PASTURE AND FORAGE IRRIGATION STUDIES

(suggested short title)

RESPONSE OF CERTAIN FORAGE SPECIES IN PURE AND MIXED SEEDINGS TO IRRIGATION

by

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M.Sc. Agronomy

ABSTRACT

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The influence of irrigation on timothy, alfalfa, ladino, bromegrass, and birdsfoot trefoil was investigated. Equal amounts of water were applied at four rates.

Irrigation effected greater root and forage yields. The most efficient rate of irrigation was 0.1 inch followed by 0.4 inch and 1.0 inch per hour. More root and forage yields were obtained from timothy, alfalfa, and ladino; and timothy, alfalfa, and bromegrass combinations. The presence of a companion crop hampered root development of forages regardless of irrigation. Density, size, and yield increased under irrigation. Plant size decreased with increased rate of seeding. Birdsfoot trefoil on a clay soil was the most responsive species to irrigation.

It is concluded from these results that with a judicious application of water on a responsive species irrigated forage in the humid climates will be beneficial.

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Robert Ben. Dadson,
B.Sc. (Agric.) London.

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I. INTRODUCTION

Irrigation is the artificial application of water to the soil to supplement rainfall and supply moisture at times and in quantities essential for maintenance of optimum plant growth. Long established in arid and semi-arid regions, irrigation is becoming increasingly important in humid temperate areas as assurance against crop failure due to drought. In some areas it is becoming a necessity against the short but frequent periods of drought during the short growing season.

Extreme drought of unpredictable duration has always been a factor to contend with in most regions of Quebec Province. The use of irrigation in Eastern Canada has been confined to horticultural crops. Our dairy farmers rely solely on natural rainfall to provide moisture required for maintainance or increase of pasture yield.

Interest generated in pasture irrigation has raised the question of how pastures respond to irrigation. In order to provide an answer, applicable to Quebec Province, the Macdonald College Pasture Committee conceived the idea of pasture irrigation research as part of their programme of pasture improvement studies. This thesis is a continuation of irrigation studies initiated in Spring of 1963 jointly by the Agronomy and Agricultural Engineering Departments. Emphasis on this research thesis is only on the agronomic phase.

The project comprises three main parts, viz. Experiment I: This was laid out in Ormstown to investigate the response of four of our adapted and predominantly used pasture species, in the Province, to four rates of irrigation. The species used were (a) Timothy (*Phleum pratense* L.), (b) Bromegrass (*Bromus inermis* Leyss), (c) Ladino white clover

(Trifolium repens L.) and Alfalfa (Medicago sativa L.).

These were used in pure and mixed seedings. Treatment differences were evaluated in terms of yield (dry matter basis), botanical composition, and root development (dry matter basis).

Experiment II: This involved the same species, rates of irrigation, seeding practice and location as in Experiment I. However, on each half of irrigation treatment oats were sown as a companion crop so that the influence of the companion crop could be determined. The treatment differences were evaluated in terms of root development (dry matter basis).

Experiment III: This experiment, dealing with seeding rates of five species under irrigation, was laid out on the horticultural field at Macdonald College from the fall of 1964 until summer of 1965. The objective was to determine an optimum stand using such criteria as plant counts, yield (dry matter) and cover.

By using the same species and methods of evaluation the three experiments can be collated to yield more information on the forage crops' response to irrigation.

II. REVIEW OF LITERATURE

A. General Considerations

1. The environment of the plant and importance of water.

Environmental factors affecting plant growth comprise the climatic, physiographic, soil and biotic factors. Of these factors affecting plant growth man can exert his greatest influence on water. In the physiology of the plant, water is of paramount importance in many ways. Daubenmire (1947) listed the importance of water as follows:

(a) As the closest approximation of a universal solvent it dissolves all minerals contained in the soil.

(b) It is the medium by which solutes enter the plant and move about through the tissue.

(c) By permitting solution and ionization within the plant it greatly enhances the chemical reactivity of both simple and elaborate compounds.

(d) It is a raw material in photosynthesis.

(e) It is essential for the maintainance of turgidity without which cells cannot function actively; and it is necessary for the mere passive existence of protoplasm, for very few tissues survive if their water content is reduced as low as 10%.

(f) Water can absorb much heat from warm surroundings with relatively little change in temperature and thus slow the rate of temperature change in protoplasm and make uniform temperature conditions affecting the rate of biochemical reactions.

Soil moisture, on which plants depend for their water, is replenished either through precipitation or irrigation. A number of problems are associated with the latter mode of providing the moisture.

2. Some problems of irrigation.

Some of the main factors in successful irrigation are the source and availability of water, the quality of water, and frequency of application. Woodward (1959) pointed out that the source of water should be close to the farm and available at the peak demands of the plant.

According to Woodward (1959) there are three factors affecting the water quality for irrigation. These are the silt content, industrial waste and salts. A relatively low amount of silt is thought to be beneficial as this improves soil fertility. In higher loads this may wear out pipes. Industrial waste like oil discharge into streams used for irrigation may be injurious to plants. Salt hazards are those of salinity, sodium and boron content of the water, and these may be overcome by using salt tolerant plants, providing adequate drainage, and applying irrigation water in excess to drain out some of the salts. Sodium hazards may be reduced through the addition of gypsum.

Provided with an adequate amount of water, therefore, the problem of irrigation is reduced to one of frequency, rate and amount of application.

(a) Frequency and amount of irrigation.

Plants will extract water from the soil between field capacity and permanent wilting point. The amount of water between field capacity and permanent wilting point, the available moisture, depends on the soil texture. The root depth determines how much water to apply at each irrigation. Thus the deeper the root depth the more water required to fill the root zone.

The frequency and amount of irrigation also depend on consumptive use of water, or evapotranspiration, which represent the amount of water transpired by the plant and evaporated from the soil. According to Mather (1959) evapotranspiration depends on climate, water content of soil, plant cover, soil type and texture, and land management. However, he considered solar energy and the resultant temperature more important than any of the other factors in determining consumptive use. Irrigation needs will, therefore, depend on the soil relation of available moisture, root depths, consumptive use of water, and amount and distribution of rainfall.

Lussier (1965) reviewed the methods in use for the determination of the frequency and amount to apply and another review will be superfluous, since no pertinent literature has been reported after his review.

3. Soil-water relation.

An understanding of soil-water relation is of paramount importance to the irrigator so as to avoid creating adverse soil conditions for plant growth. The different systems of irrigation have been reviewed by Lussier (1965) and to prevent unnecessary repetition this discussion will be confined to sprinkler irrigation.

(a) Intake rate of soils.

The rate of moisture intake is a most important consideration in planning a sprinkler system. It refers to the soil's ability to take in water during a normal water application period. Woodward (1959) stated that intake was governed by the conditions of the soil surface together with the inherent physical characteristic of the soil profile. According to him the basic intake rates, presented below, may differ for most soils.

	Basic intake rate	Reduced for poor conditions
Course sand	0.75 to 1.00"/hour	0.50"/hour
Fine sand	0.50 to 0.75"/hour	0.35"/hour
Fine sandy loam	0.50"/hour	0.30"/hour
Silt loams	0.40"/hour	0.27"/hour
Clay loams	0.30"/hour	0.25"/hour

(b) Effect of water application rate on water movement.

Water is ideally applied at a rate such that it will percolate the soil fast enough to prevent ponding. Generally, at a relatively slow rate of application the soil will fill up slowly and water will move through the soil profile at the same rate as it is being taken at the surface (Woodward, 1959). Hence ponding will be avoided. Woodward (1959) also stated that usually at a relatively fast rate of application a zone of 'wet' soil occurs throughout the first foot, but, since the top remains very wet, ponding will ensue when more water is applied. This will cause poor aeration and suffocation of roots; and also contribute to an excessive loss of moisture by capillary rise into the surface zones.

(c) Relationship between aeration and water content.

Since the amount of gases and liquids in a soil are complementary to each other, the addition of a given volume of water displaces an equal volume of soil gases. Fresh air is subsequently drawn into the soil as the moisture drains away or is used up in evaporation and transpiration. Daubenmire (1947) pointed out that addition of water to a soil partly alleviated poor aeration conditions, provided the water drained out or was used up within reasonable time. Hence superabundance of water would cause gaseous deficiencies.

B. Forage Response to Irrigation

1. Species response to irrigation and effect on botanical composition.

Extensive work on transpiration rates and wilting percentages show that different crops have different water requirements. According to Wilsie (1962) this will determine the adaptation of crops.

Studies indicate significant changes in pasture composition as a result of irrigation. Low and Armitage (1959) reported that on a sward on which no nitrogen was applied the proportion of clover to grasses increased as the average level of soil moisture tension was lowered.

Levine *et al*. (1955) found that irrigation favoured bromegrass more than it did the growth of alfalfa. Forage from non-irrigated and non-fertilized plots showed almost pure alfalfa. The proportion of grass in the irrigated plots increased by 25%. Similar results are reported by Tesar *et al*. (1958), at Michigan, who obtained 72% and 43% ladino clover from irrigated and non-irrigated plots, respectively. The increased percentage of ladino clover from irrigated plots is said to be due to greater growth of stolons and leaves of the original plants, and more seedlings favoured by irrigation. When alfalfa was included in the mixture Tesar *et al*. (1958) further found less alfalfa on the irrigated plots than on non-irrigated plots. Bromegrass also benefitted from irrigation, and ladino was superior to alfalfa in the mixture.

Pelton and Webber (1955), at Guelph, observed that irrigation and fertilizer had an effect on the relative production of grass and legumes. At each level of fertility, irrigation increased the legume content of the forage, whereas fertilizers increased the proportion of grass in the mixture.

2. Yield responses.

Several investigators have recorded yield responses to pastures in humid regions. Whitaker (1951), at Illinois, obtained better yield of ladino, bluegrass, red top, timothy, fescues and orchard grass mixture as a result of supplementary irrigation. Tesar (1958) observed that at Michigan, irrigated pasture of ladino clover-bromegrass mixture gave 23% more forage than non-irrigated pasture. Chevrette (1961), at Quebec, found that irrigating whenever moisture deficit in the top eight inches of soil reached 50%, yielded double the amount of timothy and cocksfoot (*Dactylis glomerata*), with and without ladino clover, than when no irrigation was applied.

Levine *et al*. (1955), however, reported only low increase of grass-alfalfa mixture when they applied irrigation water. The yield of bromegrass in the mixture was found to be more than alfalfa under irrigation. While irrigation resulted in a relatively small increase in yield of 860 pounds dry matter per acre, it increased the succulence and green matter yield of forage by almost 4,000 pounds per acre. Ouellet *et al*. (1963) also reported only slight increase in yield of lucerne-grass pasture and lucerne-white clover, birdsfoot trefoil-grass mixture on a clayey soil.

Vittum *et al*. (1963) concluded, from nine years of irrigation studies in North Eastern United States, that irrigation at best resulted in only slight increase in yield. The response of forage to irrigation was very variable, and not even in the driest season did all crops respond to irrigation. The average increase in 19 crop years was 0.73 tons per acre. Generally, no significant increase in yield resulted from maintenance of different amounts of available water in the root zone. Forage crops studied were able to use water held in the soil until moderate tensions (two to four atmospheres) were reached, and still maintained similar growth when water was held at lower tensions by more frequent or heavier irrigations. Too much water also decreased yields.

3. Irrigation and fertilization.

Appleton and Wynd (1951), at Michigan, reported that irrigation with fertilizer gave three times the yield of fertilizer alone. Results reported by the same workers with super-phosphate and potash showed that fertilization failed to increase yield of dry matter unless irrigation water was added. Robinson and Sprague (1952), at Pennsylvania, obtained phenomenal increase in yield both with high and no nitrogen following irrigation. Work by Pelton and Webber (1955), at Guelph, indicated that irrigation with fertilization had an effect on maintenance and relative production of legumes and grasses. However, Cooper and Klages (1962), at Montana, found that irrigation and nitrogen did not prevent yield slump during mid and late seasons.

4. Seasonal response.

Irrigation is also reported to influence the seasonality of production of forage. Studies by Schofield (1953), at Rothamsted, showed that under irrigation grass yields were increased. Controlled plots browned off between mid-June and mid-August. However, by mid-September all plots were similar in colour and yields. Hill (1956), at Ottawa, noted that not all species responded to irrigation during the dry summer period. Using mixtures of bromegrass, ladino clover, alfalfa, orchard grass, timothy, alsike clover and red clover, Hill (1956) demonstrated that some species exhibited mid summer dormancy which was not corrected by irrigation. Although irrigated plots remained luxuriantly green they exhibited very little growth. Tossel (1956) showed that irrigated plots gave the bulk of mid summer yield. He observed that ladino clover was strong and vigorous on irrigated plots, but thinned and weakened in the non-irrigated plots after a severe summer drought.

5. Soil moisture conditions and dry matter production.

Dry matter yield is of great importance in forage production. Levine *et al*. (1955) stated that irrigation was without much effect on dry matter production.

Peterson and Hagan (1952) reported that ladino clover petiole elongation, and dry matter percentage were all significantly affected by the soil moisture regime. However, there was no depression of dry matter production until the moisture reached wilting point. Reduction in dry matter production, according to these workers, was partly due to a shift in photosynthetic respiration balance. Thus, they concluded that the more frequent irrigations produced more and more fresh weight but little more dry matter than the less frequently irrigated plots.

Mather (1959) pointed out that when the root zone was well supplied with water the amount of water used was more dependent on solar energy and resultant air temperature. Hence, Ashby (1961) noted that in high summer air temperatures evapotranspiration can outstrip water uptake by roots, even when soil moisture was adequate for growth, leading to temporary wilting with closing of stomata and a halt in photosynthesis.

C. Root Studies

The underground parts of perennial grasses and legumes serve as anchorage, organs of absorption of water and nutrients, and storage of reserves. There exists significant inter-relation between herbage growth and underground development. An understanding of the responses to the environmental factors and cultural treatments, therefore, appears indispensable to a successful irrigated pasture production programme.

Plant root development depends on the inter-actions between the atmosphere and soil environments, but the latter contains and reacts upon a much more extensive portion of the root than the atmosphere. The principal soil factors affecting root growth are (i) the water content, (ii) soil air, (iii) solutes and (iv) temperature. These are under the influence of man. Above ground factors, such as defoliation, photoperiodism and shade, indirectly influence root development through the balance of photosynthesis and respiration. The only above ground factor easily influenced by man is defoliation.

1. Vertical distribution of roots

Troughton (1957) cited several workers to show that roots are not equally distributed in the whole depths of penetration, but tend to be more concentrated in the upper six inches of soil. This concentration, he stated, increases with age, and is also influenced by the soil structure, moisture and nutrient contents.

2. Influence of low and high soil water content

According to Kramer (1949) and Russell (1961) the effects of water supply on root system are indirect. They stated that in moist, fertile soil roots are shallow, for the aerial parts can use most of the carbohydrates produced. However, a drought after establishment induces deep rooting, because the first effect of water shortage in the soil is to reduce the rate of aerial growth so as to make more carbohydrates available for root growth. Russell (1961) further pointed out that where precipitation was the chief source of moisture supply a deficiency tended to concentrate roots in the upper layers of the soil. Wet surface and high water table restrict grass roots to shallow layers of the soil. Weaver and Himmel (1930), Troughton (1957), and Russell (1961) have observed that excessive water content caused poor aeration resulting in shallow, much branched root systems.

3. Influence of irrigation and drainage.

Weaver (1926) emphasized that keeping the surface soil too moist by irrigation during the early life of the plant may promote shallow rooting habit. Conversely, a delay in time and an increase in the amount of irrigation promoted deeper rooting.

Lamba *et al*. (1948) reported that under irrigation alfalfa and bromegrass made significantly more roots than timothy and red clover. Gains in weight of roots were found to be greater from 61 to 68 days than from 45 to 60 days after germination.

Bennet and Doss (1960) observed that the amount of roots and rooting depth decreased as soil moisture level increased. Working with alfalfa, ladino clover, red clover, white clover and tall fescue, these workers found that over 70% of the total root weight from core samples was in the surface 12 inches of Greenville, fine, sandy loam soil for all species except tall fescue. Alfalfa roots were reported to be larger than all other legumes; and the greatest weight of roots were found at the low soil moisture levels. Bennet and Doss (1963) also reported that root growth of grasses was at the early part of the spring and the roots were dormant during the hot summer months.

Lussier (1965) commented that irrigation had little influence on root yield. This result was attributed to an excessively high water table, weed incursion, and an unusually high rainfall in the seeding year.

Seasonal growth of roots investigated by Sprague (1933) indicated that at least half the root system of the grasses was regenerated each spring. Stuckey (1941) observed regeneration of the complete grass root system annually with active production beginning in October, continuing slowly in winter and increasing rapidly after the spring thaw and reaching a maximum in April. After the middle of June, few, if any, new roots were found. She concluded that the decrease was due to reserved food substances being used while the plant was flowering. Lussier (1965) reported a similar pattern of growth.

4. Influence of soil temperature

Soil temperature affects root growth *per se*. It speeds up division and elongation, influences the supply of carbohydrates, mineral nutrients and water. High temperatures favour rapid translocation and accelerate respiratory activity. According to Troughton (1957), excessively high temperatures check root growth especially when other conditions, such as pH and particularly aeration, are unfavourable. He stated further that lack of water may protect plants from the ill effect of high soil temperature. Brown (1943), as cited by Troughton (1957), showed that in a summer with high temperature the carbohydrate reserves of *Poa pratensis* were depleted when the plants were supplied with water, but not when they were subjected to drought. Irrigation during a drought hastened the death of older rhizomes and the decay of the older roots.

5. Influence of mixed seeding on root development

Roots of plants in association compete for moisture, nutrients and root space. Hence root growth will depend on how much of these factors are available. It is generally thought that grass in association with legumes benefits from nitrogen fixed by legumes. Troughton (1957) pointed out that nitrogen excretion from roots of legumes was rare, and that nitrogen may only become available when mineralization of the root tissues had taken place.

Toxic secretions of roots of some plants, for example couch grass, are known. Russell (1961) believes that this might be the chief mechanism which would reduce interpenetration of the root system of neighbouring plants. According to Russell (1961), Virma (1957) found that the harmful effects was most marked in the seeding stage. Lussier (1965) found no such toxicity.

6. Influence of defoliation on root growth.

Defoliation by cutting or grazing leads to a reduction in leaf area. The replenishment of this loss, accomplished through withdrawal from the root reserves, ultimately hampers root growth. Biswell et al. (1933) pointed out that the degree of influence depended on the species concerned, height and frequency of clipping, soil moisture content and fertilization. Weinmann (1948) stated that these factors interact, the interaction being a result of aerial vegatative regeneration at the expense of the roots. The root depletion he found was aggravated by nitrogen application in the presence of high temperatures or frequent irrigation.

D. Influence of Irrigation and Seeding Rate

In establishing an irrigated pasture the cost of seeding can be a major economic concern. Knutti (1958) and Swift (1960) showed that recommended rates were extravagant. Most rates have been designed to place several hundred seeds per square foot to ensure a stand. Irrigated pasture being an expensive enterprise one cannot afford to let the land lie fallow. It is, therefore, desirable to determine how irrigation would influence optimum stand and hence make provision to ensure a good take.

An extensive review regarding seeding practices in America and Europe, and calculation of seeding rates has already been done by Knutti (1958). The present review only considers rates under irrigation and species used in this experiment.

Parry (1953), in England, using perennial ryegrass and white clover seeded from 10 - 25 pounds per acre, concluded that reduced rates were not an essential feature of successful establishment of the sward in a region of high rainfall. According to him, under favourable moisture conditions it should be possible to increase the number of plants per unit area by sowing more seeds than under less favourable soil moisture regimes.

1. Seeding rates in the species under test

(a) Seeding rate in timothy

From recommendations as high as 12 pounds per acre (Wheeler, 1950), current evidence suggests that four pounds per acre approaches the optimum rate for pure seedings (Knutti, 1958). Macdonald (1955), at Ithaca, seeded timothy at 2, 4, 8, 16 and 32 pounds per acre. From the respective yields of 3620, 4250, 3940, 3470 and 2860 pounds dry matter per acre he recommended 2 - 8 pounds as the best. Lachance (1965), at Lennoxville, found that except in the third and fourth years after seeding, there was little or no influence of rate of seeding on early establishment of timothy, bromegrass and reedcanary grass.

Burger and Vetch (1958) found that early in the spring, when moisture was non-limiting, as timothy rate increased in the mixture of red clover yields were also increased.

(b) Seeding rate in bromegrass

Trends are towards a reduction in seeding rate of bromegrass. Raymond (1958), at Macdonald College, recommended eight pounds per acre in dry mid-summer seeding. He suggested that where moisture was not critical the soil could support a very large number of grass seedings.

Wilson and Peake (1959), at Alberta, studied eight rates of seeding *Bromus inermis*, *Dactylis*, *Festuca* and *Trifolium* under irrigation. The rates they used were 5, 10, 15, 20, 25, 30, 35 and 40 pounds per acre. Good stands were obtained at all sowing rates, but forage production increased with increasing rate, the 15 - 25 range giving the best balanced sward. Rates much lower than 15 pounds were subject to weed encroachment. Thus, they stated that heavier rates offered more competition to weed seedling establishment. Higher rates were ready for grazing earlier, but these workers found that there was no advantage in yield due to higher rates and so suggested a reduction in seeding rate. At Ottawa Experimental Station, a rate of 16 pounds per acre has been recommended. Knutti (1958), however, found that 12 pounds per acre was the optimum rate.

(c) Seeding rate in birdsfoot trefoil

Bubar (1963), at Macdonald College, found that five pounds of birdsfoot trefoil in bromegrass, timothy and reed canary grass gave good establishment, but it was suppressed by orchard grass.

MacDonald (1946) found that rates of seeding birdsfoot and alfalfa, respectively, at 5 and 8 pounds, 10 and 8 pounds, 15 and 8 pounds did not affect yield of dry matter. He observed that the density of trefoil population and its contribution to hay yield was not significantly different for the different rates. The number of plants per unit area decreased at the higher rates while yield increased regardless of seeding rates.

Knutti (1958) found that four pounds per acre gave the highest yield.

(d) <u>Seeding rate in ladino white clover</u>

Raymond (1958) recommended ladino seedings at two pounds per acre. However, Steppler (1964), at Macdonald College, found no significant yield difference between plots seeded at two ounces per acre and two pounds per acre.

Crocionis (1955), in Italy, observed that ladino seeded at 3.5 and seven pounds per acre gave a higher yield than at 10.5 pounds per acre in the first year and not in the second year. Manure application boosted the yields at the higher rate of seeding. Knutti (1958) reported 3/4 pound per acre as the optimum rate.

(e) <u>Seeding rate in alfalfa</u>

Raymond (1958) recommended seeding alfalfa at five pounds per acre with red clover and timothy, and eight pounds with bromegrass and timothy. Wheeler (1950) recommended 15 - 20 pounds.

Eynard (1960), in Italy, found that there was a clear advantage from irrigation in the year of establishment in the higher rates of seeding than in a year of drought. Among rates of 10, 15, 20, 30 and 40 kg. per hectare, the 10 and 15 kg. per hectare were found to be too low. He concluded that alfalfa should be sown at a minimum rate of 20 kg. per hectare.

E. Conclusion from Review of Literature

It is apparent from this review that responses to irrigation by forage and pastures are very variable. Both beneficial and detrimental effects have been recorded. For instance, irrigation may change botanical composition, increase dry matter yields or enhance the utilisation of fertilizers applied. It may also encourage weedy growth and hence intensify competition, or even cause a destruction of soil surface when it is not used judiciously.

Rates of seeding and optimum stands for pasture species under irrigation have not been clearly established.

III. EXPERIMENTATION

Experiment I. Effect of Irrigation on Some Selected Forage Species.

The experiment, started in May, 1964, was to test the effect of irrigation on four pasture species, viz. timothy, bromegrass, ladino and alfalfa in all fifteen possible combinations to different rates of application of the same amount of water. The criteria of effect were based on root weight, forage yield, and species contribution to cover. The experiment was a re-establishment of the first replicate of the 1963 seeding which was eradicated because of heavy weed incursion.

A. Materials and Methods

1. Seeds

	Identification in Text
Timothy: Certified seed of variety Climax	T
Bromegrass: Common seed, Number 1 Grade	B
Alfalfa: Certified Vernal Seed	A
Ladino: Certified Blue Tag	L

2. Location and history of experimental area

The project was located on Finlayson's farm in Ormstown in Chateauguay County. The area was previously a night pasture, and probably was not an ideal site for the experiment. However, other factors were overriding in the selection of this particular area. Some of these factors were:

(i) Meteorological data for twenty-two years indicated that Chateauguay County is the warmest and received the lowest precipitation in May through September.

(ii) There was an easily accessible river suitable for irrigation close by the Finlayson's.

(iii) There was a uniform soil over a considerable area of the County which would make results easier to extrapolate.

(iv) The Chateauguay Valley region has a number of water ways, fertile soil for field, pasture and horticultural crops, and close to city markets of Montreal. Hence the area has immense agricultural potentialities.

3. Type of soil

The soil, according to Baril and Mailloux (1950), is Ormstown silty clay loam with a high proportion (60 to 65%) of silt and clay in the different horizons. Other determinations reported by Lussier (1965) showed the soil has the following characteristic:

Field Capacity is at 27.9% soil moisture level
Permanent wilting point at 9% soil moisture level
Available moisture is 18.9% soil moisture level
Dry bulk density is 73.2 pounds per foot
Available water in the top foot is 2.7 inches

4. Irrigation system

The system of irrigation was the sprinkler system using 'Rainbird' sprinklers set on risers of half inch pipe, 12 inches in height, and two inch laterals.

The models, settings and corresponding nozzles of sprinklers to give the different rates of water application were:

Model 25 PJ; half circle; Nozzle 7/32 inch for 1 inch rate
Model 25 PJ; half circle; Nozzle 9/34 inch for 0.4 inch rate
Model 20 ; full circle; Nozzle 3/32 inch for 0.1 inch rate

5. Experimental methods

(a) Design

A split plot design with one replication was chosen. Lack of space prevented more replications. There were four main plots, for the four moisture treatments, randomised within the replicate. Each main plot comprised randomised fifteen sub-plots representing the fifteen forage seed mixtures.

(b) Field plan

The experimental area was divided into seven plots of 40 ft. x 120 ft. as shown in Figure i. Four plots were selected as the main plots and the remaining three used as buffers.

Each plot was divided into fifteen 40 ft. x 10 links sub-plots, and five 4.5 ft. x 40 ft. filler and access blocks for neutron moisture probe access pipe (Figure ii).

(c) Soil treatment

(i) Fertilization

The soil was fertilized for the 1963 experiment with 150 pounds per acre 4-24-20 NPK drilled all over the field. For the 1964 seeding on the same plots 250 pounds per acre of 4-24-20 were applied.

(ii) Drainage system

The high proportion of silt and clay was found to impede drainage in 1963. Tile drainage system was therefore installed three feet deep between all the blocks of the whole experimental area from 3rd through 5th June, 1964. Since seeding had already been done there was a loss of some 14 feet of the 40 feet length of each plot. However, enough material was left to permit collection of data.

(iii) Seeding

The seeding rates for the four species were timothy 8 pounds per acre, bromegrass 15 pounds per acre, alfalfa 8 pounds per acre, ladino 1.5 pounds per acre. The actual amounts per sub-plot are shown in Appendix Table 14.

The seeds for each sub-plot were broadcast seeded and then

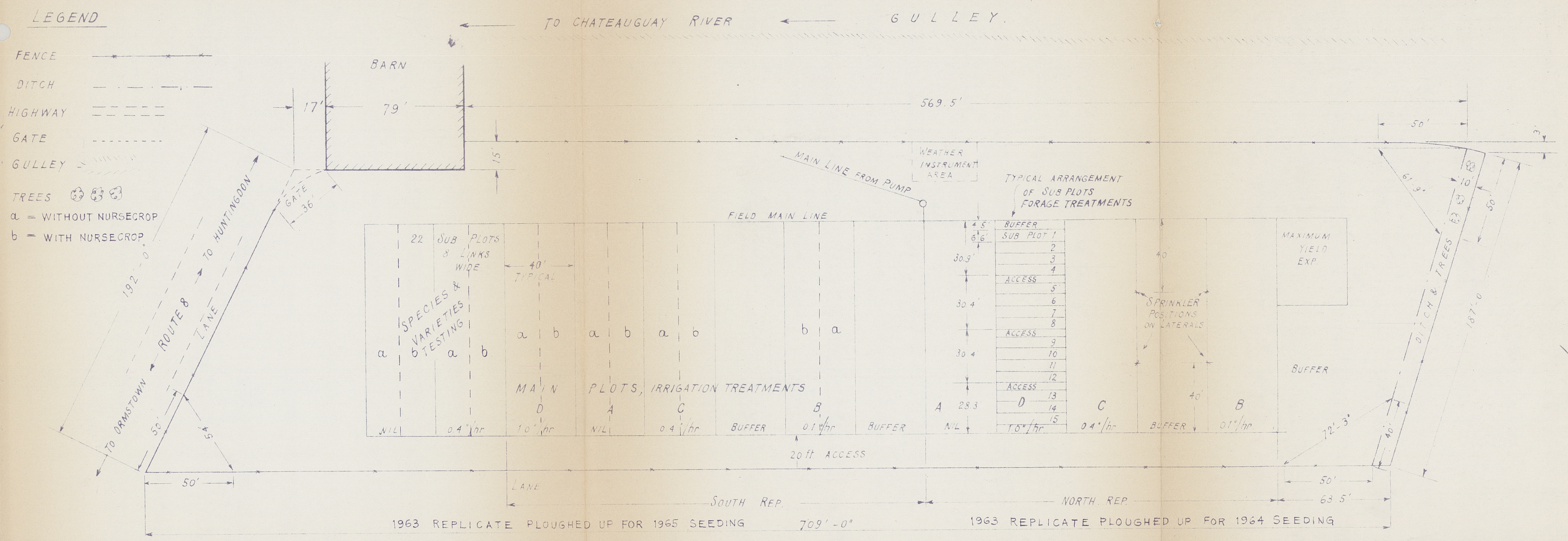


Fig. (i) SKETCH OF FIELD FOR IRRIGATION EXPERIMENTS, LOT 93, RANGE I, ST. MELLICHIE D'ORMSTOWN P. QUE. (CHATEAUGUAY COUNTY)

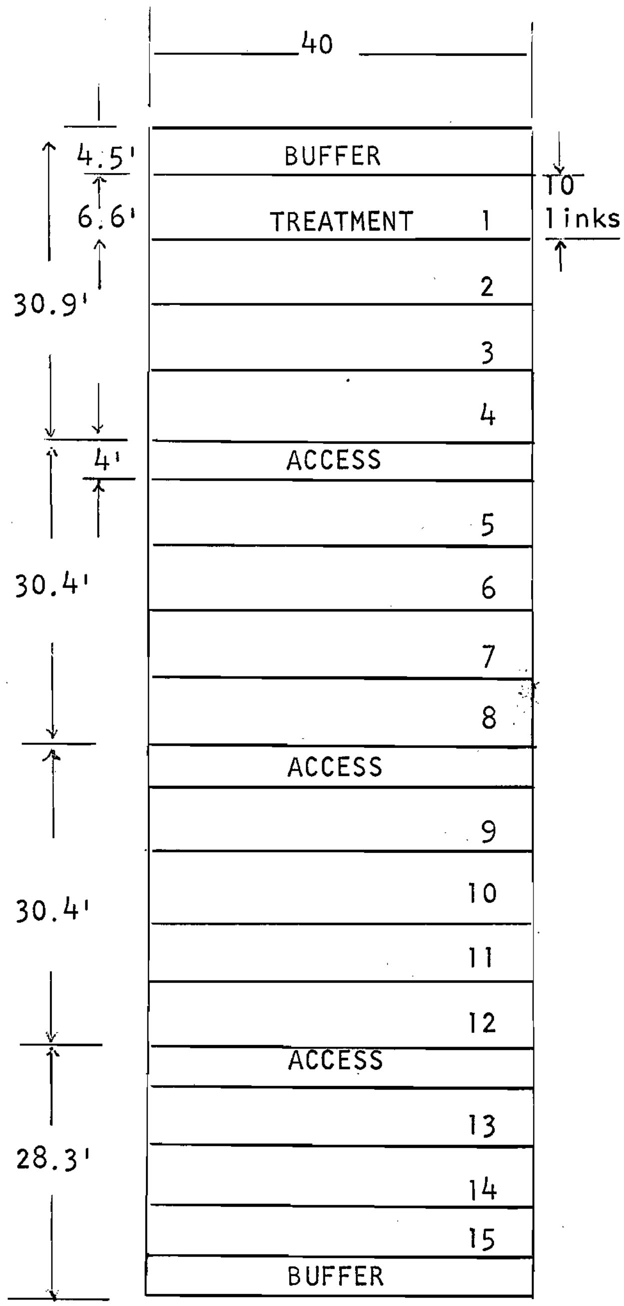
NOTE! SEE ALSO (1.) TREATMENT LAYOUT PLAN.
(2.) RANDOMIZATION PLAN.

SCALE 1" = 40'
JULY 29/1964

DRAWN - G.L.
TRACED - A.L.

Figure ii. Plan of typical arrangement of treatments

Mixtures testing



See also plan of randomization of treatments.

raked over lightly to provide shallow coverage. Moist sand was mixed with the small seeds to provide uniform distribution over the whole plot. Legumes were innoculated with the appropriate innoculant at the time of seeding.

Each access block was seeded to the same mixture used in adjoining sub-plots to the left. The buffer strips were sown with a mixture of timothy, ladino, and orchard-grass.

(iv) Moisture treatment

Water was pumped from the Chateauguay River using a horizontal centrifugal pump powered by an electrical motor and conveyed to the field through a three inch pipe. This was fed into a three inch main, and thence into two inch laterals.

The four moisture treatments were:

(A) Natural rainfall only
(B) Natural rainfall and irrigation applied at 0.1"/hr.
(C) Natural rainfall and irrigation applied at 0.4"/hr.
(D) Natural rainfall and irrigation applied at 1.0"/hr.

(A, B, C and D are used in the text to refer to the corresponding rates of irrigation)
The three irrigation plots received the same quantity of water, but only at different rates and, hence, different duration of irrigation.

Five irrigations were given in June as shown in Table 1. No irrigation was applied in August due to small showers at each time irrigation was required. Irrigation was applied, whenever 35% of the soil moisture was available, to bring the available moisture to 80%. Thus leaving a buffer of 20% in case of rain.

The need for irrigation was determined from moisture determination on dry weight basis of soil and from neutron moisture probe.

The amount of water applied also depended on the pattern and depth of root distribution, using the deepest root penetration as a guide.

TABLE 1. Dates of irrigation and inches of water applied in 1964.

Date	Inches applied from nozzles	Estimated inches of irrigation water reaching soil (80% efficiency)
June 11	0.2	0.16
15	0.4	0.32
18	0.4	0.32
22	0.4	0.32
26	1.2	0.96
July 24	1.2	0.96
Total	3.8	3.04

6. Collecting data

Data collection was made by Lussier (1965) from June until July when the present author took charge of the experiment. For the sake of completeness, part of the data collected by Lussier on this year's seeding will be used.

(a) Root yield

Weekly root samples were taken from 5th June until 15th September using a homemade core sampler two inches in diameter, and graduated into three inch intervals. Sampling was random within each subplot, and the core was pushed manually to a predetermined depth by finding the deepest root growth up to that week in all four blocks.

Each root sample was carried back in cans to Macdonald College, soaked in water for about a day, and the soil washed off on a $\frac{1}{4}$ inch mesh screen over a tub.

Weed roots were separated out as far as possible from the forage roots and the latter oven dried at 98°C. for 14 hours and then weighed in milligrams.

(b) Forage yield

Yield determinations were made on 15th July and 20th October 1964, and 29th June 1965 from an area of 20 links x 5 links in each plot, using a Gravely tractor with a five link pan, after cutting off the borders. The total vegetation harvested was weighed and a sample ranging from 200 to 800 grams, depending on the number of species seeded, taken for hand separation.

(c) Hand separation

Samples were stored in a freezer and hand separated later into seeded and non-seeded species. The separated parts were weighed fresh, oven dried and reweighed.

Dry matter yield per acre and per cent contribution by species to yield were calculated from these data.

Hand separation was done after each harvest.

(d) Point quadrats

Point quadrat readings were taken after a week's regrowth after each harvest. The point quadrat was applied as described by Levy (1933) by lowering each of the ten needles and recording first hit of each species, non-seeded species, or bare ground as the needle descended. Five stations of fifty needles were considered adequate for each plot of 20 links x 5 links.

(e) Transformation of percentage data

For analysis of variance, arcsin transformations, according to

Snedecor (1956), were done for all figures expressed in percentages which may follow a binomial rather than normal distribution. The arcsin transformation values are not presented.in this thesis.

Goulden (1952) recommended transformation unless nearly all values are between 30% and 70%. Steppler (1964) pointed out that percentages outside 30% and 70% may follow a normal distribution and hence require no transformation. However, for purposes of comparison in analyses, all percentages were transformed.

7. Meteorological conditions

1st Year; 1964. The growing season, taken from the day of seeding on 15th May until the last day of sampling in October, was characterised by the usual dryness of the area. Weather records in Appendix Table15a show evaporation exceeded precipitation, and the months of June and July were particularly dry.

Temperature trends of this season compared with twenty-one years' average from Ste. Martin, show near normal temperatures for the area. June through August were warmer than the other months (Appendix Table 15c).

2nd Year; 1965. The winter was very cold, especially in January through March. April through June was slightly warmer than normal. Appendix Table 15b shows weather records at the experimental site.

Monthly snowfall was below normal and rainfall from April through July was sparse, and evaporation great.

8. Experimental results and discussion

(1) Results

Space limitations permitted establishment of only one replicate of the irrigation treatments. The analysis of variance for the statistical design was, therefore, handled as a randomized complete block with the moisture treatments being considered as replicates.

(a) Root yield

Dry weight of roots obtained in each of the 11 weeks of sampling were analysed for statistical differences. The weekly data have been placed on file in the Agronomy Department, Macdonald College.

The overall average root yield from all the moisture treatments during each week showed weekly increases (Table 2 and Figure 1). The percentage weekly increase relative to the average weekly increase for the combined treatments is greatest between the 8th and 9th weeks after seeding. Between the 11th and 14th week after seeding, average weekly root yields are not significantly different from each other (Figure 1).

The average weekly root yield for each moisture treatment, presented graphically in Figure 2 with the analysis in Appendix Table 1a, shows considerable variation between the moisture treatments in the first 8 weeks after seeding. From the 9th week, however, ranking of mean root yield at the various rates of irrigation remains relatively uniform in decreasing order of performance of B>C>D>A. The average root yield given by B and C in successive weeks were different from A.

A summarized version of the analysis variance of root yield for each week shows that in 9 out of 11 weeks of sampling the moisture treatments demonstrated significant differences (Table 2). The irrigated plots yielded higher root weight than the unirrigated plots in almost all instances. However, in the 4th and 5th week samples the A(Check) plot outyielded the B(0.1"/hour rate) plot.

TABLE 2. Weekly mean dry weight (milligrams) of roots, summarised results of analysis of variance, and ranking of means of root yield in each week at each rate of irrigation.

RATE OF IRRIGATION

Weeks after seeding	A (Check) Mean Yield	B (0.1"/hr) Mean Yield	C (0.4"/hr) Mean Yield	D (1.0"/hr) Mean Yield	#Significance	Mean	% Weekly increase relative to mean increase
4	73.9bc+	70.5c	108.3ab	108.8a	**	90.4	-
5	109.0ab	93.0b	126.6ab	139.1a	*	117.2	41
6	154.6b	185.6ab	204.2a	167.2ab	*	177.9	94
7	194.3b	219.7ab	208.6b	271.8a	*	223.7	71
8	203.0b	350.0a	220.7b	244.7ab	**	254.6	48
9	309.0b	414.3ab	496.0a	381.7ab	*	400.3	224
10	359.0b	579.3a	454.7ab	437.0ab	*	457.5	88
11	338.7b	672.7a	530.7ab	634.0a	**	544.0	133
12	544.3a	719.3a	713.3a	593.0a	None	642.6	152
13	468.0b	649.3ab	701.3a	482.0b	*	675.2	50
14	514.0a	700.7a	651.3a	570.7a	None	609.2	100
Mean	297.1 b	423.2 a	401.4 a	366.5 ab			

* = Significance at 5% level

** = Significance at 1% level

\+ = Mean values within any week or row, with the same letters are not significantly different, according to Duncan's test

\# = Level of significant results demonstrated for that week

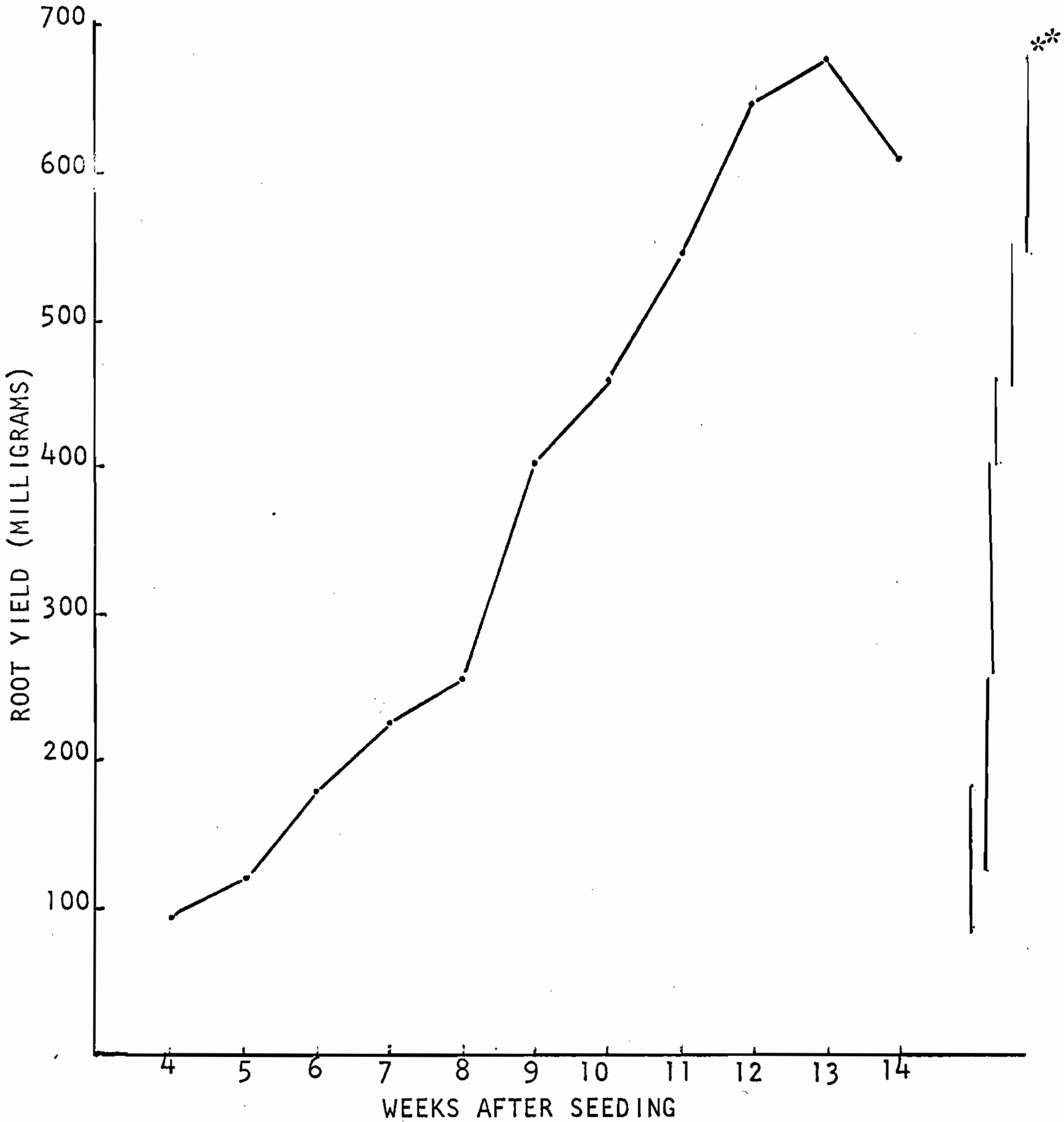


Figure 1. Mean of weekly total root yield (milligrams) at all rates of irrigation; for the 1964 season.

**Mean root yields covered by the same bar are not significantly different at 1% level.

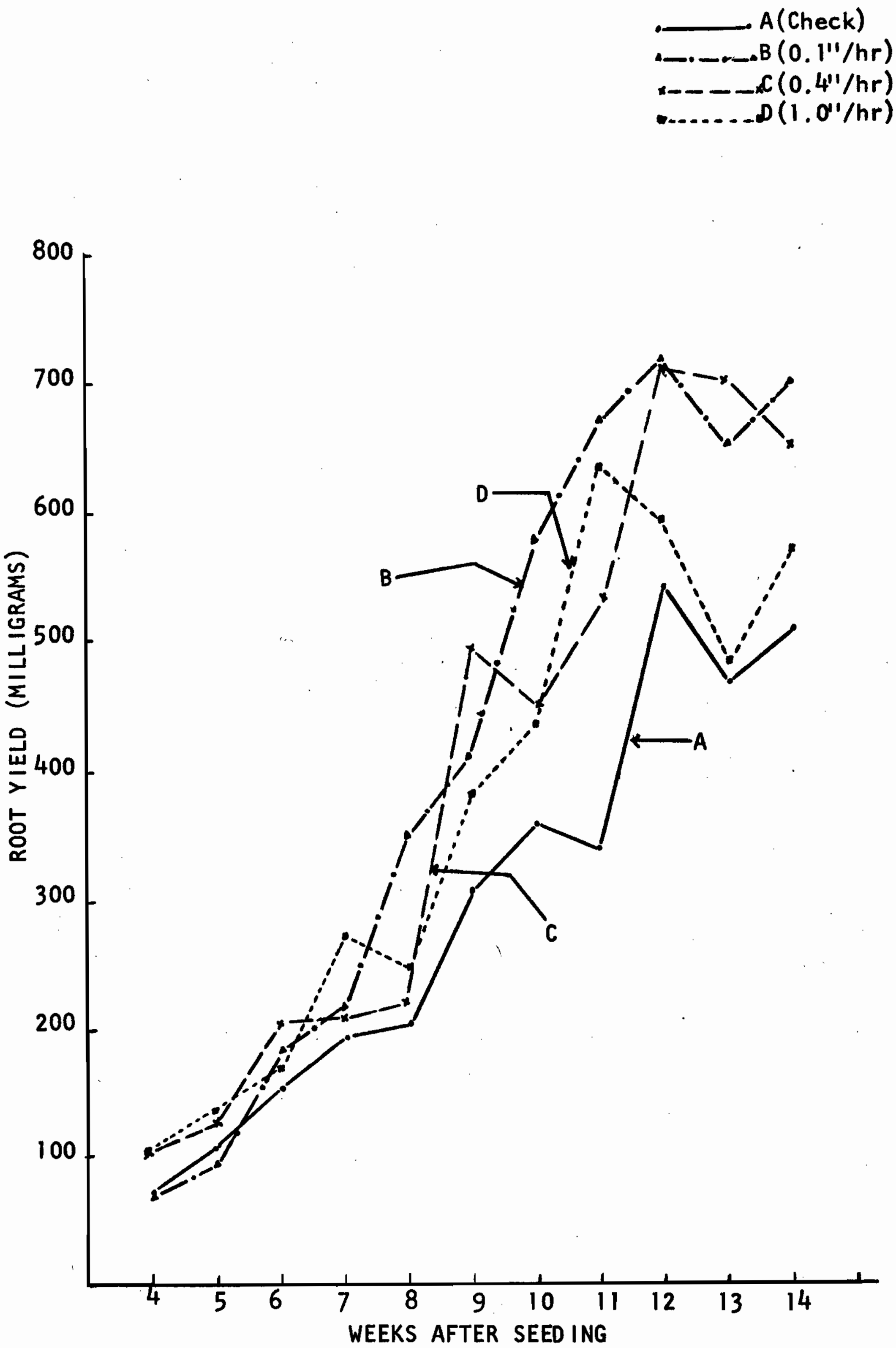


Figure 2. Mean weekly dry weight of roots (milligrams) at each moisture treatment in 1964.

Arrows point at region of greatest per cent increase in root weight at that rate of irrigation.

The average dry weight of roots for the whole season did not exhibit any significant differances between the mixtures (Appendix Tables 2a and 2b). The mixtures had an F value of 1.90 while the required F is 1.92, thus missing significance by 0.02. The moisture treatments were significantly different at 1% level. Duncan's range test showed B, C, D to be significantly different from A (Figure 3).

Only 3 out of 11 weeks of sampling showed significant differences between the mixtures (Table 3). Although the ranking is variable it indicates that the combinations T + A + B, T + A + L, A + B, and T + A gave the highest root yield in nearly every week being considered.

Early in the spring of 1965 severe winter damage was observed. Heaving was very apparent especially on the plots which were irrigated during the 1964 summer. The stand early in the season comprised, predominantly, the grass species, timothy and bromegrass. There was more alfalfa saved on the unirrigated than the irrigated plots.

Root samples taken in May to test the residual effect of irrigation demonstrated significant differences between irrigations in two out of four weeks' samples. A summarized version of the analysis of the results are shown in Table 4, and the actual data are on file at Macdonald College. Ranked mean values in Table 4 show that the highest rate of irrigation was detrimental to root survival in the winter.

Significant differences between mixtures were obtained only on samples taken on 24th May. Ranking of the means indicated that

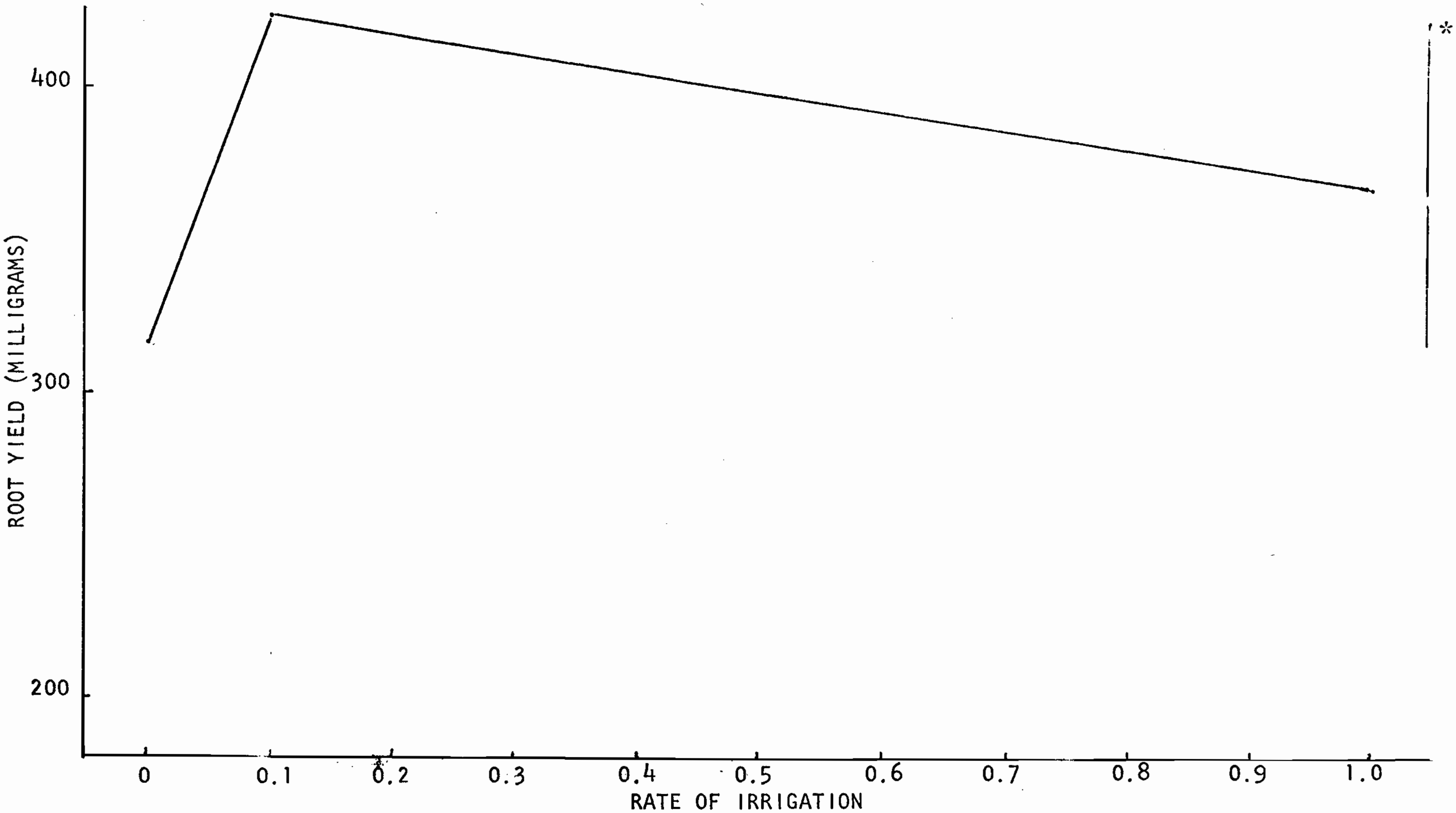


Figure 3. Mean dry weight (milligrams) of roots as influenced by rate of irrigation.

*Mean root yield covered by the same bar are not significantly different at 1% level.

TABLE 3. Summary of the analysis of variance and ranking of mean weekly root yield (milligrams) of mixtures at all rates of irrigation.in three weeks where significant variations were observed.

No.	Seeded Species (Mixture)	Weeks after seeding 5 Mean Yield	7 Mean Yield	11 Mean Yield
1	T	142.5** ab+	167.5* cd	362.5** bc
2	A	79.5 b	207.0 abcd	643.8 abc
3	L	108.0 b	178.0 bcd	437.5 bc
4	B	125.0 b	120.0 d	557.5 abc
5	T+A	135.0 ab	246.2 abcd	638.8 abc
6	A+L	95.0 b	205.4 abcd	305.0 c
7	T+L	127.5 b	166.2 cd	442.5 bc
8	T+B	117.2 b	201.2 abcd	315.0 bc
9	A+B	98.2 b	261.2 abc	802.5 ab
10	L+B	63.0 b	210.0 abcd	567.5 abc
11	T+A+L	136.0 ab	244.5 abcd	942.5 a
12	T+A+B	221.2 a	327.5 a	348.8 abc
13	T+L+B	126.0 b	235.0 abcd	425.0 bc
14	A+L+B	98.7 b	301.2 ab	562.5 abc
15	T+A+L+B	111.2 b	282.0 abc	608.8 abc

* = Significance at 5% Duncan's Range

** = Significance at 1% Duncan's Range

+ = Mean values within any week with the same letters are not significantly different, according to Duncan's Range test

TABLE 4. Summary of results of the analysis of variance and ranking of mean root yield (milligrams) at each rate of irrigation. Samples taken in May, 1965 from 1964 seeding.

Sampling	Rate of Irrigation: A(Check) Mean Yield	B(0.1"/hr) Mean Yield	C(0.4"/hr) Mean Yield	D(1.0"/hr) Mean Yield	Significance
1965					
May 12th	569.0	729.2	668.0	624.9	None
17th	655.0 a+	591.3 ab	486.7 b	437.3 b	*
24th	489.0	554.3	524.0	578.3	None
31st	460.0 ab	568.7 a	532.0 a	303.3 b	**

* = Significance at 5% Duncan's range

** = Significance at 1% Duncan's range

+ = Mean values with the same letters on a particular date are not significantly different, according to Duncan's range test

the combinations containing timothy, alfalfa and/or brome feature in the first five best yielders as shown in Table 5.

TABLE 5. Mean dry weight of roots (milligrams), taken on 24th May, 1965, from the different mixtures

No.	Seeded species Mixture	Mean dry weight of roots	1% Duncan's range+
9	A+B	957.50	a
15	T+A+L+B	798.75	ab
7	T+L	730.00	abc
5	T+A	665.00	abc
11	T+A+L	647.50	abc
14	A+L+B	582.50	abcd
8	T+B	562.50	abcd
12	T+A+B	518.00	abcd
10	L+B	515.00	abcd
4	B	463.75	bcd
13	T+L+B	456.25	bcd
6	A+L	415.00	bcd
1	T	410.00	bcd
2	A	292.50	cd
3	L	120.00	d

+Mean values with the same lower case letters are not significantly different

Results of profile sampling taken in the middle of Summer, 1965 are presented in Appendix Table 3a. Analysis of variance of the total root yield in the whole 45 cm. core demonstrated significance for only mixtures (Appendix Tables 3b and 3c). The mean values, ranked in Table 6, show alfalfa roots feature in all of the first 8 combinations.

TABLE 6. Mean dry weight (milligrams) of roots of mixtures in the whole profile (45 cm. deep). From Spring, 1964 seeding.

No.	Seeded species Mixture	Average dry weight of roots	5% Duncan's range+
2	A	1,133	a
11	T+A+L	1,075	ab
9	A+B	739	abc
6	A+L	718	abc
12	T+A+B	709	abc
14	A+L+B	700	abc
15	T+A+L+B	676	abc
5	T+A	655	bc
8	T+B	566	bc
10	L+B	564	bc
13	T+L+B	514	c
7	T+L	475	c
4	B	456	c
1	T	329	c
3	L	326	c

+Mean values with the same lower case letters are not statistically different.

On percentage basis most mixtures had more than 80% of their total root yield in the top 15 cm. and rarely more than 5% in the 30 to 45 cm. volume of soil (Figure 4). The combinations containing alfalfa had 80% or more of their roots in the top 15 cm. of soil. As shown in Figure 5, more than 80% of the roots occurred in the top 15 cm. for all moisture treatments. The check plot yielded a slightly lower percentage of its roots in the top 15 cm. than the irrigated

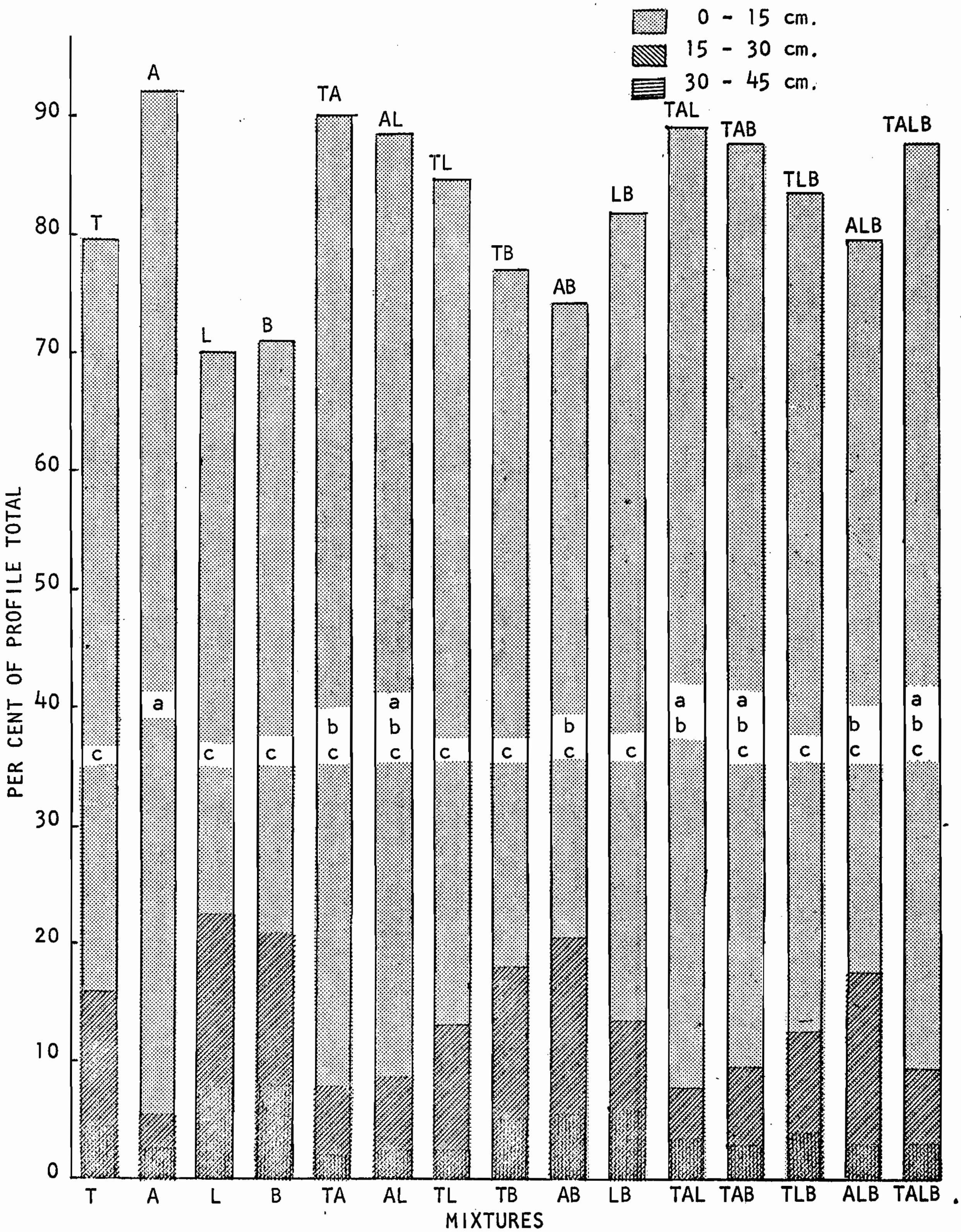


Figure 4. Per cent distribution of roots of mixtures within different soil depths.

Bars with the same lower case letters are not significantly different in root content of the 0 - 15 cm. of soil.

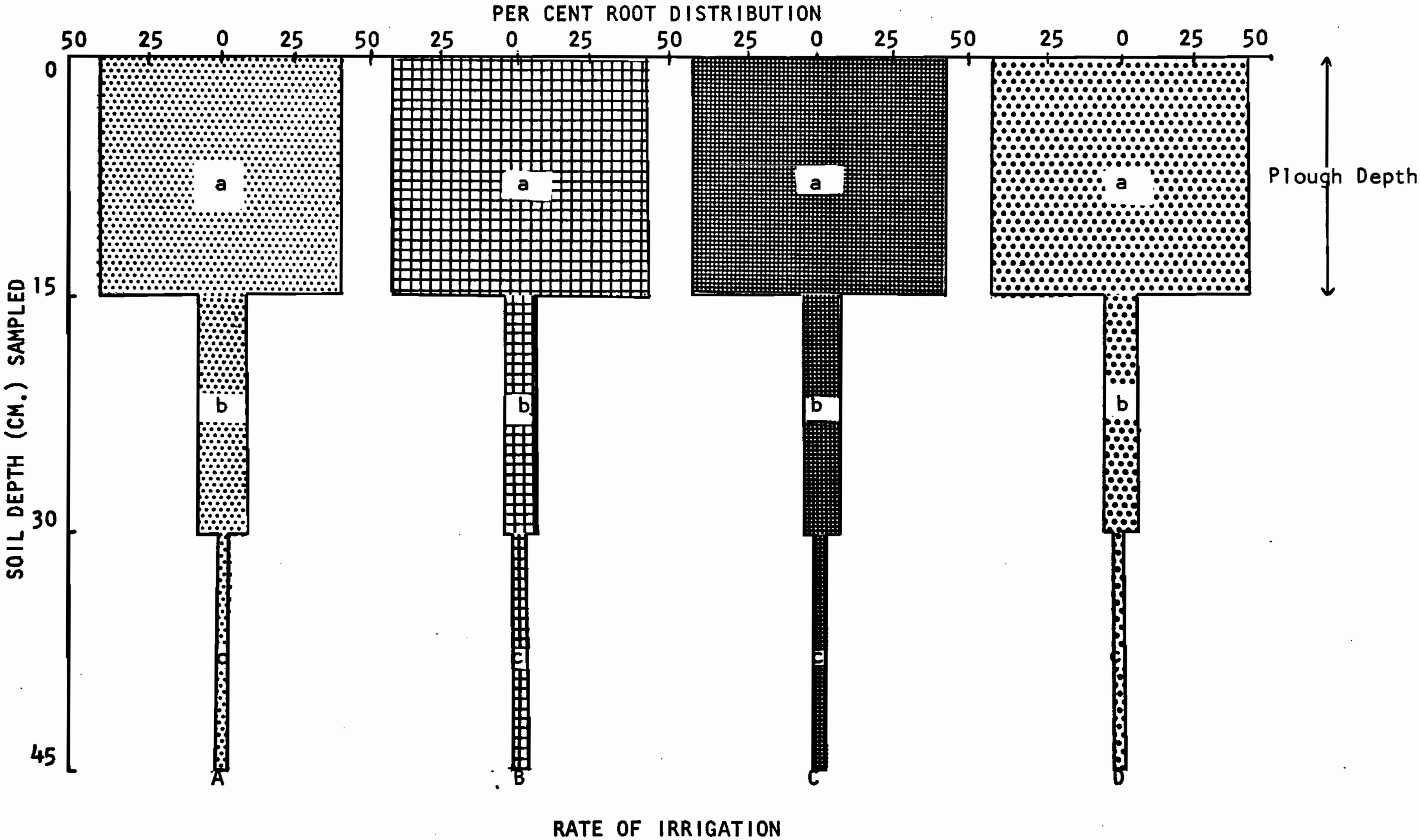


Figure 5. Per cent root distribution in the top 45 cm. of soil within each rate of irrigation. Per cent distribution with the same letter are not significantly different.

plots. This difference is made up by a higher percentage of its roots in the next 15 cm. of soil.

(b) Yield responses, 1964

During the 1964 season all the plots were very weedy. The predominant weeds were *Ambrossia* species and *Agropyron repens*.

Reports on the first cut of these plots have been presented and discussed by Lussier (1965).

The second cut yields are presented in Appendix Table 4a. Analysis of variance of total yield, seeded forage yield, and "others" (weeds) are given in Appendix Tables 4b, 4c, and 4d. A summary of the results of these analyses shows that irrigation at B and C resulted in greater yields than A (Table 7).

TABLE 7. Mean dry matter yield (lbs/acre), (a) total, (b) seeded forage mixture, and (c) "others", at each rate of irrigation, from the plots cut on 20th October, 1964. Second cut of Spring, 1964 seeding.

	Rate of irrigation			
Mean yield	A(Check)	B(0.1"/hr)	C(0.4"/hr)	D(1.0"/hr)
(a) Total**	921.0 b+	1,377.0 a	1,312.0 a	947.0 b
(b) Seeded forage**	115.0 b	254.0 a	269.0 a	181.0 ab
(c) "Others"**	806.0 b	1,123.0 a	1,043.0 a	766.0 b

**Significance at 1%

+Means with the same lower case letter within each row of means are not significantly different, according to Duncan's test.

The total yields under treatment B and C are different from total yield under treatment D. Although there is no statistical difference between the two former treatments and D, with regard to yield of seeded forage mixture, it is evident that less forage was realized under the latter treatment.

Dry matter yield of seeded forage mixtures were also highly significant (Appendix Table 4c). The mean values, ranked in Table 8, show the mixture containing T + A + L was superior.

TABLE 8. Mean dry matter yield (lbs/acre) of seeded forage mixtures from the plots cut on 20th October, 1964. Second cut of Spring, 1964 seeding.

No.	Seeded species Mixture	Mean lbs. dry matter	1% Duncan's range
11	T+A+L	442	a
7	T+L	377	a
15	T+A+L+B	365	ab
10	L+B	306	abc
14	A+L+B	290	abcd
13	T+L+B	264	bcd
6	A+L	252	bcd
3	L	194	bcd
5	T+A	147	bcd
9	A+B	120	bcd
12	T+A+B	117	bcd
1	T	72	cd
8	T+B	52	cd
4	B	39	cd
2	A	35	d

Percentage contribution made by the seeded forage in each mixture was significantly different at the 1% level for both irrigation treatments and mixtures (Appendix Tables 4e and 4f). Treatments D abd C were significantly different from A. The percentage contribution of seeded forage species to the total yield of mixtures, illustrated in Figure 6, indicates that combinations containing ladino, for example, T + A + L, T + A + L + B, T + L, etc. made a higher contribution than combinations without ladino. The percentage contribution of "others" would show the exact opposite effect since the total

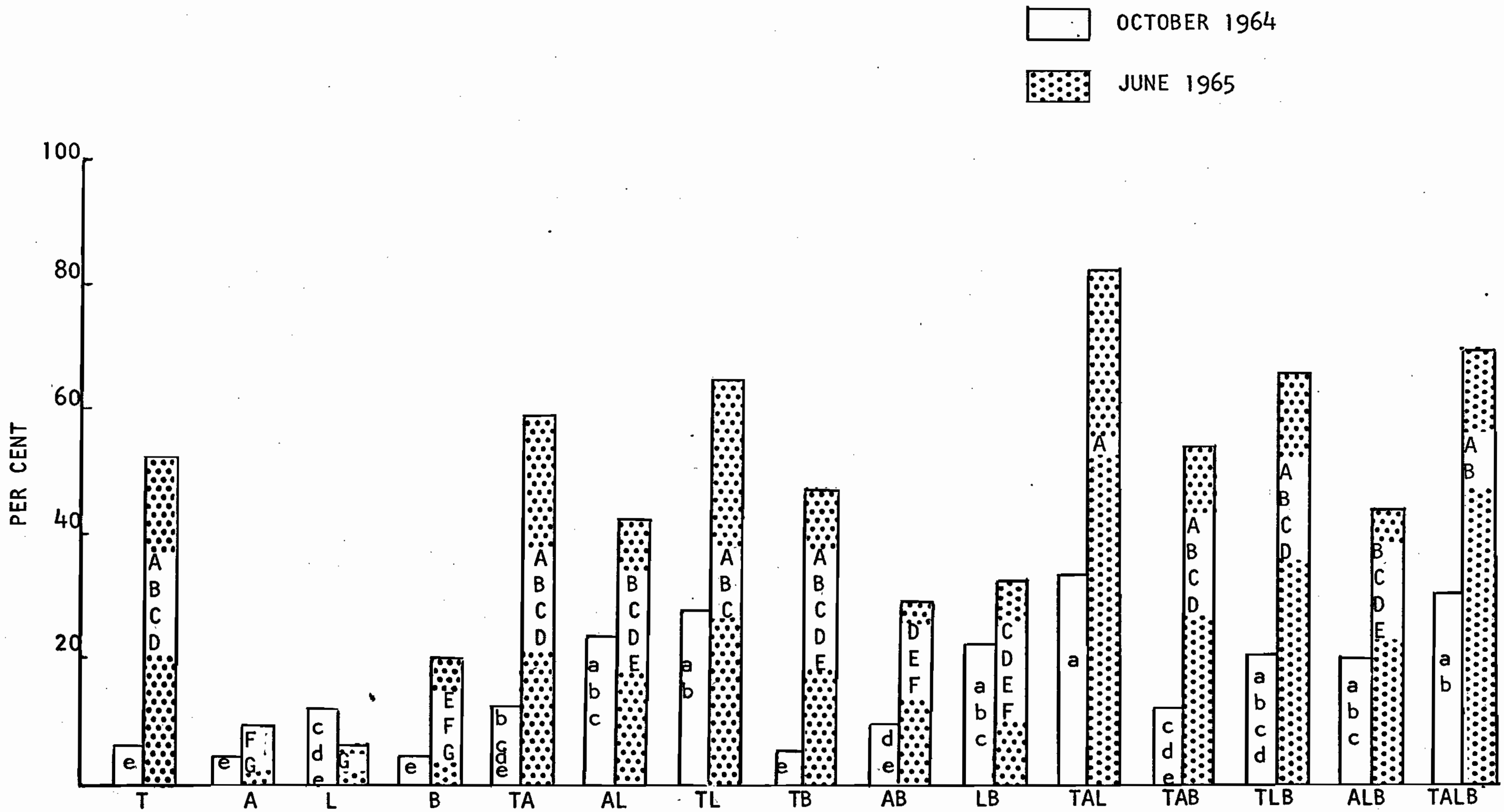


Figure 6. Per cent contribution of seeded species to total yield of each mixture in 1964 and 1965. Mixtures with the same lower or upper case letter, in a particular year, are not significantly different.

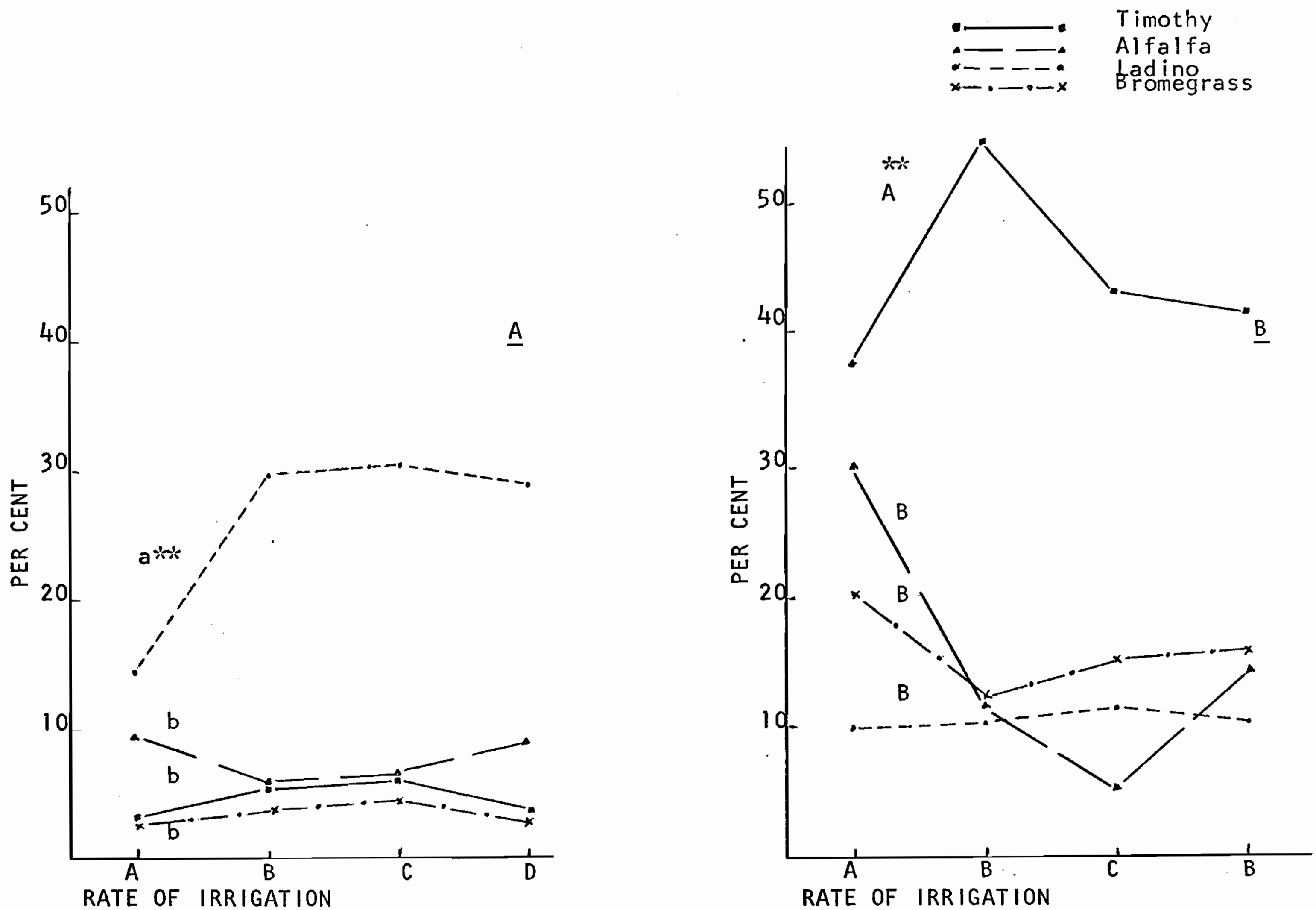


Figure 7. Per cent contribution of each species to the total yield at each rate of irrigation. A in 1964. B in 1965.

Species curves with the same lower or upper case letter are not significantly different at 1% level.

of percentage contribution of seeded forage and "others" is 100%. Thus combinations with ladino were less weedy.

The average percentage contribution of each species to total yield for each moisture treatment showed highly significant differences between the species (Appendix Tables 4g and 4h). In Figure 7a ladino is noticeably different from alfalfa, brome and timothy.

Although there is a lack of statistical difference between the moisture treatments in their influence on the species, it is apparent that irrigation more than doubled the yield of ladino. At the B and C moisture treatments the contribution of alfalfa is lower than at A and D, while all the other species made their greatest contribution at the two former rates of irrigation.

(c) Yield responses, 1965

The devastating effect of the severe winter has already been mentioned.

Results of hand separation and analysis of variance are recorded in Appendix Tables 5a, 5b, 5c, and 5d. Summaries of comparison of means after analysis of variance are presented in Tables 9i and 9ii.

In the second year of establishment the irrigation rates B and C effected significantly greater total yields than the A treatment (Table 9i). Weed incursion on the irrigated plots were also more serious than on the unirrigated plots. However, there were no differences regarding yields of seeded forage.

Examination of ranking order would reveal that most of the significant differences in the means of total yield and seeded forage in Table 9ii are associated with the presence of timothy, while

TABLE 9i. Mean dry matter yield (lbs/acre), (a) total, (b) seeded forage, and (c) "others", at each rate of irrigation, from plots cut in June, 1965. Third cut of Spring, 1964 seeding.

Mean yield	Rate of irrigation			
	A(Check)	B(0.1"/hr)	C(0.4"/hr)	D(1.0"/hr)
(a) Total*	1,843 b	2,546 a	2,594 a	2,221 ab
(b) Seeded forage	1,084 a	1,27[illegible] a	1,122 a	1,004 a
(c) "Others"	759 b	1,267 a	1,472 a	1,217 a

*Significance at 5%
**Significance at 1%
+Means with the same lower case letter within each row of means are not significantly different, according to Duncan's test

TABLE 9ii. Mean dry matter yield (lbs/acre), (a) total, (b) seeded forage mixtures, and (c) "others" in mixtures, from the plots cut in June, 1965. Third cut of Spring, 1964 seeding.

No.	Mixture	(a) Total yield *		(b) Seeded forage **		(c) "Others" **	
1	T	2,947	ab	1,503	abc	1,444	abc
2	A	2,058	bc	181	d	1,877	a
3	L	1,816	bc	184	d	1,632	ab
4	B	1,424	c	284	d	1,140	abcd
5	T+A	3,275	a	1,901	ab	1,374	abc
6	A+L	2,369	abc	1,054	bcd	1,315	abc
7	T+L	2,604	abc	1,768	abc	836	bcd
8	T+B	2,489	abc	1,226	abcd	1,263	abcd
9	A+B	2,220	abc	765	bcd	1,455	abc
10	L+B	1,956	bc	637	cd	1,319	abc
11	T+A+L	2,694	abc	2,203	a	491	bcd
12	T+A+B	2,226	abc	1,221	abcd	1,005	d
13	T+L+B	1,921	bc	1,120	abcd	801	cd
14	A+L+B	1,816	bc	883	bcd	933	bcd
15	T+A+L+B	2,704	abc	1,903	ab	801	cd

*Significance at 5%
**Significance at 1%
+Means with the same lower case letter in each column of means are not significantly different, according to Duncan's range test

the preponderance of weeds result from the presence of legumes.

The percentage contribution of seeded species to yield of mixtures and analysis of variance, in Appendix Tables 4e and 4f, show a higher contribution in the second year than in the first year and significant differences between mixtures (Figure 6). Again, the combinations containing timothy made a relatively better contribution to yield. As in the 1964 summer yields, the mixture of T + A + L was the best.

Highly significant differences were found between the average percentage contribution of each species to total yield from the various moisture treatments (Figure 7b and Appendix Tables 5g and 5h). Unlike the previous year, timothy outperformed the other species. The effect of the moisture treatments were very variable. The best performance of timothy was realized under the B treatment, while the other species performed better under the A treatment.

The ratios of forage yield to root growth at the various rates of irrigation were 1.71, 1.89, 1.89 and 1.57 for A, B, C, and D, respectively.

(d) Point quadrat results

About one week after the third cutting when regrowth had started, point quadrat determinations were made. The results and analysis of variance are recorded in Appendix Tables 6a, 6b, 6c, 6d, 6e, 6f, and 6g. Summarized versions of the results are presented in Tables 10i and 10ii.

The total ground cover under the D rate of irrigation was found to be different from the A treatment. The former treatment also effected a significantly different cover by seeded forage species from the C rate. While ground cover by "others" was the same for all treatments, the

TABLE 10i. Mean per cent ground cover and bare ground at the different rates of irrigation.

Point Quadrat results	Rate of irrigation A(Check)	B(0.1"/hr)	C(0.4"/hr)	D(1.0"/hr)
Total ground cover*	59 b+	63 ab	66 ab	67 a
Ground cover by seeded forage*	31 ab	31 ab	29 b	37 a
Ground cover by "others"	28 a	32 a	37 a	30 a
Bare ground*	41 a	37 ab	34 b	34 b

*Significance at 5% level
+Per cent values with the same lower case letters within the same row of cover or bare ground are not significantly different, according to Duncan's test

TABLE 10ii. Mean and ranking of per cent cover by seeded forage mixture and "others".

No.	Seeded species Mixture	Ground cover by mixture**	Ground cover by "others"*
1	T	22 cd+	34 cd
2	A	12 d	51 a
3	L	27 bcd	35 cd
4	B	21 cd	47 ab
5	T+A	31 abc	26 cde
6	A+L	31 abc	33 cd
7	T+L	46 a	24 de
8	T+B	25 bcd	35 cd
9	A+B	29 abc	36 bc
10	L+B	33 abc	29 cde
11	T+A+L	45 a	27 cde
12	T+A+B	33 abc	30 cde
13	T+L+B	38 ab	24 de
14	A+L+B	46 a	27 cde
15	T+A+L+B	38 ab	20 e

*Significance at 5%
**Significance at 1%
+Averages with the same lower case letters are not significantly different, according to Duncan's range test

average percentage of bare ground on the check plot was different from the irrigated plots, C and D (Table 10i).

Ground cover in the mixtures was variable, but combinations (14) A + L + B, (7) T + L, and (11) T + A + L provided higher ground cover. The alfalfa plot which gave the lowest ground cover by seeded species had the highest ground cover by "others".

2. Discussion

(a) Root yield

The general root growth curve, in Figure 1, did not show the perfect sigmoid curve reported by Priestley and Evershed (1922) and Lussier (1965). Probably, this would have been more apparent if samples were taken beyond the 14th week after seeding. However, it was demonstrated that a greater increase in root yield occurred between 56 to 63 days after seeding than at any time outside this range. Lussier (1965) found that this phenomenon was concentrated within 48 to 56 days after seeding, while Lamba et al. (1948) reported that the highest increase occurred between 61 and 68 days after sowing. The discrepancy between these results might be due to the different moisture regimes and seasonal climatic variations in the respective instances. Probably, the phenomenon is associated with the period of attainment of optimum leaf area index, since this would be the period for optimum assimilation and hence production of new roots or accumulation of reserve material. The time taken to produce the greatest percentage increase in root weight at the four rates of irrigation were, in order of increasing time, C, B, D, and A (Figure 2). This would suggest that irrigation has the beneficial effect of advancing the time of attainment of optimum leaf area index. The time varied with the different rates imposed. Leaf area determinations which would have confirmed this reasoning were not made.

The significant differences between average root weight per week for the moisture treatments are indicative of the influence of the moisture treatments in promoting root growth. Initially, the highest rate of irrigation, D, gave a higher yield of root than the others. According to Lussier (1965) impedance in infiltration at the highest rate would effect a greater retention of water by soil particles in the surface layer where the seeds are placed. On the contrary, it was observed that reduced infiltration during irrigation was liable to cause ponding and run-off leading to loss of water applied. Hence there is less available water at the highest than the lowest rate of irrigation. Ponding also promotes anaerobic conditions in the root zone and hence root suffocation (Daubenmire, 1947). This conflicting trend shown by the highest rate (1.0"/hour) is difficult to explain. However, for a silty clay loam, rate C is the recommended optimum rate (Woodward, 1959).

In subsequent weeks the superiority of B and C rates were very obvious as they consistently gave greater root weight (Table 2 and Figure 2). This is in accordance with the basic intake rate reported by Woodward (1959). With the low rate of irrigation, infiltration rate is not exceeded by the rate of application. Thus the chances of ponding and water loss are considerably minimized. Since soil water and gases are complementary the low rate regime would allow for better gaseous circulation.

The average root yield for the season under the low rate of irrigation was greater than that under the highest rate, although the two were not different (Figure 3). This further emphasizes the detrimental effect of soil surface ponding which resulted during the rapid delivery of water at the highest rate of irrigation. The soil surface and aeration would both be affected. Aeration diffusion measurements attempted gave differences within, and not between, the plots receiving the different rates of irrigation. However, crusting of the soil surface was observed any time the plots receiving the highest rate began to dry out. Consequently, further reduction in infiltration rate on subsequent irrigation and a very wet zone of soil surface occurred. Stuckey (1941) pointed out that the effect of a very wet root zone is to cause smaller roots to die off due to improper aeration. Hence, the highest rate might have caused the death of smaller roots and reduced the overall root yield under this rate of irrigation.

The relatively low yield of roots under A is an indication of moisture stress. Appendix Table 15a shows that there was a large moisture deficit (7.39") during the growing season. Since water is a photosynthetic raw material any stress will limit the assimilatory process and reduce the amount of material available for storage.

Regarding yield of mixtures, trends were very variable. However, comparing the root yield of single species and combinations in Table 3, the combination of species gave higher yields. Particularly outstanding were the combinations (9) T + B, (11) T + A + L, (13) T + A + B, and (15) T + A + L + B. Similar results have been recorded by Lamba _et al_. (1948), Bennett and Doss (1960), and Lussier (1965). There are two possible explanations of this occurrence. Firstly, roots of mixtures extract moisture and nutrients from different soil depths (Weaver, 1926). Consequently, an association which involves differential root distribution will permit a greater utilization of the full range of available moisture and nutrients, and give a better yield, than one restricted to a portion of the root zone. In support of this theory it is pointed out that alfalfa, for instance, produced a much branched, thick and relatively long tap root, while bromegrass produced a profuse amount of rhizomes which did not go as deep. Timothy and ladino produced finely branched roots mostly in the top few inches of soil. Secondly, as pointed out by Russell (1961), it is also possible that certain associations will benefit from secretions which occur from members of the association. Even though the latter hypothesis cannot be substantiated, it is a possibility which cannot be ignored entirely.

The early spring sampling in 1965 predominantly showed grass roots, because most of the roots of the legumes were dead as a result of the severe winter. A slight increase in yield of roots of timothy was found, indicating that winter growth reported earlier by Sprague (1933) and Lussier (1965) had occurred.

The better performance of the non-irrigated plots compared to the two higher rates, C and D, may be attributed to winter killing which was more severe on the two latter plots. This would suggest that more plants may be saved if the soil moisture reservoir is low on entering the winter. Soil heaving, which results when soil moisture freezes, would be kept to a minimum and thus prevent mechanical breaking of roots.

The difference shown between B and C from D is considered to be an indirect effect of the previous season's moisture treatment in causing more root damage during the winter.

The results of profile sampling showed that about 95% of the roots were in the top 36 cm. of soil. This is not in agreement with the finding of Bennett and Doss (1960) who, working on a fine sandy loam, reported only 70% for the same depth of soil. The present result is explained by the fact that as the plough and fertilization depth was no more than 18 cm. the roots were mostly restricted to this zone. This is supported by the view presented by Russell (1961) and Weaver (1926) that plants usually have a greater root concentration in the depth of plough and fertilization. The present work was done on silty clay loam, and it is possible the differences in texture of the two sites will effect different distribution.

The lack of a significant difference between the average root yield in the whole profile for each moisture treatment suggests that the treatment imposed was no longer effective. Since soil temperature determinations were not carried out, the only possible explanation of the disappearance of the influence of irrigation may be sought in the effect of temperatures at grass level. Troughton (1957), in an extensive review of underground herbage grasses, noted that high temperatures could be detrimental to root growth. Specifically, he cited the work of Brown (1943) which showed that in a summer with high temperatures the carbohydrate reserve of *Poa pratensis* were depleted when the plants were supplied with water, but not when they were subjected to drought. The conclusion, then, was that irrigation during a drought hastened the death of older rhizomes and decay of older roots.

The summer of 1965 was hot and dry (Appendix Table 15b). This condition, in the light of Troughton's (1957) report, would be most conducive for the death and decay of some roots when irrigation was applied.

Although roots of bromegrass, in pure sand and combinations, were brown, it cannot be stated categorically that the growth-inhibitory-substance theory advanced by Benedict (1941) is operative here. Probably, a more likely hypothesis to account for this will be the soil temperature effect suggested by Brown (1943), as cited by Troughton (1957).

(b) Yield responses, 1964

As a result of the very heavy invasion of all plots by weeds the true effect of irrigation are more likely to be masked. The weeds offered serious competition to the seeded forage species. This makes interpretation of yield results very difficult. However, certain generalizations are possible.

The significant difference between the total yield of vegetation taken from the B and C, and the total yield from the D and A in Table 7 means that the two former rates created conditions which promoted greater growth of all vegetation. This would suggest that probably more moisture was made available for assimilation under the two rates, B and C. Rates D and A may, therefore, be considered to have had a detrimental influence on growth. As explained earlier, in discussion of root studies, there was less water available at rate D due to ponding and run-off. Poor aeration conditions which were discussed earlier, also indirectly affected the yield of aerial growth. The low yield made by the unirrigated plots clearly indicates that moisture conditions were limiting to growth of vegetation.

The effect of B and C in promoting more growth was also shown in yield of seeded forage mixture and "others". Both D and A effected lower yields of seeded forage mixture and "others". Thus, the irrigation at a higher rate, because it leads to ponding or causes poor growth conditions, is shown to be as detrimental as no irrigation.

The significant differences between mixtures showed that (11) T + A + L, (15) T + A + L + B, (10) L + B, (14) A + L + B, and (6) T + L were the best combinations. Similar results have been reported by Whitaker (1951) and Chevrette (1961). The results, perhaps, suggest beneficial association between grass and legumes. However, since this harvest was from the seeding year such a claim cannot be stressed since mineralization required for release of nitrogen would be negligible at this time. It is interesting to note that (11) T + A + L and (15) T + A + L + B were also among the mixtures which gave the best root yield. The same trend was shown in the botanical composition (Figure 6).

Regarding species contribution to the total yield the superiority of ladino was very obvious especially under irrigation (Figure 7A). This agrees with the results of Peterson and Hagan (1952) who reported petiole elongation and dry matter percentage to be significantly increased by the different soil moisture regimes they used. Irrigation improved the stand of ladino, while alfalfa showed a lower yield under irrigation, as similarly reported by Tesar et al. (1958). The yield of grasses, although increased with irrigation, was not better than the legumes, thus, disagreeing with the finding of Levine et al. (1955). This could be due to differences in growth rhythm of grasses and legumes. Since grasses begin their growth cycle earlier in the spring, they come into maturity at mid-summer. On the other hand legumes, which start their growth cycle later than the grasses, tend to mature in late summer. The implication of this result is that while irrigation can bring the plants into an earlier maturity stage, it does not alter the developmental cycle of grasses or legumes.

(c) Yield responses, 1965

The results presented in Table 9i still show the beneficial influence of B and C rates of irrigation over A in terms of total vegetation produced. For the same reason, as in the late summer 1964 cut, rates B and C gave higher yields than D. Although there was no significant difference between the mean yield of seeded forage mixtures under these rates of irrigation, a lower yield was obtained when the water was applied at a fast rate. The higher forage to root ratios at rates B and C confirm the beneficial effects at these rates. Root growth was better at each of these rates. Hence, greater amounts of moisture and nutrients were absorbed for photosynthesis and top growth. Irrigation, particularly at moderate applications, also produced more weed growth. Yields were, however, greater this year than the late 1964 summer cut. Climatic conditions were probably more suitable for better growth of vegetation.

The yield of seeded forage species showed an improvement over last year's. Except timothy, the single species seedings performed very poorly, and were very susceptible to weed encroachment. The best combination was T + A + L. A beneficial influence of the association of legumes and grasses on yield was also shown (Table 9ii). Perhaps, this beneficial association is a result of mineralization of legumes root nodules produced in the previous year. The occurrence of this is well documented, notably by Russell (1961).

The percentage contribution of seeded species also showed significant increases over the previous year's performance. Although weed growth was reduced there was an indication that plants offered a better competition.

The grasses, as seen in Figure 7B, outperformed the legumes. This ties in with the growth cycle of grasses in general, since at the mid-summer harvest they were at a more advanced stage of maturity than the legumes. Irrigation increased the yield of timothy and, to a very small degree, ladino. The low yield made by bromegrass is difficult to explain.

(d) Point quadrat rate discussion

The results show that irrigation provided more plant growth and hence higher percentage cover. The higher percentage cover given by the seeded species under D compared with that under C is difficult to reconcile with the higher forage yield by the latter rate of irrigation. The significant difference between bare ground in the unirrigated and irrigated plots is due to the fact that irrigation was able to save more plants. The trend of point quadrat analysis for the mixtures is similar to yield of the mixtures. For instance, the single species seedings, notably alfalfa, had less ground cover provided by the seeded forage and more by "others".

Experiment II. Influence of companion crop on irrigated forage.

This experiment was started in May, 1965 to test the influence of oat companion crop on irrigated pasture. The same combinations of the species timothy, alfalfa, ladino and bromegrass used in Experiment I were employed here. Due to the short period of time available for the experiment, the only criterion of influence was based on dry matter of roots taken weekly.

A. Materials and Methods

1. Seeds

The seeds used in this experiment were the same as for Experiment I.

2. Location and history of experimental area

The experiment was located on the same farm as Experiment I. The area for this experiment was the south replicate of the 1963 plot which was ploughed up due to excessive weed growth. In the fall of 1964, 2-4-D with eight ounces of active ingredients, and Dalapon at the rate of ten pounds per acre were ploughed in with the vegetation.

3. Irrigation system

The equipment used for Experiment I was extended to the new plots.

4. Experimental methods

(a) Design

The same design as in Experiment I was used. In addition, a second split for oats as companion crop was included.

(b) Field plan

See south replicate on plan of Experiment I.

(c) Soil treatment

Fertilization. The soil was fertilized in 1963 with 150 pounds per acre 4-24-20 NPK. For the 1965 experiment 300 pounds per acre of 8-16-16 were applied.

(d) Drainage system

Tile drainage system was installed in May, 1964.

(e) Seeding

The same rates and amount of seeds used in the 1964 experiment were applied in a similar manner (Appendix Table 14).

(f) Moisture treatment

Moisture treatments were as in Experiment I. Table 11 shows the frequency and amount of moisture applied.

TABLE 11. Dates of irrigation and inches of water applied+ , 1965.

Date	Inches applied from nozzle	Estimated inches of irrigation water reaching soil (80% efficiency)
June 3rd	0.22	0.18
8th	0.70	0.56
14th	1.45	1.16
22nd	1.40	1.12
30th	1.40	1.12
July 23rd	1.40	1.12

+The same amount of water was applied on the same day to the 1964 seedings

5. Collecting data

Root yield. Since the first portion of this work had to be stopped by mid-July the only data collected was root yield. The method of sampling and washing the soil off the roots has been described in Experiment I.

6. Meteorological conditions

Weather records are presented in Appendix Table 15b. April through June was slightly warmer than average. Rainfall during this period was sparse and evaporation great.

B. Results and discussion

1. Results

Field data related to this experiment have been filed in the Agronomy Department, Macdonald College. The results presented here are only averages of the original.

The mean weekly root yield by the seeded species in presence and absence of a companion crop at each moisture treatment are given in Appendix Table 7. Significant differences were obtained between the root yield under no companion crop and root yield under companion crop from five weeks after seeding to the end of the sampling period (Figure 8). There were greater weekly increases of root weight in the absence of a companion crop than when a companion crop was present. Root yield in the latter was found to be consistently low.

Weekly mean root yield in the absence of a companion crop showed more fluctuations for rate B than C and D, which showed consistently increasing yield in the initial stages. However, between the eighth and ninth week after seeding there was a higher increase in yield under B than C or D (Figure 9). Although no differences existed in weekly trends of root production under a companion crop, performance at C rate of irrigation seems to be better in the first eight weeks than performance at A, B, and D rates of irrigation.

The average dry weight of each mixture during the experimental period demonstrated highly significant differences for both companion crop treatment and mixtures (Appendix Tables 8a and 8b). Considering the moisture application, no significant differences were found within root yield in the absence or presence of a companion crop. However,

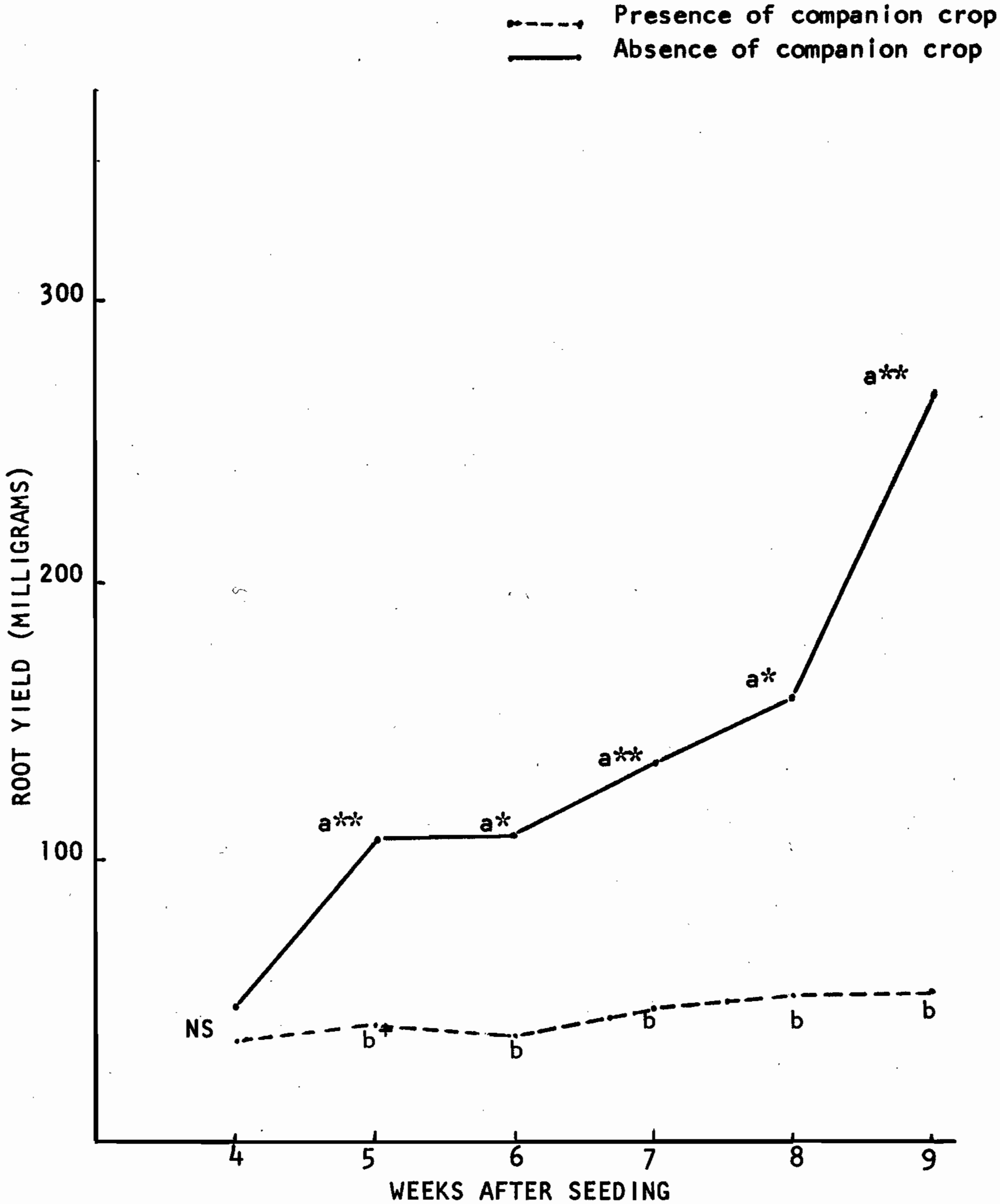


Figure 8. Mean weekly root yield of seeded forage species in presence and absence of companion crop.

NS = Not significant
*Significant at 5%
**Significant at 1%
+Mean values of any week with the same letter are not significantly different.

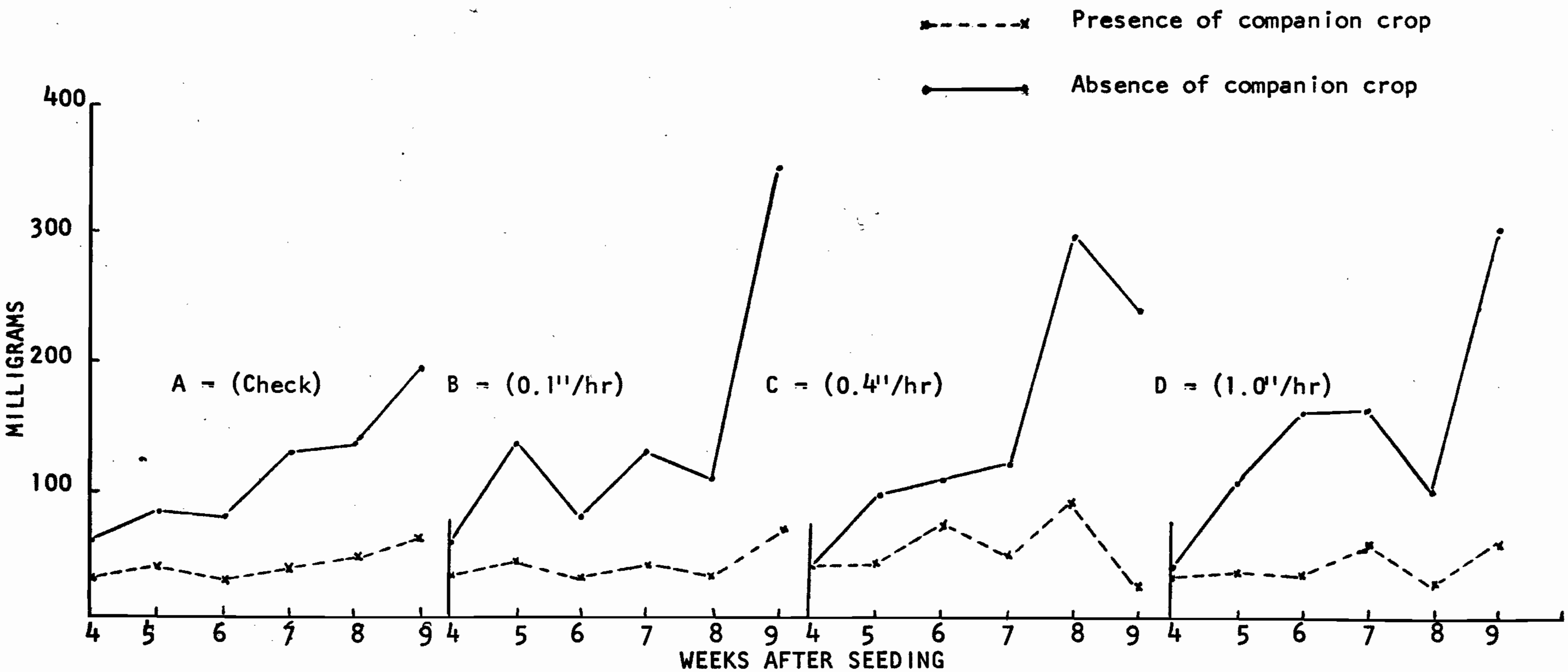


Figure 9. Weekly mean root yield, in milligrams, as influenced by rate of irrigation and in presence and absence of companion crop.

root yields of irrigated forage without a companion crop were better than the check (no companion crop and unirrigated; Figure 10). Within the companion crop treatment yields were approximately the same with the exception of treatment C, which showed a slightly higher yield.

Root yields of mixtures in the absence of a companion crop were found to be significantly different from each other, but no significant differences were shown for root yield of mixtures under a companion crop (Figure 11). The lower yield of roots under a companion crop is also very apparent, but the root yield of mixtures with two or more species combinations were less affected.

(2) Discussion

Root development, in the absence of a companion crop followed the same trend as was observed in root yield in Experiment I. For instance, as shown in Figures 8 and 9, the greatest root yield was made between 56 and 63 days after seeding. It was suggested that this period probably coincided with the time when the aerial portion attained optimum leaf area index. If assimilatory products are not immediately utilized in growth, and photosynthesis-respiration balance is maintained, then accumulation of reserve food substances will be greatest at this period.

The lower yield of roots in presence of an oats companion crop compared to root yield in the absence of oats indicates competition effect between the seeded forage and the companion crop. Plants grown in association compete for water, nutrients, and light. Since water and nutrients were in adequate supply, it can be argued that light was the limiting factor controlling the rate of growth, production of dry matter, and accumulation of carbohydrate reserves in

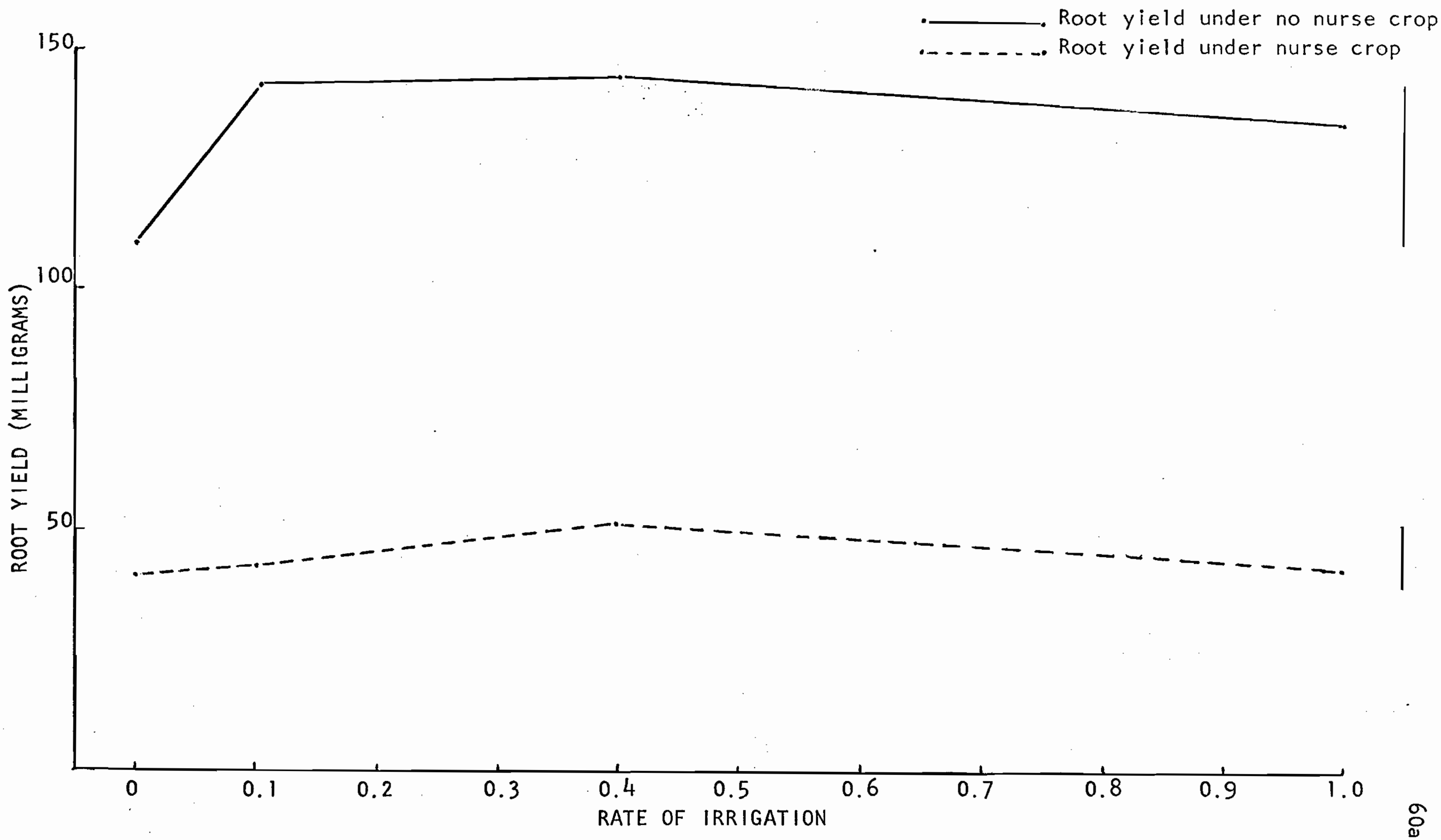


Figure 10. Mean seasonal root yield as influenced by the rate of irrigation and presence and absence of companion crop.

Mean root yields covered by the same bar are not significantly different at 1% level.

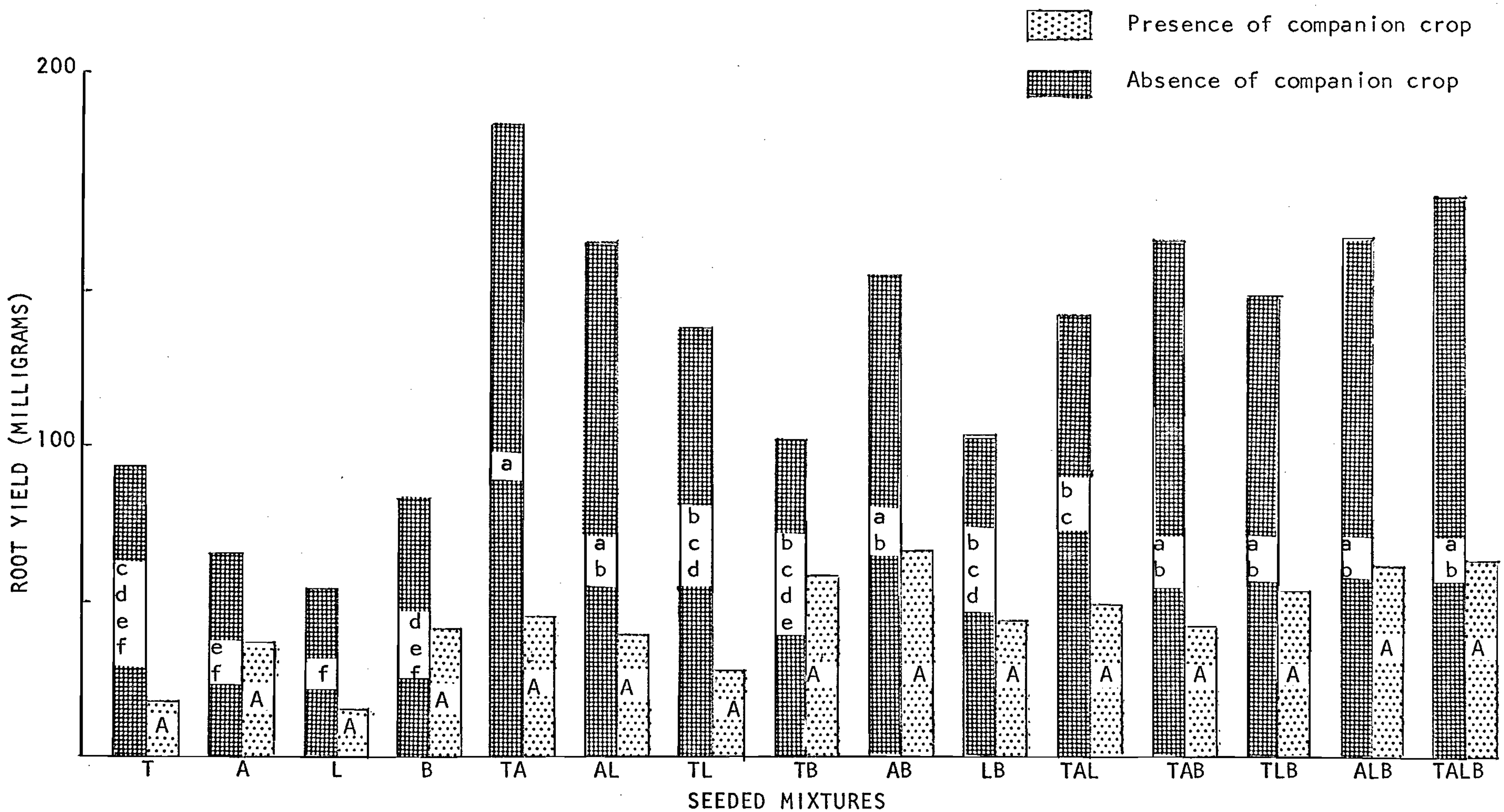


Figure 11. Mean dry weight (milligrams) of mixtures in presence and absence of companion crop for the season, in 1965.

Bars with the same lower or upper case letter are not significantly different at 1% level.

the roots. The rapidly growing oats, especially under irrigation, quickly covered the young seedlings of forage species. Under the intense shading by oats' canopy, only a small percentage of light reached the seeded forage species. Thus, the net assimilation of the forage species would be very low, and root development greatly hampered.

The vigourously growing oats would also limit root development of the seeded forage, because the oats' root system, by virtue of more available reserves, would grow at a faster rate and occupy a larger volume of soil, leaving only a small volume for the roots of the seeded forage roots.

The initial higher rate of increase under the D would tend to support the opinion expressed by Lussier (1965) that germination of seeds and establishment of roots require this highest rate of irrigation. However, it is noted that the overall root yield for the season under the highest rate was less than that under the B. The hypothesis that D rate of irrigation is detrimental to root development, by creating unfavourable growth conditions, still holds.

The lack of significant difference between root development under irrigation and no irrigation suggests that there was, probably, a higher degree of competition for light between the forage species and the companion crop under irrigation. This degree of competition is expected, because it was observed that oats grew better under irrigation. Although a higher percentage of light might have reached the leaves of seeded forage for a longer period when the crop was unirrigated, root yield was just as low as when the crop was irrigated. Presumably, the limiting factors to root yield under non-irrigation were both moisture and light. Light penetration determinations would have provided more explicit answers.

The significant differences between the mixtures showed that combinations of grass and legumes, especially bromegrass and alfalfa, gave better root development.

Experiment III. Seeding rate experiment

A. Materials and Methods

1. Origin of materials

Bromegrass: Common seed number 1 grade

Timothy: Foundation seed of the variety Milton

Birdsfoot trefoil: Certified seed of the variety Empire

Ladino: Certified Blue Tag

Alfalfa: Certified seed of the variety Vernal

2. History of the experimental area

The experiment in 1964 was located on a heavy clay loam on the horticultural plots.

Prior to this experiment, the area had been employed as red clover breeding nursery. It was ploughed and left lying fallow in 1963. In Spring, 1964 the area was worked up and light ploughing done in the fall just before seeding in August.

3. Fertilization

Before seeding 150 pounds per acre of 4-24-20 fertilizer were drilled all over the experimental area.

4. Experimental methods

(a) Design

A split-split plot design with two replicates was used. The main plot consisted of two irrigation levels (irrigation versus check). The first and second splits were made up of five species and four rates of seeding, respectively.

(b) Rates of seeding

The different rates of seeding in each species are presented in Table 12a.

TABLE 12a. Seeding rates in pounds per acre for the species used.

Species	Rates			
	1	2	3	4
Timothy	2	4	6	8
Alfalfa	2	4	6	8
Ladino	0.75	1.50	2.25	3.0
Bromegrass	6	12	18	24
Birdsfoot	2	4	6	8

These rates represent quantities of viable seeds, the viability being evaluated in a laboratory germination test.

(c) Plan (See Figure iii)

Plot size: 6 x 25 links (1 link = 7.92 inches)

(d) Germination tests in laboratory

The seeds were tested for germination on blotting paper in petri dishes. For each species 4 x 100 seeds were allowed to germinate in one week and then checked. The following percentages of germination were obtained:

Timothy:	93.50 per cent
Alfalfa:	89.00 " "
Ladino:	56.00 " "
Bromegrass:	33.50 " "
Birdsfoot trefoil:	57.00 " "

Based on these results the actual seeding rates were calculated.

As a result of the severe winter killing experienced, the experiment had to be re-established in the Spring, 1965. Laboratory germination

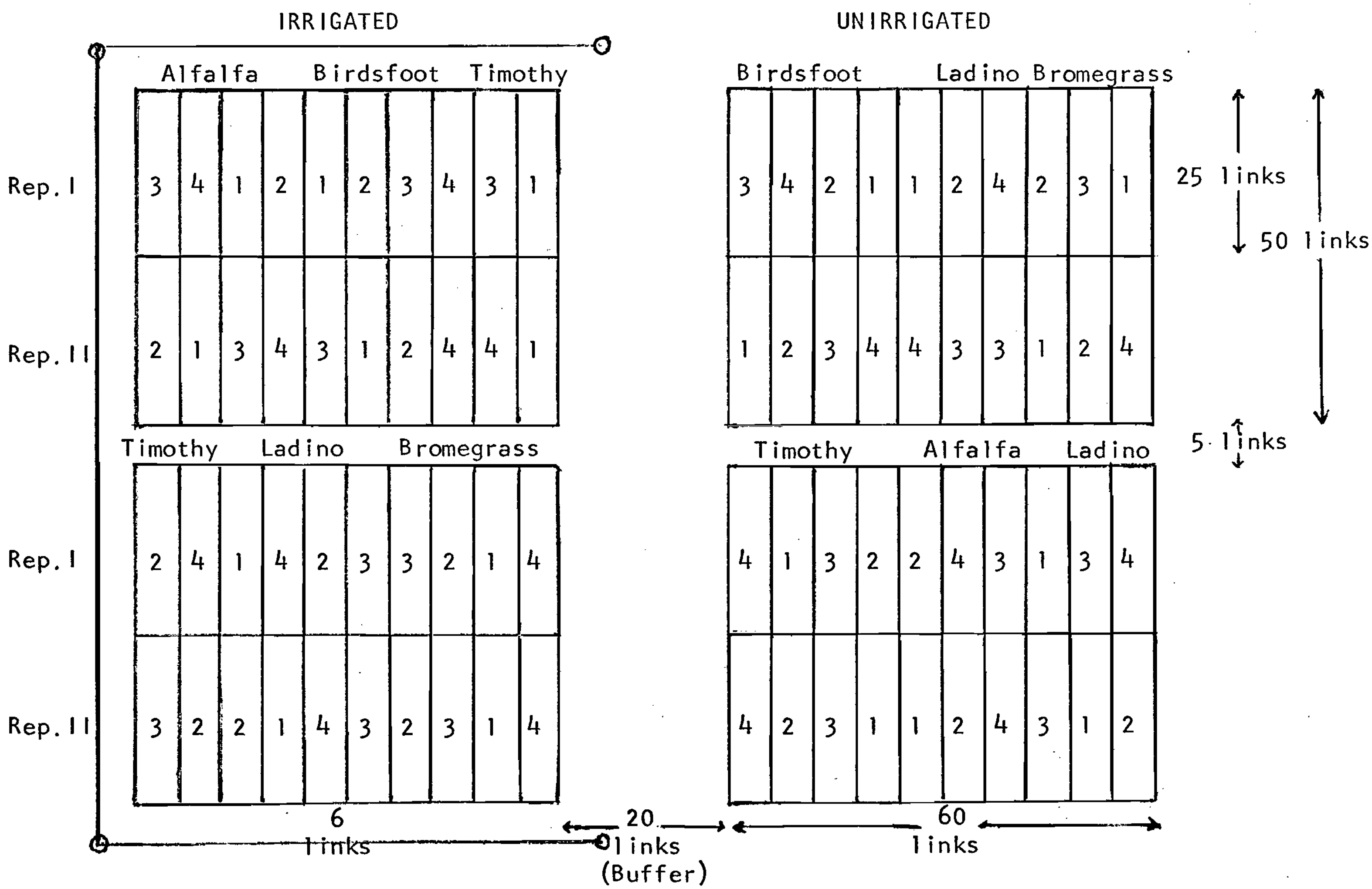


Figure iii. Field plan of experiment III.

performed on a new set of seeds gave the following results:

Timothy:	95.00 per cent
Alfalfa:	54.50 " "
Ladino:	88.00 " "
Bromegrass:	71.00 " "
Birdsfoot trefoil:	69.00 " "

Using these results the actual rates were calculated for both instances.

The hard seeds present in the legumes had insufficient time for germination in one week. Therefore, in some cases the calculated establishment percentage exceeded 100.

(e) Seeding

The plots were broadcast seeded on 25th August, 1964, and, for the spring reseeding, on 13th May, 1965. Due to the small seed quantities at the lower rates, the seeds were mixed with moist sand to ensure a good distribution over the whole plot. The legumes were inoculated with the appropriate inoculant at the time of seeding. After seeding the plots were lightly raked over to cover the seeds.

(f) Irrigation system

Water was pumped from the Ottawa River and conveyed in four-inch main pipes, and thence to the field through three-inch laterals. These fed into one-inch plastic pipes laid around the irrigated plots and the water delivered through 7/32 inch nozzle 65 PJ sprinklers with adjustable setting, on vertical risers of 12 inch height. The day and amount of water applied on the plots for both seedings are presented in Table 12b.

TABLE 12b. Dates of irrigation and inches of water applied at Macdonald College.

	Date	Inches applied from nozzle	Estimated inches of irrigation water reaching soil (80% efficiency)
1964	14th September	0.62	.50
	21st "	0.62	.50
1965	26th May	0.60	.48
	2nd June	0.50	.40
	5th "	0.32	.24
	9th "	0.32	.25
	16th "	0.32	.25
	23rd "	0.80	.64
	25th "	0.95	.75
	28th "	0.95	.75
	13th July	0.62	.50
	20th "	1.90	1.50
	27th "	1.25	1.00

5. Collecting the data

(a) Plant counts

Seed samples were checked for "1000 seed weight" by weighing out four separate lots of 100 seeds of each species. The "1000 seed weight" of the five species in the two separate seedings were as follows:

	Timothy	Alfalfa	Ladino	Bromegrass	Birdsfoot trefoil
Fall, 1964	0.4 gm.	2.05 gm.	0.55 gm.	4.40 gm.	1.00 gm.
Spring, 1965	0.4 gm.	1.80 gm.	0.50 gm.	3.20 gm.	1.00 gm.

These results were used in calculating the number of viable seeds seeded per square foot. See pertinent column in Appendix Tables 9a and 10a.

In Fall, 1964, six weeks after seeding and before freeze-up, plant counts were taken on the plots _in situ_. Five throws of a quadratic 18 x 8 inch frame (the total area for each throw representing a square foot) were sampled on each plot. Two counts were made on the 1965 seeding, six weeks after seeding and at the end of the summer in 1965. No counts were made in 1965 on the Fall, 1964 seeding since almost all the plants were wiped out by the unfavourable winter.

In the non-spreading species, timothy, alfalfa and birdsfoot, quite accurate counts were feasible. However, in the spreading species, bromegrass and ladino, difficulties were encountered in making counts. The results obtained may, therefore, be less accurate.

(b) _Forage yield_

An area of 15 x 4 links was harvested using a Graveley tractor with four link pans. Dry matter determinations were carried out as described in Experiment I. Since hand weeding was done throughout the experimental period no record of "others" was made.

(c) _Point quadrat analysis_

Botanical analysis was carried out in the field using the point quadrat method in a similar manner described in Experiment I. One set of readings was taken when regrowth started, after harvesting the Spring, 1965 seeding, in August, 1965. Seeded species, bare ground and "others" were recorded. Five stations (50 points) were chosen on each plot.

6. Meteorological conditions

Fall, 1964

August through October at Macdonald College was not a particularly dry period. Seasonal temperatures and rainfall occurred during this period.

Spring to end of Summer, 1965

Winter killing was particularly severe in this area. The early winter temperatures had been above normal. The probable result was that insufficient hardening of the plants occurred and so the plants could not withstand the February and March cold weather.

There was much more winter killing on the irrigated plots. Probably there was more moisture in this section which froze and caused more heaving and, hence, more severe winter killing. Only some of the bromegrass and timothy and, to some extent, alfalfa on the unirrigated portion survived.

Early spring was characterized by moderate rainfall, but from then on the period was very dry, especially at mid-summer when temperatures and humidity were high (Appendix Table 15d).

B. Results and discussion

(1) Results

ai. Fall, 1964 establishment

Results of plant counts made six weeks after seeding and analysis of variance, based on arcs in transformation values of percentage plants established, are presented in Appendix Tables 9a and 9b, respectively. The analysis demonstrated highly significant results for species, rates x irrigation interaction, and rates x species x irrigation interaction. Rates x species interaction was significant at the 5%. Test for differences indicated that the significance for species differences was mainly a result of higher establishment of ladino and alfalfa (Table 13).

TABLE 13. Initial establishment. Mean percentage established at the different rates of seeding and moisture treatment. Fall, 1964 seeding.

	Timothy		Alfalfa		Ladino		Brome		Birdsfoot	
Rates	Io+	I1+	Io	I1	Io	I1	Io	I1	Io	I1
1	40.50	18.35	82.80	50.40	102.85	69.43	24.43	32.14	77.14	28.33
2	52.79	28.04	73.80	87.30	101.57	95.78	24.43	31.50	34.72	26.58
3	54.23	51.23	68.40	128.54	84.00	79.29	43.72	29.15	37.43	52.57
4	48.20	29.84	67.00	117.00	91.93	59.47	35.04	28.61	62.36	44.78
Mean	40.40		84.40		85.54		31.13		45.49	

Comparison of means

Comparison of species mean values at both levels of irrigation

Ladino	Alfalfa	Birdsfoot	Timothy	Bromegrass
85.54	84.40	45.49	40.40	31.13
a+	a	b	b	b

+Mean values with the same letter are not different at the 1% level of probability.

Io = Un-irrigated) These symbols are used throughout the text to refer to un-irrigated and irrigated
I1 = Irrigated) species, respectively

At the end of the winter it was discovered that all the legumes and some grasses, especially on the irrigated section, had been winter killed. It was, therefore, decided to abandon the plots and establish new ones.

ii. Spring, 1965 seeding

Initial establishment

Plant counts made six weeks after seeding and analysis of variance, based on arcsin transformation values of percentage of plants established, are shown in Appendix Tables 10a and 10b, respectively. The analysis revealed significant differences between irrigations, species x irrigation interaction, and rate x species interaction.

More plants were saved as a result of irrigation (Table 14 and Figure 12). Regarding mean percentage of plants established by each species alfalfa proved to be the most superior, both under irrigation and no irrigation, followed by bromegrass and birdsfoot.

Initial establishment at the different rates was very variable. The grass species showed a tendency to give higher establishment with increasing rate of seeding when irrigated, while the general trend for the legumes was towards decreasing establishment when irrigation was applied. In the absence of irrigation all species showed increasing percentage of established plants, except bromegrass which decreased at the second rate of seeding.

iii. Final establishment

The term "final" is used here for convenience to imply establishment at the end of the season in August, 1965, and not necessarily a finished stage of development.

The mean number of plants resulting per square foot and, hence, per cent of plants established, are given in Appendix Table 11a, with a summary in Table 15.

Analysis of variance, based on arcsin transformation values of percentage of plants established, showed significance at the 1% level

TABLE 14. Initial establishment. Mean percentage established at different rates of seeding and moisture treatment. 1965 seeding.

	Timothy		Alfalfa		Ladino		Brome		Birdsfoot	
Rates	I_o	I_1	I_o	I_1	I_o	I_1	I_o	I_1	I_o	I_1
1	4.50	9.00	57.00	91.50	14.63	29.25	24.30	39.60	11.99	38.57
2	6.23	9.69	63.75	87.75	11.82	21.72	16.50	35.55	23.57	37.27
3	6.23	24.00	64.00	71.50	14.25	18.38	18.90	60.60	25.71	27.14
4	9.09	10.73	64.00	107.25	12.94	22.78	24.53	45.90	28.49	31.71
Mean(I)	6.51	13.35	62.19	89.50	13.41	23.03	21.06	45.41	22.44	33.67
Mean of (I_o+I) (II)	9.93		75.84		18.22		33.24		28.06	

Comparison of means

I. Comparison of a species mean values between two levels of irrigation.

	Timothy[+]	Alfalfa	Ladino	Bromegrass	Birdsfoot
I_o	6.51 a	62.19 b	13.41 a	21.06 b	22.44 b
I_1	13.35 a	89.50 a	23.03 a	45.41 a	33.67 a

II. Comparison of species mean values over both levels of irrigation.

	Timothy	Alfalfa	Ladino	Bromegrass	Birdsfoot
Mean of (I_o+I_1)	9.93 d++	75.84 a	18.22 bcd	33.24 b	28.06 bc

I. + = Mean values of a species (at different levels of irrigation) with the same letter are not different, at 1% level of probability.

II. ++ = Mean values of species (at both levels of irrigation) with the same letter are not significantly different at 1% level of probability.

TABLE 15. Final establishment. Mean percentage plants established at the different rates of seeding and moisture treatment.

	Timothy		Alfalfa		Ladino		Brome		Birdsfoot	
Rates	Io	I1	Io	I1	Io	I1	Io	I1	Io	I1
1	7.21	16.37	72.90	90.62	26.57	28.90	17.50	55.00	23.81	35.12
2	5.53	9.74	50.74	81.25	14.07	19.85	17.50	35.00	14.29	30.35
3	5.29	13.38	43.75	67.36	13.54	12.50	9.58	33.75	13.89	31.94
4	5.60	9.20	53.12	67.45	14.17	13.73	11.57	25.62	17.56	24.55
Mean	5.91	12.17	55.14	76.67	17.09	18.49	14.04	37.34	14.89	27.92
Mean of (Io+I)	9.04		65.91		17.79		25.69		16.40	

Comparison of means

I. Comparison of species mean values within a level of irrigation.

	Timothy	Alfalfa	Ladino	Bromegrass	Birdsfoot
Io	5.91 b+	55.14 a	17.09 b	14.04 b	14.89 b
I'	12.17 b	76.67 a	18.49 b	37.34 b	27.92 b

II. Comparison of species mean values over both levels of irrigation.

Timothy	Alfalfa	Ladino	Bromegrass	Birdsfoot
9.04 b+	65.91 a	17.79 b	25.69 b	16.40 b

+Mean values within any level of irrigation and with the same letter are not significantly different at 1% level of probability.

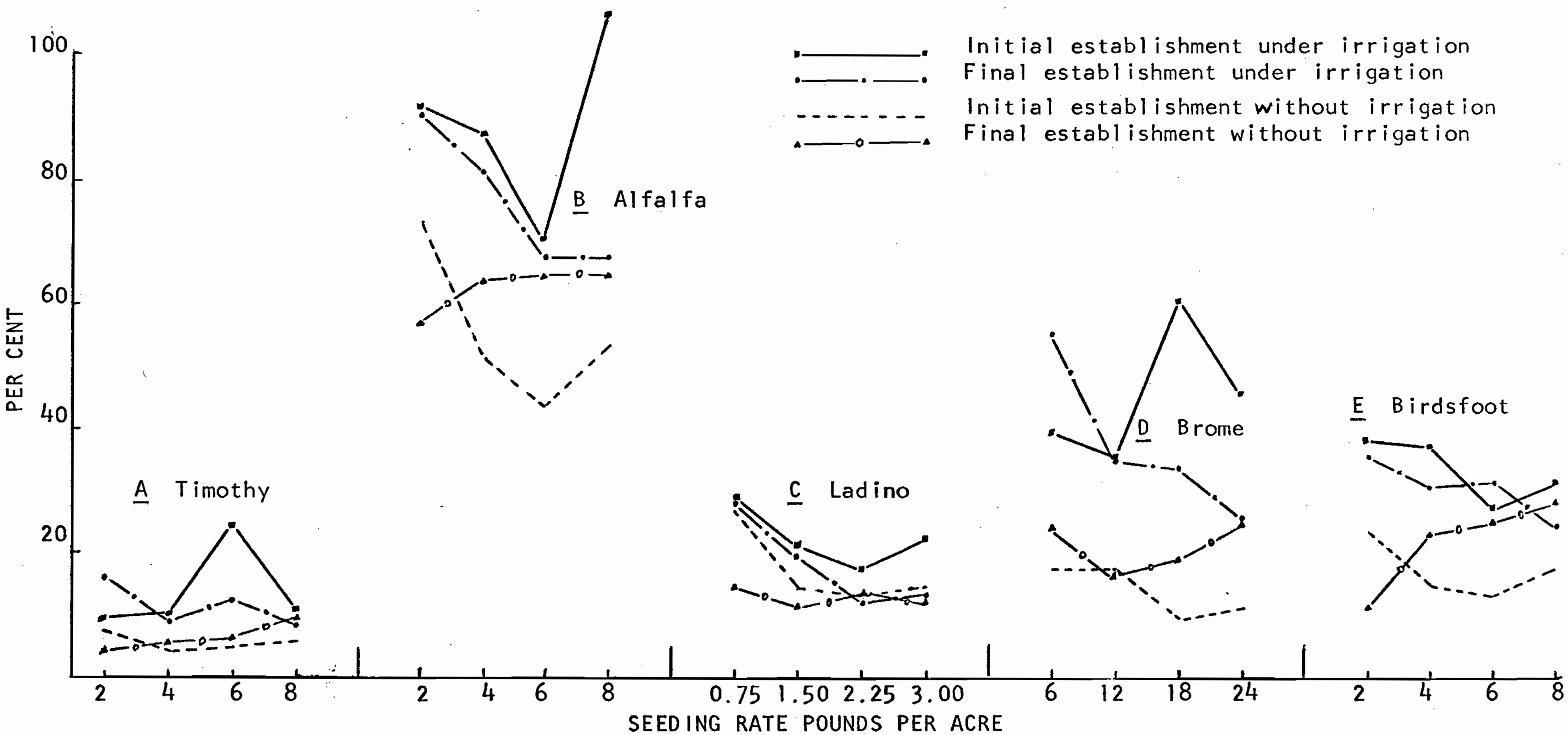


Figure 12. Establishment percentages at different rates of seeding and moisture treatment on A timothy, B alfalfa, C ladino, D brome, E birdsfoot.

for species and rates only (Appendix Table 11b). Application of Duncan's range test revealed that alfalfa was superior to the other four species, both under irrigation and no irrigation.

Irrigation effected a higher percentage of established plants than no irrigation (Figure 12 and Table 15). In either instance of irrigation treatments, the establishment decreased with increasing rate of seeding.

Regarding establishment of individual species and rates of seeding, timothy showed only small initial advantage due to irrigation. Under irrigation the final establishment was highest at two pounds per acre and levelled off between 4 - 8 pounds per acre. Under non-irrigation final establishment was relatively uniform at all rates with a lower establishment at the highest rate of seeding compared to the other rates.

Alfalfa showed decreasing percentage of established plants with increasing rate of seeding. The percentage alfalfa plants established finally under irrigation reached equalization at six pounds per acre rate of seeding. Similar trends were shown under non-irrigation. Final establishment of irrigated ladino at the different rates of seeding followed the same pattern as initial establishment, equalization being reached at 2.25 pounds per acre. Although final establishment under non-irrigation is below those under irrigation at the two lower rates of seeding there seems to be a gain in percentage establishment under non-irrigation at the two higher rates of seeding.

In the presence of irrigation, final establishment of bromegrass showed a decreasing percentage of established plants with increasing rate of seeding. The lowest percentage of plants established was at the highest rate of seeding. In the absence of irrigation, however, final establishment was approximately the same at the two first rates of seeding, and then decreased at the third rate of seeding and almost remained constant.

Birdsfoot trefoil, both in the presence and absence of irrigation, showed a decreasing percentage established plants with increasing rate of seeding, and reached equalization between the second and third rates of seeding.

Although densities (number of plants per unit area) at final establishment were low, irrigated species had a higher density than unirrigated species (Appendix Table 11a).

(b) Forage yield

Weeds were pulled out of the plots manually throughout the season. The two low rates were subject to great weed invasion.

Visual examination of the stand indicated that total yield of top growth on the irrigated plots was greater than on the unirrigated plots. However, irrigation failed to effect any statistical differences (Appendix Tables 12a and 12b). The overall average yield of alfalfa was significantly different from the yield of the remaining species (Table 16). Birdsfoot trefoil also significantly outyielded brome, timothy and ladino. When all species were irrigated, both alfalfa and birdsfoot trefoil significantly outperformed the other species in yield. However, only alfalfa yielded significantly more dry matter than the rest when no irrigation was applied. A significant interaction of species x irrigation, probably due to a high percentage increase in yield of irrigated compared to un-irrigated birdsfoot trefoil, was obtained (Table 17).

Considering forage yields at the different rates of seeding, dry matter production indicated highly significant differences between

TABLE 16. Mean dry matter yield (lbs/acre) of each species at each rate of seeding

Rates	Timothy	Alfalfa	Ladino	Brome	Birdsfoot	Average
1	474 b	3,193 b	537 b	1,078 b	2,034 b	1,463
2	884 ab	3,476 b	894 ab	1,363 ab	2,025 b	1,728
3	1,172 a	3,700 ab	871 ab	1,378 ab	2,667 a	1,957
4	1,121 a	4,056 a	1,214 a	1,636 a	2,515 ab	2,108
	913	3,606	879	1,364	2,310	
	c	a	c	c	b	

Rate means values with the same bar are not statistically different at 1% level of probability.

Rate means for a species with the same lower or upper case letters are not different at 1% level of probability.

TABLE 17. Percentage increase in yield of irrigated over unirrigated species at each rate of seeding.

Rates	Timothy	Alfalfa	Ladino	Brome	Birdsfoot
1	161	135	295	133	599
2	252	52	332	130	428
3	170	64	71	84	403
4	141	38	138	98	449

TABLE 18. Size of plants at different rates of seeding unirrigated and irrigated species.

	Timothy		Alfalfa		Ladino		Brome		Birdsfoot	
Rates	Io	I1	Io	I1	Io	I1	Io	I1	Io	I1
1	0.70	0.83	2.18	4.12	0.50	0.99	1.85	1.37	1.02	4.82
2	0.68	1.36	2.46	2.15	0.75	2.29	1.18	1.36	1.08	2.67
3	0.77	0.81	1.84	1.90	0.99	1.83	1.69	0.88	1.01	2.21
4	0.56	0.83	1.22	1.54	0.80	1.94	1.12	1.07	0.53	2.06

average yields (Table 16). The two higher rates (four and three) were greater than the lowest rate of seeding, while the third rate significantly outyielded only the lowest rate of seeding. No statistical differences existed between means of a species at different levels of irrigation. Disregarding levels of irrigation, however, within species differences revealed that in 60% of the test rate four was the highest yielder. Rate one was the lowest yielder in all tests.

Percentage increase in yield of irrigated over unirrigated plots at each rate of seeding showed an inverse relationship with increasing rate of seeding (Table 17).

Equalization in production at the different rates of seeding was not attained when irrigation was applied (Figure 13). Most unirrigated forage species, however, indicated equalization at the third rate of seeding. Both irrigated and unirrigated timothy reached the highest, and almost uniform level of production at six pounds per acre seeding. Irrigated alfalfa gave increasing yield with increasing rate of seeding, while without irrigation indications of levelling production occurred from the two pounds per acre rate of seeding. Ladino and birdsfoot trefoil responded to irrigation erratically, but they reached plateaux of production in the absence of irrigation, at 2.25 pounds and six pounds per acre, respectively. Although bromegrass was less variable in yield response to irrigation and different seeding rates there was no sign of attaining a levelled production, but instead it continued to rise with irrigation and increasing rate of seeding.

Irrigation considerably increased plant size (Table 18). Specifically, irrigated alfalfa and birdsfoot trefoil were, respectively increased to twice and four times their sizes under non-irrigation.

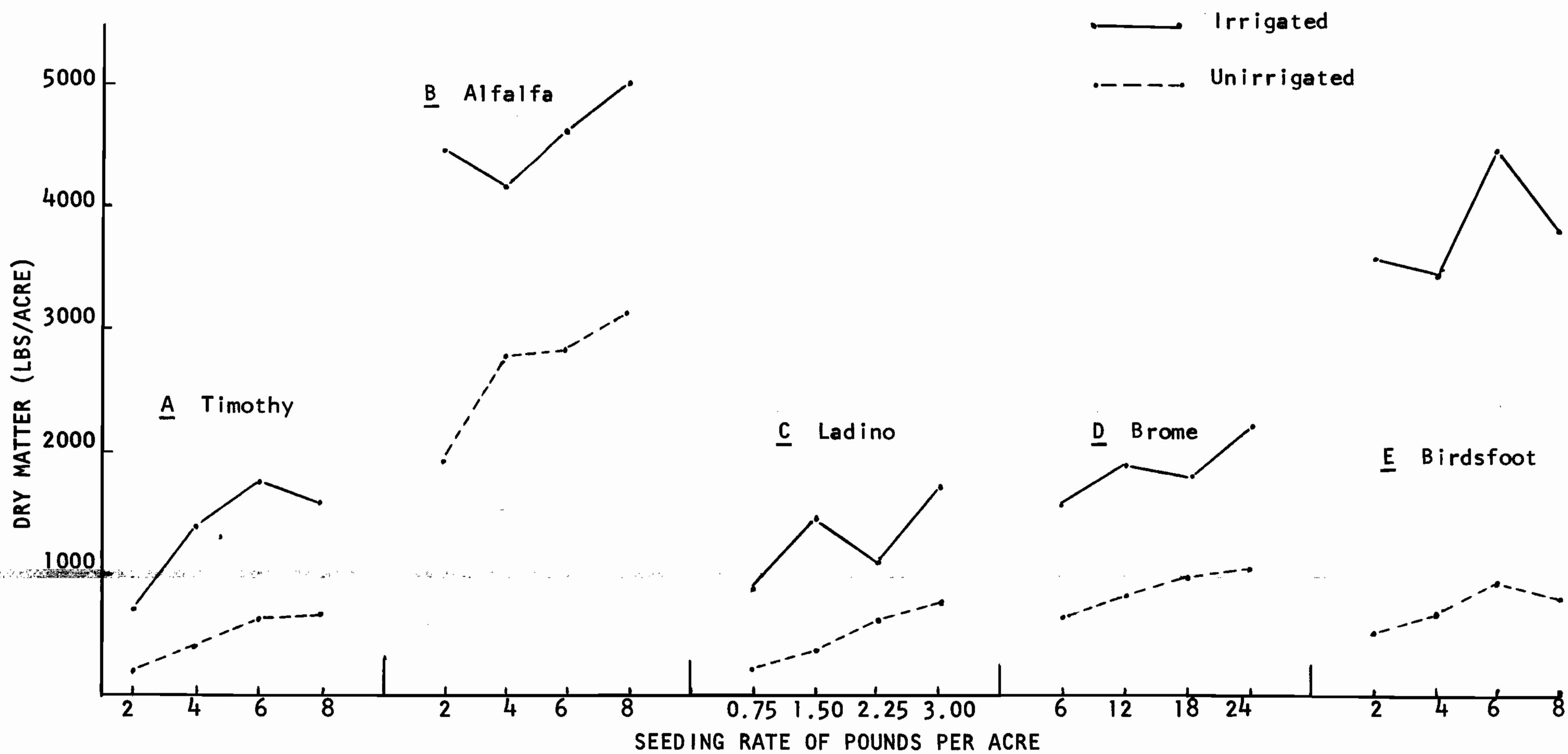


Figure 13. Forage yield per acre of A timothy, B alfalfa, C ladino, D bromegrass E birdsfoot. at different rates of seeding and moisture treatment.

Even though it was not always very apparent, increasing the rate of seeding, gave smaller plants whether or not irrigation was applied. The trend in ladino is rather anomalous, since size increased with seeding rate.

(c) Point quadrat analysis

Detailed results of the readings have been filed in the Agronomy Department, Macdonald College. Analysis of variance of cover by seeded species is presented in Appendix Table 13. Table 19 shows the mean percentage of the seeded species.

Irrigation did not significantly influence percentage cover. Only timothy and ladino gave positive response in cover to irrigation.

Percentage of ground cover by species and at different rates of seeding both demonstrated significant differences. Ladino and bromegrass gave the highest ground cover and were different from the rest. Increasing the rate of seeding resulted in increased ground cover.

Rates three and four seedings of irrigated timothy gave significantly more cover than rate one. A levelling off in cover was reached from six pounds per acre seeding. Similar plateaux were realized in the other species when they were irrigated, except bromegrass which did not exhibit any tendency to equalization in percentage cover. Ground cover by all the species, in the absence of irrigation, increased with increased rate of seeding with only alfalfa giving a decreased percentage cover at the highest rate of seeding.

Correlation coefficients calculated between mean percentages of ground covered by the seeded species and mean densities at final establishment gave the following results:

Species	No irrigation	Irrigation
Timothy	0.746	0.969*
Alfalfa	0.969*	0.923
Ladino	0.920	0.772
Bromegrass	0.986*	0.859
Birdsfoot trefoil	0.789	0.996**

Significance according to Table 7.6.1 by Snedcor (1956) for two degrees of freedom.

TABLE 19. Mean percentage cover at the different rates of seeding and moisture treatment one week after cutting plots at final establishment in August, 1965.

	Timothy		Alfalfa		Ladino		Brome		Birdsfoot	
Rates	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1
1	24	37	30	17	52	68	63	44	41	47
2	22	48	41	27	71	73	76	50	52	52
3	60	65	46	49	66	82	70	58	68	62
4	49	66	60	50	77	84	81	76	67	63

2. Discussion

(i) Initial establishment of Fall, 1964 seeding

Several uncontrollable difficulties mentioned earlier were encountered in the conduct of this experiment. These difficulties have obscured the effects of the treatments imposed and made interpretation difficult. However, a few observations are possible from the information available.

In general, percentage of plants established by the non-irrigated species showed decreasing values with increasing rate of seeding, while percentage of plants established by irrigated species increased with increasing rate of seeding up to the third rate. Even though the percentages of plants established by non-irrigated species were higher than the percentages of plants established by the irrigated species the indication is that in the non-irrigated species moisture supply was becoming critical and hence causing the death of plants at higher rates.

The response of alfalfa was, perhaps, more normal. Due to a more rapid germination and establishment alfalfa seedings were less affected by any of the factors to which reference has been made. Irrigation clearly saved more alfalfa plants, initially, than when no irrigation was applied. The gradual but consistent fall in percentage plants established with increased rate of seeding unirrigated alfalfa suggests that less seeds germinated or mortality was high when moisture shortage occurred.

Because the stand became seriously injured in the winter of 1964-1965 the test was discontinued after collecting one set of data.

(ii) Initial establishment of Spring, 1965 seeding

The results of counts made demonstrated that irrigation had a beneficial influence on initial establishment. Visual examination in the field revealed that germination was earlier under irrigation.

The significance attained for species response establishes the fact that different species respond differently to irrigation. In this regard alfalfa, bromegrass and birdsfoot trefoil gave the most positive response to irrigation.

Differences in growth type between the grasses and legumes may account for the tendency exhibited by the irrigated grass species to increase in percentage plants established with increasing seeding rate, while the legumes showed a decreasing percentage of established plants. In the initial stage of growth the legumes generally produce broad and spreading leaves compared to the straight and narrow leaves of the grasses. Thus, it can be envisaged that the legumes will form a closed canopy earlier than the grasses. Under such conditions, and in the presence of adequate moisture, competition for light will start earlier in the legumes than the grasses. Mortality may occur in the legume community before the grasses attain a closed canopy. Therefore, initial determinations of establishment may show an increasing per cent establishment of grasses when legumes are decreasing. Although no literature is available to support this opinion it could account for the result obtained.

Percentage of plants established increased with increasing rate of seeding in the unirrigated plots suggesting that moisture was perhaps not critical.

(iii) Final establishment of 1965 seeding

The final establishment determination revealed that changes in density (the number of plants per unit area) had occurred. Considering both irrigation and non-irrigation percentage plants established had decreased as the rate of seeding increased (Figure 12). However, the overall effect of irrigation was to save more plants.

Mortality increased with increased rate of seeding (Table 14). The trend, therefore, suggests that within the various communities intra-species competition tended to give an equilibrium. The fact that less plant losses was observed as a result of irrigation clearly indicates that the equilibrium level can be changed by moisture availability. This deduction is logical, for, if water is one of the factors of competition then provision of water should remove this factor. Therefore, within space limitations, there should be an increase in stand under a liberal provision of water, as opposed to a scarcity. The question raised then is whether yield per unit area increased and what effect increased density under irrigation had on plant size in this experiment. This question is discussed under forage responses.

Optimum densities on the heavy clay were 6 - 8 and 15 - 17 plants per square foot for unirrigated and irrigated species, respectively. Knutti (1958), working on a light sandy soil, reported densities of 28 - 50 and 20 - 25, for all species, in the first and second year establishment, respectively. The discrepancy in the results from the two experiments may be due to differences in soil type, for irrigated species also failed to attain the stand Knutti (1958) reported. Under the present conditions, the optimum densities of 6 - 8 plants and 15 - 17 plants per square foot for unirrigated and irrigated species, respectively, may be justified, because of the difficulties of working the heavy clay on which the work was done.

b. Forage yield

A cursory examination of the stand in the field indicated that top-growth under irrigation was better. The yield data gave a definite confirmation. Stabilization of yield under non-irrigation occurred around the third rate of seeding, while no indication of stabilizing yield was found under irrigation. Yield under irrigation, instead, increased with increasing rate of seeding. Therefore, the higher the density the greater the total yield. This is in agreement with the view held by Donald (1963) who, in a review of competition among crop and pasture plants, stated that in less dense stand the ceiling leaf area (maximum leaf area) is reached later, but the leaf area index and light values are eventually the same as in the denser crop. According to him final yield was greater in the denser stand, because the leaf area duration (the integral of leaf area index over the whole growth period) was greater.

Computations of plant size revealed that size and density were inversely related (Table 18). This agrees with Donald's (1963) finding that individual weight of more crowded seedling of subterranean clover, growing under conditions of adequate water and nutrients supply, at ten days after emergence was 10% less than that of sparse seedings, and at 17 days was 25% less. If irrigation increased density then it is expected that plant size will be smaller with irrigation than without irrigation. On the contrary, irrigation increased both density and plant size. This demonstrates that irrigation was profoundly beneficial and that it offset the tendency towards reduction of plant size as density increased. The logic here is that as liberal amounts of moisture became available the competition in the community reduced solely to the light factor, while both light and moisture were critical when irrigation was withheld.

c. Cover

Even though density differences existed between irrigation and non-irrigation for all species, sward cover differences could seldom be detected with the point quadrat, partially owing to the high variability of external conditions on the day when the data were taken. Determinations on the irrigated portion were made at a time when the prevailing wind was lower than when readings on the unirrigated fields were taken. It was noted in the field that high cover could be associated with irrigation and density.

The significant correlation coefficients indicated that where applicable, higher species covers were associated with higher rates, and vice versa. Where correlation coefficients were not significant, it signifies that the smaller number of plants in the treatments with lower seeding rates occupied the same area as the larger number of plants in the treatments with higher rates. Under the last condition a denser sward does not necessarily mean a sward with higher cover.

IV. GENERAL DISCUSSION

The objective of the present studies was to determine the response of forage species to irrigation. There were indications, both from visual observation in the field and data collected that irrigation was beneficial. However, in some cases statistical analysis did not demonstrate significance, primarily, due to the small number of replications used. Several adverse conditions also tended to mask the influence of irrigation. Despite the variable information available some comments can be made.

It was self-evident from root studies and forage yield that one of the important considerations in irrigation is the application rate of water. The high rate of application caused ponding on the soil surface, and, hence, unfavourable air and water relations for plant growth, and also resulted in crust formation as the surface dried out. Crust formation also encouraged ponding on subsequent irrigation. The ponding action increased the cloddiness of the soil and obviated the beneficial effects of any tillage operations before irrigation. The resultant effect was poor root development which failed to supply enough moisture and nutrients. In contrast with the effect of high rate of irrigation on vegetational growth, lower rates of application, which did not exceed infiltration rate, promoted the growth of all vegetation.

Normally, a better root system is established if nutrients and water are present in adequate amounts. The roots can make these readily available for photosynthetic processes and a build up of more dry matter. The key to successful and profitable irrigation, therefore, is to ensure a proper root development through maintenance of good soil and water relations.

Another aspect of irrigation encountered in this experiment, and which has been widely reported, is the excessive weed incursion which accompanies irrigation (Lussier, 1965; Wilson and Peake, 1959). Both weeds and seeded forage benefit from available moisture. From the nature of their shallow root system and rapid developmental cycle, weeds are able to compete very successfully with crop plants by utilising mois-ure and nutrients in the soil surface and establishing before cultivated plants. Hence, a strong recommendation is for adequate weed control measures under any irrigation practice, especially, in the initial es-tablishment. This may mean a loss or success of forage and pasture es-tablishment, as found in this experiment.

Irrigation advanced the period of greatest increase in root weight in a volume of soil. This was interpreted as an earlier attainment of optimum leaf area index by the irrigated species. Evidence for this interpretation is adduced from Experiment III which showed that irriga-tion increased the density of plant. According to Donald (1963) more dense stands have an initially more rapid growth-rate because they dis-play more photosynthetic surface per unit area of ground at germination than do less dense stands. In this regard, root development will be faster under irrigation than non-irrigation. Irrigated plots should therefore come into grazing before unirrigated plots. Whether or not earliness to utilisation under irrigation is accompanied by a high nu-tritive value of the forage is not recorded, and may be an interesting angle to explore in the future.

The second cut total yields were very low for both irrigated and un-irrigated species. Barring the effect of competition presented by weeds, it can be stated that moisture alone was not the critical factor to yield. Similar manifestations were reported by Hill(1956) who also noted that not all species respond to irrigation during a hot dry summer period. The grasses in the present report, for instance, exhibited a mid-summer dormancy which was not corrected by irrigation. The summer of 1964 was hot and dry. Mather (1959) formed the opinion that the amount of water used in presence of adequate supply of moisture is dependent on solar energy and the resultant air temperature. In high air summer temperatures evapotranspiration could outstrip water uptake by roots, even when soil moisture was adequate for growth, leading to temporary wilting with closing of stomata and a halt in photosynthesis. Since the legumes, especially, responded to irrigation at this period the question may be posed whether or not we are irrigating the right species of grasses. Selection in grasses has produced cultivars which either give spring grazing or early summer hay. Hence, mid-summer irrigation does not affect our given cultivars. Information from the species and varieties test (not reported here) should give a useful lead.

Irrigation in the present studies, increased the density and plant size of the species under test. The implication is that when moisture stress is removed more plants will result on a unit area. Donald (1963) reported that a dense crop of subterranean clover would give a much greater vegetative production early in the season, for example, for early grazing or early silage. This, probably, will explain the earliness in production from the irrigated compared to un-irrigated plots.

Regarding seeding rate, Donald (1963) has emphasized that the optimum rate depended on the stage of harvest. Constancy of final yield of dry matter which may take several years to attain in the case of perennial grasses has been confirmed by Holliday (1953), as cited by Donald (1963). Hence, the long term yield would be independent of seeding rate. From the economic standpoint, one cannot afford to let land under irrigation lie fallow. It is, therefore, desirable to seed at a rate which will yield close to final expectations. Thus, irrigated timothy may be seeded at six pounds per acre since at this rate both maximum density and yield were achieved. No comparable figures were available in the literature. Under dry land seeding, four pounds per acre will be as good as six pounds per acre. However, since the four pounds rate was subject to weed invasion six pounds may be used. MacDonald (1955) and Knutti (1958) recommended 2 - 8 pounds and four pounds, respectively.

Irrigated alfalfa may be seeded at eight pounds per acre to give both the highest yield and density, and for better weed control. Eynard (1960), in his work at Italy, showed that 18 pounds per acre for irrigated alfalfa gave the best stand. Weed problems were found to be very acute at lower rates in his work. In the present studies eight pounds, the maximum rate used, gave the highest yield and density. With unirrigated alfalfa six pounds was as good as eight pounds, but the latter rate controlled weed growth best. If the cost of seed is the overriding factor then six pounds may be recommended. This rate is lower than the eight pounds recommended for the province as shown in the Recommendations of the Quebec Seed Board (1965). However, they were given for mixtures and not for pure stands.

Ladino, both irrigated and unirrigated, may be seeded at 1.5 to three pounds per acre. The 3/4 pound per acre under no irrigation recommended by Knutti (1958) gave a very low density which left much bare ground for weed invasion.

Since bromegrass under irrigation gave the same density at 12 pounds and 18 pounds per acre seedings, but, the latter rate outyielded the former, 18 pounds may be recommended. The present study agrees with Knutti's (1958) finding that 12 pounds per acre is close to the optimum rate of seeding bromegrass.

Birdsfoot trefoil may be seeded at six pounds per acre when irrigation is applied, since this rate produced both the highest density and yield. Four to six pounds rate may be used when no irrigation is applied. Bubar (1963) and Knutti (1958) reported five pounds and four pounds rates, respectively, as being the optimum.

The present rates of seeding under irrigation have been recommended at moderate soil fertility. Crocionis (1955) reported a boost in yield at higher rates of seeding ladino when manure was applied. However, it was not mentioned whether manuring increased the density of plants or yield _per se_. It will, therefore, be useful to investigate the influence of irrigation and fertility on optimum stand in future experimentation.

The opinion has been expressed that irrigated pastures in the humid temperate regions are not profitable. The basis for this conclusion is that over a decade of experimentation irrigation in the Eastern United States failed to give a significant increase in dry matter production even in a year of extreme drought (Vittum _et al._, 1963). Since the role of water in increasing leaf area index, and especially leaf area duration, was clearly recognized by Donald (1963) when he outlined the factors in pasture competition, it may be inferred that a very fundamental aspect of the problem of increased crop production has not been adequately explored. This aspect relates to the limit of the genotype as governed by the light supply of the environment. Applied to pastures, irrigation can only effect increased production within the range of response made by the species. Hence, the importance of irrigating a responsive species cannot be over emphasized.

V. SUMMARY AND CONCLUSION

Literature related to the general aspects of irrigation, and some of the findings applicable to our humid temperate region were reviewed.

Two experiments were conducted at Ormstown, firstly, to study the response of timothy, alfalfa, ladino and bromegrass to irrigation; and secondly, the influence of companion crop on irrigated pasture. A third experiment was performed at Macdonald College to evaluate the influence of irrigation on optimum stand.

From the results of these three experiments the following conclusions were drawn.

1. Root development, on dry weight basis, was better when the pasture species were irrigated.

2. The highest (1.0"/hour) rate of irrigation was responsible for ponding, and created unfavourable air and water relations for plant growth. Consequently, root development was poorer under this rate of irrigation.

3. Approximately 85% of root growth at all moisture treatments was confined to the plough and fertilization depth.

4. The best root development was given by timothy, alfalfa and ladino; timothy and brome; and alfalfa and brome combinations.

5. The second cut composition was predominantly legumes with the grasses making a very small contribution to yield. Ladino benefitted profoundly from irrigation. Alfalfa yielded less under irrigation; and timothy and bromegrass exhibited a dormancy which was not corrected by irrigation.

6. Adverse conditions, especially weed prevalence, affected the

magnitude of influence of irrigation on dry matter yields by the seeded forage species. However, the low and medium rates of irrigation effected better vegetational growth.

7. The third cut results showed a better contribution of the grasses to total yield. Timothy predominated in all the yields of mixtures. Irrigation greatly influenced the botanical composition. The best combination was timothy, alfalfa and ladino.

8. Root development of the forage species was hampered by the companion crop regardless of irrigation and mixture combinations.

9. Irrigation saved more plants per unit area, and also increased the size of plants. Size decreased with increased seeding rate.

10. Plant densities remained a function of the seeding rate at the end of the seeding year in the spring seeded experiment.

11. Yield increased with irrigation and density.

12. Weed ingress was more serious at the low rates, especially, with irrigation.

13. Recommended rates of optimum pounds viable seeds per acre for pure seeding are:

Species	Irrigated	Un-irrigated
Timothy	6	4
Alfalfa	8	6
Ladino	1.5 to 3	1.5 to 3
Bromegrass	18	12
Birdsfoot trefoil	6	4 to 6

14. Density and cover by timothy and birdsfoot trefoil under irrigation were found to be associated. No association was found in the other species.

The pasture species studied gave variable response to different rates of irrigation. The lower rates of irrigation promoted better growth. Since irrigation also increased plant size and density, it is concluded that with a judicious application of water the species studied will respond to irrigation.

VI. RECOMMENDATIONS FOR FUTURE WORK

It is considered that the present irrigation studies should be intensified so as to have readily available information for future development in this field of investigation.

The studies may be continued along the following lines:

1. As a prerequisite of irrigation, a clean seed bed should be developed. This will prevent the weed problem associated with irrigation.

2. Increased replication is desired to exercise a greater control over the large variability which tended to mask the influence of irrigation.

3. The effect of earliness to utilization, made possible by irrigation, on the chemical composition and nutritional value of forage and pastures should be investigated.

4. Fertilizer studies may be introduced at this juncture to determine the potential response of our pastures under irrigation and fertilization.

5. The seed rate experiment should be continued using mixtures in various proportions in the presence and absence of fertilizers.

6. Birdsfoot trefoil, in pure stand, gave the greatest response to irrigation, and it will be worthwhile to investigate its performance in mixtures.

7. Selection and breeding of genotypes which are more responsive to irrigation should be initiated.

VII. LITERATURE CITED

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APPENDIX

APPENDIX TABLE 1. Analysis of variance of weekly mean dry weight (milligrams) of roots at each rate of irrigation. (Computed from Table 2) 1964 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	100,406.94	33,468.75	8.64**	2.92	4.51
Weeks	10	1,704,548.91	170,454.89	43.99**	2.16	2.98
Error	30	115,255.14	3,875.17			
Total	43	1,920,210.99				

**Significance at 1%. Unless otherwise stated this will apply whenever it occurs in an analysis of variance table.

APPENDIX TABLE 2a. Mean dry weight (milligrams) of roots at each rate of irrigation for the growing season in 1964.

	Seeded Species (Mixture)	Rate of irrigation A (Check)	B (0.1"/hr)	C (0.4"/hr)	D (1.0"/hr)	Mean
1	T	229	435	352	254	317
2	A	292	453	375	335	364
3	L	223	444	347	315	332
4	B	486	409	365	383	411
5	T+A	285	482	438	353	390
6	A+L	231	337	448	358	344
7	T+L	243	419	329	364	339
8	T+B	210	354	373	377	328
9	A+B	460	411	447	398	439
10	L+B	260	353	374	397	346
11	T+A+L	294	608	455	379	434
12	T+A+B	290	502	526	416	433
13	T+L+B	320	403	358	359	360
14	A+L+B	287	396	355	388	356
15	T+A+L+B	345	342	479	415	395
	Mean	297	423	401	366	

APPENDIX TABLE 2b. Analysis of variance of mean dry weight (milligrams) of roots at each rate of irrigation for the growing season in 1964.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	136,991.81	45,663.94	13.33**	2.84	4.31
Mixtures	14	91,245.21	6,517.51	1.90	1.92	2.52
Error	42	143,916.78	3,426.59			
Total	59	372,153.80				

APPENDIX TABLE 3a. Vertical distribution of actual dry weight (milligrams) of roots of seeded mixtures on 19th July, 1965. From the 1964 seeding.

		Rate of irrigation												
		A(Check) Depth(cm)			B(0.1"/hr) Depth(cm)			C(0.4"/hr) Depth(cm)			D(1.0"/hr) Depth(cm)			Mean
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	
1	T	210	60	10	130	60	30	310	20	10	395	70	10	329
2	A	1,300	50	25	1,950	100	60	480	50	15	445	45	10	1,133
3	L	285	160	45	225	60	20	35	20	15	370	50	15	326
4	B	205	140	5	550	50	70	380	75	50	165	120	15	456
5	T+A	375	60	30	380	50	10	890	80	10	720	10	5	655
6	A+L	1,200	120	15	395	45	20	520	80	5	430	10	30	718
7	T+L	230	30	5	485	50	10	540	60	10	350	110	20	475
8	T+B	405	130	50	530	80	20	340	60	10	470	135	35	566
9	A+B	180	135	15	400	90	70	950	145	15	660	235	60	739
10	L+B	440	65	20	680	80	35	260	70	60	440	85	20	564
11	T+A+L	1,120	80	30	800	50	15	690	150	40	1,215	50	60	1,075
12	T+A+B	490	130	30	280	50	40	840	35	15	870	50	5	709
13	T+L+B	510	70	20	445	50	30	440	70	25	320	65	10	514
14	A+L+B	510	260	5	545	60	40	430	75	35	740	95	5	700
15	T+A+L+B	160	50	25	870	110	25	460	40	20	880	60	5	676
Mean		508	103	22	578	66	33	504	69	22	564	79	20	

APPENDIX TABLE 3b. Total dry weight (milligrams) of roots of mixtures in the whole profile sampled on 19th July, 1965. (Computed from Appendix Table 3a) From Spring, 1964 seeding.

	Mixture seeded	Rate of irrigation A (Check)	B (0.1''/hr)	C (0.4''/hr)	D (1.0''/hr)	Mean	
1	T	280	220	340	475	329	c+
2	A	1,375	2,110	540	500	1,133	a
3	L	495	305	70	435	326	c
4	B	350	670	505	300	456	c
5	T+A	465	440	980	735	655	bc
6	A+L	1,335	460	605	470	718	abc
7	T+L	265	545	610	480	475	c
8	T+B	585	630	410	640	566	bc
9	A+B	330	560	1,110	955	739	abc
10	L+B	525	795	390	545	564	bc
11	T+A+L	1,230	865	880	1,325	1,075	ab
12	T+A+B	650	370	890	925	709	abc
13	T+L+B	600	525	535	395	514	c
14	A+L+B	775	645	540	840	700	abc
15	T+A+L+B	235	1,005	520	945	676	abc
Mean		633	676	595	664		

+Mean of mixtures followed by the same lower case letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test.

APPENDIX TABLE 3c. Analysis of variance of total dry weight (milligrams) of roots of mixtures in the whole profile sampled on 19th July, 1965. From Spring, 1964 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	59,041	19,680.33	0.20	2.84	4.31
Treatment	14	2,963,301	211,664.36	2.19*	1.92	2.52
Error	42	4,054,779	96,542.36			
Total	59	7,077,121				

*Significance at 5%. Unless otherwise stated this will apply whenever it occurs in an analysis of variance table.

APPENDIX TABLE 4a. Dry matter yields (lbs/acre) of seeded forage mixtures and "others", after hand separation, on 20th October, 1964. Second cut of Spring, 1964 seeding.

		Rate of irrigation									
		A		B		C		D		Mean	
No.	Mixture	Seeded species	Others	Seeded Species	Others	Seeded Species	Others	Seeded Species	Others	Seeded Species	Others
1	T	51	1,230	141	1,093	47	950	48	748	72	1,005
2,	A	30	804	49	1,073	18	1,100	43	726	35	926
3	L	45	852	318	1,445	266	1,504	148	1,255	194	1,264
4	B	55	867	22	915	66	1,189	15	591	39	891
5	T+A	67	782	209	973	237	1,290	77	691	147	934
6	A+L	268	980	208	1,194	319	1,110	212	408	252	923
7	T+L	89	519	346	1,539	661	964	414	600	377	905
8	T+B	37	950	73	1,095	64	758	34	883	52	921
9	A+B	5	357	82	975	47	736	344	1,024	120	774
10	L+B	58	657	265	971	608	993	292	886	306	877
11	T+A+L	262	655	576	1,167	659	1,320	272	506	442	912
12	T+A+B	84	771	148	982	156	921	80	648	117	831
13	T+L+B	259	1,286	242	875	369	1,048	184	771	264	995
14	A+L+B	104	572	606	1,316	166	764	284	1,058	290	927
15	T+A+L+B	311	801	529	1,241	346	1,005	273	688	365	934
Mean		115	806	254	1,123	269	1,043	181	766		

Conversion factor 1 lb. per acre = 1.121 kg/ha

APPENDIX TABLE 4(b,c,d). Analysis of variance of dry matter yields (lbs/acre). Second cut of Spring, 1964 seeding.

4b Total yield

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	2,572,472	857,491	9.33**	2.84	4.31
Mixtures	14	1,701,895	121,564	1.32	1.92	2.52
Error	42	3,858,173	91,861			
Total	59	8,132,541				

4c Seeded forage

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	226,916	75,639	5.40**	2.84	4.31
Mixtures	14	1,002,783	71,627	5.11**	1.92	2.52
Error	42	588,241	14,006			
Total	59					

4d "Others"

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	1,391,173	472,794	9.42**	2.84	4.31
Mixtures	14	644,401	46,029	0.91	1.92	2.52
Error	42	2,107,356	50,175			
Total	59	4,142,930				

APPENDIX TABLE 4e. Actual percentage composition of each mixture in the material harvested on 20th October, 1964. 2nd cut of Spring, 1964 seeding. (Botanical Composition computed from Appendix Table 4a)

MIXTURE No.	Species	Rate of irrigation A %F+	A %0++	B %F	B %0	C %F	C %0	D %F	D %0	AVERAGE %F	AVERAGE %0
(1)	T	4.0	96.0	11.4	88.6	4.7	95.3	6.0	94.0	6.5	93.5
(2)	A	3.6	96.4	4.4	95.6	1.6	98.4	5.6	94.4	3.8	96.2
(3)	L	5.0	95.0	18.0	82.0	15.0	85.0	10.5	89.5	12.2	87.8
(4)	B	5.9	94.1	2.4	97.6	5.2	94.8	2.4	97.6	4.0	96.0
(5)	T+A	7.9	92.1	17.6	82.4	15.5	84.5	10.0	90.0	12.8	87.2
(6)	A+L	21.5	78.5	14.8	85.2	22.3	77.7	34.2	65.8	23.2	76.8
(7)	T+L	14.6	85.4	18.3	81.7	40.7	59.3	40.8	59.2	28.6	71.4
(8)	T+B	3.7	96.3	6.2	93.8	7.8	92.2	3.7	96.3	5.3	94.7
(9)	A+B	1.4	98.6	7.7	92.3	6.0	94.0	25.1	74.9	10.1	89.9
(10)	L+B	8.2	91.8	21.4	78.6	38.0	62.0	24.8	75.2	23.1	76.9
(11)	T+A+L	28.6	71.4	33.1	66.9	33.3	66.7	35.0	65.0	32.5	67.5
(12)	T+A+B	9.8	90.2	13.1	86.9	14.5	85.5	10.4	89.6	11.9	88.1
(13)	T+L+B	16.8	83.2	21.7	78.3	26.1	73.9	19.3	80.7	20.9	79.1
(14)	A+L+B	15.3	84.7	31.5	68.5	17.8	82.2	21.1	78.9	21.4	78.6
(15)	T+A+L+B	28.0	72.0	29.9	70.1	25.6	74.4	28.4	71.6	28.0	72.0

+% Forage

++% Others in mixture

APPENDIX TABLE 4f. Analysis of variance, based on arcsin transformation values, of per cent contribution by mixtures to total yield. 2nd cut of Spring, 1964 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	295.00	98.33	4.51**	2.84	4.31
Mixtures	14	3,578.57	255.54	11.71**	1.92	2.52
Error	42	917.66	21.83			
Total	59	4,789.23				

Comparison of irrigation means

Rate of irrigation	D	C	B	A
Mean contribution	24.09	23.93	23.22	18.69
	a+	a	a b	b

+a is significantly different from b at 1% level of Duncan's range.

APPENDIX TABLE 4g. Mean percentage contribution by each species to total yield at each rate of irrigation.

Species	Rate of irrigation A (Check)	B (0.1"/hr)	C (0.4"/hr)	D (1.0"/hr)	Mean	
Timothy	3.08	5.21	6.10	3.48	4.48	b[+]
Alfalfa	9.75	5.45	6.14	8.82	7.54	b
Ladino	14.42	29.52	30.15	28.76	25.71	a
Brome-grass	2.82	3.43	4.41	2.53	3.30	b
Mean	7.52 a	10.90 a	11.70 a	10.90 a		

[+]a is significantly different from b at 1% level of probability determined by Duncan's range test.

APPENDIX TABLE 4h. Analysis of variance, based on arcsin transformation values, of mean percentage contribution by each species to total yield at each rate of irrigation.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	23.05	7.68	0.74	3.86	6.99
Species	3	1,002.37	334.12	32.13**	3.86	6.99
Error	9	93.61	10.40			
Total	15	1,095.98				

APPENDIX TABLE 5a. Dry matter yields (lbs/acre) of seeded forage mixtures and "others", after hand separation, on 29th June, 1965. Third cut of Spring, 1964 seeding.

		Rate of irrigation									
		A		B		C		D		Mean	
No.	Mixture	Seeded forage	Others	Seeded forage	Others	Seeded forage	Others	Seeded forage	Others	Seeded forage	Others
1	T	1,753	712	2,032	1,929	1,136	1,811	1,091	1,323	1,503	1,444
2	A	112	731	112	2,221	94	2,685	405	1,871	181	1,877
3	L	2	732	312	2,143	192	2,012	230	1,639	184	1,631
4	B	449	1,290	413	1,087	141	820	134	1,362	284	1,140
5	T+A	1,674	556	2,330	1,279	2,510	2,287	1,092	1,373	1,901	1,374
6	A+L	2,047	916	1,089	1,045	487	1,544	594	1,755	1,054	1,315
7	T+L	718	718	2,405	650	2,037	1,351	1,912	627	1,768	837
8	T+B	697	1,060	2,094	1,269	1,098	1,395	1,014	1,327	1,226	1,263
9	A+B	186	682	215	1,716	851	1,884	1,807	1,537	765	1,455
10	L+B	731	933	137	1,385	1,128	1,478	551	1,480	637	1,319
11	T+A+L	2,154	183	2,683	568	2,024	864	1,952	347	2,203	491
12	T+A+B	1,868	630	953	1,339	853	1,053	1,510	999	1,221	1,005
13	T+L+B	1,767	1,103	1,045	263	1,113	997	556	841	1,120	801
14	A+L+B	265	704	1,561	840	595	1,116	1,110	1,070	883	933
15	T+A+L+B	2,141	438	1,806	1,273	2,569	784	1,098	708	1,903	801
	Mean	1,084	759	1,279	1,267	1,122	1,472	1,004	1,217		

Conversion factor 1 lb. per acre = 1.121 kg/ha

APPENDIX TABLE 5(b,c,d). Analysis of variance of dry matter yields (lbs/acre). Third cut of Spring, 1964 seeding.

5b Total yield

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	4,424,044	1,474,681	3.32*	2.84	4.31
Mixtures	14	13,555,965	968,283	2.18*	1.92	2.52
Error	42	18,630,548	443,584			
Total	59	36,610,557				

5c Seeded forage

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	601,370	200,457	0.73	2.84	4.31
Mixtures	14	23,449,570	1,674,969	6.07**	1.92	2.52
Error	42	11,582,173	275,766			
Total	59	35,633,113				

5d "Others"

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	4,040,771	1,356,924	10.94**	2.84	4.31
Mixtures	14	7,562,689	540,192	4.53**	1.92	2.52
Error	42	5,209,827	124,043			
Total	59	16,843,287				

APPENDIX TABLE 5e. Actual percentage composition of each mixture in the material harvested in June, 1965. Third cutting of 1964 seeding. (Botanical Composition computed from Appendix Table 5a)

MIXTURE No.	Species	Rate of irrigation A %F+	%O++	B %F	%O	C %F	%O	D %F	%O	AVERAGE %F	%O
(1)	T	71.0	29.0	51.0	49.0	38.6	61.4	45.1	54.9	51.5	48.5
(2)	A	13.3	86.7	4.8	95.2	3.4	96.6	17.8	82.2	9.8	90.2
(3)	L	0.3	99.7	1.3	98.7	8.7	91.3	12.3	87.7	5.7	94.3
(4)	B	25.8	74.2	27.6	72.4	14.7	85.3	9.0	91.0	19.3	80.7
(5)	T+A	75.1	24.9	64.5	35.4	52.3	47.7	44.3	55.7	59.1	40.9
(6)	A+L	69.1	30.9	51.0	49.0	23.9	76.1	25.3	74.7	42.4	57.6
(7)	T+L	50.0	50.0	78.7	21.3	60.1	39.9	75.3	24.7	66.0	34.0
(8)	T+B	39.7	60.3	62.3	37.7	44.0	56.0	43.3	56.7	47.7	52.3
(9)	A+B	21.5	78.6	11.1	88.9	31.1	68.9	54.1	45.9	29.4	70.6
(10)	L+B	43.9	56.1	10.4	89.6	43.3	56.7	27.1	72.9	31.2	68.8
(11)	T+A+L	92.2	7.8	82.5	17.5	70.1	29.9	84.9	15.1	82.4	17.6
(12)	T+A+B	71.3	28.7	41.6	58.4	44.7	55.3	60.2	39.8	54.5	45.5
(13)	T+L+B	61.6	38.4	79.9	20.1	52.7	47.2	39.8	60.2	58.3	41.7
(14)	A+L+B	27.3	72.7	65.0	35.0	34.8	65.2	50.9	49.1	44.5	55.5
(15)	T+A+L+B	83.0	17.0	58.6	41.4	76.6	23.4	60.8	39.2	69.8	30.2

+% Forage

++% Others in mixture

APPENDIX TABLE 5f. Analysis of variance, based on arcsin transformation values, of per cent contribution by mixtures to total yield. Third cut of Spring, 1964 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	262.01	87.34	1.11	2.84	4.31
Mixtures	14	12,344.20	881.73	11.19**	1.92	2.52
Error	42	3,310.09	78.81			
Total	59	15,916.29				

APPENDIX TABLE 5g. Mean percentage contribution by each species to total yield at each rate of irrigation.

Species	Rate of irrigation A (Check)	B (0.1"/hr)	C (0.4"/hr)	D (1.0"/hr)	Mean	
Timothy	37.78	54.99	43.42	41.98	44.54	a+
Alfalfa	30.33	11.46	5.07	14.22	15.27	b
Ladino	9.93	10.06	11.17	10.10	10.32	b
Brome-grass	20.10	12.11	15.15	15.64	15.75	b
Mean	24.53 a	22.15 a	18.70 a	20.48 a		

+a is significantly different from b at 1% level of probability determined by Duncan's range test.

APPENDIX TABLE 5h. Analysis of variance, based on arcsin transformation values, of mean per cent contribution by each species to total yield at each rate of irrigation.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	48.91	12.30	0.46	3.86	6.99
Species	3	1,305.18	435.06	16.39**	3.86	6.99
Error	9	240.85	26.54			
Total	15	1,594.94				

APPENDIX TABLE 6a. Sward cover in percentages on 6th July, 1965 from 1964 seeding. Point quadrat method (one week after third cut). Ormstown.

		A(Check)				B(0.1"/hr)				C(0.4"/hr)				D(1.0"/hr)			
No.	Mixture	TGC	SF	"0"	BG	TGC	SF	"0"	BG	TGC	SF	"0"	BG	TGC	SF	"0"	BG
1	T	58	28	30	42	52	26	26	48	54	19	35	46	60	16	44	40
2	A	50	12	38	50	60	11	49	40	82	12	70	18	62	14	48	38
3	L	54	21	33	46	62	30	32	38	64	23	41	36	60	34	36	40
4	B	58	4	54	42	74	26	48	26	62	15	47	38	60	40	40	40
5	T+A	60	30	30	40	60	29	31	40	42	21	21	58	66	45	21	34
6	A+L	54	28	26	46	72	33	39	28	74	35	39	26	54	27	27	46
7	T+L	64	44	20	36	74	46	28	26	80	49	31	20	64	47	17	36
8	T+B	54	31	23	46	64	23	41	36	58	21	37	42	66	27	39	34
9	A+B	58	31	27	42	60	38	22	40	64	18	46	36	80	29	51	20
10	L+B	60	33	27	40	60	29	31	40	58	38	20	42	72	33	39	28
11	T+A+L	54	38	16	46	66	40	26	34	88	52	36	12	82	51	31	18
12	T+A+B	56	36	20	44	64	30	34	36	74	33	41	26	60	34	26	40
13	T+L+B	66	46	20	34	60	36	24	40	56	26	30	44	68	45	23	32
14	A+L+B	68	43	25	32	60	35	25	40	78	38	40	22	86	67	19	14
15	T+A+L+B	66	43	23	34	54	32	22	46	58	40	18	42	64	46	18	36

TGC = Total ground cover
SF = Seeded forage
"0" = "Others"
BG = Bare ground

APPENDIX TABLE 6(b,c,d,e). Analysis of variance, based on arcsin transformation values, of per cent cover or bare ground. Point quadrat analysis of Spring, 1964 seeding. Data taken one week after third cut.

6b Total ground cover

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	638	212.67	2.97*	2.84	4.31
Mixtures	14	1,419	101.36	1.42	1.92	2.52
Error	42	3,003	71.50			
Total	59	5,060				

6c Ground cover by seeded forage mixture

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	198.08	66.03	2.81*	2.84	4.31
Mixtures	14	2,307.44	164.82	7.03**	1.92	2.52
Error	42	985.15	23.46			
Total	59	3,490.67				

6d Ground cover by "Others"

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	214.27	71.42	1.56	2.84	4.31
Mixtures	14	1,511.14	107.94	2.35*	1.92	2.52
Error	42	1,926.19	45.86			
Total	59	3,665.60				

6e Bare ground

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	248.60	82.87	3.02*	2.84	4.31
Mixtures	14	572.60	40.90	1.49	1.92	2.52
Error	42	1,151.77	27.42			
Total	59	1,972.97				

APPENDIX TABLE 6f. Actual per cent ground cover by each species at each rate of irrigation. (Computed from the original data, taken one week after third cut, of point quadrat analysis)

Species	Rate of irrigation A (Check)	B (0.1"/hr)	C (0.4"/hr)	D (1.0"/hr)	Mean	
Timothy	27.49	23.50	23.50	27.97	25.61	a+
Alfalfa	19.28	17.85	16.95	17.36	17.86	b
Ladino	19.73	26.64	26.56	27.39	25.08	a
Brome-grass	22.30	20.70	20.88	23.11	21.75	ab
Mean	22.20	22.17	21.97	23.96		

+a is significantly different from b at 1% level of probability determined by Duncan's range test.

APPENDIX TABLE 6g. Analysis of variance, based on arcsin transformation values, of per cent ground cover by each species at each rate of irrigation. (Computed from original data)

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Replications	3	10.30	3.43	0.58	3.86	6.99
Species	3	153.73	51.24	8.64**	3.86	6.99
Error	9	5.93				
Total	15	217.42				

APPENDIX TABLE 7. Mean weekly dry weight (milligrams) of roots at each rate of irrigation, and in the presence and absence of a companion crop. Spring, 1965 seeding.

Weeks after Seeding	Rate of irrigation								Mean	
	A		B		C		D			
	a+	b++	a	b	a	b	a	b	a	b
4	62.53	25.67	51.67	35.33	42.00	43.00	39.67	38.33	48.97	35.58
5	84.67	40.00	137.00	45.33	98.00	42.33	107.67	39.33	106.83	41.75
6	79.33	31.67	79.00	33.67	111.33	52.67	162.00	33.67	107.92	37.92
7	128.00	39.00	131.00	43.00	120.00	50.33	163.67	57.33	135.67	47.42
8	134.00	44.67	106.67	35.00	297.67	92.00	99.00	29.00	159.33	50.17
9	192.67	63.33	345.67	60.67	239.00	28.33	301.00	59.00	269.58	52.33

++b = Root yield (milligrams) in presence of a companion crop

++a = Root yield (milligrams) in absence of a companion crop

APPENDIX TABLE 8a. Mean dry weight (milligrams) of roots of mixtures at each rate of irrigation and in presence and absence of a companion crop, from four to nine weeks after seeding.

		Rate of irrigation							
		A(Check)		B(0.1"/hr)		C(0.4"/hr)		D(1.0"/hr)	
	Mixture	a+	b++	a	b	a	b	a	b
1	T	65	12	111	18	76	33	94	12
2	A	80	40	80	44	15	29	86	35
3	L	53	13	37	14	88	18	40	18
4	B	93	44	115	40	110	35	15	47
5	T+A	138	51	211	36	168	57	295	38
6	A+L	154	43	157	38	257	32	96	44
7	T+L	79	16	141	32	109	36	224	30
8	T+B	114	42	67	49	170	95	138	51
9	A+B	146	51	163	43	214	108	98	66
10	L+B	112	30	113	51	153	41	131	55
11	T+A+L	80	64	104	59	184	48	199	27
12	T+A+B	139	26	137	59	165	56	223	27
13	T+B+L	136	38	153	64	104	38	197	72
14	A+L+B	141	89	300	40	123	73	103	42
15	T+A+L+B	173	54	241	46	201	73	104	80

+a = Root yield in absence of a companion crop

++b = Root yield in presence of a companion crop

APPENDIX TABLE 8b. Analysis of variance of mean dry weight (milligrams) of roots of mixtures four to nine weeks after seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
Blocks(irrig.)	3	6,392.89	2,130.96	1.37	9.28	29.46
Nurse crop(N.C.)	1	237,016.44	237,016.44	152.27**	10.13	34.12
Error (a)	3	4,669.79	1,556.60			
Mixtures(M.)	14	83,395.68	5,956.83	4.19**	1.82	2.32
	14	38,802.57	2,771.61	1.95*	1.82	2.32
Error (b)	84	119,509.44	1,422.73			
Total	119	489,786.81				

APPENDIX TABLE 9a. Initial Establishment. Number of Viable Seeds seeded (V.S.) and Mean Number of plants resulting per square foot (No.); and Percentage Established (%E.). Six weeks after seeding in Fall, 1964.

(I) UN-IRRIGATED

	Rates	TIMOTHY V.S.	TIMOTHY No.	TIMOTHY %E.	ALFALFA V.S.	ALFALFA No.	ALFALFA %E.	LADINO V.S.	LADINO No.	LADINO %E.	BROME V.S.	BROME No.	BROME %E.	BIRDSFOOT V.S.	BIRDSFOOT No.	BIRDSFOOT %E.
REP. I	1	52	13.68	26.31	10	11.16	111.60	14	12.60	90.00	14	3.60	25.71	21	13.68	65.14
	2	104	63.72	61.27	20	19.80	99.00	28	25.20	90.00	28	7.56	27.00	42	15.48	36.86
	3	156	96.84	62.08	30	24.12	80.40	42	35.64	84.86	42	26.28	62.57	63	23.40	37.14
	4	208	102.96	49.50	40	29.16	72.90	56	35.64	63.64	56	12.60	22.50	84	49.32	58.71
REP. II	1	52	28.44	54.69	10	5.40	54.00	14	16.20	115.71	14	3.24	23.14	21	18.72	89.14
	2	104	46.08	44.31	20	9.72	48.60	28	31.68	113.14	28	6.12	21.86	42	13.68	32.57
	3	156	72.36	46.38	30	16.92	56.40	42	34.92	83.14	42	10.44	24.86	63	23.76	37.71
	4	208	97.56	46.90	40	24.84	62.10	56	67.32	120.21	56	26.64	47.57	84	55.44	66.00

(II) IRRIGATED

	Rates	TIMOTHY V.S.	TIMOTHY No.	TIMOTHY %E.	ALFALFA V.S.	ALFALFA No.	ALFALFA %E.	LADINO V.S.	LADINO No.	LADINO %E.	BROME V.S.	BROME No.	BROME %E.	BIRDSFOOT V.S.	BIRDSFOOT No.	BIRDSFOOT %E.
REP. I	1	52	6.84	13.15	10	2.16	21.60	14	11.16	79.71	14	3.24	23.14	21	5.76	27.52
	2	104	36.00	34.62	20	16.20	81.00	28	33.48	119.57	28	12.24	43.71	42	12.96	30.86
	3	156	113.04	72.46	30	38.60	128.67	42	36.00	85.71	42	10.44	24.86	63	34.92	55.43
	4	208	53.28	25.62	40	47.52	118.80	56	43.56	77.79	56	13.32	23.79	84	38.16	45.43
REP. II	1	52	12.24	23.54	10	7.92	79.20	14	8.28	59.14	14	5.76	41.14	21	6.12	29.14
	2	104	22.32	21.46	20	18.72	93.60	28	20.16	72.00	28	5.40	19.29	42	9.36	22.29
	3	156	46.80	30.00	30	38.52	128.40	42	30.60	72.86	42	14.04	33.43	63	31.32	49.71
	4	208	68.76	33.06	40	46.08	115.20	56	23.04	41.14	56	18.72	33.43	84	37.08	44.14

APPENDIX TABLE 9b. Analysis of variance, based on arcsin transformation values, of initial percentage plants established 6 weeks after seeding in Fall, 1964.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
BLOCKS	1	81.33	81.33	11.61	161.4	4052
IRRIGATION (I)	1	368.17	368.17	52.59	161.4	4052
ERROR (a)	1	7.00	7.00			
SPECIES (S)	4	17,152.50	4,288.13	17.52**	3.84	7.01
I x S	4	1,777.10	444.27	1.81	3.84	7.01
ERROR (b)	8	3,073.92	244.79			
RATES (R)	3	287.72	95.91	1.26	2.92	4.51
R x I	3	1,396.58	465.53	6.11**	2.92	4.51
R x S	12	1,947.61	162.30	2.13*	2.09	2.84
R x S x I	12	2,604.64	217.05	2.84**	2.09	2.84
ERROR (c)	30	2,286.28	76.21			
TOTAL	79	30,982.85				

APPENDIX TABLE 10a. Initial establishment. Number of Viable Seeds seeded (V.S.) and Mean Number of plants resulting per square foot (No.); and Percentage Established (%E.). Six weeks after seeding in Spring, 1965.

(I) UN-IRRIGATED

		TIMOTHY			ALFALFA			LADINO			BROME			BIRDSFOOT		
	Rates	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.
REP.I	1	52	1.44	2.77	12	5.04	42.00	16	2.16	13.50	20	2.52	12.60	21	2.16	10.28
	2	104	6.84	6.58	24	14.40	60.00	32	2.52	7.88	40	7.20	18.00	42	10.08	24.00
	3	156	7.20	4.62	36	25.20	70.00	48	5.76	12.00	60	12.60	21.00	63	18.36	29.14
	4	208	19.80	9.52	48	37.44	78.00	64	8.64	13.50	80	23.40	29.25	84	14.40	17.14
REP.II	1	52	3.24	6.23	12	8.64	72.00	16	2.52	15.75	20	7.20	36.00	21	2.88	13.71
	2	104	6.12	5.88	24	16.20	67.50	32	5.04	15.75	40	9.00	15.00	42	9.72	23.14
	3	156	12.24	7.84	36	20.88	58.00	48	7.92	16.50	60	10.08	16.80	63	14.04	22.28
	4	208	18.00	8.65	48	43.56	90.75	64	7.92	12.38	80	15.84	19.80	84	33.48	39.85

(II) IRRIGATED

		TIMOTHY			ALFALFA			LADINO			BROME			BIRDSFOOT		
	Rates	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.	V.S.	No.	%E.
REP.I	1	52	5.04	10.38	12	11.52	96.00	16	5.04	31.50	20	6.48	32.40	21	7.92	37.71
	2	104	6.84	6.58	24	18.00	75.00	32	6.84	22.06	40	10.80	27.00	42	16.56	39.40
	3	156	47.52	30.46	36	29.52	82.00	48	9.36	19.50	60	32.40	54.00	63	19.80	31.42
	4	208	15.84	7.44	48	54.00	112.50	64	14.04	21.94	80	28.08	35.10	84	28.80	34.28
REP.II	1	52	3.96	7.62	12	10.44	87.00	16	4.32	27.00	20	9.36	46.80	21	8.28	39.43
	2	104	13.32	12.81	24	24.12	100.50	32	6.84	21.38	40	17.64	44.10	42	14.76	35.14
	3	156	27.36	17.54	36	21.96	61.00	48	8.28	17.25	60	40.32	67.20	63	14.40	22.86
	4	208	29.16	14.01	48	48.96	102.00	64	15.12	23.62	80	45.36	56.70	84	24.48	29.14

APPENDIX TABLE 10b. Analysis of variance, based on arcsin transformation values, of initial percentage established 6 weeks after seeding in Spring, 1965.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
BLOCKS	1	110.59	110.59	11.38	161.4	4052
IRRIGATION (I)	1	2,394.77	2,394.77	246.62*	161.4	4052
ERROR (a)	1	9.71	9.71			
SPECIES (S)	4	20,914.57	5,228.64	193.03**	3.84	7.01
S x I	4	499.94	124.99	4.61*	3.84	7.01
ERROR (b)	8	216.69	27.09			
RATES (R)	3	307.44	102.48	2.71	2.92	4.51
R x I	3	52.94	17.65	0.47	2.92	4.51
R x S	12	1,178.87	98.24	2.60*	2.09	2.84
R x S x I	12	655.68	54.64	1.44	2.09	2.84
ERROR (c)	30	1,134.34	37.81			
TOTAL	79	27,475.54				

APPENDIX TABLE 11a. Final Establishment. Number of Viable Seeds seeded (V.S.) and Mean Number of plants resulting per square foot (No.); and Percentage Established (%E.)

(I) UN-IRRIGATED

	Rates	TIMOTHY V.S.	TIMOTHY No.	TIMOTHY %E.	ALFALFA V.S.	ALFALFA No.	ALFALFA %E.	LADINO V.S.	LADINO No.	LADINO %E.	BROME V.S.	BROME No.	BROME %E.	BIRDSFOOT V.S.	BIRDSFOOT No.	BIRDSFOOT %E.
REP. I	1	52	3.00	5.77	12	7.00	58.30	16	3.00	18.75	20	4.00	20.0	21	2.50	11.90
	2	104	4.50	4.33	24	12.00	50.00	32	5.00	15.63	40	6.50	16.25	42	4.50	10.71
	3	156	9.00	5.77	36	15.00	41.66	48	4.00	8.33	60	5.00	8.33	63	7.00	11.11
	4	208	12.00	5.77	48	32.00	66.66	64	8.00	12.50	80	9.00	11.25	84	14.50	17.26
REP. II	1	52	4.50	8.65	12	10.50	87.50	16	5.50	34.38	20	3.00	15.00	21	7.50	35.71
	2	104	7.00	6.73	24	10.50	51.47	32	4.00	12.50	40	7.50	18.75	42	7.50	17.86
	3	156	7.50	4.81	36	16.50	45.83	48	9.00	18.75	60	6.50	10.83	63	10.50	16.66
	4	208	11.30	5.43	48	19.00	39.58	64	10.00	15.83	80	9.50	11.88	84	15.00	17.85

(II) IRRIGATED

	Rates	TIMOTHY V.S.	TIMOTHY No.	TIMOTHY %E.	ALFALFA V.S.	ALFALFA No.	ALFALFA %E.	LADINO V.S.	LADINO No.	LADINO %E.	BROME V.S.	BROME No.	BROME %E.	BIRDSFOOT V.S.	BIRDSFOOT No.	BIRDSFOOT %E.
REP. I	1	52	8.00	15.38	12	11.50	95.83	16	5.75	35.93	20	10.00	50.00	21	8.00	38.10
	2	104	7.75	7.45	24	22.00	91.66	32	7.70	24.06	40	16.50	41.25	42	13.25	31.54
	3	156	23.00	14.74	36	25.25	70.13	48	7.00	14.58	60	21.50	35.83	63	16.25	25.79
	4	208	18.50	8.89	48	40.25	83.85	64	11.75	18.33	80	22.50	28.12	84	23.25	27.67
REP. II	1	52	8.50	16.35	12	10.25	85.41	16	3.50	21.87	20	12.00	60.00	21	6.75	32.14
	2	104	12.50	12.02	24	17.00	70.83	32	5.00	15.63	40	11.50	28.75	42	12.25	29.16
	3	156	18.75	12.02	36	23.25	64.58	48	5.00	10.42	60	19.00	31.66	63	24.00	38.09
	4	208	19.75	9.50	48	24.50	51.04	64	5.85	9.12	80	18.50	23.12	84	18.00	21.42

APPENDIX TABLE 11b. Analysis of variance, based on arcsin transformation values, of final percentage plants established. Spring, 1965 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
BLOCKS	1	6.89	6.89	0.03	161.4	4052
IRRIGATION (I)	1	1,704.87	1,704.87	6.73	161.4	4052
ERROR (a)	1	253.44	253.44			
SPECIES (S)	4	13,310.79	3,327.70	43.43**	3.84	7.01
S x I	4	555.21	138.80	1.81	3.84	7.01
ERROR (b)	8	306.51	76.63			
RATES (R)	3	1,067.83	355.94	16.73**	2.92	4.51
R x I	3	90.72	30.24	1.42	2.92	4.51
R x S	12	347.12	28.93	1.36	2.09	2.84
R x S x I	12	150.28	12.52	0.59	2.09	2.84
ERROR (c)	30	638.17	21.27			
TOTAL	79	18,431.82				

APPENDIX TABLE 12a. Dry matter yield (lbs/acre) of seeded forage at final establishment. From 1965 seeding.

		TIMOTHY		ALFALFA		LADINO		BROME		BIRDSFOOT	
	Rates	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1
REP. I	1	221	575	2,205	4,596	152	557	629	1,244	142	2,713
	2	339	532	2,832	4,601	396	1,133	810	1,212	298	3,440
	3	577	584	2,947	4,352	275	1,138	893	1,471	683	4,167
	4	613	883	3,329	5,046	572	1,663	1,143	1,864	645	3,964
REP. II	1	303	795	1,608	4,362	282	1,156	667	1,772	875	4,402
	2	443	2,221	2,691	3,776	275	1,768	842	2,688	991	3,370
	3	690	2,834	2,662	4,840	1,009	1,062	1,048	2,096	1,085	4,729
	4	700	2,286	2,893	4,955	865	1,754	1,056	2,481	904	4,346

Conversion factor 1 lb. per acre = 1.121 kg/ha

I_0 = Unirrigated

I_1 = Irrigated

APPENDIX TABLE 12b. Analysis of variance of Forage yield (lbs. dry matter per acre) at final establishment. From 1965 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
BLOCKS	1	2,501,367	2,501,367	2.10	161.4	4052
IRRIGATION (I)	1	47,799,228	47,799,228	40.06	161.4	4052
ERROR (a)	1	1,193,161	1,193,161			
SPECIES (S)	4	85,279,937	21,319,984	37.68**	3.84	7.01
I x S	4	15,833,184	3,958,296	7.00*	3.84	7.01
ERROR (b)	8	4,526,017	565,752			
RATES (R)	3	4,622,051	1,540,684	21.91**	2.92	4.51
R x I	3	83,693	27,898	0.40	2.92	4.51
R x S	12	964,556	80,380	1.14	2.09	2.84
R x S x I	12	2,489,647	207,471	2.95**	2.09	2.84
ERROR (c)	30	2,309,407	70,314			
TOTAL	79	167,602,248				

APPENDIX TABLE 13. Analysis of variance, based on arcsin transformation values, of percentage cover 1 week after harvesting plots in August, 1965. From Spring, 1965 seeding.

Source of Variation	d.f.	S.S.	M.S.	F(calc.)	F.05	F.01
BLOCKS	1	12.20	12.20	0.08	161.4	4052
IRRIGATION (I)	1	85.76	85.76	0.54	161.4	4052
ERROR (a)	1	160.11	160.11			
SPECIES (S)	4	3,909.87	977.47	22.83**	3.84	7.01
I x S	4	456.57	114.15	2.67	3.84	7.01
ERROR (b)	8	342.50	42.81			
RATES (R)	3	2,628.99	876.33	45.25**	2.92	4.51
R x I	3	20.56	6.85	0.35	2.92	4.51
R x S	12	175.00	14.58	0.75	2.09	2.84
R x S x I	12	459.16	38.26	1.98	2.09	2.84
ERROR (c)	30	581.05	19.37			
TOTAL	79	8,831.67				

APPENDIX TABLE 14. Species and quantities of seeds sown in the 15 sub-plots of each main plot.

Identification number	Species in the mixture+	Quantity of seeds sown++ lbs/acre	gms/plot
1	T	8	21.8
2	A	8	21.8
3	L	1.5	4.09
4	B	15	40.86
5	T+A	8+8	21.8+21.8
6	A+L	8+1.5	21.8+4.09
7	T+L	8+1.5	21.8+4.09
8	T+B	8+15	21.8+40.86
9	A+B	8+15	21.8+40.86
10	L+B	1.5+15	4.09+40.86
11	T+A+L	8+8+1.5	21.8+21.8+4.09
12	T+A+B	8+8+15	21.8+21.8+40.86
13	T+B+L	8+15+1.5	21.8+40.86+4.09
14	A+L+B	8+1.5+15	21.8+4.09+40.86
15	T+A+L+B	8+8+1.5+15	21.8+21.8+4.09+40.86

+T = Timothy

A = Alfalfa

L = Ladino

B = Bromegrass

++The order of quantity of seeds sown corresponds to the order of species in the mixture.

APPENDIX TABLE 15a. Mean maximum and minimum temperatures and total precipitation and evaporation for the growing season of 1964.

PERIOD	Temperature MAXIMUM	MINIMUM	MEAN	Rainfall (inches) TOTAL	Pan Evaporation (inches) TOTAL	
May 15-22	65.42	48.00	51.71	0.66	1.69	
23-29	67.28	52.00	59.64	0.71	2.06	
30-June 5	62.57	43.42	52.99	0.52	1.13	
June 6-16	72.55	51.18	61.86	0.08	2.23	
17-23	81.14	57.57	69.36	0.18	2.01	
24-30	80.14	57.85	68.99	0.26	1.93	
July 1-10	76.87	57.66	67.26	1.90	1.67	
11-21	81.42	60.25	70.84	0.50	2.36	
22-28	81.42	61.42	71.42	0.26	1.52	
29-Aug.4	78.71	59.14	68.92	1.02	1.75	
Aug.5 -11	77.28	54.14	65.71	0.55	1.54	
12-18	81.06	62.72	71.89	1.22	1.23	
19-25	81.71	60.28	70.99	2.06	1.17	
26-Sep.1	78.85	54.57	66.81	0.08	1.29	Moisture*
Sep. 2-30	67.90	44.00	55.90	1.56	4.01	deficit
Oct. 1-15	55.60	35.10	45.30	1.79	2.59	
Total				13.35	30.18	7.39

APPENDIX TABLE 15b. Mean maximum and minimum temperatures, and total precipitation and evaporation for the growing season of 1965.

PERIOD	Temperature MAXIMUM	MINIMUM	MEAN	Rainfall (inches) TOTAL	Pan Evaporation (inches) TOTAL	
May 1-12	68.75	40.16	54.40	1.20	1.29	
13-17	70.20	45.00	57.60	0.27	1.04	
18-24	67.42	42.85	55.13	0.00	1.38	
25-31	70.00	46.14	58.07	0.33	1.58	
June 1- 8	73.50	49.87	61.68	0.14	1.72	
9-15	68.00	46.42	57.21	0.22	1.27	
16-22	80.57	57.85	69.21	0.00	2.19	
23-28	79.16	54.66	66.91	0.06	1.80	
29-Jul.5	80.14	53.71	66.92	0.58	1.93	Moisture*
July 6-12	77.28	52.71	64.99	0.89	1.87	deficit
13-19	77.00	57.14	67.07	0.33	1.77	
Total				4.12	17.84	4.33

*Moisture deficit = potential evapotranspiration - (Rainfall ± soil moisture change)

1964 season: Approximately = 0.8 x 30.18" - (13.35" + 3.4") = 7.39"

1965 season: Approximately = 0.8 x 17.84" - (4.12" + 3.4") = 6.85"

APPENDIX TABLE 15c. Monthly average rainfall, and maximum and minimum temperatures in 1964 and the preceding 20 years.

MONTH	RAINFALL IN INCHES		TEMPERATURE IN DEGREES F.					
			1964			1943-1963		
	1964	1943-1963	Maximum	Minimum	Mean	Maximum	Minimum	Mean
MAY	1.93	2.84	68.9	47.8	58.3	65	42	53.5
JUNE	1.03	3.28	74.5	52.8	63.5	75	54	63.5
JULY	2.91	4.16	79.4	59.2	69.3	78	58	69.0
AUG.	3.68	4.59	73.3	58.1	62.0	74.5	56	65.25
SEPT.	1.56	2.47	67.9	44	55.9	66.6	48.6	57.6
OCT.	1.79	2.88	55.6	35.1	45.3	60	37.6	48.8
TOTAL	12.90	20.22						

APPENDIX TABLE 15d. Maximum, minimum and monthly mean temperatures, and monthly total precipitation at Macdonald College in 1965, and long term norms at Dorval, Quebec.

Month	Temperature (°F)[+]						Precipitation (inches)[++]	
	Mean Minimum		Mean Maximum		Monthly Mean			
	1965	Norm	1965	Norm	1965	Norm	1965	Norm
April	31.3	33.5	49.7	50.8	40.5	42.3	2.43	3.02
May	45.7	49.8	68.2	65.8	57.1	56.2	1.97	2.37
June	53.9	55.8	75.3	75.7	64.9	65.8	0.52	3.12
July	56.9	57.8	76.7	78.9	66.8	70.0	2.49	3.67
August	57.0	58.1	75.0	76.3	66.0	66.9	7.37	3.63