (ppm)	168	153	119	117
Boron (ppm)	31	30	29	28
Copper (ppm)	32	15	15	17
Zinc (ppm)	49	37	33	29
Molybdenum (ppm)	1.82	2.16	3.27	2.13

TABLE 13

SOME NUTRIENT CONCENTRATIONS IN BIRDSFOOT TREFOIL AT TWO HARVEST DATES

Element	Harvest Dates (1966)	
	July 5	August 9
Calcium (%)	1.37	1.90
Magnesium (%)	0.46	0.59
Sodium (%)	0.04	<0.01
Manganese (ppm)	40	47
Iron (ppm)	-	237
Boron (ppm)	27	37
Copper (ppm)	16	20
Zinc (ppm)	30	38
Molybdenum (ppm)	3.15	6.04

TABLE 14

SEASONAL NUTRIENT CONCENTRATIONS IN NATIVE
UPLAND (INWOOD SOIL) VEGETATION

Element	Harvest Dates (1966)			
	June 15	July 11	July 26	August 9
Calcium (%)	0.53	0.39	0.62	0.64
Magnesium (%)	0.26	0.21	0.35	0.30
Sodium (%)	<0.01	<0.01	<0.01	0.04
Manganese (ppm)	46	36	39	35
Iron (ppm)	105	94	91	101
Boron (ppm)	15	12	18	18
Copper (ppm)	29	14	19	30
Zinc (ppm)	48	35	42	44
Molybdenum (ppm)	1.09	1.15	1.92	1.10

Sodium, while not required for plant growth, is absorbed by plants. The sodium content was usually very low (<0.01 ppm) in brome-alfalfa, birdsfoot trefoil, and upland native vegetation; however, in fertilized meadow vegetation, it was considerably greater (Tables 8, 9, 12, 13 and 14). Fertilization of meadow vegetation increased the sodium content over the unfertilized treatment (Tables 8, 9 and 10). No satisfactory correlation has been achieved between sodium accumulation in plant shoots with soil conditions, however, it has been established that plants differ greatly in their inherent abilities to absorb or exclude and translocate sodium (16). The large differences in sodium content among different forages are probably due to such species differences.

Micronutrients. Manganese content of upland and meadow vegetation ranged from 23-54 ppm (Tables 8, 9, 10 and 14). Manganese values were consistently slightly higher in the forage receiving the double fertilizer rate than in unfertilized forage. Brome-alfalfa and birdsfoot trefoil ranged in manganese content from 23-47 ppm (Tables 12 and 13). These values correspond to concentrations of 16-40 ppm found in various parts of meadow fescue by Fleming (29).

Iron content values ranged from 84-193 ppm for native meadow and upland vegetation and brome-alfalfa; birdsfoot trefoil appeared to have a slightly greater concentration (Tables 8, 9, 10, 12, 13 and 14). Forage samples are readily contaminated by traces of soil and may also be contaminated by certain types of mills used for grinding. The possibility that contamination occurred should be borne in mind when interpreteting this data.

Boron content of meadow vegetation ranged from 11-27 ppm, 14-34 ppm, and 19-36 ppm for nonfertilized, fertilized at recommended rate, and double rate, respectively (Tables 8, 9 and 10). Boron appeared to accumulate over the season, generally showing the greatest concentration at the final harvest date. Fertilization seemed to increase the uptake of boron, however, this may be due to a higher uptake by certain weeds which were stimulated by improved soil fertility. The boron content of brome-alfalfa averaged 29 ppm (calculated from data in Table 12). According to Berger (8) alfalfa is deficient in boron if the concentration is less than 10 ppm.

Copper content of fertilized meadow appeared to be slightly higher than in unfertilized vegetation (Tables 8, 9 and 10). The unfertilized meadow vegetation, if cut before August, is marginal in copper content for animal requirements according to the 10 ppm figure set by A.R.C. (2). Brome-alfalfa, birdsfoot trefoil and upland native vegetation was adequate for animal nutrition (Tables 12, 13 and 14). Similarly, Robertson (57) found the levels of copper of selected Interlake forages to be marginal compared to the recommended levels for cattle and sheep. Mason and Miltimore (47) noted that copper deficiencies in animals were often induced by high molybdenum contents. The values reported compared fairly well to wheat straw which contained 9-18 ppm copper; the range for normal growth in most plants usually falls between 5 and 20 ppm (16). It is not suspected that copper was deficient from the standpoint of plant nutrition.

Zinc concentrations in meadow vegetation ranged from 34-46 ppm, with no differences between treatments, and no apparent seasonal trends (Tables 8, 9 and 10). The range for brome-alfalfa, birdsfoot trefoil and upland native vegetation was 29-49 ppm (Tables 12, 13 and 14). Zinc is normally found in grasses and legumes in concentrations ranging from 51 to 60 ppm (72), and is generally not a problem in grazing animals.

Molybdenum concentrations in meadow vegetation ranged from 1.10 - 2.97 ppm, 1.58 - 4.31 ppm, and 3.15 - 6.64 ppm for fertilizer levels one, two, and three, respectively (Tables 8, 9 and 10). Cunningham, Brown and Edie (24) reported molybdenum toxicity to livestock at concentrations of 25 ppm in the Swan River Valley of Manitoba. In general, reports of molybdenum toxicity in cattle vary from 15 - 300 ppm (25). All molybdenum concentrations in this study were below 15 ppm, however, values of 5 ppm or greater, may create problems with copper nutrition. Birdsfoot trefoil had a considerably higher molybdenum concentration than brome-alfalfa (Tables 12 and 13). Upland native vegetation was generally lower in molybdenum than unfertilized meadow vegetation (Tables 10 and 14).

3. Effect of fertilization on in vitro digestibility, botanical composition and residual response.

Digestibility. Digestibility of native meadow forages was considerably improved upon fertilization (Tables 15 and 16). All meadow forages showed an increase in digestibility near the latter part of August, possibly because of new growth following rain. The native upland (Table 17) and meadow vegetation tended to show a gradual decline in digestibility with advancing maturity. This is similar to results obtained elsewhere. The digestibility of meadow vegetation fertilized at level one increased until late August and then declined. Dry matter digestibility fluctuated only slightly for meadow vegetation fertilized at level two. Brome-alfalfa was much more digestible than fertilized or unfertilized native vegetation (Tables 15, 16 and 17). Substituting brome-alfalfa for native species would provide Interlake farmers with a more digestible and nutritious forage compared to native vegetation.

Botanical Composition. The grass species growing on the ridges of a

TABLE 15

IN VITRO DIGESTIBILITY (12 HRS.) OF NATIVE INTERLAKE MEADOW VEGETATION AS AFFECTED BY FERTILIZATION AND SEASONAL CHANGES

Harvest Dates 1966	Digestibility and Treatment		
	Check (%)	Level 1 (%)	Level 2 (%)
June 15	28.33	-	-
July 11	21.10	23.90	26.03
July 26	23.34	34.53	34.74
August 9	25.57	31.59	34.07
August 23	-	32.28	34.61
September 6	24.16	30.55	36.31
September 20	20.85	29.14	35.21

TABLE 16

IN VITRO DIGESTIBILITY (48 HRS.) OF NATIVE INTERLAKE MEADOW VEGETATION AS AFFECTED BY FERTILIZATION AND SEASONAL CHANGES

Harvest Dates 1966	Digestibility and Treatment		
	Check (%)	Level 1 (%)	Level 2 (%)
June 15	40.28	-	-
July 11	31.50	41.39	49.95
July 26	34.74	44.84	48.73
August 9	33.29	45.29	49.56
August 23	-	48.46	50.56
September 6	38.49	43.12	53.16
September 20	35.09	42.86	49.92

TABLE 17

IN VITRO DIGESTIBILITY OF NATIVE UPLAND FORAGES AND BROME-ALFALFA AT VARIOUS HARVESTING DATES

Harvest Dates 1966	Forage Material	Digestibility 48 hrs. (%)	Digestibility 12 hrs. (%)
June 15	Inwood Native	48.93	35.14
	Brome-alfalfa	60.04	48.73
July 11	Inwood Native	41.12	28.51
	Brome-alfalfa	54.74	39.23
July 26	Inwood Native	41.12	30.58
	Brome-alfalfa	54.54	41.46
August 9	Inwood Native	40.83	28.72
	Brome-alfalfa	59.21	41.14

Clarkleigh-Lundar soil complex were mainly *Poa compressa* L., Canada blue grass, and *Agropyron smithii* Rybd., western wheat grass. Canada blue grass grows on soils of low fertility or those having poor drainage characteristics according to Campbell, Best, and Budd (15). Both upland species provide good pasture in their vegetative state and are usually closely cropped by cattle. Swale vegetation, however, is not utilized to the same extent, permitting it to become coarse and unpalatable. By late July, Canada blue grass was in the heading stage and in late August it was in advanced maturity. The species that predominated in the depressions of the plot area were *Spartina pectinata* Link, (prairie cord grass), *Calamagrostis inexpansa* A. Gray, (northern reed grass), and *Calamogrostis canadensis* (Michx.) Beauv., (marsh reed grass).

Canada blue grass was also the dominant species on the Inwood soil (Site 2). Usually, however, dense stands of *Populus tremuloides*, Michx., (aspen poplar) grow on Inwood soils; in this case, blue grass was occupying an area that had been cleared by man. Canada blue grass was fully mature in early August on the Inwood soil.

Weed response was considerable on the fertilized meadow plots in 1966. By the end of July more than 60% of the forages in the high fertilizer treatment consisted of *Ambrosia psilostachya* DC, (perennial ragweed) and *Sonchus arnensis* L., (perennial sow thistle). The percentage of weeds in the treatment receiving the recommended fertilizer rate was considerably less, about 40% of the total forage yield. Weeds of lesser importance were *Aster* spp., *Grindelia perennis* A. Nels., (gumweed) and *Hordeum jubatum* L., (wild barley). In 1967 satisfactory weed control was obtained with one application of 2,4-D amine. Many of the perennial weeds were not killed by the herbicide, however, their growth was subdued to a large extent.

Scolochloa festucacea (Willd.) Link, (spangletop) grows in solid stands in the deeper depressions of Clarkleigh-Lundar meadows. The percent dry matter was 25.8 and the dry matter yield was 1724 lbs./acre on June 15, 1966. It can readily be seen that this grass outyielded other types of native vegetation from the same area. Other characteristics of spangletop in mid-June were: Crude protein 12.5%, phosphorus 0.223%, potassium 2.42%, calcium 0.29%, magnesium 0.23%, and digestibility (12 hours) 35.0%. According to Campbell, Best and Budd (15) this species is palatable both for pasture and hay. They recommend it be cut for hay as soon as the water recedes and the land becomes dry enough to carry machinery.

Spangletop compared very favourably to other native vegetation with respect to crude protein, potassium and phosphorus content. The concentrations of manganese, iron, boron, copper, zinc and molybdenum in ppm were 95, 93, 12, 32, 69, and 1.18, respectively. Spangletop appears to have a higher copper content than other meadow vegetation.

Residual response from Fertilizer. Dry matter yield of native meadow vegetation was affected by the fertilizer treatments of the previous year (Figure 4). The yield from the plot which received the high fertilizer rate in 1966 was almost half a ton per acre greater than the yield from the plot which had not received any fertilizer. Eighty pounds of nitrogen increased yields of native meadow vegetation, on all plots, regardless of the previous year's treatment. Increases in yield from 80 lbs. nitrogen per acre obtained over that received from the unfertilized plot were about 500 lbs. and 1400 lbs. per acre from the 1966 fertilized plots, levels one and two, respectively.

Additions of phosphorus alone did not appear to affect yields, (Figure 4). Taking two year's yield data into consideration, the returns from fertilizer

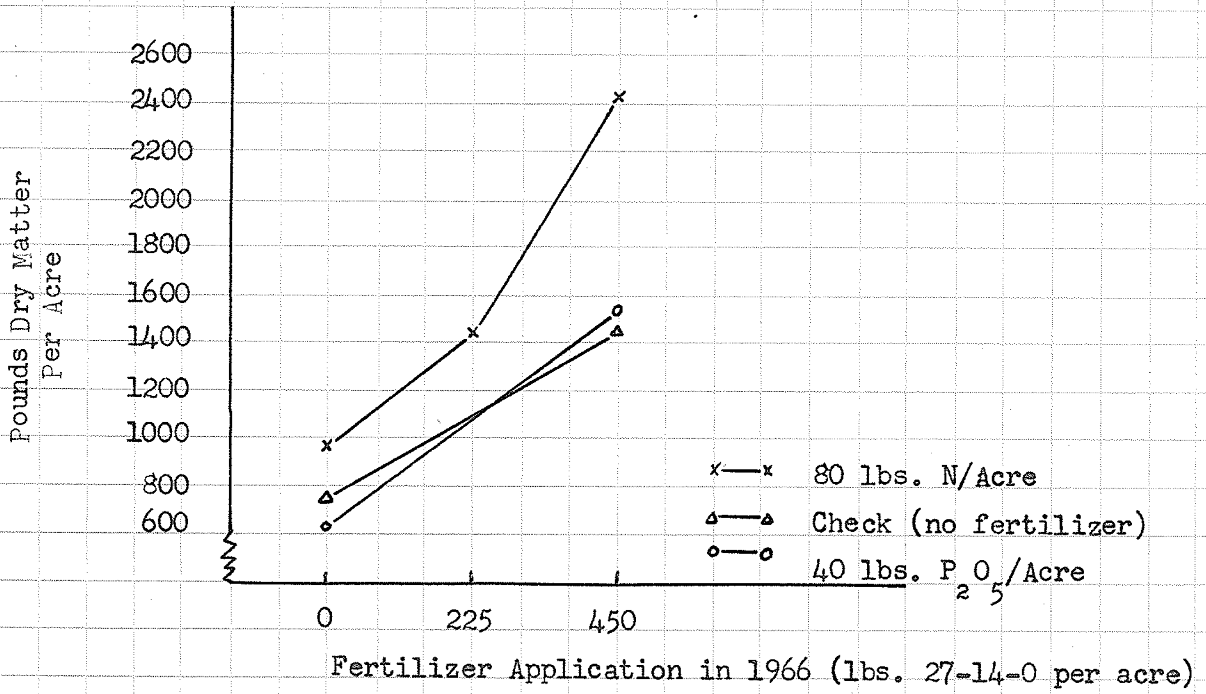

Figure 4. Effect of nitrogen and phosphorus on dry matter yield of native meadow vegetation (harvested June 13/67) previously treated with 0, 225 lbs., and 450 lbs. 27-14-0 per acre.

on native stands were not economical at this time.

C. Production of Cultivated Forages

Forage establishment on the Clarkleigh-Lundar soil. Due to extremely droughty conditions in 1966 (Appendix 1) germination of some grasses was seriously impaired and delayed; emergence of legumes occurred much earlier than grasses. Of all the species sown, alfalfa was the most successful from the standpoint of visual observations. White clover was ranked next to alfalfa and alsike clover, third. According to establishment data (Table 18) all three legumes attained approximately equal ground cover, however, alfalfa yielded much higher than the other legumes tested (Table 19). Some of the other grasses germinated later in summer when the moisture regime was improved. Seeded blue grass failed to establish and consequently no establishment counts or yields were taken from blue grass plots.

The establishment of the remaining eight species in 1967 is shown in Tables 18 and 20. From the data in Table 20 it is evident that meadow fescue was the only grass to establish satisfactorily. Due to high variability in the emergence pattern of some species no clear trend is apparent from the effect of fertilization on establishment. In general, however, both legumes and grasses appeared to establish better on fertilized plots. In three cases, the double fertilizer rate appeared to improve establishment of grasses over the recommended rate, but in legumes there appeared to be no effect. The percent bare ground decreased slightly as the fertilizer rate increased, overall averages of 82.5%, 79.5%, and 76.2%, were obtained for the check, single rate (225 lbs. 27-14-0 per acre) and double rate (450 lbs. 27-14-0 per acre), respectively.

Sow thistle was present in every plot ranging from 2% cover in alfalfa to 18.7% cover in a fertilized timothy plot. Fertilization stimulated the

TABLE 18

PERCENT COVER OF FOUR LEGUMINOUS SPECIES AND WEEDS AT THE MEADOW SITE UNDER THREE SOIL FERTILITY LEVELS

Species	Fertilizer Treatment	Established Species	Canada Thistle	Sow Thistle	Perennial Ragweed	Wild Barley	Canada Bluegrass	Other Weeds	Bare Ground
Alfalfa	Check	9.3		8.0				2.8	79.9
	Level 1	10.7		6.7			1.4	2.0	79.2
	Level 2	10.7		2.0		0.7	8.7	0.7	77.2
B. Trefoil	Check	2.0		12.0	1.4				84.6
	Level 1	4.7		10.7			0.7		83.9
	Level 2	4.7		10.7	0.7			3.5	80.4
Alsike Clover	Check	7.8		12.9	0.7		0.7	1.4	79.3
	Level 1	11.4	0.7	10.7	1.4		1.4	1.4	73.0
	Level 2	10.0		9.3	1.4		2.7	2.4	74.2
White Clover	Check	6.7		8.7	0.7		0.7	0.7	82.5
	Level 1	12.0		6.0		0.7		1.4	79.9
	Level 2	14.7	0.7	4.7			2.7	2.7	74.5

TABLE 19

FORAGE YIELDS IN 1967 FROM ESTABLISHED CROPS ON CLARKLEIGH-LUNDAR SOIL

Forage Crop	Fertilizer Treatment and Yield (lbs/acre)		
	Check	Level 1	Level 2
White Clover	32	224	394
Birdsfoot trefoil	42	128	362
Alsike Clover	21	383	576
Alfalfa	320	1130	1514
Timothy	-	288	1418
Reed canary	32	277	1514
Brome	139	533	970
Meadow fescue	267	693	1652

TABLE 20

PER CENT COVER OF FOUR GRASS SPECIES AND WEEDS AT THE MEADOW SITE UNDER THREE SOIL FERTILITY LEVELS

Species	Fertilizer Treatment	Established Species	Canada Thistle	Sow Thistle	Perennial Ragweed	Wild Barley	Canada Bluegrass	Other Weeds	Bare Ground
Meadow Fescue	Check	7.3		7.3				0.7	84.7
	Level 1	12.7		6.0	0.7		2.0	2.0	76.6
	Level 2	18.7	0.7	3.6				1.4	75.6
Reed Canary Grass	Check	0.7		14.3					85.0
	Level 1	0.7		7.1			1.4	2.8	88.0
	Level 2	6.4		6.4	0.7	2.9	5.7	2.1	75.8
Timothy	Check	1.4		14.7				1.4	82.5
	Level 1	2.0		18.7			4.7		74.6
	Level 2	7.3		14.0		1.4	1.4	0.7	75.2
Brome Grass	Check	1.4		15.0			1.4	0.7	81.5
	Level 1	2.8		10.7	2.1		2.8	0.7	80.9
	Level 2	0.7		10.0		.7	5.0	0.7	76.6

growth and vigor of sow thistle considerably within twenty days of fertilizer application, but this does not appear to be reflected in the percent cover data. Wild barley occurred in some of the fertilized plots and perennial ragweed was present in a number of plots. Canada blue grass regenerated in many plots, particularly in the heavilily fertilized (450 lbs. 27-14-0 per acre) alfalfa plot and contributed considerably to the total yield. This species also regenerated on grass plots where the grasses were weakly established.

Spraying with MCPB in 1966 did not provide satisfactory weed control. Most of the weeds could have been controlled by spraying 2,4-D, however, this was not possible on the experimental area because of the legumes present. Spraying with 2,4-D was also infeasible because of the advanced stage of growth of the legumes. It is likely that in future reseeding trials, severe weed competition will again be encountered. It is suggested that grasses be established first, to permit satisfactory weed control with 2,4-D, following this, the legume could be introduced into the grass sward by sod seeding.

On June 6, 1967, a light frost occurred in the area. It was observed that the fertilized forages were able to withstand the frost injury better than the unfertilized forages. Increased frost tolerance could be an important consideration in forage yields and persistence.

Although the soil was classified non-saline, some areas in the mid-slope position definitely appeared to be saline. In these saline areas the sown species failed to establish and salt-tolerant species dominated. The salt concentration may have increased with cultivation, particularly if evapotranspiration exceeded precipitation. There was some evidence of salt crusting on the plots during the summer of 1966. However, spring sampling in 1967 did not indicate a salinity problem. Further work is required to study the water table levels and the salt content of the subsoil.

Forage Yields. Forage yields in 1967 from unfertilized plots of white clover, aslike clover, bridsfoot trefoil, timothy, brome, and reed canary grass were almost negligible (Table 19). The yield of unfertilized alfalfa and meadow fescue were slightly higher, but still very low. It is apparent that any renovation program would require applications of nitrogen and phosphorus fertilizers.

Meadow fescue, the only grass to establish satisfactorily, yielded higher than any other grass species in each respective fertilizer treatment. Similarly, alfalfa outyielded all other legumes (Table 19). On the June 22 harvest date unfertilized alfalfa was in the vegetative state, while fertilized alfalfa was mostly in the bud stage. There was a distinct increase in the yield of meadow fescue from the double fertilizer rate over the single rate (225 lbs. 27-14-0 per acre). Most of the grasses were in the boot stage when harvested.

Reed canary grass, which had not established satisfactorily, appeared vigorous in the fertilized treatment where it was become established in small patches. This species merits further study. Similarly, some of the other grasses which failed to establish satisfactorily, might have established if conditions after seeding had been more favourable.

Alsike and white clover established satisfactorily, but due to their prostrate growth habit contributed very little to forage yield. These species would be more suitable for pasture. Birdsfoot trefoil did not attain a satisfactory stand and yielded unsatisfactorily. On July 26 alfalfa had made good seed set on all fertilized plots and meadow fescue was very mature. The yields of alfalfa and meadow fescue were considerably below those yields expected on upland soils under similar fertility programs.

Establishment of Forages on Inwood Soil. The forage plot on Site 4 was inadvertently seeded by the co-operator, thus the seeded oats and alfalfa were considered as a base. The droughty conditions of 1966 resulted in poor emergence of all sown species. This plot was therefore abandoned, but a similar plot was established at site 5 on recently-broken land. In the first year of establishment at site 5, alfalfa responded fairly well to 430 lbs. 11-48-0 per acre (Table 21). White clover responded slightly to the intermediate rate, but did not increase in yield with additional fertilization. Birdsfoot trefoil established weakly since the seed was not innoculated satisfactorily. In general, however, all legumes established well.

The only grass that failed to establish was Kentucky blue grass; meadow fescue, reed canary, and brome established satisfactorily. Meadow fescue and timothy did not seem to respond to soil fertility treatments, while brome grass and reed canary grass did respond in the first year. It is not known why the former two species failed to respond, but this may be due to variable stands obtained in the first year or to the low quantity of nitrogen involved in the treatments. It appears that on an upland Interlake soil like Inwood, there are no serious problems in establishing the tested forage crops, with the possible exception of Kentucky blue grass. Fertilization is recommended since available phosphorus was low, particularly on soils that have been cultivated for a number of years. Soper (61) made similar observations with alfalfa grown on a Lundar soil in the Interlake.

TABLE 21

EFFECT OF THREE SOIL FERTILITY LEVELS IN THE DRY MATTER YIELD OF NINE FORAGE CROPS ON INWOOD SOIL

Forage Species	Fertilizer Treatments (lbs. 11-48-0 per acre)		
	0 (lbs/A)	215 (lbs/A)	430 (lbs/A)
White Clover	874	1193	1173
Alsike Clover	1300*	1358	1407
Timothy	1151	1279	1279
Reed Canary Grass	874*	1418	1812*
Blue Grass	810**	-	-
Meadow Fescue	1013	1066	1151*
Birdsfoot Trefoil	704*	981*	853**
Brome Grass	608*	1375*	1311
Alfalfa	1279	1358	1844

* Based on two replicates

** Based on one replicate

Crude protein content of the established forages is shown in Table 22. The variation in crude protein content between the three soil fertility levels was very small for each species. It is noted that timothy had the lowest crude protein content of all grasses. Legumes were generally higher than the grasses in crude protein content. There is no evidence that fertilization increased the crude protein content of the forage crops tested. The lack of fertilizer response was probably due to droughty conditions.

D. Greenhouse Experiment

The purpose of the greenhouse experiment was to compare forage yields between three different Interlake soils at several soil fertility levels. Emergence counts taken did not indicate differences between soils or soil fertility treatments. Kentucky blue grass did not emerge satisfactorily on the soil (Garson) tested and consequently yielded less than all other grasses tested at comparable fertility levels. White clover which was also tested on the Garson soil only, emerged very well. The total dry matter yield of white clover was less than alfalfa at each fertility level, (5.22 g. vs. 7.19 g., 7.32g. vs. 8.05 g., and 6.62 g. vs. 8.76 g. for the check, medium and high fertilizer rate, respectively), and the second cut yields from both species were considerably greater than those obtained from the first cut.

Dry matter yields (Tables 23 and 24 and Figure 5) from the Clarkleigh-Lundar and Inwood soils were generally greater than those obtained from the Garson soil. This difference could be due to physical soil characteristics, since it was observed that the soil structure of the recently-broken Inwood soil was considerably better than the Garson soil which had been cultivated for a number of years. In most cases, the highest yields were obtained from the Inwood soil at the first cut.

TABLE 22

EFFECT OF THREE SOIL FERTILITY LEVELS ON CRUDE PROTEIN CONTENT OF NINE FORAGE CROPS ON INWOOD SOIL

Forage Species	Fertilizer Treatment (lbs. 11-48-0 per acre)		
	0	215	430
	(%)	(%)	(%)
White Clover	17.3	18.6	17.6
Alsike Clover	16.8*	18.1	18.2
Timothy	9.7	9.2	8.8
Reed Canary Grass	13.3*	12.9	14 *
Bluegrass	16.7**		
Meadow Fescue	13.6	15.7	11.9*
Birdsfoot Trefoil	14.1*	19.5*	18.2**
Brome Grass	14.5*	15.9*	14.8
Alfalfa	18.5	17.8	16.7

* Based on two replicates
** Based on one replicate

TABLE 23

DRY MATTER YIELD (GRAMS/POT) OF SIX FORAGES GROWN ON THREE SOILS AND THREE SOIL FERTILITY LEVELS

Forage Crop	Fertilizer Treatments*	Clarkleigh-Lundar		Inwood		Garson	
		Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
Brome	a_o	2.3	2.0	2.1	1.5	1.0	0.7
	a_1	4.0	2.0	4.0	2.5	2.3	1.2
	a_2	4.8	3.3	4.7	2.7	4.3	1.5
Timothy	a_o	2.5	3.1	4.0	1.6	1.4	1.2
	a_1	3.8	4.0	5.0	2.5	2.5	1.1
	a_2	4.9	4.1	4.5	3.4	4.8	1.6
Reed Canary	a_o	2.9	2.1	3.4	1.6	1.0	1.2
	a_1	4.8	2.1	5.7	2.5	3.5	1.4
	a_2	5.4	3.9	6.1	2.7	4.7	1.8
M. Fescue	a_o	2.9	2.0	3.0	1.6	1.4	1.1
	a_1	3.6	2.3	4.3	2.8	4.0	1.5
	a_2	6.3	2.5	5.7	3.7	4.8	1.9
Alfalfa	a_o	2.3	3.7	2.4	3.9	2.8	4.4
	a_1	4.1	4.5	3.8	4.5	3.3	5.7
	a_2	5.0	5.5	4.1	5.1	3.7	5.0
B. Trefoil	a_o	0.6	1.9	0.7	0.9	0.3	0.3
	a_1	1.6	2.2	1.3	1.5	1.2	0.6
	a_2	1.1	3.0	1.4	1.5	1.5	1.0

* a_o - Check (no fertilizer)
a_1 - 45 ppm N + 20 ppm P
a_2 - 90 ppm N + 40 ppm P

TABLE 24

SUMMARY OF STATISTICAL ANALYSES OF DATA IN TABLE 23 (DUNCAN'S MULTIPLE RANGE TEST - ANY TWO TREATMENT MEANS NOT UNDERLINED ARE SIGNIFICANTLY DIFFERENT)

Cut I

Species	B. Trefoil	Brome	Alfalfa	Timothy	Meadow Fescue	Reed Canary
Means	1.07	3.27	3.49	3.67	4.01	4.16
		———	———	———	———	———
Soils	Garson		Cl.-Lundar		Inwood	
	2.69		3.48		3.67	
	———	———	———	———	———	
Fertilizer	0		45 ppm N + 20 ppm P + 45 ppm K		90 ppm N + 40 ppm P + 90 ppm K	
Means	2.05		3.46		4.71	
			———	———	———	

Cut 2

Species	B. Trefoil	Brome	Reed Canary	Meadow Fescue	Timothy	Alfalfa
Means	1.43	1.91	2.03	2.15	2.53	4.70
	———	———	———	———		
		———	———	———	———	
Soils	Garson		Inwood		Cl.-Lundar	
Means	1.84		2.58		2.95	
	———	———	———			
			———	———	———	
Fertilizer	0		45 ppm N + 20 ppm P + 45 ppm K		90 ppm N + 40 ppm P + 90 ppm K	
Means	1.92		2.50		2.94	
	———	———	———			
			———	———	———	

Probability level = 0.05

Figure 5. Reed canary grass fertilized with 90 ppm N and 40 ppm P growing on (left to right) Garson, Clarkeigh-Lundar, and Inwood soils.

Comparing species for total yield, it is apparent that alfalfa outranked all other species tested (Table 24). In many instances, however, during the first cut, grasses yielded higher than alfalfa. Birdsfoot trefoil ranked last and produced only slightly more from the double fertilizer rate than from the single rate.

The differences due to fertilizer treatments were highly significant. Increases from the medium fertilizer rate (45 ppm N and 20 ppm P) over the check were generally quite large. The increase from the highest fertilizer rate over the medium was not as marked. The largest percentage yield increases of grasses from fertilizers occurred on the Garson soil, possibly because of its very low nitrate-nitrogen status. Reed canary grass seemed particularly promising on the Clarkleigh-Lundar soil since it yielded well and increased its cover by sending out new shoots from rhizomes (Figures 6 and 7). Meadow fescue also yielded very well on all soils, but is less desirable than reed canary grass because of its short persistence. The problems encountered in the field trial in establishing grasses at the Clarkleigh-Lundar site were not repeated in the greenhouse study, probably due to optimum moisture conditions.

From growth measurements taken after the first cut it appears that in many instances the tallest growth of grasses was made at the single fertilizer rate or the unfertilized treatment as well. Growth measurements as performed in this study, were not sensitive enough to evaluate fertilizer response. Dry matter yield proved to be a better indicator of fertilizer response. Similar results from growth measurements of legumes indicated this test as not being sufficiently sensitive to detect small or intermediate differences.

E. Special Observations with Suggestions for Future Research

1. Problems in Establishment of Forage Seedlings

In view of the severe weed competition encountered in establishing

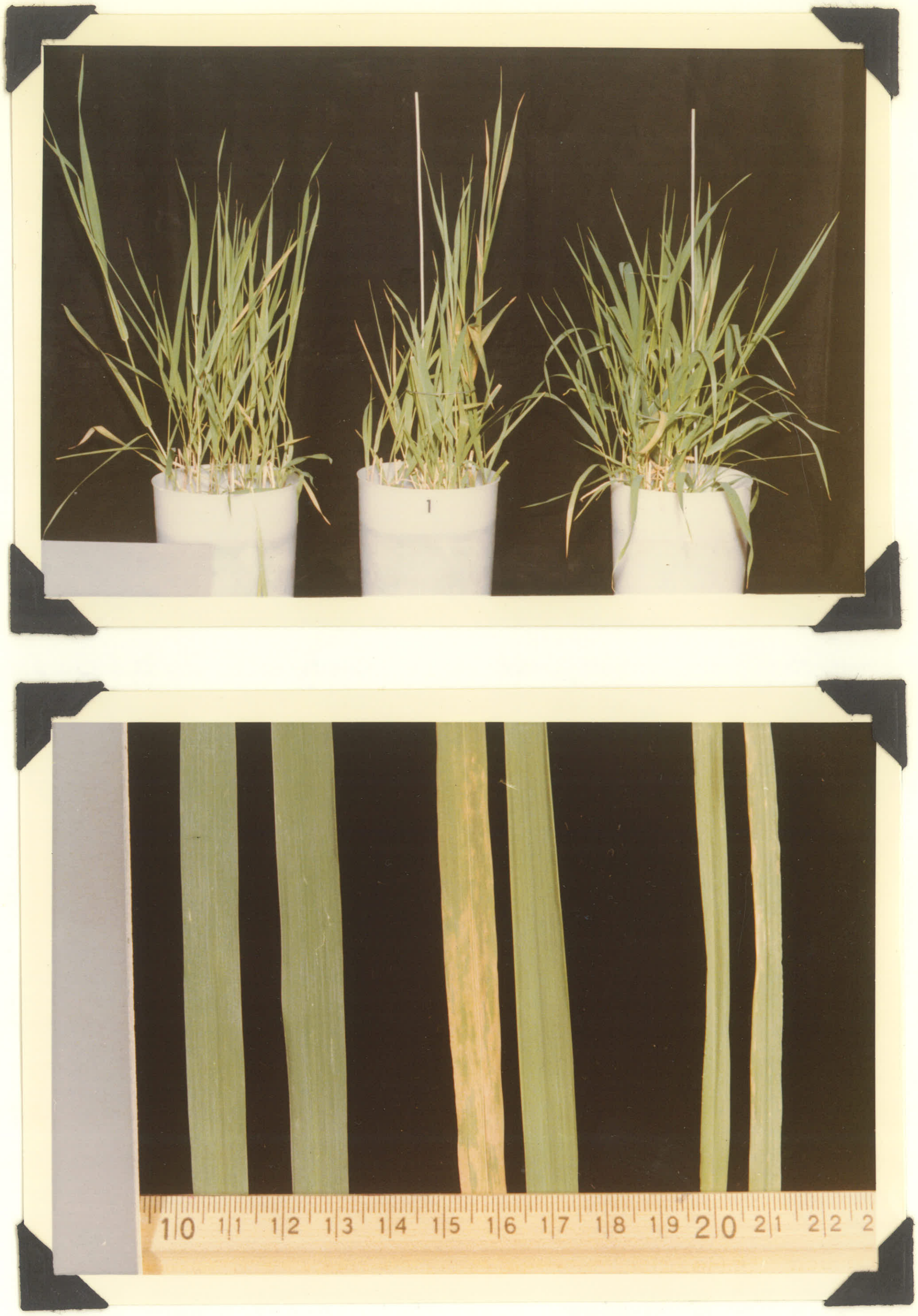

Figure 6. Reed canary grass growing on Clarkleigh-Lundar soil at three soil fertility levels. (TOP) left to right, check, single fertilizer rate (45 ppm N + 20 ppm P), and double fertilizer rate. (BOTTOM) Typical reed canary grass leaves, (left to right), double rate, single rate, and check.

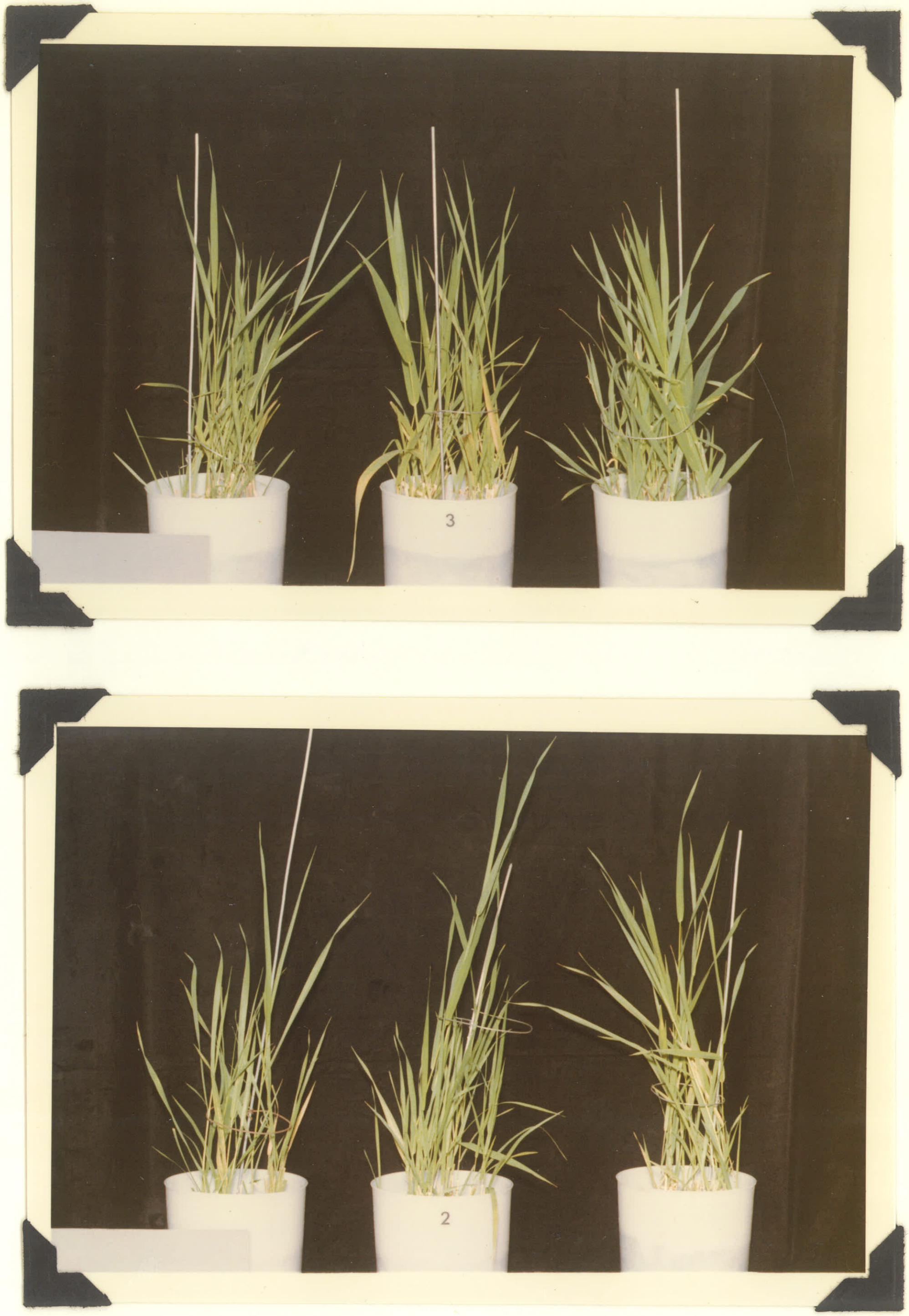

Figure 7. Reed canary grass growing under three soil fertility levels on Inwood (top) and Garson (bottom) soils. Left to right, check, single fertilizer rate (45 ppm N + 20 ppm P), and double fertilizer rate.

forage crops on meadow soils, a study to reduce this competition would be warranted. It has been observed (28) that successful establishment could be attained on saline clay soils by directly seeding grasses into stubble without prior cultivation. Fertilizer was applied and broad-leaved weeds were controlled by spraying 2,4-D with subsequent direct sod seeding of alfalfa in late fall of the third year. Other methods involving minimal soil disturbance also merit consideration such as direct sod seeding using special equipment or sod seeding following application of herbicides, e.g. paraquat. Seeding with pelleted seed in late fall could result in early establishment. A nurse crop such as barley or oats could possibly subdue weed growth. While unsuccessful weed control was obtained in this study with MCPB an early spraying with MCPA or 2,4-DB might control weed growth so that a grass-legume mixture could be established in one seeding operation.

2. Forage Crop Species for Interlake Meadow Soils

The species that appeared to establish satisfactorily, namely alfalfa, meadow fescue, and reed canary grass require evaluation on a larger scale and in various combinations. Some of the other species tested, although they did not establish well in 1966, should not necessarily be disregarded in future studies. It might also be desirable to test various salt-tolerant species such as slender intermediate wheat grass, Russian wild rye grass, and Lolium spp. It is recommended that studies be continued with birdsfoot trefoil, since this species has done well in difficult environments in other areas of the world.

Establishment studies require clear definition of objectives as to whether trials are designed for pasture or for hay use. Interlake farmers would be interested in obtaining a forage mixture that would provide either late or early spring grazing for their cattle.

3. Soil Salinity Investigations

It is known that small areas within Clarkleigh-Lundar meadows are very saline to the extent that only salt-tolerant species will grow. It has also been observed that big bluestem, *Andropogon gerardi* Vitman, may be an indicator plant for delineating areas where successful forage establishment may occur. Correlating soil salinity with native plants could possibly provide more indicator plants. In general though, more reliable methods are required for predicting whether a certain forage mixture will be productive in a given area, and what proportion will fail due to salinity and/or other factors.

V. SUMMARY AND CONCLUSIONS

A study of native meadow vegetation in the Interlake area confirmed that unfertilized vegetation was marginal in copper content and inadequate in crude protein and phosphorus content for livestock production. Unfertilized meadow hay is also very low in productivity. Fertilization with nitrogen and phosphorus increased dry matter yield, digestibility, crude protein content, phosphorus and potassium, as well as concentrations of calcium, magnesium and sodium. Trace element concentrations of manganese, boron, copper, and molybdenum, appeared to increase with fertilization while zinc was not affected. Molybdenum content increased considerably with fertilization, but did not reach the toxicity level for livestock. Dry matter yield, dry matter digestibility, crude protein and phosphorus content were consistently higher throughout the season in fertilized vegetation than in unfertilized, showing that native meadow vegetation can be improved for livestock production by fertilization. These values were also continuously higher in vegetation fertilized at level 2 than in vegetation fertilized at level 1 (225 lbs. 27-14-0 per acre). From foliar nutrient concentration data, none of the microelements appear to be deficient for plant nutrition.

A general seasonal decline of dry matter yield, digestibility, crude protein, phosphorus, and potassium was recorded in all treatments of native meadow vegetation. Calcium, magnesium, and boron as well as percent dry matter appeared to increase throughout the season. From consideration of all factors studied, it appears that both unfertilized and fertilized native meadow vegetation should be harvested between late June and middle of July. This vegetation, however, is decidedly inferior to brome-alfalfa or birdsfoot trefoil.

Severe weed infestations were encountered upon fertilizing native meadow vegetation as well as in new sowings on cultivated soil. Due to droughty conditions, most of the grasses tested, except meadow fescue, failed to establish satisfactorily on the Clarkleigh-Lundar soil. Reed canary grass indicated potential from its vigorous establishment in small patches. Alfalfa established and yielded considerably higher than all other legumes and grasses tested in field and greenhouse studies. Grass emergence problems, similar to those in the field, were not encountered in the greenhouse.

On upland soils such as Inwood, no particular establishment problems were encountered, however, both nitrogen and phosphorus applications are required for satisfactory forage production. Many problems, however, still exist in establishing forages on meadow soils and further work will be required to resolve these problems.

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APPENDIX I

MONTHLY PRECIPITATION RECORDS* FOR THE 1966 & 1967 GROWING SEASONS AT ERIKSDALE, MANITOBA

Month	Precipitation	
	1966	1967
	(inches)	(inches)
May	1.26	.49
June	1.30	1.89
July	2.61	2.85
August	1.26	1.11
September	1.15	.28

* Department of Transport, Meteorological Branch. Monthly Record Meteorological Observations in Canada. 1966 & 1967.