# PLANT ECOLOGY

# PLANT ECOLOGY

and

# A COMPARATIVE STUDY OF METHODS OF REPRODUCTION OF CERTAIN PASTURE PLANTS

with

# AN INVESTIGATION OF THE SOIL VIABLE SEED FLORA

by

Lucien J. Boulet

.......

A Thesis

presented to the Faculty of Graduate Studies and Research of McGill University in partial fulfillment of the requirements for the degree of Master of Science.

May, 1937.

## ACKNOWLEDGMENTS

Acknowledgments are due to Mr. L.C. Raymond, Assistant Professor of Agronomy and Chairman of the Macdonald College Pasture Committee, and Dr. G.W. Scarth, Professor of Botany for invaluable advice and criticism during the course of this study, and to Mr. R. Summerby, Professor of Agronomy for aid in relation with the statistical problems of this work.

M. Sc. Agronomy

LUCIEN J. BOULET

Plant Ecology and a Comparative Study of Methods of Reproduction of Certain Pasture Plants with An Investigation of the Soil Viable Seed Content.

These ecological results were recorded from the Sherbrooke district on Appalachian upland podsol soils.

A comparative study of the seminal and vegetative reproductions in certain permanent pasture plants was made under different conditions of pasture management, and different sward types, through direct and indirect methods.

By direct observation, we grouped in two categories, chosen young plants originating immediately, either from seeds, or from vegetative devices. Eleven pasture plants, weedy in nature, were thus observed.

Indirectly, the comparative importance of seminal reproduction was studied from the correlations worked out between the surface vegetation and the top-soil viable seed content. These correlations were calculated between species of a habitat, or within a species in various environments. A plant well represented in both floras was assumed to be reproduced in varying degrees by both methods.

The investigation of the soil buried seed content was made under different sward types and at two different soil layers.

CONTENTS

Page

Plant Ecology and a comparative study of methods of reproduction of certain pasture plants with an investigation of the pasture-soil viable seed content.

# PLANT ECOLOGY AND A COMPARATIVE STUDY OF METHODS OF REPRODUCTION OF CERTAIN PASTURE PLANTS

with

# AN INVESTIGATION OF THE SOIL VIABLE SEED CONTENT

## I. Introduction

Grassland problems may be studied from two fundamental complementary points of view, ecological and nutritive value. In the former, a study is made of the relationship between the environmental factors constituting the habitat, and the vegetation. In the latter, we study the relationship between the vegetation and the stock. But in both these interdependent points, the grassland vegetation expresses the nature of the habitat, being submitted either to the dictates of the soil and climate, or to the selective grazing of the different classes of stock.

Increasing attention is, nowadays, devoted to plant ecology, a knowledge of it being considered fundamental to the solution of grassland problems. A more precise knowledge of ecology throws light on many secondary phases of these problems.

The vegetation is the living expression of the habitat. The predominating species of any plant community express their better fitness to the nature of the adverse external factors involved in the natural selection. The other species, representing a smaller percentage of the population, which are not so well fitted to the particular environment, are partly eliminated according to their lack of agreement with the environment. The predominating species owe their persistence and dominance to characteristics specially adapted to resist the adversity of the habitat; they are better organized in the struggle for life under a certain set of circumstances.

The ecological relationship, then, is the agreement between a particular plant and a particular environment. The nature of that agreement may be morphological or physiological. The three points growth-forms, root system and methods of reproduction, can be regarded as morphological characters important in the study of plant ecology.

Some recent investigations made by Stapledon (1928) on Cocksfoot (*Dactylis glomerata*) have revealed a very interesting and important fact in the ecology of grassland vegetation. Specimens of that plant, collected from many different habitats of various countries and grown for comparison and classification, have proved that this plant species has evolved, under natural selection, many very different ecotypes, depending on the nature of the habitat to which each of them has been subjected. We have realized that the vegetation is the faithful living expression of the habitat, and that to a greater extent than we had thought.

What has been revealed with *Dactylis glomerata* is undoubtedly more or less true with each specific plant. This point is now a fundamental consideration in any plant-breeding programme; it means also that in the natural vegetation there will always be some unknown and new ecotypes of particular growth-form worthy of our best attention. A systematic exploration in this field, abroad or in our own country, but in countries of temperate climate, would be a step of fundamental importance in the progressive solution of our grassland problems.

Root-system studies are also of very great importance. They were started long ago, but following the careful and successful investigations done by Pavlechenko on the root systems of some arable plants, useful or weedy, it would be ecologically and practically interesting to see this new studying method applied to researches on the root systems of our grassland vegetation, and that under conditions as natural as possible. These practical studies were introduced and that new method applied last year (1936) by the Macdonald College Pasture Committee. No results have been obtained up to the present.

In this comparative study we shall deal with the methods of reproduction, seminal and vegetative, which prevail in certain permanent pasture plants.

This can be experimentally done from two points of view. The direct method of observation will show the actual comparative importance of the seminal and vegetative methods of reproduction, under different habitats. The indirect method of study will not be so precise, but is expected to corroborate the findings of the direct one.

## II. A Study of the Comparative Importance of the Seminal and Vegetative Reproductions by Direct Observation Method

### a. Introduction

An extensive and scientific understanding of the comparative importance of the seminal and vegetative reproduction-methods of some pasture plants would undoubtedly help in the solution of some grassland problems. A knowledge of the great variations expected in the importance of the reproductive methods under different sets of environmental factors would also be a further step towards the understanding of those problems.

The central point here involved is the study of the relationship between methods of reproduction in permanent pasture species and the environmental factors that are partly under human control, the most important being the grazing factor and the fertilization practices.

If we understood this relationship under varying circumstances, we could more easily maintain the best botanical composition of a pasture sward in a particular habitat, or renovate an old pasture sward, and attack the weed-control problem. Even, however, were it not of practical value, it would be very interesting ecologically to know more about this.

In the past, serious mistakes have been made in the grazing management of pasture-ranching areas. In those arid regions, the grass-vegetation is reproduced through self-seeding to a very important degree, a point which has been appreciated only during the past few years. Too drastic cropping has exterminated the more useful species, both in the surface vegetation and in the seed content of the soil, and it is now quite a problem to renovate the sward of those ruined grassland areas.

Under our climatic conditions, the more useful plant species of our permanent pastures to a large extent reproduce, vegetatively, but the seminal reproduction is by no means negligible.

An approximate mathematical expression of the comparative importance of both methods of reproduction under different sets of circumstances was felt useful. This was studied by the direct observation method in this phase of the work.

b. Nature and Processes of the Two Methods of Reproduction

Seminal reproduction occurs when a plant originates directly from seed. This is found amongst all biological forms: annuals, biennials, and perennials.

Individual plants may be identical from the seminal-origin point of view, but their life cycle(1) may differ in length

(1)This part dealing with the life-history has been partly taken from C.Raunkiaer in "The Life-Forms of Plants and Plant Geography.

and nature.

This whole life-history in true annuals may be completed during a 12-month period, germination taking place (under our temperate climate) in the late summer or fall, and the young plant surviving the winter in the form of a rosette from which flowering shoots are produced during the next spring; the life-history may last only one growing season, the plant being adapted to survive the drought-period in a latent vegetative stage, and the cold winter season in the seed-stage; finally, the life-history may take only a few weeks, the plant passing both the dry summer and the cold winter unfavourable periods in the latent seed stage. These three types of life-history, varying in length only, can be said to be of similar nature, that is to say, the persistency of the species is insured only through the seed method.

Some seminally reproduced plant-individuals may have a quite different life-cycle, from the point of view of both length and nature. This is seen in perennial species. Besides the possibility of assuring their specific conservation through the seed organ, their persistency is also due to the survival of the lower part of the plant, and that even when the individual has already set seeds and the aerial part (stem) has dried and died. We refer to the vegetative method of reproduction. These persistent plant organs may survive for several years, depending principally upon the species.

The lowest parts (growing points) in perennial plants, "are protected by the soil-surface layer and withered leaves, remaining alive for several years and bearing buds destined in the next period of growth to form shoots that carry leaves and flowers. In most plants of this category, the surviving portion of the single shoot persists for several years, so there is formed a more or less branched contracted system of shoot-bases being situated in the soil." (Raunkiaer).

"Great diversity prevails in these plants, a diversity connected with" the persistency of the shoot system and "the manifold devices for vegetative reproduction and distribution." (Raunkiaer).

"In some the primary root persists, as it does in most Phanerophytes, and the whole shoot system lives as long as the individual," as in Plantago major, Taraxacum officinale, Ranunculus acris. "In most of them, the primary root dies after a longer or shorter time, and the individual becomes attached by advantitious roots. Not only does the primary root die, but the shoot system gradually dies from behind so that vegetative reproduction takes place by division, the individual parts of the shoot system becoming free by the dying of the older portions which held the younger together." (Raunkiaer).
This latter case may be represented by Hieracium aurantiacum, Hieracium pilosella, Achillea Millefolium, Lycopus uniflorus, Chrysanthemum Leucanthemum, Rumex acetosella, Veronica

serpyllifolia, Prunella vulgaris.

A brief description of the devices concerned in vegetative reproduction and met with during this experimental study is given as follows:

Stolon - "A slender stem (branch) that creeps over or slightly beneath the surface of the ground, taking root and sending up new shoots at the nodes. The internodes of a stolon may be more or less elongate, and as they desintegrate the new shoots become independent plants," (Johnson). "We often find in the axils of the leaves of the stolon buds which are capable of forming new individuals, either by immediately making an upright shoot" (Hieracium aurantiacum, Fig. I) "which takes root, or by sending out horizontal stolons which immediately bend their tips upwards and become rooted at the bases" (Raunkiaer) (creeping bent grass).

Veronica serpyllifolia herein studied forms creeping stems, which constitutes a vegetative device of reproduction, (Fig. VI).

Rootstock or rhizome - "A stout or slender subterranean stem, simple (Rumex acetosella) (Fig. II), (Viola spp.) (Fig. V), or branched (Kentucky blue grass), having internodes usually very short and leaves reduced to scales, which in time desintegrate leaving only the fibrous framework" (Johnson).

Runner - "A slender, stolon-like branch, commonly with single node near the middle between long internodes running along the ground and taking root at the end, that is at the terminal node." (Johnson), (Fragaria).

Caudex - "A short or elongated rootstock which persists at or near the surface of the ground after the season's aerial shoot dies down. New shoots arise from buds produced on the upper portion - that is below the base of the old stem," (Johnson), (Prunella vulgaris, (Fig. III), Chrysanthemum Leucanthemum).

Tuber - "A thick subterranean stem or branch, the thickening being the result of storage of food materials and water," (Johnson). "Lycopus uniflorus (Fig. IV), during summer, produces stolons which may be entirely beneath the surface, half-beneath, or completely aerial. In fall the flowering stem dries out, and a little later on, the part beneath the surface disappears; the stolons become independent and also are destroyed, except for the terminal part, which swells into a tuber. This part stays alive and enlarges during the winter, giving rise next spring to a new flowering stem,"(Translated from Victorin 1935).

Vegetative reproduction is a method found in individual plants originating directly from the mother-plant by means of manifold devices other than seed.

A true example of a plant which owes its existence to this method of reproduction is one which has been produced by a vegetative organ and which has gained its independent state by separation from the mother-plant, securing its nutrients by itself. This implies a root system of its own, and at least physiological separation (self-feeding) from the mother-plant.

No individual plant, in this sense of the word, was produced vegetatively by Ranunculus acris, Taraxacum officinale and Plantago major. But the tap root, persistent in these, may have subdivided to give rise to branches (Taraxacum officinale), or may produce new shoots from buds formed on the crown (Plantago major and Ranunculus acris) of the root. A fundamental difference is being made between these shoots, and individuals produced vegetatively, such as in Achillea Millefolium. All shoots are not individuals, but each individual vegetatively produced was once a shoot.

In some species (Chrysanthemum Leucanthenum and Prunella vulgaris), (Fig.III), the mother-plant may branch profusely, forming caudices or shoots that sooner or later will take root and gain their independence by division, at least physiologically speaking.

c. Experimental Technique

A comparative study of the vegetative and seminal reproduction was made experimentally by the direct-observation method. It consisted in the counting of chosen young individual specific plants and the placing of them in two categories:

those produced directly from seeds, and those originated from the mother-plant by means of vegetative devices other than seed.

A clear description was made of the fundamental characters used in the choice of young specimens of plant and in the numbering of them into one of the two groups above mentioned.

The specimens were selected at random over the whole experimental pasture-unit; they were all young enough so that the nature of their source of production was clearly indicated by organs, the character of which could not be morphologically confused. Only evident cases were selected. They were old enough so that their identification was certain. They had the evident appearance of young specimens.

The survey was made on five pasture-units, representing different sets of conditions, such as types of grazing management, soil fertility and soil humidity.

Eleven pasture plants, considered as all weedy species, were examined. This work is considered preliminary to a possible extensive survey, involving grasses and some dicotyledonous plants. Information of that kind concerning the more useful and predominant species of our permanent pasture sward should be practical, economical, and ecologically interesting.

The number of specimens observed for each species on each experimental pasture-unit varied from 20 to 50, depending upon the comparative importance found for each method of reproduction. When the distribution of the individuals showed about equal occurrence of the two methods of reproduction, the number of specimens examined was higher; otherwise it was lower.

The specimens were dug out with sufficient soil so as to preserve and distinguish conspicuously the vegetative characters used as an observation-basis in the grouping relative to the methods of reproduction.

d. Location and some characteristics of the Pastures Surveyed.

This experimental study has been conducted in the Eastern Townships of Quebec, more precisely in the Sherbrooke district. The counties here involved are Stanstead, Compton and Wolfe.

A map has been prepared to show the geographical distribution of the surveyed pastures in relation to soil zonation. Under the Macdonald College Pasture Committee, Wrenshall[1] has made a soil-reconnaissance in the Eastern Townships of Quebec in anticipation of a soil zonation. He has visualized the results of his investigation on a map, a part of which has been copied by the author and used to show the geographical distribution of the surveyed pastures in relation with this soil zonation (c.f. Map I.).

Eight different pastures were studied and their respective geographical distribution is indicated by a circled-number

(1) Unpublished data.

(c.f. Map I). As it will also be seen on this map, all the pastures which have been studied are distributed on the Appalachian upland podsol soils with, perhaps, two exceptions, that is, pastures numbered 1 and 8.

The topography, climate and soil type have all a profound influence on the agriculture of that district. The nature of those environmental factors are separately dealt with as follows:

Topography: The topography of this region has a considerable influence on the climate and soil characteristics of this area, and hence on agriculture. This district, mentioned above as formed of Appalachian upland podsol soils, is broken and hilly. The elevation is hundreds of feet (400-2000) above the main sea level. Some areas are much higher up than others. Mountains are also present. These topographical aspects have considerable importance. They are the characteristical features of the region.

Climate: The climate of this area is severe. The elevation over the main sea level makes the temperature colder in the winter season and cooler during the summer months. It increases also the snowfall and rainfall. As a matter of fact the total precipitation is abundant, but the monthly distribution is irregular, causing a drought period during July and the first part of August. The growing season is relatively short. Due to lakes and especially to the higher and more numerous mountains in the northern part of that zone, the growth-start is, therefore, a few days later.

The elevation above the sea level, and the exposures, affect the climate profoundly.

Soil nature: The pedological characteristics of that zone are those of the Appalachian upland podsol soils.

"Typical podsolized soils have a high accumulation of partly decayed organic matter in the surface soil, and very poor subsoils in which little organic matter or valuable mineral matter is present," (McKibbin and Pugsley). They are stated to be characterized by complete leaching of carbonates from the mature soils profile. Their basic element status is relatively low (that is the condition of Ca, Mg, K, Na), (Wrenshall).

Podsol soils are invariably open-textured in the surface foot or so, being of sandy, gravelly, stoney texture. The chemical composition of the prevalent metamorphic and sedimentary rocks from which the mineral part of most of the soils has arisen, was relatively poor in lime (McKibbin).

Summarizing the environmental factors, treated above, the relatively low winter temperatures found in this region, the relatively short growing season, the drought period during July and August, the heavy total rainfall and snowfall, the chemical composition of the mineral from which the soils have originated and the rugged and rocky surface, all contribute to make the grassland problems in this district difficult ones to solve.

Characteristics of some Pastures Studied: On Hodge's pasture, but light grazing was practised during the first part of the 1936 season. To maintain a sward of better constitution and nutritional value, the horse-mower was used to top the tall vegetation which had gone into the flowering or the seeding stage. This pasture had a relatively young sward and was apparently more fertile than some others surveyed.

On Coates' field, close grazing was practised throughout the pasturing season. Its botanical composition, together with that of any one of the other fields, is shown in Table II.

Goudreau's pasture was the poorest type of field in the group, the fertility being apparently excessively low, acidity high and the sward consequently very weedy in nature.

Boucher's area is a lowland pasture, a marsh-type of soil; the soil humidity was fair, the sward, apparently around twelve years old, was predominantly composed of *Agrostis tenuis* and *Festuca rubra*.

e. Presentation and Discussion of Results

Results obtained from the direct survey of the reproductive methods of certain pasture species have been condensed and are presented in Table I. These results are expressed on a comparable basis, that is in percentage of seminal reproduction.

On the basis of average of percentages, Hieracium aurantiacum, Achillea Millefolium, Chrysanthemum Leucanthemum, Rumex acetosella, Veronica serpyllifolia and Lycopus uniflorus and Viola spp. are species reproducing, and propagating (in general,) especially by vegetative means, having respectively, as average of percentages of seminal reproduction, the following numbers: 16.7; 6.0; 28.5; under 25; under 25; 0.0; under 25. The others, Ranunculus acris, Taraxacum officinale and Plantago major, have been found to reproduce almost entirely from seeds, being deprived completely of those vegetative organs which help the distribution and spreading of the species over the field. Their respective percentages of seminal reproduction were 100, 88 and 100. Prunella vulgaris belongs to both groups, reproducing to about an equal extent by both typical methods.

The above grouping is based upon averages of different percentages collected on different pasture swards representing different soil conditions. These different percentages, of course, vary from one pasture to another, but in some cases, a consistent trend in the variations is clearly indicated.

From the tabulated results, the grazing-management factor seems to have influenced the comparative importance of the seminal reproduction. That can be taken only as suggestive, because the proof cannot be really and scientifically made by statistical methods due to a lack of replication.

It is interesting, however, to note the consistent decrease of the percentage of the seminal reproduction of five species (Hieracium, Achillea, Prunella, Chrysanthemum and Taraxacum) on Coates' pasture, where grazing was relatively intense throughout the year compared to those prevailing on Hodge's pasture. This consistent decrease can be seen on Graph I.

The most striking difference between these two pasture-habitats is, undoubtedly, the grazing management, which was intense in one and light in the other. The fertility level is said to influence the seed germination and seedling establishment, but this could not be the primary cause of that difference in the seminal reproduction. Some species thrive better under a rather light or very light grazing management, but, in general, the stand of seedlings is more favoured by short vegetation (due to close grazing) and open sward than by taller vegetation (due to light grazing) and close sward (Jones,1934). Jones (1934) has studied extensively the grazing-management influence on the sward. Generally under good conditions, his conclusion was that the grazing factor makes the sward composition. This corroborates our findings.

The relationship between this grazing factor and the sward is a point that is still not completely cleared up. Among others, the methods of reproduction and the growth-forms are two main points closely related to that grazing factor.

Some plant species insure their persistence in the field through seed production. Bearing this in mind, it will be seen that a close continual grazing, in checking seed production, would thus control and steadily decrease the surface population of those species in the sward. This would be true of Taraxacum officinale, Plantago major, Ranunculus acris, according to our experimental results. Their relative percentages, both in the surface vegetation on Hodge's and Coates' pastures (Table II), and in the comparative importance of their seminal reproduction (Table I), support this assumption.

However, two other points have to be considered: palatability, and growth-forms. Plantago major is sometimes found very abundant in lawns that are closely and frequently cut. This must be due to a period, during the growing season, in which that plant species has gone into the seed stage, producing flowers and fruits close to the ground; then, the seedling-establishment being favoured by the short vegetation, the young plants, with their flat growing-form would withstand the drastic cuttings of the lawn-mower. Ranunculus acris has a bitter taste. When growth is rapid and grazing light, selective cropping will be practised by the stock; the taller plants of Ranunculus acris will be left ungrazed and may go through the seeding stage. Consequently, to help in the eradication of plant species reproducing mostly from seeds, the main point is to keep down the seed stage.

Hieracium aurantiacum, Achillea Millefolium and Rumex acetosella are, among the specific plants observed, the best equipped for rapid vegetative spreading. Chrysanthemum Leucanthemum and Prunella vulgaris and Viola spp. possess vegetative organs of reproduction and propagation, but they must spread mainly by the seminal method, their seeds being naturally or artificially disseminated.

Achillea Millefolium having a good spreading vegetative device and a pronounced horizontal aerial stem-growth, and being, moreover, almost entirely reproduced vegetatively, could easily survive very close grazing. Its great predominance in some lawns that are very closely cut is evidence supporting this assumption. This weedy species could not be well controlled in a permanent pasture by proper grazing management. Plantago major is equally well adapted in its growth-form to resist close cropping, but since it is reproduced mainly by seeds (unlike Achillea Millefolium), continual close grazing management should control it better than it can with Achillea.

Recent investigations made by the Macdonald College Pasture Committee have proved fertilization practices to be rather generally effective in weed eradication from the permanent pasture sward. However, the biotic factor might help even in the eradication of weed species which reproduce mainly by vegetative means, judging by the percentages of both the surface population of Achillea and the comparative importance of its seedlings on Hodge's and Coates' pastures.

Chrysanthemum Leucanthemum and Prunella vulgaris, which have their stems and caudices growing relatively more upright than Achillea and Hieracium plants and reproduce to a considerable extent seminally (especially Prunella vulgaris), should be fairly well controlled by a proper pasture grazing management, placing those two species in a medial position between Achillea and Ranunculus. Their percentages in the surface population and in the comparative importance of their seminal reproduction, on both Hodge's and Coates' fields, here also support the importance of the biotic factor in their eradication from permanent pastures.

The comparative importance of the seminal reproduction may change under different conditions of soil fertility and soil reaction. The physiological effect may be the inhibition of seed germination or injury to seedling-growth, but this could be confused with the effect of sward density and shortness of the vegetation on the seedling establishment.

Regarding the soil factors the results of previous investigations studied from the literature show different opinions and on some points apparent contradiction. Contrary to Whittet (1935), Maxton (1927) found that mixing dry fertilizer with seeds did not cause any noticeable injury, that happening only, according to Maxton, when moist soil is also mixed with the fertilizer and seed. Sherwin (1923) found that germination was inhibited by inorganic fertilizer and the seedlings injured by organic fertilizers, while Hicks (1900) and Shive (1917), using inorganic fertilizers, found that injury occurred to the seedling. Maxton has shown a reduction of germination due to fertilizers. Various fertilizers have a different influence on the same specific seed or on different specific seeds according to Maxton's and Whittet's investigations. Salter and Ilvaine (1920) found that soil reaction has a noticeable physiological effect on seed soil germination and growth of seedlings.

According to the above resume of literature on the effect of soil fertility and acidity on germination and growth of seedling, no general deductions could be made. It would depend, among other factors, on the kind of seed, and the kind of fertilizer. So the apparent conditions must be due to different experimental conditions, or to different material used.

Consequently with the present situation of our experiment having no replication from that standpoint to make a sound proof, and only a few variates within a small sample of the population in hand, nothing very suggestive could be drawn. However, Hieracium and Achillea were found reproducing very little through the seed method in the Goudreau-field (c.f. Graph I). According to this review of previous investigations on the effect of soil fertility on germination, the very poor state of the fertility of this pasture would have increased the germination rate. This low soil fertility, should also have favoured more or less the growth of seedlings. But for a good seedling establishment we are inclined to believe that favourable conditions would be a higher soil fertility and soil reaction of a pH around 5 or 6 (Salter and Ilvaine). Some pasture investigations on Goudreau-field with fertilizers have suggested a big lime deficiency. This may constitute a handicap for a better seedling establishment. Two other factors may have influenced the seedling establishment, that is a poor sward density favouring this establishment and a very lenient cropping by the stock which probably would be a competition factor against this establishment.

A soil chemical analysis would have indicated different degrees of soil fertility and, from that and data collected abundantly in the direct observation method on the comparative importance of the seminal reproduction regarding many specific plants, some interesting correlations could probably be secured.

Nothing consistent or suggestive can be deduced from the results collected on Boucher's pasture.

This phase of the work would have been more conclusive and extensive in its contribution if in the study some replications had been secured to enable us to study the results by statistical methods. Replications would mean similarity from the points of view of pasture sward-type, or of grazing management, and different, as far as possible, only from the factor of which the effect would be studied. But the serious effort of selecting pasture-replications would have to be made, if this work was to be proceeded with.

## III. A Study of the Comparative Importance of the Reproduction Methods by an Indirect Method, with an Investigation on the Soil Seed-flora of Pastures

### a. Introduction

The indirect method of studying the comparative importance of seminal and vegetative reproduction is rather new. It is based upon the ratio-value, for each specific plant, of the sum of germinated seed from a sample of the top soil-layer and its representation in the surface vegetation. The basic idea of this method is an assumption. Its preciseness is only an approximation, due to different characteristics of each specific plant. It is proposed for what it is worth.

This assumption is some kind of a biological law applied to the reproductive functions. To keep its importance and its integrity, each organic function must be necessary in the living activities of the plants (or any living thing): otherwise it will atrophy. So in plant evolutions and in the formation of species, varieties, strains and ecotypes, the seed-production function has been more or less necessary for the survival and propagation of the plants; under some dictates of habitat some plants may have evolved in the direction of vegetative reproduction and propagation - the seminal type being unnecessary or not useful, has decreased and atrophied more or less. For that reason (a biological law), between the types of plant reproducing exclusively by seeds or by the vegetative method, we find all degrees of comparative importance of the two methods of reproduction and propagation.

From that standpoint, then, the more a plant is reproduced and propagated by the vegetative method and is common in the surface vegetation, the lower should be the ratio-value above mentioned; and that, nothwithstanding the characteristics of the specific plant, such as the number of seeds produced, the size of the plant, its longevity, etc. A perennial plant, even though reproducing entirely by the seminal method (Plantago major) does not have to go to seed so freely as an annual to maintain the same surface representation.

The immediate results of the application of this indirect method may be of an approximate practical value, but also highly significant theoretically. It is worth further investigation.

Besides a knowledge of the comparative importance of the seminal reproduction within a species in different environments, and between species of plants within a habitat, an actual measurement of the soil's viable-seed content is found. In this regard, Stapledon, R.G., writes "It was considered then not only of great interest but probably of considerable practical value to conduct a survey of the buried (and viable) seeds underlying all main types of vegetation. Milton's paper set out the results obtained from the extensive survey, results which, it will be seen, are in fact of the greatest practical value to the land improver and are also of high significance from the ecological point of view," (1936).

A knowledge of the soil's viable seed content under different types of vegetation being acquired, it may be useful and economical in certain circumstances (in a renovation plan of the sward) to make use of that stored seed content, particularly when we know that under an artificial and new habitat (created by tillage and fertilization) the seed content of the soil will influence greatly the immediate sward of the renovated pasture. Such knowledge, for example, might be useful in the maintenance of a desirable pasture species (<u>Agrostis alba</u>) in the sward, or in the eradication of certain weedy plants.

We have in the province of Quebec many old permanent pastures that seem not greatly improved through fertilization or grazing practices alone. In the Sherbrooke district, where pasture researches have been conducted by the Macdonald College Pasture Committee, some pastures (McClary's at Hatley, MacKay Brothers at Sawyerville, and Goudreau's at Weedon Centre) did not give the expected results last year (1936). An investigation of the soil's viable seed content may throw light upon that question, in any case clearing up a doubt regarding the apparent deficiency of the soil's buried-seed flora.

Goudreau's pasture has been investigated from that point of view in this present study.

b. Material and Technique

i. Pastures Chosen

An attempt was made to have a few but definite different complexes of conditions under survey, with replications in each set of circumstances so as to control the data by statistical methods.

Three modifying factors were expected to be brought under statistical control; types of vegetation, fertilization and age of permanent pasture.

The types of vegetation were determined by the predominance of a specific plant or plants, or the turf-physiognomy of the pasture. The "Festuca-type" was represented by Coates' and Chartier's pastures at East Angus and Wottonville respectively; the "Danthonia-type" by Goudreau's area at Weedon Centre; the "Festuca-Agrostis-Poa-Trifolium-type" by Hodge's, Little's and Boucher's at Cookshire, Hatley and Garthby, respectively; the Poa-Trifolium-type by Johaan's at Coaticook. The district in which the survey was made is north and south of Sherbrooke in a podsol-soil-type region.

Four pastures surveyed were partly fertilized with mineral elements, affording then the analysis of the influence of that factor on the soil's buried-seed content. These pastures are Chartier's and Hodge's, which received applications of chemical fertilizers in the fall of 1935. The other two, fertilized in 1934 and 1933, are Little's and Johaan's respectively.

Permanent pastures of varying ages were studied. Chartier's and Hodge's areas were the last ones to be established, being approximately of 5 to 7 years old.

ii. Botanical Analysis of Surface Vegetation

The method used in the botanical analyses is based upon an ocular estimation of the percentage of ground covered by each individual species in quadrats. This is the method found best fitted for this type of work. It has proved satisfactory in similar botanical studies made under the Macdonald College Pasture Committee during the past five or six years.

The grid-quadrat consisted of a wooden frame with fine wires dividing the quadrat into 25 small sub-quadrats of equal size, 10 x 10 cm. each.

The area surveyed on each pasture was more or less restricted, and being chosen as representative as possible of the ordinary conditions of a certain pasture sward-type. Care was taken to select a uniform area as regard to topography, grazing conditions and sward-type. Striking variations in the same pasture-unit would have probably increased the variance to be recorded as experimental error.

For each pasture-area, 100 sub-quadrat readings, generally, were made, 5 sub-quadrats for each placement of the grid-quadrat frame. These placements, twenty in number, were uniformly distributed at random over all the unit of area.

"The percentage of ground covered was obtained by estimating the proportion of each sub-quadrat occupied by each individual species. Space not covered by any plants was recorded as "bare-ground," (Dore 1935). Each square was given the value of 100, and the smallest value in percentage allotted was 5%.

iii. Soil Sampling

A study of some correlations between the soil's surface vegetation and the soil's seed content of the top layer was planned. The soil sampling had, then, to be done on the same delimited area where the botanical readings were made, and that for any pasture surveyed.

Most of the soil's seed content lies in the first and second inches of surface soil. However, a second layer (1½" - 6") was examined and tested, but to a lesser extent than the first one.

The soil-sampler, a very simple apparatus, was a pipe 20 inches in length and 4 inches in diameter. To help with the sampling, one end of the pipe was sharpened and the other one fitted with an iron cross bar.

A single representative soil sample was made for each layer on each pasture, and submitted to the germination test. Twenty circular blocks of soil, $1\frac{1}{2}$ inches thick, uniformly distributed over the whole pasture-unit and taken at random, were thoroughly mixed to form the material of the representative sample of the first layer. Ten circular blocks of the second layer were considered enough to form a proper sample, as at that depth the seed flora is not so variable.

The soil samples of the first and second layers were measured volumetrically so as to represent, respectively, 100, and 40, square inches of pasture surface-area.

The stems and roots of the sample were removed. The soil was stored in fruit-jars till October, 1936, the time at which the germination tests were started in the greenhouse.

IV. Germination Test

The representative soil samples were thinly spread on sterilized soil in flats in the greenhouse.

A control-flat was also kept to check the sterilization processes and the contamination from foreign seed.

The flats were regularly and properly watered during the test, starting early in October and ending late in March.

Temperature and insect destruction were closely controlled.

Botanical identification was made as soon as the seedlings clearly showed their identity, and at intervals.

During the test, the soil surface (not the thin sterilized layer) became hard. A fine mulch was made by breaking and mixing the top layer.

c. Discussion of Results

i. Comparative Study of Seminal and Vegetative Reproduction by the Indirect Method

From a first glance at Tables III and IV, it is apparent that no correlation exists between the surface vegetation and the viable seed flora of the top soil-layer whatever may be the experimental-unit considered. Two Graphs, II and III, one made from data collected on Goudreau's pasture and representing a very poor type of vegetation, the other one drawn from the results gathered on Hodge's unfertilized field and showing a fairly good botanical composition, both illustrating this point. That lack of correlation was expected after being proved by other investigations, (Dore, Milton et al).

Why this lack of correlation? The actual vegetation is the living expression of the present habitat, but also bears traces of the past environment. It is the resulting effect of the environmental factors (edaphic, climatic and biotic) that prevail now and influence the botanical composition of the sward, and those factors that have slowly dictated the life-forms of the present specific vegetation which struggles more or less successfully in the natural selection. We thus find annuals mixed with perennials and seminally reproducing plants with vegetatively reproducing ones in the same permanent pasture sward.

The perennial vegetatively reproducing species, however, are predominant, being the expression of the unfavourable seasons (cold winter periods and summer droughts), the continual close-grazing management, and the competition-factor between plant species. They are the specific plants the best adapted to survive under such a habitat as prevails in our climate. They are may be, types, which, when seminal reproduction is checked by some environmental factors, can spend their energy in vegetative reproduction. But in this group of plants, the seeding function, not being necessary or being checked rather continuously in such circumstances, decreases in importance and may atrophy slowly and progressively. It is a biological law; an organ keeps its integrity only if impelled by necessity.

Annual plants and those reproducing largely by seeds are biological types that have followed another direction in the constant evolution of the plant kingdom, or have not evolved so far in that direction. Their presence in our permanent pastures is controlled by certain environmental factors, especially the grazing management and plant competition which are very drastic in their dictates; some of those plants may have life-forms of such a nature that they produce seeds even under a fairly close grazing set of conditions. Plantago major and Cerastium vulgatum flower close to the surface of the ground and thus escape grazing. This is the reason, among others, of their great abundance in the seed content of a pasture soil with close grazed sward conditions.

From the above consideration it should follow that the more a specific plant is depending upon its vegetative devices to survive and propagate, and the greater its surface population, the smaller should be, generally, the proportion of its seed content found in the top soil-layer. In reality, however, under experimental conditions, many disturbing factors interfere with this biological law and confuse its experimental expression, spoiling then the expected negative correlation. However, a table has been worked out on ratio-basis to prove this assumption. It is very suggestive.

This Table IV, showing ratios, is made out in four columns. All plant species met, either in the botanical readings or in the germination tests, figure in column 1. The sums of percentages of ground covered by each specific plant in the botanical readings of eleven pasture areas are presented in the second column. The sums of germinated seeds for each specific plant from the eleven corresponding soil-samples are listed in column 3. The fourth column shows ratios made with the number of column 3 over the corresponding number of column 2 for the same specific plant.

Those ratios show an approximation of the negative correlation between the vegetative reproduction habit and the seed-production habit met in the same plant, habits which are mutually opposed.

From the figures in column 4, plants were classified, the classification being based upon the ratio-value. Table V shows this tentative grouping. Three groups were made, according to the importance of the vegetative reproduction.

A specific plant well represented in the sward and poorly in the soil seed flora of the top-layer is assumed to be reproducing mainly from vegetative organs. This forms the first category of Table V, and corresponds to ratios of very low value. When the plants are rather well represented in both surface vegetation and top soil seed flora, they are assumed to be endowed with the habits of vegetative and seminal reproduction, which are both of considerable usefulness in the persistence of the plant. They figure in the second category (II) of Table V, and have ratio-values of medium size. In category (III), all plants are listed which have a very high ratio, or which are not represented in the sward.

It is interesting to note that this artificial and tentative grouping of Table V, though of pure theoretical value, corresponds to the findings made through the direct observation method of Table I, with a few marked divergencies only, such as in the cases of Taraxacum officinale, Rumex acetosella. Many possibilities may explain those exceptional cases, it may be a weakness in the experimental technique, or a lack of knowledge of some ecological points, such as the comparative seed-viability, or periodicity in germination, (Brenchley and Warrington, 1930) ( Stoa 1933). "Scarcity of viable seeds of some species in the soil may be due in some measure to the seeds remaining on the surface of the soil and germinating without any period of dormancy", (Chippendale and Milton). Other causes may be birds, rodents, etc.

The ratios of Achillea Millefolium, Hieracium aurantiacum, Lycopus uniflorus, Prunella vulgaris, Chrysanthemum Leucanthemum, Veronica serpyllifolia and Viola spp. in Table V support very well the results obtained by the direct observation method.

We must admit that the surface vegetation of a permanent pasture is more unstable than the soil-seed flora. The first flora reflects more intensely the environmental factors; the second flora, especially the seed flora of the second soil layer, can tell more about the history of the sward, keeping longer traces of the habitat.

ii. Soil Viable Seed Flora in Two Different Soil Layers

The general trend of the results of the germination tests gathered here in Table VI, shows a greater number of seeds in the surface soil layer, but we expected a greater difference and a better consistency, even with a thin soil layer as the top one (0 - 1½").

These results could not be treated successfully by statistical methods on account of an absence of replications of the same type of pasture sward. It would be "dangerous to draw any conclusion regarding seeds from the mere fact of their position in the soil taken by itself," (Chippendale and Milton, Jour. of Agric. Sci. Vol.22).

In Table VI the seeds germinated from each soil sample have been summed up regardless of species. Hodge's and Goudreau's turf layers are considerably higher than their respective sub-turf layers. This is not the case with Coates' layers, the difference being to the advantage of the sub-turf layer.

The inconsistency of those pairs of totals seems to be due to differences in the grazing management. Improper grazing on both Hodge's and Goudreau's pastures allowed the vegetation to set seeds. On the other hand on Coates' area the close grazing set of conditions throughout the year has kept the vegetation in the vegetative stage, decreasing apparently the soil seed content proportionately. This point is supported by Brenchley's results.

This should be a suggestion in view of weed eradication. Drastic grazing management would keep back from the seeding stage those plants that are mainly seminally reproduced, and finally decrease the surface vegetation and soil seed flora. The seed stock of the second soil layer, however, would be a more stable reserve of seeds which will be ready to grow only if favourable germinating conditions appear, being the case when the pasture is renovated by ploughing or harrowing. In other words a weed eradication plan never ends on account, specially, of the soil seed-flora.

iii. Seed of Meadow Plants in Young Pasture Soil

The seed stock of a soil does not follow closely the variations of the surface vegetation. On account of the viability and longevity of the seeds, the seed content of arable plants will gradually and slowly disappear. The longer the time since a permanent pasture was established from a meadow or other arable area, the smaller the reflection of that fundamental change of the habitat in the soil seed flora. "There is a close association between the buried seed flora and the history of the soil," (Brenchley). "In the light of Korsmo's results, there can be no doubt that the weed seed contents of field soils are greatly increased by seeds being carried to them from hay lofts and barns through the medium of manures. He found large quantities of Chenopodium album, Spergula arvensis, Stellaria media and Rumex acetosella seeds in the soil and manure samples," (Milton 1936). Chenopodium album was represented both in Hodge's and Boucher's soil samples. The presence of these specific plants were not detected in the surface vegetation.

iv. Quick-Germination Species in the Greenhouse-Test

Ranunculus acris, Cerastium vulgatum, Rumex acetosella, Spergula arvensis, Chenopodium album, Brassica spp. were the first specific plants to show up in this germination test, and that with great consistency in all soil-samples where they grew at all. Poa pratensis and Agrostis alba were two useful species, that grew relatively early also.

These results are of ecological significance. As a matter of fact, these quick germinating species are either annual arable-field plants, or pasture plants most widely represented in the soil-viable seed flora, proving to some extent that the seed-producing-organ is still a primary necessity to insure their survival and persistence. The quick-awakening habit in germination has been selected because the plant probably depended on the seminal reproduction method to persist in certain habitats. Otherwise the seed that is very persistent in its latent life-stage, in other words, having greater dormancy, would have been the selected type and probably the late germinating species in the greenhouse test.

A practical aspect of these germination-test results is that they indicate the sward that will result when the old pasture sward is to be renovated by various tilling methods.

Considering the useful specific plants, Agrostis alba and Poa pratensis, that have germinated relatively early, this bears a practical and economical value when a permanent pasture is to be re-established. "The buried seed investigations made on the soils some months before ploughing would show what species would have to be contended with and in what amounts," (Milton 1936 ).

Goudreau's pasture is of little grazing-value, the sward being so largely weedy in nature. However, the germination test shows Agrostis alba to be present in a fairly good quantity in the soil viable seed-content. Why is its presence in the sward so poor? It is principally an edaphic reason, precipitation being certainly favourable for germination and establishment at certain times of the year, and the sward density being poor and open. A renovation programme would first pay attention to the soil question; were the seeding of useful species necessary, or economical, however, buried-seed investigation would show what species would have to be contended with and in what amount.

To support this assumption, Stapledon has said: "it was found that the heavy manuring of molinia areas with phosphates and nitro-chalk if supported by heavy grazing soon let to Agrostis spp. (chiefly canina) almost completely taking the place of the molinia. It was obvious, moreover, that this colonization by Agrostis was largely due to the establishment of new plants derived from buried and viable seed."

v. Fertilization Effect on Soil Viable Seed Flora

It should be expected that the seed germination and seedling establishment would be influenced by a more or less fertilized seed bed and from that standpoint, all other environmental factors being equal, fertilization should influence the soil viable seed content, if the grazing management is drastic enough to hold the vegetation in the vegetative stage.

The results do not suggest any particular effect on the viable seed-flora. The types of vegetation are too different and the biotic factor, predominantly effective on both the sward and the seed-flora, so varying, that the pastures, here studied comparatively, cannot be compared even approximately.

To study this point the choice of material should be made with two things in mind; types of vegetation and grazing management.

vi. Correlation within a Species on Eleven Different Pasture Areas, Between Its Representation in the Surface Vegetation and in the Soil Seed-Flora

Results of eleven different areas have been gathered to find if there is a correlation within a species between its representation in the surface vegetation and in the seed flora. The pastures here considered are listed in Table VIII, and the species, of which the correlation coefficients have been calculated, are mentioned in the following table with their respective coefficients.

TABLE VII

Coefficient of Correlation within a Species over Eleven Pasture Areas, between the Surface Vegetation and the Soil Seed Flora.

| Specific plant | Correlation coefficient | Quality of the coefficient |
|---|---|---|
| 1 Poa pratensis | 0.810 | Highly significant |
| 2 Cerastium vulgatum | .686 | " " |
| 3 Plantago major | .626 | " " |
| 4 Rumex acetosella | .590 | " " |
| 5 Veronica serpyllifolia | .346 | Not significant |
| 6 Ranunculus acris | .324 | " " |
| 7 Agrostis alba | .133 | " " |
| 8 Trifolium repens | .0669 | " " |

The methods used to calculate these coefficients is clearly explained by Wallace (1931). An example is given of all formulae and calculations involved in one of these problems in Table VIII, and illustrated by Poa pratensis, and Graph IV visualizes this particular correlation.

Significant correlation coefficients were found in four species out of eight; Poa pratensis (0.810), Cerastium vulgatum (0.686), Plantago major (626), and Rumex acetosella (0.590). In reality there are probably some other species met with during this experimental study with a significant correlation, but the limited population dealt with and found in the germination test may not be entirely representative of the actual situation if the data were more numerous. In real similar conditions (from the biotic factor, especially) over all the pastures that we could find, we should have a very good correlation from that point of view for each specific plant, if the heredity of the ecotypical plants is quite stable and fixed.

Judging by the success found in these correlation coefficients, we can guess to a certain extent the quantitative presence of the particular species in the soil seed-content of a particular sward, but a seed test would give better information, before attempting any pasture improvement involving tillage and seeding.

vii. Types of Sward and Soil Seed Flora

Theoretically, and according to what we have said above, each different type of soil should have its particular and characteristic seed flora. But the biotic factor makes the sward and may quickly spoil the correlation, between the surface vegetation and the seed flora, and within a species over many pastures of the same sward-type.

In this experimental study no characteristic of the seed content has been found for each type of vegetation, notwithstanding the very different types we worked on. There is an exception, however, *Poa pratensis* has been found more abundant in the seed flora where its surface representation was the greater and that with a highly significant correlation coefficient. This is a characteristic to be considered. *Festuca rubra* had more germinated seeds on Chartier's and Coates' pastures, the two "Festuca-types" of sward.

## IV. General Conclusions

The results obtained in this study seem to justify the following conclusions:

1. Under the average conditions of this experiment, the percentages of seminal reproduction for eleven pasture plants were as follows: Achillea Millefolium, 6.0; Chrysanthemum Leucanthemum, 28.5; Hieracium aurantiacum, 16.7; Rumex acetosella, under 25.0; Veronica serpyllifolia, under 25.0; Lycopus uniflorus, 0.0; Viola spp., under 25.0; Ranunculus acris, 100; Taraxacum officinale, 88; Plantago major, 100; Prunella vulgaris, 50.

2. Drastic grazing management has decreased the importance of seminal reproduction, and the viable seed content of the top layer.

3. The data obtained in the direct observation method of studying seminal and vegetative reproduction were fairly well corroborated by those worked out in the indirect method. Only two exceptions (Taraxacum officinale and Rumex acetosella) were found unexplained.

4. There was no correlation between the order of quantitative-importance of the specific plants constituting the surface vegetation and that of the top-soil seed-flora.

5. A significant correlation was found within a specific plant between its representation in the surface vegetation and in the top-soil seed content of eleven pasture-units for the following species: *Poa pratensis*, *Cerastium vulgatum*, *Plantago major* and *Rumex acetosella*. This correlation was not significant for *Veronica serpyllifolia*, *Ranunculus acris*, *Agrostis stolonifera major* and *Trifolium repens*. An irregular grazing management is suggested as the chief distrubing factor of this correlation.

6. The sward types were characterized to some extent in the soil seed flora. The best "*Poa pratensis*" type of sward had in general the highest amount of seeds of that specific plant. The same thing was found for the best "*Festuca rubra*" pastures.

7. The soil of the young pasture-swards contained more seeds of arable plants.

8. The quick-germinating species found in this study should be well represented in the immediate sward resulting from the renovation of an old pasture by tilling methods.

9. An investigation of the soil's viable seed content as a preliminary operation in a renovation programme of the old permanent pasture-swards would give indication as to which useful plant species we would have to contend with in the seed mixtures and in what amount. This would be important for *Agrostis alba* under conditions similar to those of this experiment.

## BIBLIOGRAPHY


Bates, G.H. (1930): Effect of consolidation upon the botanical composition of poor grassland. Jour. Min, Agr. (Gt. Brit.) 37:583-589.

Brenchley, W.E. and Warrington, K. (1930): Weed seed population of viable soil. Jour. Ecol. 18: 235-272.

____________________ (1933): Weed seed population of viable soil. Jour. Ecol. 21: 103-27

Brown, E. (1930): The vitality of buried seeds. Science, Vol. LXXI, No. 1848: 561.

Chippendale, H.G., and Milton, W.E.J. (1936): Notes on the sampling of soil to determine the content of buried seeds. Herbage Reviews 4 (1-2): 12.

____________________ (1932): Note on the occurrence of buried seeds in the soil. J. of Agric. Science 22: 451-2.

____________________ (1934): On the viable seeds present in the soil beneath pastures. Jour. Ecol. 22: 508-31.

Christ, J.H. (1934): Reseeding burned-over lands in northen Idaho. Idaho Agri. Exp. Sta. Bul. 201.

Crocker, W. (1916): Mechanics of dormancy of seeds. Amer. Jour. Bot.(3) (3): 99.

Darlington, H.T. (1931): The fifty-year period for Dr. Beal's seed viability experiment. Amer. Jour. Bot. 18.

Dore, W.G. (1935): Ecological aspects of the pasture-conditioned climax in the Eastern Townships of Quebec (partly published).

Dunton, H.L., and McGee, C.R. (1934): The comparative ability of seedings of alfalfa, clovers and grasses to survive drought. Mich Sta. Quart. Bul. 16 (4):258-259.

Duvel, J.W.T. (1904): The vitality and germinations of seeds. U.S.D.A. Bur. Pl. Ind. Bul. 58.

Fischer, M.L. (1918): The dormant period of timothy seed after harvesting. Proc. Indiana Acad. Sci., p. 276.

Fryer, J.R. (1915): Weed seeds in farm lands. Agr. Gaz. of Canada 2 (1): 21-23.

Goss, W.L. (1924): The vitality of buried seeds. Jour. Agri. Res. 29: 349-362.

Griffiths, D. (1915): Native pasture grasses of the United States. U.S.D.A. Bul. 201.

Griffith, M. (1935): A preliminary report on the work of the Cahn Hill Improvement Scheme. Welsh Jour. Agric. XI: 140-147.

Hein, M.A., and Vinall, H.N. (1933): Persistence of grass and legume species under grazing conditions. Jour. A.S.A. Vol. 25: 595-602.

Hicks, G.H. (1900): The germination of seeds as affected by certain chemical fertilizers. U.S.D.A. Div. Bot. Bul. 24.

Howard, W.L. (1915): An experimental study of the rest period in plants: seeds. Miss. Agric. Exp. Sta. Res. Bul. 17.

Jones, L. I. (1934): Pasture management and its effect on the sward. Welsh Jour. Agric. X:246-265.

Johnson, A.M. (1931): Taxonomy of the flowering plants. The Century Co. New York.

Jones, M.G., and Jones, L.I. (1930): The effect of varying the periods of rest in rotational grazing. Welsh Plant Breeding Station Ser. H. (11), seasons 1921 - 1929.

McKibbin, R.R., and Pugsley, L.I. (1930): Soils of the Eastern Townships of Quebec. Macdonald College Tech. Bul. 6.

Maxton, Jacob L. (1927): Effect of fertilizers on the germination of seeds. Soil Science 23: 335-341. May.

Milton, W.E.J. (1936): The buried viable seeds of enclosed and unenclosed hill land. Welsh Plant Breeding Station Ser.H (14).

______________ (1933): The palatability of the self-establishing species contributing to different types of grassland. Empire Jour. Exp. Agric. I: 347-360.

Nichols, G.E. (1934): The influence of exposure to winter temperatures upon seed germination in various native American plants. Ecology 15: 364-373.

Raunkiaer, C.: The life-forms of plants and statistical plant geography. At. The Clarendon Press Oxford, 1934.

Rose, D.H. (1911): A Study of delayed germination in economic seeds. Bot. Gaz. 51: 220, 59:425.

Salter, R.M., and McIlvaine, T.C. (1920): Effect of reaction of solution on germination of seeds and growth of seedlings. Jour. Agr. Res. 19: 73-95.

Sherwin, M.E. (1923): The effect of fertilizers on germination and seedling growth. Jour. A.S.A. 15: 66-73.

Shive, J.W. (1917): The effect of salt concentration on the germination of seeds. N.J. Agric. Exp. Sta. Ann. Rpt. 1916: 455-457.

Stapledon, R.G. (1936): Investigations on the improvement of hill grazings. Welsh Pl. Br. Station Ser. H. (14).

____________ (1936): The improvement of hill land. The Scottish Jour. of Agric. Vol. XIX (1). Dept. of Agric. for Scotland.

____________ (1936): The improvement of hill land. The Scottish Jour. of Agric. XIX: 14-24.

____________ (1934): The Cahn Hill Improvement Scheme. Jour. Ministry Agric. XLI: 542-550.

____________ (1928): Cocksfoot grass (Dactylis glomerata) ecotypes in relation to the biotic factor. Jour. Ecology 16: 71-104.

Stoa, T.E. (1933): Persistence of viability of sweet clover seed in a cultivated soil. Jour. A.S A. 25 (3): 177-181.

Thomas, M.T.: The introduction and maintenance of nutritious and palatable species and strains. Welsh Plant Breeding Station Ser. H. (14). 1936.

Trumble, H.C., and Davies, J.G. (1934): The establishment, persistency and productivity of selected pasture species on an irrigated reclaimed swamp. Aust. Council for Sci. and Ind. Res. Bul. 80.

Turner, J.H. (1933): The viability of seeds. Kew Bul. of Miscellaneous Information (6).

Victorin Fr. Marie (1935): Flore Laurentienne. Imprimerie de LaSalle, Montreal.

Whittet, J.N. (1935): Effect of fertilizers on some pasture plant seeds. Agric. Gaz. N.S.W. 47: 7-8.

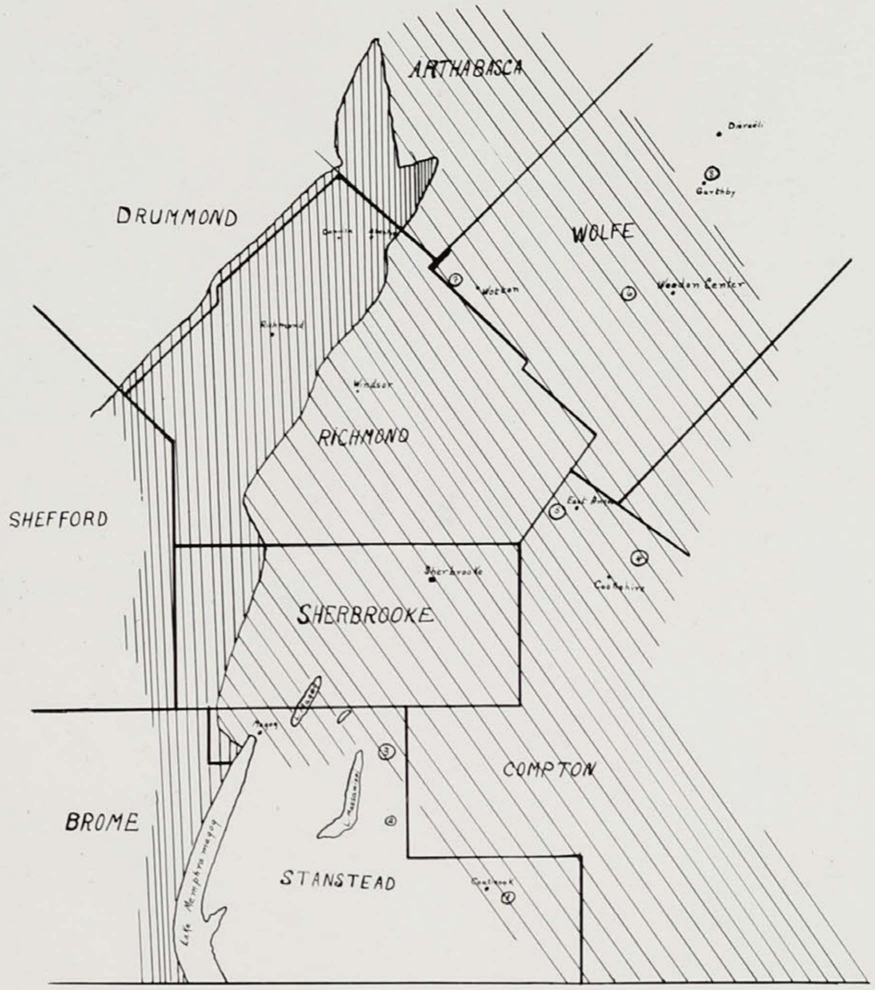
Wrenshall, C.L. (1936): Report of soil zonation studies. Pasture projects. (unpublished results.)

Pavlychenko, T.K. (1936): Quantitative study of the entire root systems of weed and crop plants under field conditions. (unpublished results.)

Wallace, H.A. and Snedecor, G.W. (1931): Correlation and machine calculation. Ames, Iowa.

# APPENDIX

GEOGRAPHICAL DISTRIBUTION OF SURVEYED PASTURES IN RELATION WITH SOIL ZONATION




LEGEND:

Transitional brown forest soils.

Appalachian upland podsol soils.

1. Johaan's farm, at Coaticook.
2. H. A. McClary's farm at Hatley.
3. Little Brothers' farm at Hatley.
4. Reginald Hodge's farm at Cookshire.
5. S.C. Coates' farm at East Angus.
6. G. Goudreau's farm at Weedon Centre.
7. N. Chartier's farm at Wotton.
8. Boucher's farm at Garthby.

Map I: Geographical distribution of surveyed pastures in relation with soil zonation.

TABLE I - Data Collected in the Direct Observation Method to find out the Percentage of Young Plants reproducing seminally.

Pasture Areas Surveyed - With some Dates of Survey.

| Specific Plants Observed. | | Hodge's 17/7/36 | Coates' 23/7/36 | Goudreau's 29/7/36 | Boucher's 30/7/36 | Little's unfertilized A | Little's unfertilized B | Little's fertilized A | Little's fertilized B | Little's average | McClary's | Average percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Hieracium aurantiacum | No. of Specimens | 50 | 40 | 40 | 25 | 25 | 25 | 25 | 25 | 25 | | |
| | No. of seedlings | 12 | 8 | 4 | 2 | 6 | 5 | 2 | 5 | 4.5 | | |
| | Percentage of " | 24 | 20 | 10 | 8 | 24 | 20 | 8 | 20 | 18 | | 16.7 |
| 2. Plantago major | No. of specimens | 50 | 30 | | 20 | | | | | | | |
| | No. of seedlings | 50 | 30 | | 20 | | | | | | | |
| | Percentage of " | 100 | 100 | | 100 | | | | | | | 100 |
| 3. Chrysanthemum Leucanthemum | No. of specimens | 50 | 40 | | | | | | | | | |
| | No. of seedlings | 21 | 6 | | | | | | | | | |
| | Percentage of " | 42 | 15 | | | | | | | | | 28.5 |
| 4. Taraxacum offinale | No. of specimens | 25 | 40 | | 20 | | | | | | | |
| | No. of seedlings | 24 | 28 | | 20 | | | | | | | |
| | Percentage of " | 96 | 70 | | 100 | | | | | | | 88. |
| 5. Ranunculus acris | No. of specimens | 25 | 20 | | 20 | | | | | | | |
| | No. of seedlings | 25 | 20 | | 20 | | | | | | | |
| | Percentage of " | 100 | 100 | | 100 | | | | | | | 100 |
| 6. Achillea Millefolium | No. of specimens | 40 | 44 | 25 | 33 | 20 | 20 | 20 | 20 | 20 | | |
| | No. of seedlings | 9 | 2 | 1 | 4 | 1 | 0 | 0 | 0 | .25 | | |
| | Percentage of " | 22.5 | 4.5 | 4 | 12.1 | 5 | 0 | 0 | 0 | 1.25 | | 6.0 |
| 7. Prunella vulgaris | No. of specimens | 50 | 47 | | 41 | 25 | 25 | 25 | 25 | 25 | | |
| | No. of seedlings | 25 | 18 | | 31 | 11 | 11 | 13 | 14 | 12.5 | | |
| | Percentage of " | 50 | 38.3 | | 75.5 | 44 | 44 | 52 | 56 | 50 | | 52 |
| 8. Lycopus uniflorus | No. of specimens | | | | | | | | | | 30 | |
| | No. of seedlings | | | | | | | | | | 0 | |
| | Percentage of " | | | | | | | | | | 0 | |

9. Veronica seryyllifolia — reproduced mainly by vegetative method.

10. Viola spp. — reproduced mainly by vegetative method.

11. Rumex acetosella — reproduced mainly by vegetative method.

Note: We refer here to <u>true</u> seedlings.

TABLE II - BOTANICAL READINGS PRESENTED IN PERCENTAGE GROUND COVERED ON AN AVERAGE BASIS OF 100.

| PASTURE AREAS READ = | Goudreau's | Chartier's fertilized | Chartier's unfertilized | Johaan's fertilized | Johaan's unfertilized | Little's fertilized | Little's unfertilized | Hodge's fertilized | Hodge's unfertilized | Coates' unfertilized | Boucher's | Little's fertilized (A) | Little's fertilized (B) | Little's unfertilized (A) | Little's unfertilized (B) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF READINGS | 100 | 50 | 50 | 100 | 100 | 100 | 100 | 100 | 125 | 100 | 100 | 100 | 100 | 100 | 100 |
| SPECIFIC PLANTS | | | | | | | | | | | | | | | |
| Bare ground | 8.65 | 5.3 | 20.4 | 6.75 | 14.25 | 14.25 | 24.7 | 7.45 | 11.72 | 12.9 | 12.60 | 12.3 | 16.2 | 21.2 | 28.2 |
| Mosses | 47.45 | 20.5 | 13.7 | 19.10 | 18.85 | 19.75 | 15.9 | 27.40 | 19.88 | 28.65 | 22.90 | 14.3 | 25.2 | 14.6 | 17.2 |
| Trifolium repens | .95 | 26.3 | 4.4 | 23.70 | 11.00 | 13.65 | 4.6 | 14.85 | 13.72 | 1.15 | 6.95 | 14.8 | 12.5 | 5.7 | 3.5 |
| Agrostis stolonifera major | .50 | 9.5 | 9.0 | 9.2 | 5.85 | 5.10 | 3.3 | 7.9 | 7.24 | 4.55 | | 8.5 | 1.7 | 4.1 | 2.5 |
| Agrostis tenuis | | | | | | | | | | | 24.35 | | | | |
| Agrostis hyemalis | | 2.0 | 0.5 | | | | | .10 | .04 | | | | | | |
| Phleum pratense | 0.2 | 3.3 | 2.4 | 3.25 | 4.60 | 1.85 | 1.55 | 4.10 | 2.60 | 1.4 | .6 | 2.7 | 1.0 | 2.5 | .6 |
| Festuca rubra | | 17.5 | 20.7 | | .80 | 5.85 | 9.3 | 8.05 | 13.04 | 30.9 | 11.35 | 11.7 | | 17.9 | .7 |
| Poa pratensis | .05 | .1 | .3 | 13.1 | 8.25 | 10.00 | 5.85 | 1.35 | 2.36 | 1.15 | 2.55 | 9.1 | 11.1 | 5.9 | 5.8 |
| Danthonia spicata | 15.35 | .3 | 2.6 | | | 9.9 | 8.45 | .85 | 1.48 | 2.95 | | 7.4 | 12.4 | 7.7 | 9.2 |
| Panicum spp. | 2.8 | .8 | 1.0 | | | .2 | 0.85 | 2.80 | 1.24 | 1.3 | | .3 | .1 | 1.0 | .7 |
| Lycopus uniflorus | 7.4 | 3.7 | 3.9 | | | 0.85 | 2.5 | .65 | .56 | 2.6 | .05 | .4 | 1.3 | 2.4 | 2.6 |
| Hieracium aurantiacum | 12.85 | 4.3 | 13.2 | 12.55 | 10.15 | 3.75 | 6.6 | 4.20 | 3.28 | .4 | .6 | 2.3 | 5.2 | .9 | 12.3 |
| Fragaria virginiana | .15 | | | | .05 | .05 | 2.35 | .75 | .36 | | .30 | .1 | | 2.5 | 2.2 |
| Achillea Millefolium | .5 | .4 | 1.3 | 2.65 | 9.25 | 5.25 | 5.05 | .20 | .84 | .8 | .30 | 1.7 | 8.8 | 3.6 | 6.5 |
| Sisyrinchium augustifolim | .1 | | | .05 | | .15 | .25 | .3 | .08 | .15 | .10 | | .3 | .3 | .2 |
| Solidago spp. | .1 | | | | | | | .1 | | | | | | | |
| Rumex acetosella | .65 | .20 | 1.0 | .8 | .8 | .15 | .7 | .15 | .28 | .2 | | .2 | .1 | .7 | .7 |
| Hypericum perforatum | .05 | | | | | | | .05 | | .05 | | | | | |
| Potentilla simplex | .30 | | .10 | .05 | .05 | .9 | .45 | .1 | | .05 | | .9 | .9 | .4 | .5 |
| Hydrocotyle americana | .2 | | | | .15 | | | .35 | .08 | .2 | | | | | |
| Prunella vulgaris | .2 | .3 | .7 | .05 | 1.0 | .45 | .25 | .95 | 1.08 | .25 | 2.0 | .8 | .1 | .1 | .4 |
| Viola spp. | .25 | .5 | .5 | .65 | 1.45 | .55 | .55 | .95 | 1.24 | 15.3 | .2 | 1.1 | | .9 | .2 |
| Anaphalis margaritacaea | .05 | | | | | | .25 | | | | | | | .40 | .10 |
| Lobelia inflata | .05 | .1 | | .1 | | .05 | .1 | | | | | .1 | | .2 | |
| Chrysanthemum Leucanthemum | | .1 | .4 | .4 | 1.35 | .1 | | 2.35 | 1.84 | 1.1 | | .2 | | | |
| Plantago major | .05 | .1 | .1 | .35 | .95 | .05 | | 6.81 | 4.08 | 1.0 | 4.75 | .1 | | | |
| Ranunculus aeris | | 1.2 | 1.2 | 2.15 | 5.45 | 1.5 | 1.1 | 2.15 | 2.84 | .7 | 5.45 | 2.5 | .5 | 1.0 | 1.2 |
| Taraxacum officinale | | | .4 | 3.45 | 2.95 | 1.55 | 1.2 | 2.15 | 1.44 | 1.05 | 3.0 | 2.40 | .7 | 2.10 | .30 |
| Veronica officinalis | | | | .10 | .25 | .45 | .05 | | .48 | .05 | .4 | .90 | | .10 | |
| Carex spp. | .10 | .20 | .10 | .15 | .65 | .3 | .45 | .2 | .56 | .25 | .2 | .5 | .1 | .5 | .4 |
| Oxalis europaea | | .1 | .8 | .15 | .25 | .15 | .25 | .35 | .84 | .60 | .20 | .20 | .10 | .30 | ,20 |
| Antennaria neglecta | | | | | .55 | .35 | .60 | | | .20 | .45 | .40 | .3 | .2 | 1.0 |
| Lycopodium spp. | .6 | | | | | | | | | | | | | | |
| Veronica serpyllifolia | | .5 | .4 | | | 1.05 | 1.9 | .25 | 1.48 | | .2 | 1.1 | 1.0 | 2.0 | 1.8 |
| Juncus spp. | .35 | 2.5 | | | | | .05 | .65 | .24 | | .05 | | | .1 | |
| Spirae spp. | .1 | | | | | | | | | | | | | | |
| Cerastium vulgatum | | .1 | .1 | .7 | .3 | .35 | .3 | .45 | .52 | .05 | .15 | .4 | .3 | .1 | .5 |
| Geum spp. | | | | | .15 | | | | | | .05 | | | | |
| Galium spp. | | .1 | | .05 | .15 | | .05 | | | .05 | .05 | | | .10 | |
| Potentilla norvegica | | | | | | .05 | | | .24 | | | .1 | | | |
| Agropypon repens | | | | | | | | .4 | 3.6 | | | | | | |
| Erigeron spp. | | | | | .1 | | .15 | .3 | .12 | | | | .1 | .2 | .1 |
| Trifolium pratense | | | | .2 | .25 | | | .2 | .16 | | | | | | |
| Leontodon autumnalis | | | | .15 | | | | | .16 | | | | | | |
| Festuca elatior | | | | .05 | .05 | .25 | .25 | | .28 | | | .5 | | .1 | .4 |
| Euphrasia canadensis | | | .6 | | .05 | | | | | | | | | | |
| Circium spp. | | | | .1 | .05 | | | .1 | | | | | | | |
| Plantago lanceolata | | | | | | .05 | | | | | | | | .1 | |
| Oenothera perennis | | | .2 | | | .05 | | | | | | | | .1 | |
| Vicia cracca | | | | | | | .1 | | | | | .2 | | | |

Note: Little's fertilized and unfertilized are averages of Little's fertilized A and B and unfertilized A and B respectively.

Table III - NUMBER OF SPECIFIC SEEDS GERMINATED ON EACH PASTURE SOIL-SAMPLE

| PASTURE SOIL-SAMPLE | Johann's fertilized | Johann's unfertilized | Hodge's fertilized | Hodge's unfertilized | Hodge's turf | Hodge's sub-turf | Goudreau's turf | Goudreau's sub-turf | Little's fertilized | Little's unfertilized | Little's fertilized (A) | Little's fertilized (B) | Little's unfertilized (A) | Little's unfertilized (B) | Chartier's fertilized | Chartier's unfertilized | Coates' turf | Coates' sub-turf | Boucher's turf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC PLANTS | | | | | | | | | | | | | | | | | | | |
| Cerastium vulgatum | 27 | 28 | 60 | 39 | 62 | 19 | | | 6.5 | 12 | 3 | 10 | 8 | 16 | 3 | 5 | 4 | | 22 |
| Rumex acetosella | 15 | 11 | 24 | 12 | 33 | 6 | 12 | 3 | 6. | 14 | 1 | 11 | 9 | 19 | 15 | 22 | 2 | 3 | 3 |
| Ranunculus acris | 2 | 7 | 7 | 30 | 16 | 28 | 114 | 9 | 3. | 10.5 | 2 | 4 | 15 | 6 | 20 | 9 | 5 | 13 | 4 |
| Agrostis alba | 32 | 29 | 6 | | | | 23 | 9 | 4. | 12.5 | 2 | 6 | 13 | 12 | | 6 | 6 | 1 | 12 |
| Veronica serpyllifolia | 3 | 5 | 10 | 1 | 14 | 5 | 1 | | 0.5 | 2 | | 1 | 2 | 2 | 2 | 4 | 1 | 1 | 10 |
| Poa pratensis | 14 | 1 | 1 | 3 | | 1 | 2 | | 5. | 6 | | 10 | 5 | 7 | | | 1 | | 1 |
| Oenothera perennis | | | 1 | | 3 | | | | 0.5 | 0.5 | | | 1 | | 14 | 7 | | | |
| Plantago major | 1 | | 3 | 2 | 5 | 4 | | | | | | | | | 1 | | 4 | | 2 |
| Crucifera spp. | | | 1 | 12 | 4 | 1 | | | | | | | | | | | 1 | 1 | |
| Lobelia inflata | 1 | 2 | | | | | 12 | 1 | 0.5 | | | 1 | | | | | 5. | 3 | |
| Chrysanthemum Leucanthemum | | | 2 | | 3 | 2 | | | | 0.5 | | | | 1 | | | | | |
| Phleum pratense | 1 | 11 | | | 1 | | | | | | | | | | | | | | |
| Spergula arvensis | | | 1 | 4 | 7 | | | | | 2.5 | | | | 1 | 4 | 7 | 2 | | |
| Festuca rubra | | | | | | | 9 | 2 | 4 | 0.5 | 2 | 6 | | 1 | | 5 | | 1 | |
| Danthonia spicata | | | | | | | | | | | | | | | | | | | 2 |
| Chenopodium album | | | 1 | | 3 | 2 | | | | | | | | | | 1 | | | 1 |
| Trifolium repens | 1 | | 2 | 1 | 1 | | | | | | | | | | | | 1 | | 4 |
| Prunella vulgaris | | 2 | | | 1 | | | | | | | | | | | | | | 3 |
| Poa compressa | | | | 1 | | | | | 0.5 | | 1 | | | | 1 | | | | 1 |
| Gallium spp. | | | | | | | 1 | | | | | | | | | | | | 1 |
| Hieracium aurantiacum | 1 | | | | | | | | | | | | | | | | | | |
| Taraxacum officinale | | | 1 | | | 2 | | | | | | | | | | | | | |
| Equisetum arvense | | | | | | 1 | 7 | | 3.5 | 3.5 | 4 | 3 | 6 | 1 | 12 | 7 | | 4 | |
| Panicum spp. | | | | 2 | 1 | | | | | | | | | | | | | 1 | |
| Luzula campestris | | | | | | | 25 | 19 | 2 | 3 | | 4 | 6 | | 29 | 11 | | 7 | 2 |
| Carex spp. | | | 3 | | | 1 | | | | | | | | | | | | | |
| Achillea Millefolium | | 1 | | | | | | | | 0.5 | | | 1 | | | | | | |
| Oxalis europaea | | 1 | | | | | | | | 0.5 | | | 1 | | | | | | |
| Viola spp. | | | | | | | | | | | | | | | | | | | |
| Circium spp. | | 1 | | | | | 2 | | | | | | | | | | | | |
| Anaphalis margaritacea | | | | | | | | | | | | | | | | | | | |
| Antennaria spp. | 1 | | | | | | | | | | | | | | | | | | |

Table IV. Showing ratio of the sums of percentages of ground-covered by each specific plant and its sum of germinated seeds on eleven pastures.

| Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|
| Specific Plants | Sum of percentages of ground-covered by each specific plant on 11 pastures | Sum of germinated seeds for each specific plant on 11 pastures | Ratio= Column 3 / Column 2 |
| Agropyron repens | 4.0 | 0.0 | 0.0 |
| Lycopus uniflorus | 22.21 | 0.0 | 0.0 |
| Fragaria virginiana | 4.01 | 0.0 | 0.0 |
| Juncus spp. | 3.84 | 0.0 | 0.0 |
| Potentilla simplex | 2.0 | 0.0 | 0.0 |
| Agrostis stolonifera compacta | 24.35 | 0.0 | 0.0 |
| Agrostis hyemalis | 5.64 | 0.0 | 0.0 |
| Veronica officinalis | 1.78 | 0.0 | 0.0 |
| Viola spp. | 22.04 | 0.5 | 0.0226 |
| Achillea Millefolium | 26.54 | 1.0 | 0.39 |
| Hieracium aurantiacum | 71.88 | 3.0 | 0.04 |
| Trifolium repens | 121.27 | 6.0 | 0.049 |
| Festuca rubra | 117.49 | 15.5 | 0.131 |
| Taraxacum officinale | 17.19 | 1.0 | 0.058 |
| Oxalis europaea | 3.69 | 1.5 | 0.406 |
| Danthonia spicata | 41.88 | 18.5 | 0.44 |
| Antennaria neglecta | 2.15 | 1.0 | 0.46 |
| Phleum pratense | 25.85 | 12.5 | 0.48 |
| Plantago major | 18.24 | 13.0 | 0.71 |
| Poa pratensis | 45.16 | 34.0 | 0.75 |
| Chrysanthemum Leucanthemum | 7.64 | 7.0 | 0.91 |
| Prunella vulgaris | 7.23 | 7.0 | 0.96 |
| Agrostis stolonifera major | 62.15 | 130.5 | 2.09 |
| Panicum spp. | 10.99 | 35.0 | 3.18 |
| Ranunculus acris | 23.74 | 141.5 | 5.96 |
| Veronica serpyllifolia | 5.78 | 39.5 | 6.83 |
| Carex spp. | 3.16 | 75.0 | 23.73 |
| Rumex acetosella | 4.93 | 143.0 | 27.1 |

Table IV - Continued

| Column 1 | Column 2 | Column 3 | Column 4 |
| --- | --- | --- | --- |
| Lobelia inflata | 0.4 | 16.5 | 41.2 |
| Cerastium vulgatum | 3.02 | 206.5 | 68.37 |
| Oenothera perennis | 0.25 | 22.5 | 90.0 |
| Brassica spp. | 0.0 | 13.0 | 0.0 |
| Spergula arvensis | 0.0 | 5.0 | 0.0 |
| Chenopodium album | 0.0 | 3.0 | 0.0 |
| Sisyrinchium augustifolium | 1.18 | 0.0 | 0.0 |
| Solidago spp. | 0.20 | 0.0 | 0.0 |
| Hypericum perforatum | 0.15 | 0.0 | 0.0 |
| Hydrocotyle americana | 0.98 | 0.0 | 0.0 |
| Anaphalis margaritacea | 0.3 | 2.0 | 6.66 |
| Lycopodium spp. | 0.6 | 0.0 | 0.0 |
| Spirae spp. | 0.1 | 0.0 | 0.0 |
| Linaria spp. | 0.05 | 0.0 | 0.0 |
| Geum spp. | 0.2 | 0.0 | 0.0 |
| Galium spp. | 0.45 | 2.5 | 0.0 |
| Potentilla norvegica | 0.29 | 0.0 | 0.0 |
| Erigeron spp. | 0.67 | 0.0 | 0.0 |
| Trifolium pratense | 0.81 | 0.0 | 0.0 |
| Leontodon autumnalis | 0.31 | 0.0 | 0.0 |
| Festuca elatior | 0.88 | 0.0 | 0.0 |
| Euphrasia canadensis | 0.65 | 0.0 | 0.0 |
| Cirsium spp. | 0.25 | 0.0 | 0.0 |
| Plantago lanceolata | 0.05 | 0.0 | 0.0 |
| Vicia cracca | 0.10 | 0.0 | 0.0 |

Table V. A Tentative List of Plants Reproducing by Different Methods. Their Grouping Being Based on the Ratio-Value.

| Category I | | Category II | | Category III | |
|---|---|---|---|---|---|
| Vegetative Reproduction most Important | | Both Seminal and Vegetative Reproductions Important | | Seminal Reproduction Alone or Most Important | |
| Specific Plants | Ratio-Value | Specific Plants | Ratio-Value | Specific Plants | Ratio-Value |
| Agropyron repens | 0.0[1] | Agrostis stolonifera var. major | 2.09 | Chenopodium album | 0.0[2] |
| Viola spp. | 0.0226 | Poa pratensis | 0.75 | Spergula arvensis | 0.0 |
| Achillea Millefolium | 0.037 | Phleum pratense | 0.48 | Brassica spp. | 0.0 |
| Hieracium aurantiacum | 0.04 | Danthonia spicata | 0.44 | Oenothera perennis | 90. |
| Trifolium repens | 0.049 | Panicum spp. | 3.18 | Cerastium vulgatum | 68.3 |
| Festuca rubra | 0.13 | Rumex acetosella | 27.1 | Lobelia inflata | 41.2 |
| Lycopus uniflorus | 0.0 | Chrysanthemum Leucanthemum | 0.91 | | |
| Fragaria virginiana | 0.0 | Plantago major | 0.71 | | |
| Juncus spp. | 0.0 | Ranunculus acris | 5.96 | | |
| Potentilla spp. | 0.0 | Carex spp. | 23.7 | | |
| Agrostis stolonifera var. compacta | 0.0 | Oxalis europaea | 0.406 | | |
| Agrostis hyemalis | 0.0 | Veronica serpyllifolia | 6.83 | | |
| Veronica officinalis | 0.0 | Antennaria neglecta | 0.46 | | |
| Taraxacum officinale | 0.058 | | | | |

(1) Ratio-values of that column represented by a (0.0) are those of plants present in the surface vegetation and not in the viable seed-content that has germinated.
(2) Ratio-values of that column represented by a(0.0) are those of plants absent in the surface vegetation and present in the viable seed-content as shown in Table III.

TABLE VI

Comparison of Soil Viable Seed Flora in Two Different Layers

| Specific Plants | Hodge's | | Gaudreau's | | Coates' | |
|---|---|---|---|---|---|---|
| | Top-layer | Sub-top-layer | Top-layer | Sub-top-layer | Top-layer | Sub-top-layer |
| Cerastium vulgatum | 62 | 19 | | | 4 | |
| Rumex acetosella | 33 | 6 | 12 | 3 | 2 | 3 |
| Ranunculus acris | 16 | 28 | 44 | 9 | 5 | 13 |
| Agrostis stolonifera major | | | 23 | 9 | 6 | 1 |
| Veronica serpyllifolia | 14 | 5 | 1 | | 1 | 1 |
| Poa pratensis | | 1 | 2 | | 1 | |
| Oenothera perennis | 3 | | | | | |
| Plantago major | 5 | 4 | | | 4 | |
| Crucifera spp. | 4 | 1 | | | | |
| Lobelia | | | 12 | 1 | 1 | 1 |
| Chrysanthemum Leucanthemum | 3 | 2 | | | 5 | 3 |
| Phleum pratense | 1 | | | | | |
| Spergula arvensis | 7 | | | | | |
| Festuca rubra | | | | | 2 | |
| Danthonia spicata | | | 9 | 2 | | 1 |
| Chenopodium album | 3 | 2 | | | | |
| Trifolium repens | 1 | | | | | |
| Brunella vulgaris | | 1 | | | 1 | |
| Poa compressa | | | | | | |
| Galium spp. | | | | | | |
| Hieracium aurantiacum | | | 1 | | | |
| Taraxacum officinale | | 2 | | | | |
| Equisetum arvense | | 1 | | | | |
| Luzula campestris | | | | | | 1 |
| Panicum spp. | 1 | | 7 | | | 4 |
| Carex spp. | | 1 | 25 | 19 | | 7 |
| Achillea Millefolium | | | | | | |
| Oxalis europaea | | | | | | |
| Viola spp. | | | | | | |
| Cirsium spp. | | | | | | |
| Gnaphalium spp. | | | 2 | | | |
| Antennaria neglecta | | | | | | |
| Total | 153 | 73 | 138 | 43 | 32 | 35 |

TABLE VIII

Summary of Calculations of the Correlation Between the Representation of <u>Poa fratensis</u> in the surface vegetation and the Top-soil Seed Flora on Eleven Pasture Areas.

| | A | X | AX | $A^2$ | $A^2$ |
|---|---|---|---|---|---|
| Different Pasture-areas | Percentage of surf-veget. | Representation in the top soil seed flora | | | |
| 1 Johaan's fertilized area | 13.1 | 14.0 | 183.4 | 171.61 | 196 |
| 2 Little's fertilized area | 10.1 | 5.0 | 50.5 | 102.01 | 25 |
| 3 Johaan's unfertilized area | 8.25 | 1.0 | 8.25 | 68.06 | 1 |
| 4 Little's unfertilized area | 5.85 | 6.0 | 35.1 | 34.22 | 36 |
| 5 Boucher's unfertilized area | 2.55 | 1.0 | 2.55 | 6.50 | 1 |
| 6 Hodge's unfertilized area | 2.36 | 3.0 | 7.08 | 5.56 | 9 |
| 7 Hodge's fertilized area | 1.36 | 1.0 | 1.36 | 1.84 | 1 |
| 8 Coates' unfertilized area | 1.15 | 1.0 | 1.15 | 1.32 | 1 |
| 9 Chartier's unfertilized area | 0.30 | 0.0 | 0.0 | 0.09 | 0 |
| 10 Chartier's fertilized area | 0.10 | 0.0 | 0.0 | 0.01 | 0 |
| 11 Goudreau's unfertilized area | 0.05 | 2.0 | 0.1 | 0.0 | 4 |
| Total: | 45.17 | 34.0 | 289.49 | 391.25 | 274.0 |
| Mean: | 4.1063 | 3.09 | | | |

<u>Formulae and Calculations:</u>

$$AS(M_X) = 45.17 \times 3.09 = 139.57$$
$$SA(M_A) = 45.17 \times 4.1063 = 185.4815$$
$$SX(M_X) = 34.0 \times 3.09 = 105.06$$
$$SA^2 - SA(M_A) = 391.25 - 185.48 = 205.77$$
$$SX^2 - SX(M_X) = 274 - 105.06 = 168.94$$

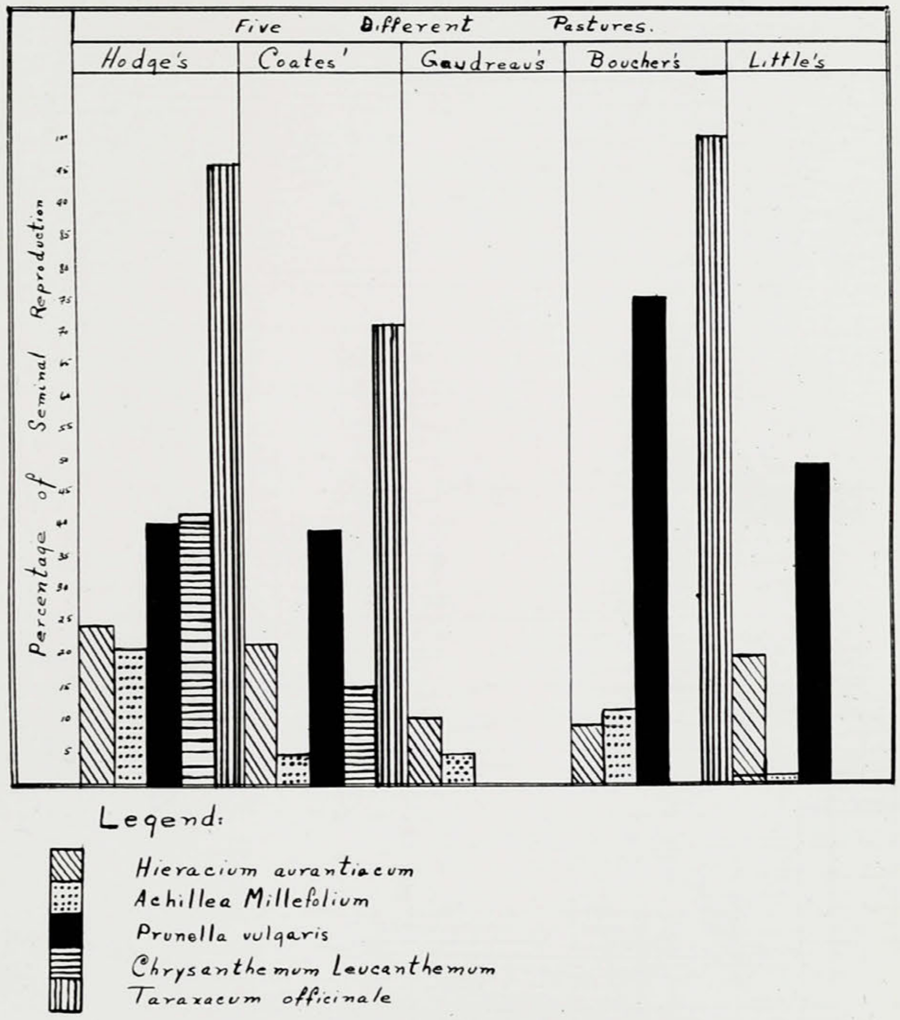
$$r = \frac{S(Ax) - S(A)\ (Mx)}{\sqrt{SA^2 - SA(M_A)}\sqrt{SX^2 - SX(M_X)}} \qquad r = \frac{149.92}{186.40} = .804$$

Correlation Coefficient = .804

With 10 degrees of freedom and 2 variables, 0.576 is the least value which can be considered significant, and 0.708 is the least value which can be considered highly significant.

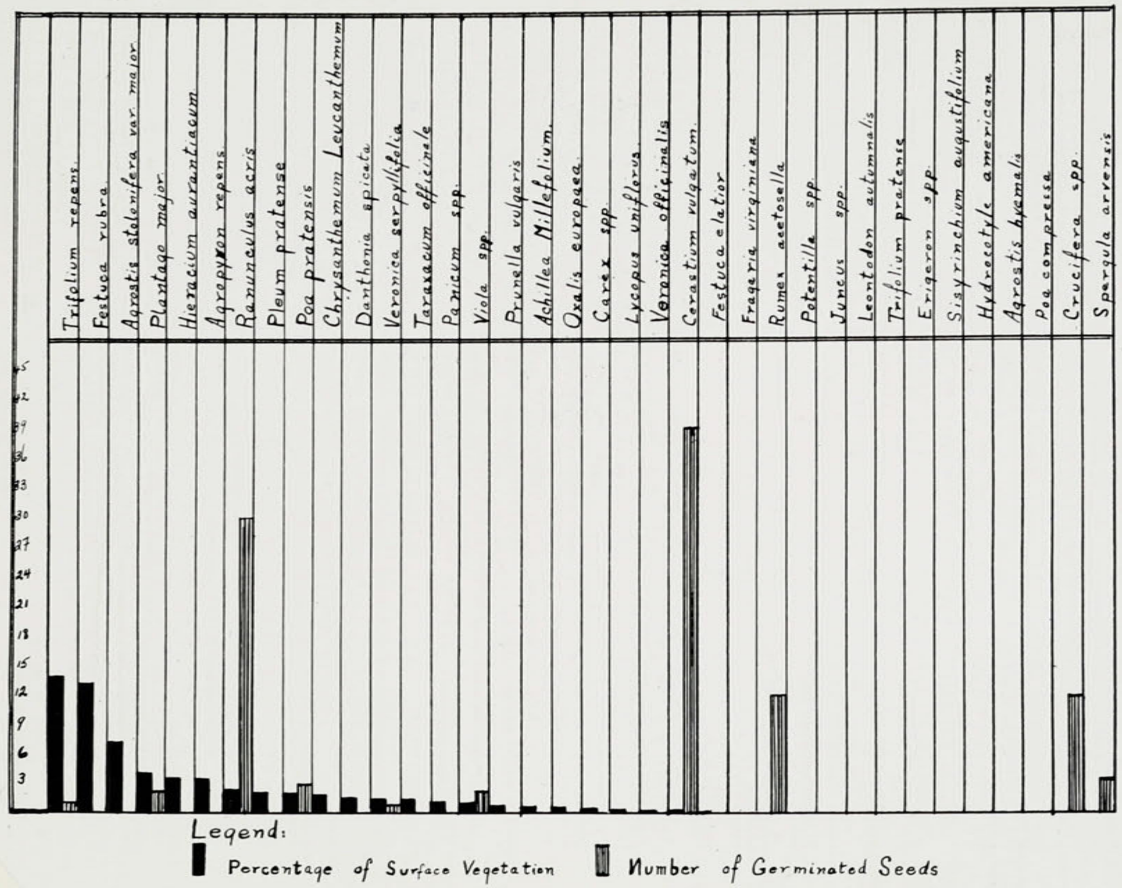
So "r" is highly significant.

GRAPH I. SHOWING A COMPARISON OF THE PERCENTAGES OF SEMINAL REPRODUCTION FOR A FEW SPECIES UNDER DIFFERENT SET OF CONDITIONS.



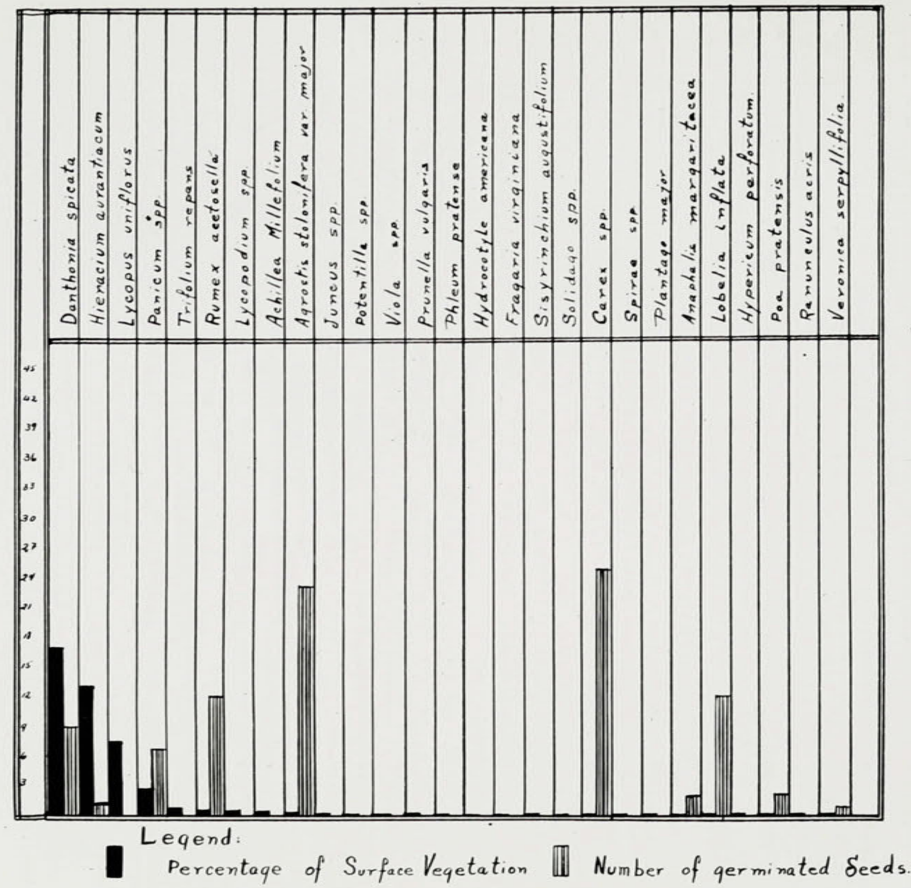

Graph I. Showing a comparison of the percentages of seminal reproduction for a few species under different set of conditions.

GRAPH II. SHOWING CORRELATION BETWEEN FLORAS OF THE SURFACE VEGETATION AND THE VIABLE SEED CONTENT OF THE TOP SOIL-LAYER ON HODGE'S PASTURE.



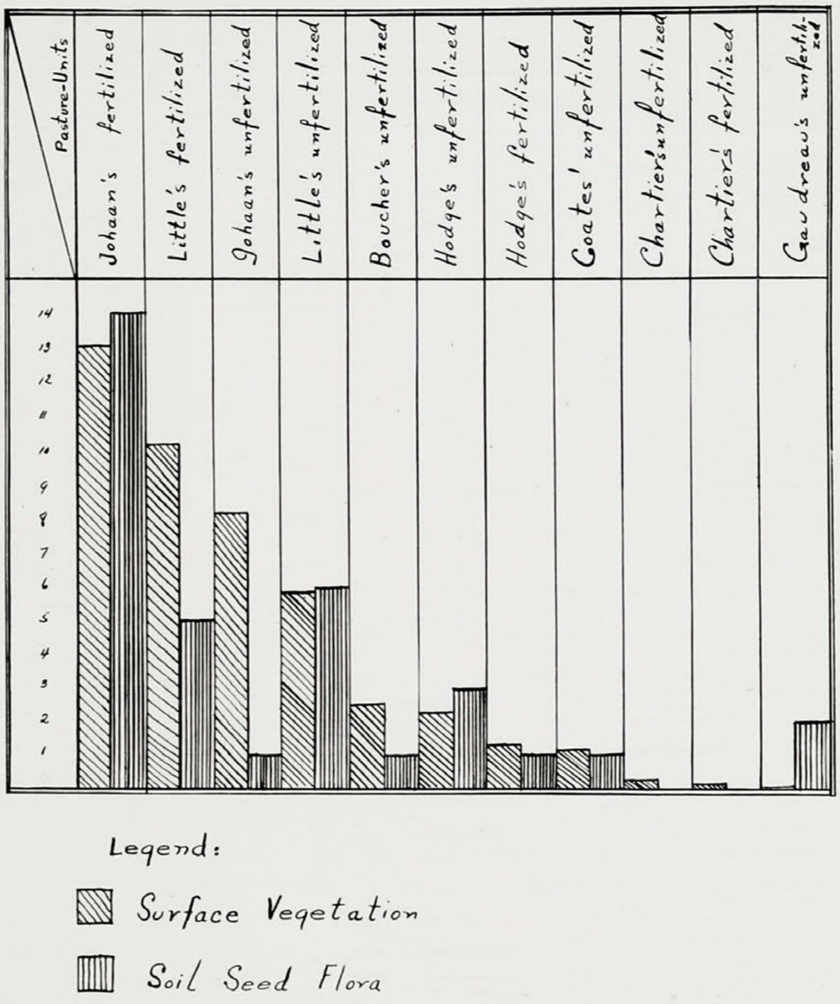

Graph II. Showing correlation between floras of the surface vegetation and the viable seed content of the top soil-layer on Hodge's pasture.

GRAPH III. SHOWING CORRELATION BETWEEN FLORAS OF THE SURFACE VEGETATION AND THE VIABLE SEED CONTENT OF THE TOP SOIL LAYER ON GAUDREAU'S PASTURE.




Graph III. Showing correlation between floras of the surface vegetation and the viable seed content of the top soil-layer on Gaudreau's pasture.

GRAPH IV. SHOWING A CORRELATION WITHIN A SPECIES (POA PRATENSIS) BETWEEN ITS REPRESENTATION IN THE SURFACE VEGEATION AND IN THE SEED FLORA OF THE TOP SOIL-LAYER.




Graph IV. Showing a correlation within a species (Poa pratensis) between its representation in the surface vegetation and in the seed flora of the top soil-layer.

Fig. I. Hieracium aurantiacum

Fig. II. Rumex acetosella

Fig. III. Prunella vulgaris

Fig. IV. Lycopus uniflorus

Fig. V. Viola spp.

Fig. VI. Veronica serpyllifolia