A STUDY OF THE CHANGES IN THE GROWTH AND FOOD RESERVES IN THE UNDERGROUND PARTS OF SONCHUS arvensis L. AND AGROPYRON repens (L) BEAUV. DURING THE GROWING SEASONS 1931 - 1932.

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By

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TABLE OF CONTENTS

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TABLES, CHARTS AND ILLUSTRATIONS

Illustrations Continued.

A STUDY OF THE CHANGES IN THE GROWTH AND FOOD RESERVES IN THE UNDERGROUND PARTS OF SONCHUS arvensis. L. AND AGROPYRON repens (L) BEAUV. DURING THE GROWING SEASONS 1931 - 1932.

I N T R O D U C T I O N.

When it has been necessary to enter upon a study of any of our most notorious weeds, the investigator has found himself faced with a vast amount of literature on control, a surprisingly small part of which consists of fundamental research or even critical study of the plant in question. It was a realization of this lack that prompted the various bodies vitally interested in the weed problems of Western Canada to approach the National Research Council with a request that they undertake the organization of a program of investigation in the control of weeds by chemicals. A meeting was called at Edmonton on October 4, 1929. In accordance with their usual methods of procedure the National Research Council invited representatives of the various departments of Agriculture, Experimental Stations and Universities, Farmers' Organizations, Loan Companies and others interested in the question to ascertain the extent of work already in progress and what would be the best method for future attack. The meeting had not progressed very far until it was realized that a wider field would have to be included and the associate committee on weed control was organized to institute investigations, with a sub committee on "Chemical Experiments." These committees included representatives of all the agencies interested and a comprehensive program was outlined in conjunction with the investigations already in progress. Besides a general program of investigation each of the provinces undertook to carry out a study on some specific phase of the work in which they were particularly interested or for which they were specially equipped. These studies in general were undertaken by the Universities and were made possible by funds supplied by the National Research Council.

In Manitoba Dr. McRostie had outlined a very comprehensive program covering all phases of weed control which was being undertaken as time, funds and conditions permitted and one of these problems on which he had been able to do some preliminary investigation was the change taking place in the underground parts of couch grass, A. repens. There are also a series of soil tanks filled with the main soil types of the province, situated in the field area of the

Agronomy Department, Manitoba Agricultural College, so it was decided that Manitoba should undertake physiological and ecological studies with particular emphasis on the growth and food reserves in the underground parts of sow thistle (S. arvensis) and couch grass (A. repens).The following is a report of part of this investigation which was undertaken by the writer under the supervision of Dr. McRostie. The financial assistance granted by the National Research Council made this and the other studies possible, and with the further grant for labor in the summer of 1932, by the Manitoba Weeds Commission, a considerable quantity of material has been accumulated which will go a long way toward pursuing this problem to its natural conclusion at such time in the future when funds are again available for the carrying on of the necessary analysis.

HISTORY

Sonchus arvensis L. var. glaberescence Gunth.

Sonchus arvensis L. has been known practically as long as we have any botanical writing as Gerard (9) 1639 lays the blame on Deoscarides and Theophrastus for some mix up in naming in the first edition Aconitum Paradaliancnes afficinarium, called Aconitum Paradaliancnes through the negligence of Dioscordes and Theophrastus in not saying the color was yellow. At that time it was evidently not giving so much trouble in agriculture although reported as being common in gardens but was evidently of the glandular type. In the early descriptions both in Europe and America the first and most common was the glandular type and it is fair to assume that the glaucus type arose through a mutation with survival value although there is little foundation for the theory sometimes expressed that the point or origin was in North Western America, as Stevens (23) reports Hooker as describing the smooth type and remarking on its vigor in the Handbook of the British Flora, 1892. The same writer ascribes the first description of the smooth type in Manitoba, to about 1894, although this was not the first introduction as in 1887 according to Ellis (6) it was reported in Hanover county and at that time the glandular type was scattered in small patches throughout the Red River Valley. Although the two types are morphologically distinct and to some extent distinct in the choice of habitat, the difference is no more than varital and is held in common with the other species of Sonchus on this continent, as shown by Jackson (15) who examined numerous herbaria in North America, and found glaberous and glandular types in S. asper and the other common species in almost equal numbers.

Sow thistle is reported by the early collectors in America, Stevens (23) but the first mention of it as a serious weed in Canada is Fletcher (7) in 1891, when he quotes an article in the Stouffville Tribune, on the seriousness of sow thistle. Mention is also made in the same report of couch grass in Eastern Canada, but up to this time A. smithii is the only species reported in the West. The glaberous type of S. arvensis is reported by Muenscher (21) as having been introduced with seed from the North Western states into New York about 1918, although the glandular type had been common for over 100 years. No matter where the glaberesence variety originated, it evidently found its home in the Red River Valley and adjacent territory and although a fairly definite change in vegetation, including weed types, can be observed as the soil and climate change as found by Joel (16) but the writer has observed large tracts of dry Russian thistle areas of Manitoba that are almost equally infested with sow thistle, a condition that was considered almost impossible Jackson (15) before we knew to what extremes this plant could adapt itself. At the present time there are large areas in Western Canada, where the whole of the cultivated land would be occupied exclusively by sow thistle if it was not given special treatment and that this area is still extending may be readily believed when we consider the development in North Western Manitoba, Swan River, and various parts of Saskatchewan. In 1927 these areas were just becoming infested Batho (3) and although most farms had sow thistle on them it was in small patches in the majority of cases. Part of this area came under the writer's observation as Weed Inspector in 1928, and at that time fifty percent of the farms could have been cleaned up by hand digging and another forty percent by taking out the cultivator and going over the various small patches about once a week, which would not have taken half a day on the worst farms. The other ten percent were already in a condition where a vigorous system of complete summerfallow was necessary. In the course of a weed survey by Dr. McRostie and the writer, in the summer and fall of 1931-32, it was found that practically the whole of this area had progressed to this point. In spite of this fact there was not a total of 1000 acres of black summerfallow. This is not an exceptional sequence of development but merely a repetition of what has happened in all areas previously enveloped and it might be interesting to speculate as to what extent a vigorous campaign of eradication carried out in the early stages of infestation, would have checked the invasion. From a single infestation in the 19th century this weed has spread till it has to be battled with for every acre of cultivated land in the Red River Valley, Eastern and large areas of Central Manitoba. That the end is not yet is obvious from a perusal of report and maps of a weed survey conducted by Manson in 1930-31.

This expansion is taking place in spite of the fact that methods have been devised for control that are fairly effective. That these are not adequate to confine the weed to its present area is due mainly to the disinclination of the farmers in the newly invaded areas to change their methods of summerfallow. This is often due to the extra cost and to the fact that the other weeds already present are controlled more efficiently by other methods.

Our present methods of weed control have been arrived at mainly from a system of trial and error with very little study given to the cause of either success or failure.

Information of a detailed nature regarding the life history seems one of the first necessities if we wish to find a reason for the apparent idiosyncrasies of the plant. More detailed information is necessary also before modifications of our present system can be intelligently devised.

Agropyron repens (L) Beauv.

This plant has been recognized as a weed of extreme persistence for centuries, Gerard (9) referring to it in 1633, as being well established and a great pest at that date. Fletcher (7) makes mention of it as a serious weed in Eastern Canada in 1892, but it is of comparative recent introduction in the west. Foulds (8) submitted evidence of its introduction with brome grass seed from Russia, about the end of the last century. Roberts (22) also traced the same source of infestation in the U.S.A., and reported that of ninety-two samples of brome grass examined from the Northern States, forty-five contained couch. At present this weed is considered about the worst one there is to control and in some areas has caused the abandonment of numerous otherwise desirable farms. There are several areas where it has spread to a greater extent than others, the Swan River Valley being one of the most extensive areas, (Manson 18). As this weed does not spread by wind blown seed single farms are often found in districts that are practically free, but when once introduced it is very easily spread and the increase within the last few years has been alarming. Willing (27) reports couch in Saskatchewan in 1908, but it was most likely established sometime before this date.

A considerable amount of information is available on the seeds of Agropyrons but very little is to be found on their life history.

The variability of success attendant upon the various methods of control used point to a necessity for fundamental information even more urgent than in the case of sow thistle.

PROBLEM

The underground parts of both sow thistle and couch grass appeared to be the greatest cause of spread and persistence. In both plants these parts act as storage tissue for reserve food material, so a study of life history was undertaken. This study was divided into two parts: (a) The morphological changes taking place throughout the growing season. (b) The physiological changes taking place as reflected in the trend of food stored in the underground parts.

The study was directed mainly to acquiring information that could be used in modifying and improving summerfallow, or other methods of control or eradication.

REVIEW OF LITERATURE

Losses due to weeds have been estimated in various ways and from different angles but it is practically impossible to take into account all the variety of losses caused directly or indirectly by them. Martin (19) in Ontario, reviewing information obtained at a conference of weed inspectors, placed the figure at 30 million dollars. Harrison (12) in reviewing the weed situation in 1922, estimated that Manitoba lost 25 million dollars annually through weeds. McRostie et.al. (20) estimated an average loss in yield due to weeds of around 18% which amounted to 40 million dollars in the Prairie Provinces, at the low prices of 1931-32. He also pointed out the numerous other losses such as increased cost of cultivation, handling charges, freight, cleaning, loss of grade and spread of certain diseases. All these losses were not due to the two weeds under discussion, but sow thistle was found to be 100% more efficient in reducing yields than a number of annuals growing in the same field.

Increased cultivation together with the loss of the use of the land, constitute a direct cost chargeable against weeds. Under dry farming conditions Hopkins and Barnes (4) found that preventing weed growth was the only benefit obtained from cultivation. This same conclusion was arrived at by Call and Sewell (5) after an extensive study in the Central United States. In the Red River Valley the excessive cultivation often used to control sow thistle usually causes such a rank growth of straw that losses from lodging and rust are greatly increased.

Despite the enormous amount of literature on weeds, there is very little that is of use in a detailed study of the plants themselves. Stevens (23) in 1922, made a very complete study of S. arvensis, discussing the differences of the two varieties and their habit of growth. He found that together with the glandular hairs on the older type the bracts were not so closely constricted after the flower heads had fallen. Otherwise the plants behaved exactly the same and there was no difference in the appearance of the underground parts.

Flowering habits of sow thistle were discussed, the terminal head being the first to open, followed alternately by the heads next in order down the stem, and at the same time by terminal heads of the side branches, the number of which is determined by the amount of room the plant has for development.

The same conditions were found to obtain by West (25) in Manitoba. His experiments also bore out Steven's findings that on the whole, sow thistle is open pollenated and seeds were viable almost immediately after pollenation.

Together with the study mentioned above Stevens (23) also made a critical examination of the underground parts. He concluded that the underground runners were true roots, consisting to a large extent, of parenchyma tissue used for the storage of food material. The vertical branches were considered to be essentially the same. He was in doubt as to the point at which the lateral system originated but found all parts of it to be viable. New plants were obtained from root cuttings as small as one quarter inch either from a bud through the epidermis or from the cut surface. The possibility of a resting period is discussed in connection with cuttings of the current year's growth of thickened roots. Root cuttings from plants developed in the green house were planted in May, but did not develop until late summer, and in another case where conditions were rather dry, plants that commenced growth and later appeared to be dead, revived the following spring and made vigorous growth. In cultivated soil between 300 and 400 plants out of a total of 728 originated from small pieces cut up by cultivating machinery and 120 from vertical roots below the depth of plowing. Vertical roots were followed to a depth of six or seven feet. The maximum length of life of vertical roots is considered to be not more than two years. Horizontal roots developed to a radius of six feet in one season. Jackson (15) found roots as long as eighteen feet.

Kilts (16) in a review of numerous studies on underground parts of plants pointed out that the terms rhizome or rootstock should be applied only to underground creeping parts that were structurally stems. The application of the term to thickened roots, he concluded, was incorrect.

Heimpel (13) remarked on the lack of definite knowledge as to the origin and duration of both the roots of sow thistle and rootstocks of couch.

That couch grass has been a troublesome weed for a long time and that we have not advanced far in our methods of controlling it is evidenced by the following extract from Gerard (9) in 1633: "Gramen caninum, Couch, Quitch or Dogs' Grass, ---greyish color, it creepeth in the ground hither and thither with long white roots, jointed at certain distances and having a pleasant, sweet taste; they are platted or wrapped one within another very intricately insomuch as where it hapneth in gardens among pot-herbs, great labor must be taken before it can be destroyed, each piece being apt to grow and in every way delate itself -- grows in arable land as an infirmitie or plague of the fields, nothing pleasing the husbandman for after the field is plowed they are constrained to gather the roots together with harrows and rake, and being so gathered and laid upon heaps they set them on fire lest they should grow again."

Arny (1) found that spring cultivation delayed the development of the plant and seed from spring plowed fields did not ripen. Rootstocks did not appear for two to four months after germination. Annual spread eight to ten feet. The increase of rootstocks reported in developing sod from 2.42 tons per acre in April to 6.3 tons in November.

Studies were made by the U. S. Bureau of Plant Industry, (24) to determine the effect different types of treatment had on the depth of the sod. Rootstocks were found in seven inches of soil on deeply plowed land, three inches in meadows and two inches in closely grazed land.

The identification of Agropyron seed with particular reference to differentiating between A. repens and A. tenerum has been the subject of several papers, a very complete study being made by Foulds (8). He pointed out that one character alone was not sufficient to distinguish between A. repens and

A. tenerum. Three main characters were mentioned: the type and extent of the hairs on the lemma and paelet, the smoothness of the calus and the shape of the rachis.

Hume and Sloan compared A. repens and A. smithii from the other species of the genus. Information regarding food storage in the underground parts of plants was gathered from several sources. In 1923 Wiggans (28) found that persistent cutting of pasture grasses reduced the yield of both foliage and roots. The reduction in food reserves weakened the resistance of the plants to winter killing, but a short period of rest in the early part of the season returned the grass to a fairly healthy condition.

Welton, Morris, Hartzler (26) found the lowest food storage in the roots of Cirsium arvense occurred at the bud stage and early mowing delayed storage. Persistent cutting over several years accomplished almost complete eradication in pastures. Analysis was made on crude protein, reducing sugars, sucrose and easily hydrolised carbohydrates in mature roots which would include both the current year's and the previous year's growth in some cases. The percentage of protein was higher in the spring than at any other time during the season. Reducing sugars increased till the bud stage of the plant was reached, at which time there was a rapid reduction. Sucrose represented as invert sugar increased in the early growth stages but soon began to decrease. This continued till the bud stage after which there was a gradual increase. Easily hydrolised carbohydrates followed the same general trend as invert sugar.

Grandfield (11) also found that the lowest point in food storage of several pasture weeds was at the bud stage and that persistent cutting previous to this reduced the number of plants.

Arny (2) has lately completed a detailed study of the organic reserves stored in the underground parts of five perennial weeds including both S. arvensis and A. repens. The material was dug and the percent moisture determined. The sample for chemical analysis was stored in alcohol till required. Crude protein and amino nitrogen was calculated and the carbohydrates were divided into reducing sugars, sucrose, readily available carbohydrates, true starch and crude fibre. The samples were not separated into old or new roots, but composite samples taken as they occurred in the sod. The general trends were as follows.

Sonchus arvensis: Amino nitrogen and total nitrogen were high when growth commenced, and declined rapidly in the early summer till mid July. Reducing sugars conformed to this general trend. Readily available carbohydrates were low during the middle of July. Starch storage increased rapidly till the first frost when the percentage of sucrose rose as that of starch fell, leaving a predominance of the former for winter.

Agropyron repens: There was no concentration of either reducing sugars or amino nitrogen when the first samples of couch grass rootstocks were taken. There was a trend downward till mid July but this was very gradual. Sucrose increased gradually till the end of the growing season. A fraction designated as true starch and supposed to have been soluble starch, remained almost constant at a little under one percent all through the season. The various constituents in couch grass rootstocks were also calculated in pounds per acre.

EXPERIMENTAL METHODS

FIELD METHODS.

Preliminary work was started in 1930, when samples of the roots of sow thistle and couch grass rootstocks were obtained during the growing season.

In 1931 financial assistance from the National Research Council permitted the investigation to be extended and it was proposed to obtain material under a variety of conditions. It was intended that undisturbed material would be obtained from the proposed site of the University Science building, where the land had been uncultivated for over a year, but this patch was inadvertently cut while the writer was away from the college on July 29th. Material from cultivated land was obtained from the North half of Range O of the Agronomy plots. A sweet clover field which was plowed and cultivated after the hay crop was removed, yielded a further series of samples. This series is designated "Sweet Clover Summerfallow" in the tables.

Couch grass rootstocks were obtained from a meadow field of alfalfa and meadow fescue situated in the bend of the river east of the college buildings. The material in the interior of the field was subject to considerable competition while that on the edge had been subject to occasional cultivations so samples were taken of both types of growth. Later in the season material was obtained from a well established sod on the roadside just East of the Dominion Rust Laboratory, to constitute a third series. Sampling was started on April 30th, and continued at weekly intervals, when possible, for the remainder of the season. At the time samples were dug the sow thistle had developed buds and shoots below ground but nothing was yet appearing above. Couch grass had made considerable leaf growth from the overwintering crowns.

As soon as possible after being dug the roots and rootstocks were taken to the laboratory and cleaned without the use of water, and separated into old and new growth. New growth consisted of true rootstocks, and thickened roots that had developed within the current season. Some difficulty was experienced in distinguishing old and new couch grass rootstocks in the later part of the season. The first growth of the season lost its sheath and fibrous roots had developed from the nodes, the new roots also became discolored and old looking. The type of growth developing from the rootstock, and particularly the state of the branches which have grown from the primary branch, will usually determine when it was produced but practise is the main factor.

Because of their definite cycle of development sow thistle roots are quite easily separated and also the old roots show very definite signs of deterioration before the new roots have attained very great thickness.

Moisture content was determined and the remainder of the sample dried on a large experimental drier belonging to the Agronomy Department and illustrated on the next page. The time elapsing between digging and drying was less than one hour and during this time the material was protected from evaporation. When dry the samples were ground finely enough to pass through a sieve having round holes 1 m.m. in diameter, and stored in tight containers.

In 1932 weekly sampling was repeated, the sow thistle being taken from a field in Fort Garry, the use of which was kindly permitted by Mr. Chevrier. This field had been abandoned for over two years, and carried an almost perfect stand of sow thistle, which made it ideal for experimental purposes. The whole field was laid out for a cultural experiment in plots two by eleven rods. Cultivation was commenced on four of these each week, and continued at weekly intervals until the end of the growing season. Several different types of cultivators were used and composite root samples taken from each of the series every week, together with a sample from the undisturbed plots.

Couch grass material was again obtained from the alfalfa field but rootstocks from newly developing sod were taken from a plot that had developed from a few root cuttings transplanted into the weed garden in the spring of 1931.

Moisture determinations were not run on any of the samples in 1932, as the previous results did not justify the time consumed. To overcome an error introduced through the previous

Description of Experimental Drier

Drier consists of two chambers, the lower one a heating chamber containing a series of heating coils over which the air is drawn by the fan seen on the right of the illustration. The air is then blown through the upper or drying compartment which contains the material to be dried. The material is placed in baskets made of copper screening and racked in five layers in the driers shown through the open door.

Fresh air can be introduced from the outside by the shaft on the left which is open to the outside air. The amount of air can be regulated by a slide just above the drying chamber.

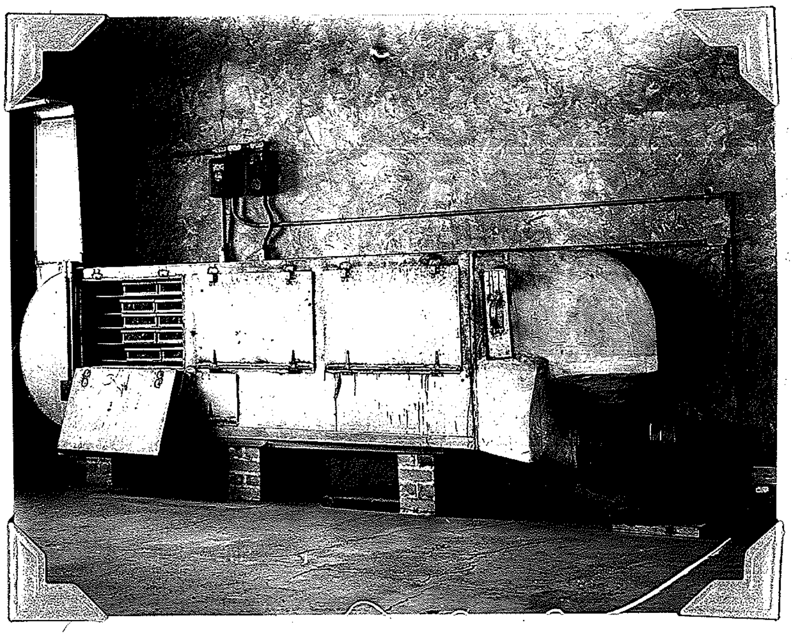
Hot air can be let out of the system through the vent on the right side of the drying chamber.

Even distribution of the heated air is obtained by baffles placed at the entrance of the chamber.

The system is thermostatically regulated and a temperature of 250°C. can be maintained.

ILLUSTRATION I.

Experimental Drier.



year's samples not being entirely free of earth and sand, this year's material was carefully washed before being separated and dried, otherwise the field methods are the same.

Notes were taken at each sampling regarding the progress and development of the underground parts and on the condition of the above ground parts of the plant.

LABORATORY METHODS AND EQUIPMENT.

In general the methods used were those outlined in Association of Official Agricultural Chemists methods of analysis (30) but as certain modifications were used, these will be outlined.

Ash:

Sample was ignited in air before being incinerated.

CARBOHYDRATES.

Extraction of Sample:

As the sample was ground and stored dry, the method of extraction was modified to some extent. A five gram sample was weighed into an Erlemmeyer flask with 150 cc. of 50% alcohol and heated on a water bath for 1 hour. A 100 cc. of 95% alcohol were added and allowed to stand over night, after which it was filtered through a No. 50 hardened filter paper supported on a platinum cone into a suction flask. After being washed with 95% alcohol the residue was saved for starch determination.

Reducing Sugars

The filterate after being reduced to approximately 20 cc. on a steam bath, was transferred to 100 cc. vol. flask and clarified with lead acetate (5 cc.), made up to volume, filtered and deleaded with anhydrous sodium carbonate and again filtered. A 25 cc. aliquot was made up to 50 cc. and reducing sugar determined by the Quisumbing and Thomas method (29)(30). Sugar was calculated by direct weighing of cuperous oxide.

Sucrose:

25 cc. of the deleaded solution was made up to 50 cc. in a 100 cc. vol. flask and neutralized with HCl. after which it was hydrolized by leaving 24 hours at room temperature with 10 cc. HCl. (sp.gr. 1.1029) added. When hydrolized the sample was poured into a beaker and neutralized with sodium carbonate, made up to vol. and a 25 cc. aliquot taken for reduction as above.

Starch

Starch was determined by the acid hydrolysis method. The residue from the sugar extraction was made up to 250 cc. and after the addition of 20 cc. H.Cl.(sp.gr. 1.125) was boiled on a water bath 2½ hours, cooled, transferred to 500 cc.vol., cleared with alumina cream and filtered. A 50 cc. aliquot was taken for sugar determination as above.

All calculations for sugars were made from the Quisumbing and Thomas tables (30).

Considerable time in manipulation was saved by the use of apparatus designed and made by Mr. Binnington of the Chemistry Department. To prevent the necessity of setting up both reflux condensers and still-heads for the recovery of the alcohol, a duplex reflux and still was designed so that by opening a pinch-cock it could be changed from a reflux condenser to a still. Four of these were set up and left in position.

Another time saving device designed by Mr. Binnington, was a set of four Gooch crucible holders mounted on a single frame with a common outlet to the suction flask. This enabled the filtering of four samples at one time, and pinch-cocks on the rubber connection allowed any filter to be cut out at will.

Crude Protein

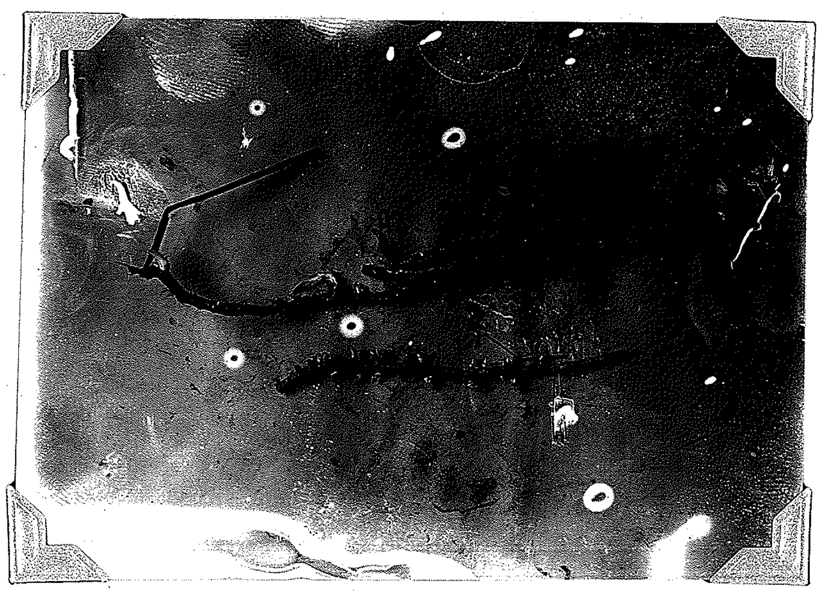
Total nitrogen was determined by the Gunning, Arnold, modification of the Kjeldahl method using the potassium sulphate, copper sulphate mixture in the digestion flask. Crude protein was calculated by multiplying total nitrogen by 6.25.

Text for illustrations on opposite page.

(a). Spring growth from thickened roots cut up by discing a few weeks previous to digging.

(b). Increase in buds on lateral roots due to cutting.

ILLUSTRATION 11.



CHANGES TAKING PLACE IN SONCHUS arvensis DURING THE GROWING SEASON.

MORPHOLOGICAL CHANGES.

The most important agency in the spread of sow thistle is the extensive system of lateral, thickened roots and the greatest cause of its persistence is the system of vertical thickened roots that develop from this system. When the sow thistle plant has become well established in the spring, a system of lateral roots develop from the old root directly below the new crown. At first these roots are no heavier than the fibrous roots but they are different in that they extend long distances parallel to the surface of the ground and do not branch. Whether they attain their full length before they begin to thicken it has not been possible to accurately determine but these threadlike roots have been followed to a distance that makes it certain that the greatest extent of their elongation takes place before any appreciable thickening takes place. Once thickening has commenced it continues very rapidly, and between the bud and seed stage of the parent plant the new system having reached a thickness of over an eighth of an inch, sends shoots to the surface and there form rosettes of leaf material.. Later vertical roots are sent down, usually from directly below the rosettes.

The above description of the root system is made to give a clearer idea of the conditions that obtain in the spring. The sequence and possible effect of this development will be discussed later.

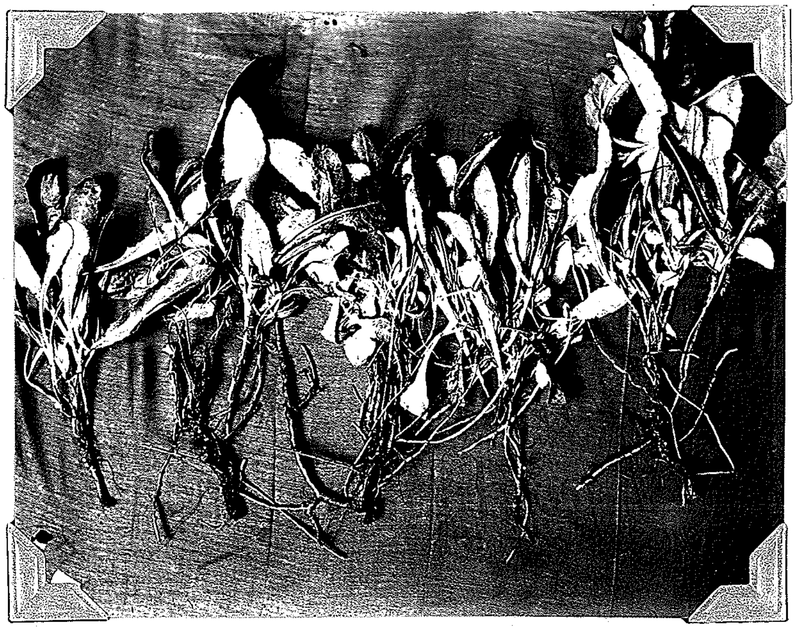
Under the rigorous conditions of our winters all the above ground parts of sow thistle are frozen down to at least the ground level and often to some distance below, and it is usually well on in May before any green growth appears above ground in the Red River Valley, and often early in June, in the more northerly parts of the province. In areas where the lateral roots have not been disturbed the new growth may originate from buds developed on the thickened lateral roots, or from the point at which vegetative shoots had been frozen off, the previous fall, thus practically all spring growth originates from the thickened roots of the previous growing season. The old flowering stalk is dead and the laterals from which it originated have died during the previous growing season but a green shoot will often be found from what looks to be the completely rotted base of the old stem. Cases have also been observed where pieces of root which looked to be completely rotted have produced vigorous new growth. From this and the evidence of other workers it seems that cambium tissue is extremely well protected in this plant and is the last to lose its vitality.

Where sow thistle has been left for a few years, as was the case in Fort Garry plots previously mentioned. Growth has established an equilibrium with its environment and only enough new material is produced to replace the old, so that the numbers of stalks per foot of root are few in comparison with more recently cultivated land and most of them originated from the point where the previous year's leaf rosette had been frozen off. This was not accomplished by the continued growth of the shoot but was more in the nature of a budding from the frozen surface and in cases where the frozen surface had rotted the budding took place out of the side stem below the rotted tissue. The spring development on badly infested land that has been fall plowed or cultivated is essentially the same as in the undisturbed areas, only the roots from which the new growth originates are broken up into pieces of varying lengths and scattered throughout the first five or six inches of soil instead of radiating from the old, dead seed stalk. New growth on these cut pieces of roots originates almost entirely from new buds or from the broken surfaces. Another source of new growth on cultivated land is the vertical roots which are stimulated to budding by being severed from the lateral system, new shoots from this source have been observed to push their way through 14 inches of Red River clay. Cutting also stimulates budding on the laterals and 16 buds per inch of root are quite common where the roots have been broken up by cultivation. The vitality of root cuttings is evidently not correlated with its thickness as it is common to obtain vigorous growth from extremely thin roots, in one case a 3 inch piece of root 3/32 inches thick produced three vigorous shoots through 6 inches of clay.

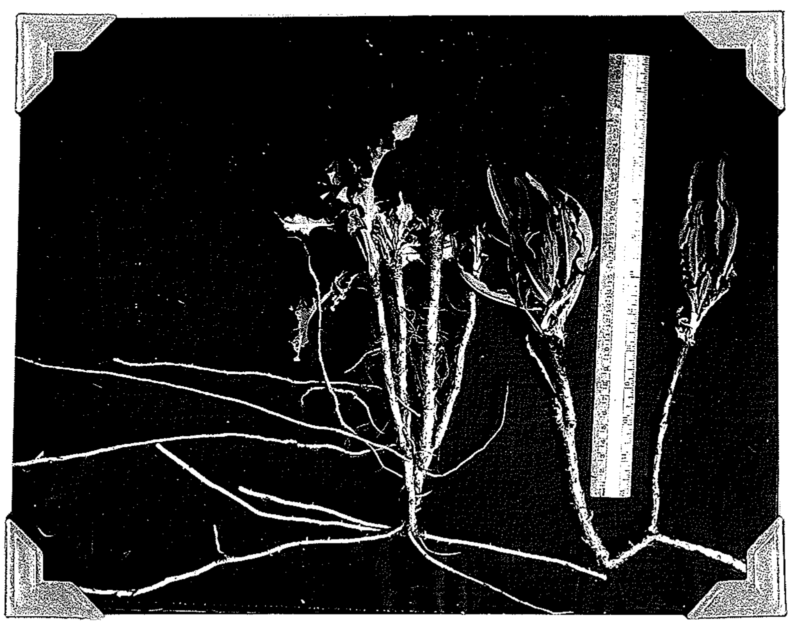
The morphological classification of the shoots that originate at considerable depths in the soil has never been quite clear in the writer's mind. That it originates as stem material is quite clear but when the top part of the plant develops there is an enormous development of adventitious roots and eventually the development of a new lateral system of thickened roots, the lower parts at least take on the characteristic appearance of root material, but if this extended deeper than the epidermis there has not been opportunity to observe.

There is a noticeable difference in the type of growth originating from vertical roots as compared with that from lateral. Absence of branching is one of the noticeable characteristics of the ordinary sow thistle system of thickened roots and they normally extend in a more or less straight line from the point of origin to their end where they may turn down almost vertically and sometimes give the appearance of bifurcated termination. Vertical roots originate from these, descending straight down without branches to a depth of at least 7 feet, and leaf producing shoots are sent straight up without branches, but new growth originating from vertical roots which have been cut by cultivation very often proliferates into numerous stems and branches as illustrated, also

ILLUSTRATION III.



Proliferation of New shoots from vertical roots, July 7, two weeks after cultivation.

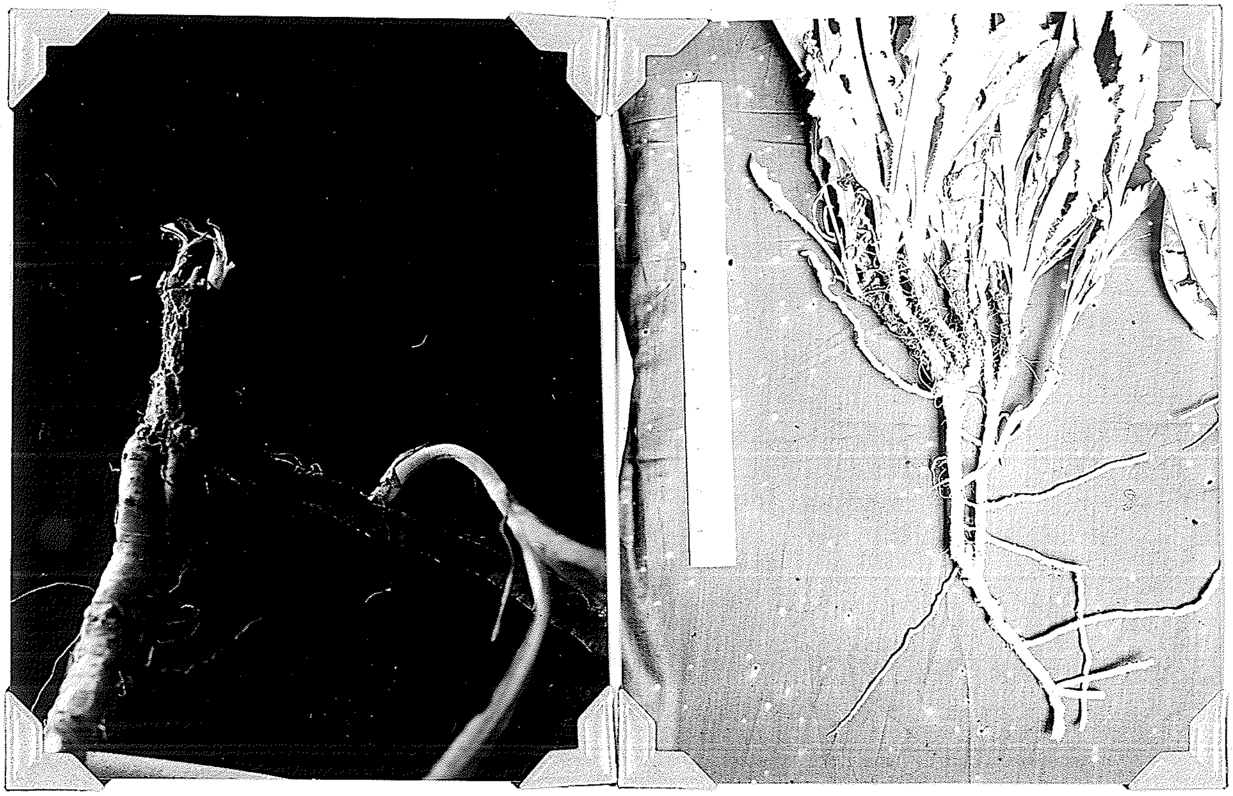


Spring growth from vertical roots allowed to develop on cultivated land the previous summer. Note depth of laterals and calouses where cultivation cut off the growth during the summer.

sending out laterals at all points. Where several cultivations have taken place during the development of this system, each cultivation is marked by a suture and callus growth. New growth in spring started from the point where it had been frozen the previous fall, or just below. Instead of a single shoot there were often several started at different points around the cortex, each developing the characteristic callus growth which has the effect of separating the new stems and giving them more freedom. The accompanying photographs show the development of new growth from the frozen surface of the old root quite plainly and illustrate the possible production of leaf surface from one of these crowns. The production of new laterals is noticably earlier from this type of growth than from the ordinary bud development which leads one to conclude that probably the periodism of thickened root development and maturity of the plant are not very intimately connected. A new system had quite definitely begun to develop by June 3rd, on cultivated lots but the same stage of development was not reached for twenty days on the undisturbed areas.

Under normal conditions the shoots which are produced in the spring, develop into flowering plants the same year, and are the point of origin for a radiating system of lateral roots which develop at a time which varies according to the conditions under which the plant is growing. In 1931 on an area where sow thistle was very well established but on

ILLUSTRATION IV.



(a) (b)

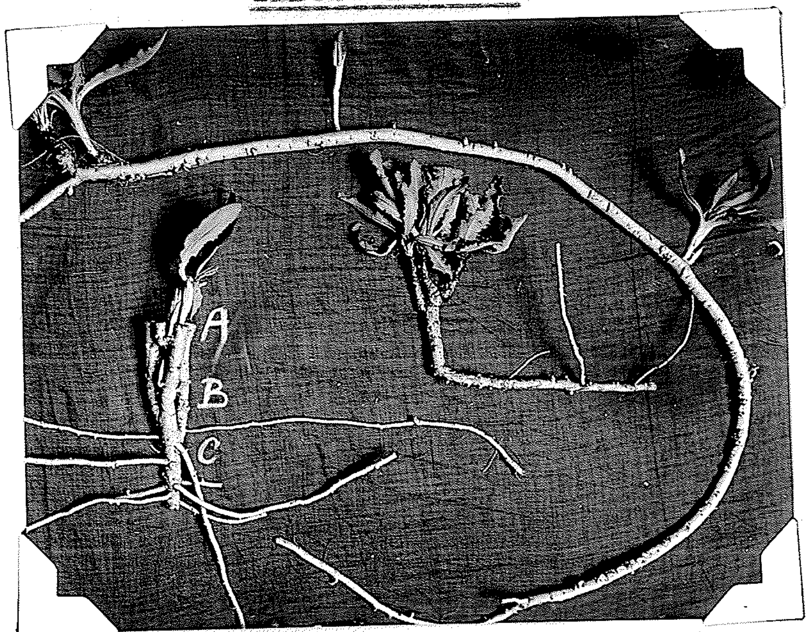
(a). Illustration of method by which the crown of branches arise from cultivated verticals.

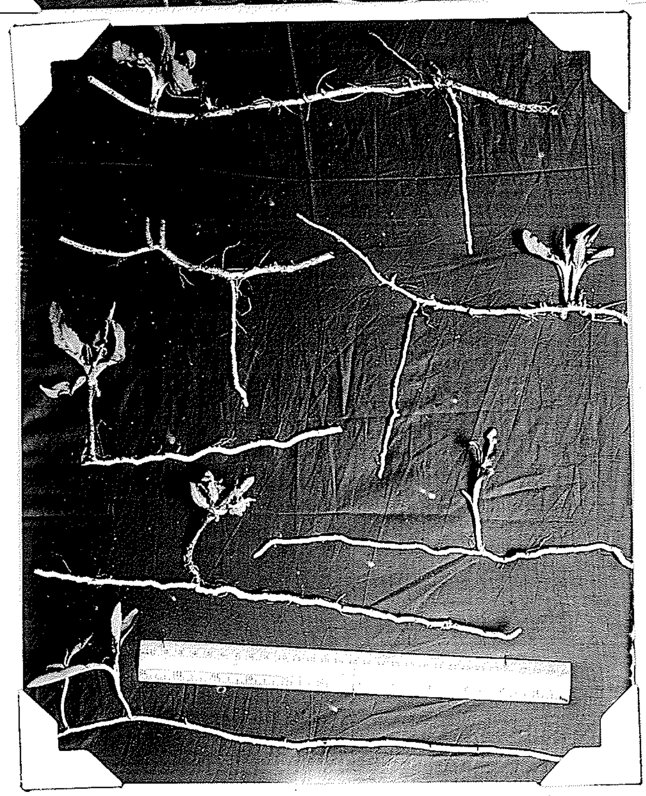
(b). Enormous leaf surface produced from one of these crowns. Sutures and calous growth can be plainly seen where the cultivator cut the growth at different times during the previous summer.

which there were numerous patches that were bare of this plant, a lateral system had developed by June 15th, that interlaced all of the clear areas and by the time the parent plants were in bloom on June 30th, they had sent out new leaf growth to the surface which quickly developed till it almost covered the ground, and vertical branches were being sent down by July 23rd. Under conditions where the stand of thistles was so heavy that they had reached a maximum there was very little development of a new lateral system when the plants had progressed to the flowering stage June 28th, and the production of leaf growth from these roots was delayed. On land that was cultivated several times the previous year, new growth had started by June 3rd. The production of leaf growth from the new laterals stimulates the rate of food storage as shown by diameter of the roots which increase from 1/8 to a ¼ inch between July 27th and August 3rd in 1931. This increase in diameter takes place first in the area of the root adjacent to the new stalk on the side away from the parent plant and there is often a definite bulb formed when the growth conditions are favorable. This increase is somewhat paralleled by the rapid increase in new roots where cultivation has not been sufficient to keep the leaf growth down. On these areas the production of laterals begin as soon as the green leaves reach the light and actual measurement shows the production of 5 feet in one direction between September 1st and 10th. Under these conditions new roots produced leaf buds and leaves immediately and the area of leaf surface is increased enormously in a very short time. It would appear from observations that most of the energy of this leaf surface is devoted to food storage, as in the last few weeks of the growing season, when the cultivation had been discontinued the roots increased so rapidly in size that on October 13th when the last sample was taken, they were at least three times the diameter of the normal roots, both of which are illustrated on the following page. When growth is developed from the vertical roots, as is the case where cultivation kills off the lateral growth without keeping leaf production entirely in check, there is a tendency on the part of the plant to establish a lateral system considerably deeper in the ground than is normally the case as shown by illustration No. Here a lateral system had developed 8 inches below the surface at the point where the old vertical root had died off after producing new top growth.

Cutting sow thistle after it comes into bloom is quite a common practice. Although not generally considered as a control measure it has been supposed to have some virtue in reducing the spread of roots, but observations in both 1931 and 1932, seem to indicate that cutting the flowering stalks at certain stages at least, stimulates the production of lateral roots. When one considers the structure of the sow thistle plant this reaction is not so strange as it may first appear. A large percentage of the leaf surface is close to the ground and when the flowering stalk is cut a large part of the leaf surface is still left in tact and a considerable

ILLUSTRATION V.



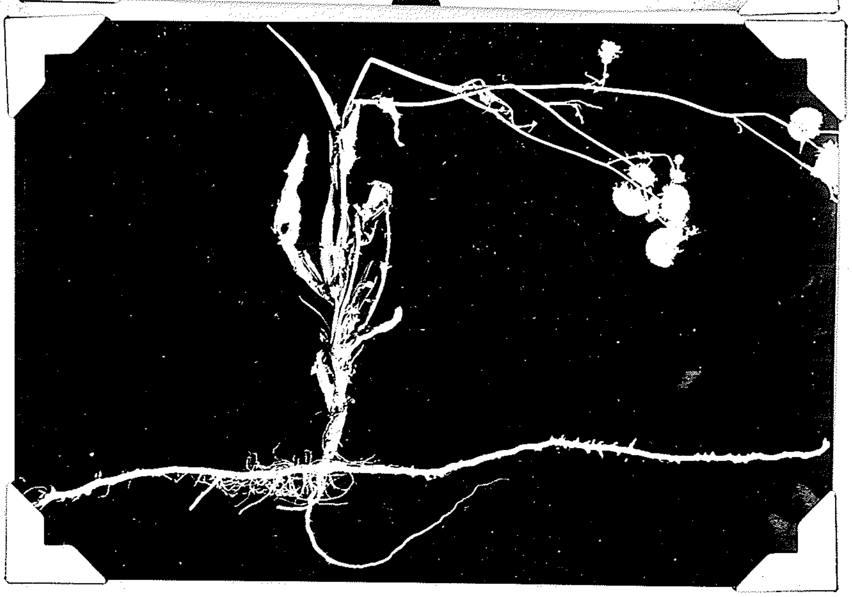


Upper picture illustrates the enormous size of roots developed in insufficiently cultivated summerfallow as compared with normal roots illustrated below.

drain on reserves is eliminated in the removal of the flowering parts. It is not supposed that this physiological reaction is entirely due to an increase in the products of photosynthesis available to the underground part of the plant but it seems reasonable to suppose that this has some bearing on the matter. After being cut the plant at once begins to send up new flowering stalks from the nodes immediately below the point at which the old stalk was cut, and if each crop of these stalks are cut as they come into bloom, several crops of stalks and flowers will be produced in a season, most of which are in the nature of flowering brances from the main stem, but under some conditions these may be entirely new developments from the current year's system of thickened roots, and occur by the stimulation of some of the leaf rosettes into the production of flowering stalks, a specimen of which is illustrated on following page.

The rotting and disappearance of the old root system is influenced by numerous factors which interact to such an extent under field conditions that any conclusions arrived at must necessarily be very general. Under normal conditions where the plants are left undisturbed the old roots disappear quite quickly after the new system is established, leaving the seed plant with an extensive fibrous root system developed between the point of juncture and the surface of the ground. On the other hand the continued cutting of the shoots before they produce green leaves, hastens the disappearance of the old system before a new one is developed. Between these two

ILLUSTRATION VI.



Above is a photo of normal lateral development from the seed plant with leaf rosettes well grown and vertical roots just being produced.

Below is illustrated a seed plant produced on the current year's root growth due to persistent cutting of parent plant.

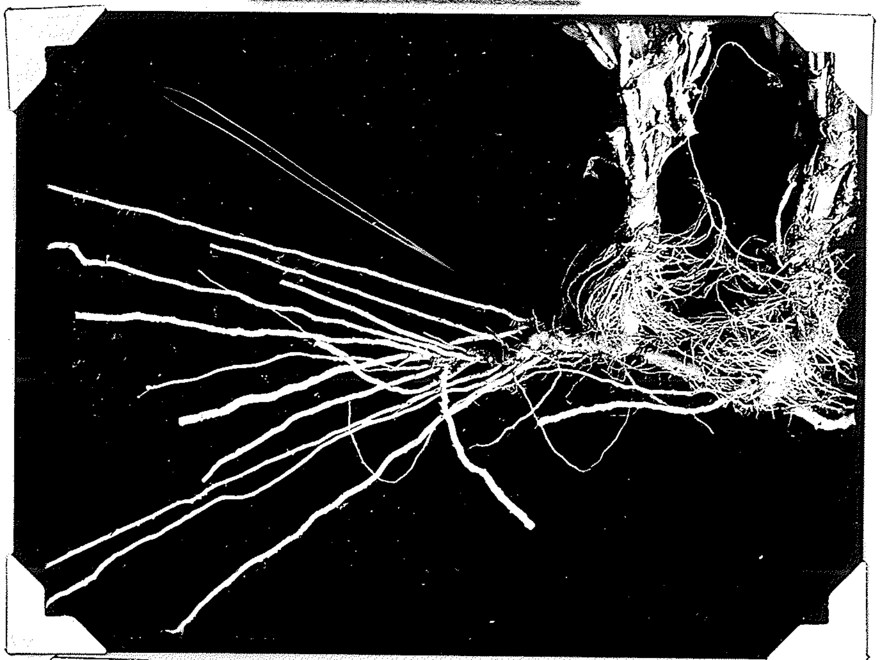
extremes numerous factors come into play including moisture, temperature, competition, nature and physical condition of the soil, any of which may determine how the plant will react to certain treatment, but several general statements may be made, first that if a new system is not produced but green leaves are allowed to develop, the rotting is delayed as is also the case to a lesser extent, when roots are just transplanted by cultivating machinery without the shoots being cut off. Dry conditions also tend to preserve roots from deterioration, but the period of the growing season has a considerable effect on this. Vertical roots seem to persist longer than laterals and as they usually only produce one bud at a time, they take longer to exhaust their food reserve. It is possible that vertical roots may persist more than one year.

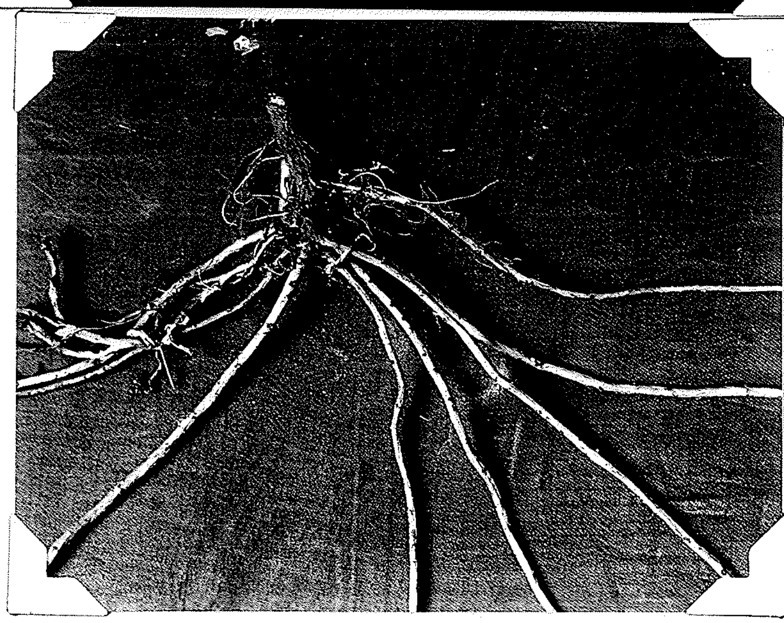
In the early part of the season the laterals produce an absorbing system of fibrous roots which are supplemented, and later as the old root dies are altogether replaced by an extensive system of fibrous roots at the base of the newly established flowering plant.

When a new seed plant is well established it generally loses contact with its parent root on the side nearest the original plant first and the woody structural material which is developed within the lower stem often continues into the old root for the latter days, making a pseudo tap root with a very efficient fibrous root system which shows no suture or mark to indicate where it once was joined to the parent root. From this tap root originates the new system of thickened roots and in their early stages close observation and careful handling are nefessary to distinguish them from the fibrous root. The accompanying illustration shows 13 branches developed before the complete disappearance of the old root and also shows the manner in which this pseudo tap root is developed.

The survival of the sow thistle plant depends largely on the establishment of thickened roots of one kind or another, where growth has originated from a vertical root at a depth of ten or twelve inches, the surviving structure is not true root material in its origin but as can be seen by referring to illustration No. , it develops all the characteristics of a root and is possibly better able to survive than the common lateral system. After a plant has established a well developed system of thickened roots its chances of survival are greatly increased due to the fact that a small part of any one of these roots which survive the winter is capable of producing at least one new plant and they are remarkably well equipped to survive. As has been mentioned the thickness of the root need not be very great to contain enough reserve to produce new plants and the exhaustion of this reserve is a much more difficult matter in the new roots which show an inclination to go into a resting stage, particularly if cut from the parent plant. No definite experiments have been carried out in Western Canada, but the

ILLUSTRATION VII.





Above, 13 new lateral roots developing at base of seed plant which looks almost like tap root. Old laterals almost gone.

Below, appearance of the above the following spring. Old seed plant dead and rotting.

observations made during the progress of cultural experiments have led to the same conclusion, being arrived at independently by the writer, and several workers in Saskatchewan, have tended to confirm the experimental evidence of Stevens. This worker found that root cuttings from a plant grown in the green house and planted out under good growing conditions in May, did not begin to produce new growth till late in the summer and that root cuttings that did produce some top growth in the summer, but were killed down by lack of moisture, still retained vitality enough to produce strong, healthy plants in the following spring. The effect of dry conditions in the spring, particularly if this is due to successful competition by other plants, i.e. sweet clover, is to restrict the amount of new growth produced from old roots and although deterioration is delayed it progresses quite rapidly so that when root material was dug out of a good stand of sweet clover in July 1931, there were only a few spindling shoots above ground and a large proportion of the old roots had rotted before any noticable development of a new lateral system was established. Later when this field was plowed the new shoots that were sent up were extremely thin and weakly and in most cases were so badly twisted and misshapen that they produced a growth of from 12 to 18 inches to penetrate 3 or 4 inches of soil. Elimination of these plants is comparatively easy but as cultivation increased the moisture, patches of healthy growth began to appear here and there over the field and examination showed that these were originating from vertical roots below the depth of cultivation. To appreciate the effect that competition has on the growth of sow thistle it is interesting to note that at this time, adjoining fields that were sown to cereal crops, had patches of sow thistle in them that were in full bloom and had produced a new lateral system extending from two to five feet beyond their margins and leaf material for the manufacture of reserves had already been established. The structure of spring sown grains makes them particularly ineffective in competing with sow thistle, due to their upright habit of growth, as compared with the smothering effect of the first whorl of leaves on the sow thistle which often cover 1.5 sq. feet and have been found in some cases by actual measurement to completely cover 2.2 sq. feet. Fall sown grain is more successful due to the winter crown established in the fall, but in all cases where crop plants successfully compete with sow thistle there must be a maximum stand of healthy plants covering the whole field.

Although it has not been possible to observe any correlation between the successive stages in the development of the thickened root system and the stages of development of the above ground parts. There is a definite sequence in the stages of flowering and seed setting which keep new flower heads forming from the time the first terminal head opens till late in the fall.

The terminal head at the apex of the plant is always the first to open and in general the next in order down the stem. At first glance this sequence does not seem to apply because of the establishment of groups of heads on the subsequent stalks which exhibit the same sequence among themselves. Exact observation is further complicated by the development of secondary branches out of the main stem all of which show the same sequence of flowering. At the time just subsequent to flowering there is a rapid elongation of stems and between the time a bud begins to swell and the flower head opens, the pedicle will increase three or four times in length so that while each head when it is in full bloom, is the apex of its own particular group. After it fades there are several other heads that have grown up beyond it, and the same thing applies to the secondary branches each of which pushes up to a point of vantage often higher than the main branch. The expansion of the flowers is greatly influenced by the intensity of the sunlight so it is possible that this sudden elongation is a type of heliotropism particularly as it is growing amid a heavy crop or where the sunlight is somewhat obstructed.

The effect of cutting down the flowering stalks has been mentioned before and the new stalks that originate from the old stem are in the nature of the secondary stalks mentioned here and can be produced from any of the nodes above the ground. The writer has not made any study of the germinability of sow thistle but is indebted to Mr. H. M. West, for the following date which he collected during a rather intensive study of the flowering habits, several years ago, at Manitoba Agricultural College, and confirm the conclusions arrived at by Stevens (23) in North Dakota.

No seed was set when flowers were enclosed in bags without pollenation but from 16.6% to 72.3% of seed was set on hand pollenated heads under the same conditions and no seed was set when insects were excluded but the wind allowed access to the flowers, whereas the normal rate of seed setting is over 30%, these data indicate that sow thistle is cross pollenated through the agency of insects.

The effect of moisture was tested by planting 50 seeds from a single head in each of 40 duplicate pots representing 20 heads and 2000 seeds. One set were watered every other day and the other set every day and all were placed together in the green house. Germination from the alternate wet and dry sample varied from 0% to 82% with an average of 27.5% and the continually wet from 34% to 98% with an average of 65%. It is quite well known that sow thistle always starts in damp places in a field but the above may partly explain why sow thistle seedlings are almost unheard of over a period of years and then appear in large numbers for one season.

Temperature effects were tested by germinating seeds at 70°F. and 86°F. Germination started in 6 days at 86°F. and in 10 days at 70°F. After 21 days the average germination was 12.7% and 2.4% respectively. At this time both lots were removed to the green house where they were subjected to fluctuations of temperature ranging from 44°F. to 88°F. Germination was speeded up and in thirteen days the germination had increased to 74.5% and 80.4%.

From plants cut at the stage when the corallas had dropped from the involucre which were still closed, there was an average germination of 37.6% and a range from 0 to 72%. This variation was fairly well correlated with the maturity of the seed as indicated by the color which ranged from yellow to dark brown. The involucre stays closed for several days before the papus appears and this will account for the difference in maturity, but it is quite obvious that cutting plants after some of the heads have lost their corollas will not entirely prevent the production of germinable seed.

West found that the depth at which a seed was planted had a great influence on the percentage to germinate. Below one inch there was no germination and only 50% germinate at one inch while the germination where the seed was barely covered was between 85 and 100% for 4000 seeds.

In their early stages sow thistle seedlings are very delicate and an effort to establish seedlings in the field was a failure because those that germinated could not survive the dry weather of late spring. These data shed further light on the periodic appearance in cultivated fields of sow thistle seedlings, due evidently to a combination of special conditions and these only obtain occasionally in anything but very restricted areas such as the edges of sloughs and more or less permanent wet spots in cultivated fields. Therefore it may be concluded that the vital cause of the spread of sow thistle is from the thickened roots that have been left after cultivation or reintroduced from infested areas.

PHYSIOLOGICAL CHANGES.

In outlining the study of the various products stored in the sow thistle roots during the growing season time, was a consideration that had to be considered. As it was considered essential that as clear a picture as possible be obtained, of the trend of carbohydrate storage, it was necessary to determine at least the three main groups i. e. reducing sugars, sucrose, and some measure of starch. Several comparative tests were made between the acid hydrolysis and taka-diastase method and the difference was not considered significant enough to make up for the increased time required and increased difficulty of manipulation also it is quite possible that the error caused by the inclusion of certain of the pentosans and cellulosses might not be much greater than the exclusion of some of the carbohydrates that would not be hydrolized by taka-diastase.

One source of error that was unexpected occurred in the material collected during the summer of 1931, which made it necessary to compute all the results on an ash and moisture free basis. On determining the ash on these samples the results were extremely erratic and in most cases very high. As there was a possibility of soil not being entirely removed from the sample before drying, a test was run and all the plant material floated off five gram samples, with carbon tetrachloride and the residue of sand dried and weighed. The results vary from about 1.5% to 15% which made it necessary to calculate all results on an ash free basis. This error was avoided in 1932 by washing all material before drying.

The moisture content of the roots as they came from the field are recorded in table No. 1, together with the precipitation for the months from May to October. This gives very little information relative to the physiological behaviour of the plant, and most of the fluctuations in moisture content seem to be more related to the available moisture in the ground than to any progressive change as shown by Graph No. 1. The only constant variation seems to be a tendency for the old roots to increase in moisture as they approach decay.

There are some variations in the trend of the different carbohydrates in the two years, but in general they are very much alike and the same conclusion may be drawn from either year. The translocation of materials for growth in the spring is shown in the high percentage of reducing sugar and sucrose. The heavy call upon carbohydrates is reflected first in the reduction of the amount of starch which would naturally be hydrolized to sucrose and later in the reduction in the percentage of sucrose itself which lasts till there is a development of leaf area. The results of photosynthesis are naturally correlated with the production of leaf area and in the early part of the season this is noticable in an increase for a short time, of both starch and sucrose in the old roots, but as deterioration sets in and there is an increased demand for material for the development of a new thickened root system and possibly stalks and flowers, there is a rapid decline. At the same time as this decline is taking place there is a rapid increase in all the carbohydrates in the new root system. This is best shown by Table 3, and Graph 3, of the carbohydrates in the new roots of 1932, because in this season, samples were obtained from the earliest development whereas the first sample was not taken in 1931 till a good strong system had been established. When the first samples were taken in 1932, the new roots were so fine that a considerable portion of fibrous root was also included and then only enough could be obtained to give a two or three gram sample of dry material, so that quantity must be considered as well as quality when considering the accompanying tables and charts.

That the blossoming of the plant has no great effect on the carbohydrate reserves can be determined by examination of the tables in relation to the blossoming period. In both years this occurred about the same time on undisturbed areas, i.e. the first heads were in bloom about June 25th and the plants in full bloom by July 7th, which coincided with the high point for reserves in old roots and the period of increase in the new roots. The rapid decline in the old roots in 1931 and 1932 is correlated with the formation of seed but at this time the old roots have deteriorated and it is evident from observation that the plant is quite capable of producing an abundance of seed even when there is no old root system from which to draw. Also seed setting continues vigorously after the old root system has entirely disappeared. During the seed setting the carbohydrates continue to build up in the new roots and it is not till the last week in August or the first week in September, that there is a drop. This drop seems to coincide with the last change which takes place in the kind of carbohydrate which is being stored. The dominant fraction in the early life of the new roots is sucrose, but there is a progressive change and starch is gradually accumulated till, towards fall, it is dominant. Later another change takes place and sucrose again increases partly at the expense of starch so that at the end of the growing season there is probably about an equal amount of each. This change is supposed by Arny (2) to be incident upon the first frost but this is not true here as the drop takes place previous to a temperature as low as 32°F. It seems more probable that this change is a physiological expression of approaching maturity. Spring finds the predominence of sucrose greatly increased and the amount of reducing sugar more than trebled.

These changes are quite normal processes in the life history. Simple sugars in the early growth stages and accumulation of more complex carbohydrates as the leaf surface increases. Later there is a replacement of old storage tissue by new, which builds up a reserve from the translocation of sucrose in the formation of starch. As the days shorten there is a change from starch back to sucrose which latter properly predominates during winter.

The changes which are recorded in the following tables as protein should be more properly reported as total nitrogen, expressed as protein. The early increase in nitrogen in May and which is maintained till mid June corresponds to the period in which other workers have found a high amono nitrogen fraction. This accumulation of nitrogen is rapidly dissipated as the amount of structural material preparatory to the production of flower heads and seed increases. The nitrogen content of the very fine roots which made up the first two samples was evidently quite high but when the roots became well established there was a drop to about the level of the old roots. There was a gradual increase during the remainder of the season with the exception of one drop which occurred at the period of high seed production, leaving the plant at the end of the growing season with a good reserve for the production of new growth the following spring. The protein curve for both years is of the same order where the land has not been cultivated, but table No. 4 shows remarkable difference where cultivation prevented the plant going to seed. The most logical explanation seems to be that these plants had a rather large leaf area in comparison with the amount of roots produced and as this leaf surface never progressed much beyond the large decumbent crown leaves the elaboration of ameno acids caused an accumulation of nitrogen as no flowering parts developed. A slight reduction in the percentage of protein is noticable in a period in the fall which corresponds to the time when an excessive enlargement of the roots was progressing. This period which covered the last few weeks of growth showed an increase in thickness in most of the roots on the cultivated plots up to $\frac{3}{4}$ of an inch, whereas the normal conditions of growth never produce roots much more than $\frac{3}{8}$ of an inch. It is quite logical to expect that the major part of this enlargement is due to the storage of carbohydrates.

The nitrogen in the old roots dug out of a sweet clover field that had been summerfallowed remained exceptionally high. This was most likely due to the fact that there was very little growth on these plots and the supply present in the spring was never exhausted. The samples obtained were extremely small and the results would be of no practical significance.

Separating old and new material has not been practised by previous investigators but in the opinion of the writer a better view is obtained of the progress of food storage. The practical significance of the information obtained will be discussed later.

TABLE 1.

PRECIPITATION AND MOISTURE IN SOW THISTLE ROOTS 1931

Date	Precipi -tation	Cut At Flowering Old	Cut At Flowering New	Cultivated Old	Cultivated New	Sweet Clover Summerfallow Old	Sweet Clover Summerfallow New
	inches		%		%		%
May 1	.....	...	...	77.8	...	...	...
4,5,6.	0.30	...	...	....	...	...	...
8	Tr.	...	...	78.6	...	...	...
10	.25	...	...	....	...	...	...
18	.44	...	...	81.41	...	...	...
19,20,21.	.24	...	...	....	...	...	...
25	Tr.	...	...	89.5	...	...	...
June 1	.03	...	...	84.9	...	...	...
6,7,8.	.04	...	...	85.6	...	...	...
9,11,12,14.	.78	...	...	....	...	...	...
16	...	...	...	86.6	...	...	...
18	.02	...	...	....	...	...	...
24	.22	...	...	88.6	...	..	...
27	.20	...	...	....	...	...	...
July 1	.10	...	...	....	...	...	...
4,5,6,7,8.	1.20	77.8	78.1	88.0	...	...	...
19,20	1.14	...	...	....	...	...	...
27	.62	81.6	77.7	89.1	87.6	79.3	77.4
Aug. 1,2	1.06	80.8	74.4	....	...	...	...
9,10.	.28	78.8	75.5	....	...	...	...
15,	...	...	...	88.6	87.2	81.1	79.2
21,	.24	...	...	....	...	...	...
23.	...		72.3		78.7	...	...
28,29	1.20	...	...	....	...	...	...
Sept. 1	...		74.4		77.4	85.7	85.0
10	...		72.5	....	83.3	84.4	85.3
14-17	.69	...	...	....	...	...	...
18	...		72.2		82.3	...	...
20-27	3.03		70.5	....	...	...	...
Oct. 13	...		73.8	....	74.9	...	...

TABLE 11.

CARBOHYDRATES IN SOW THISTLE ROOTS, 1931

Date Dug	Reducing Sugars (Dextrose)	Sucrose (Invert)	Starch (Dextrose)	Total
	%	%	%	%
Old Roots				
May 1	6.34	43.66	10.74	60.70
" 8	9.14	42.74	9.12	61.00
" 18	8.29	36.51	9.64	54.43
" 25	9.53	33.32	15.10	57.98
June 1	6.29	40.00	11.18	57.47
" 9	6.54	43.56	12.65	62.75
" 15	3.92	44.35	12.42	60.67
" 23	3.72	41.18	21.96	66.86
July 6	3.78	24.00	16.60	44.38
" 13	1.92	14.38	00.00	16.30
" 23	1.66			
New Roots				
June 23	1.77	40.27	15.28	57.31
July 6	1.81	45.30	25.06	72.17
July 24	2.92	15.02	31.42	49.36
Aug. 3	2.52	17.07	33.38	41.01
" 10	2.25	22.04	41.80	66.09
" 23	3.55	21.44	26.40	51.39
Sept. 9	3.51	12.16	39.64	55.31
" 30	1.71	20.76	38.32	60.81
Oct. 13	1.96	28.16	36.10	66.00

Note:-
Thistle started to bloom June 30th.
" " to seed July 13th.

TABLE IV.

PERCENTAGE PROTEIN IN SOW THISTLE ROOTS, 1931.

Date		Undis-turbed	Cut Once	Cut Twice	Cult. 3 Times	Cult. 4 Times	St. Cl. S. Fallow.
		%	%	%	%	%	%
Old Roots							
May	1	7.40					
"	8	11.77					
"	18	11.91					
"	25	13.93					
June	1	11.34					
"	9	12.29					
"	15	9.23					
"	23	8.03					
July	6	3.77				3.00	
"	19						5.51
Aug.	15						9.87
Sept	1						9.92
"	8						8.75
New Roots							
June	28				10.65		
July	5	6.58			9.67		
"	13			7.17			
"	20	&7.14					7.45
"	26	7.10		6.67	12.00		
Aug	2			7.90	14.12	11.92	
"	9		6.94	8.56	15.96		
"	16				14.14		10.61
"	23		9.94	6.69	9.63	8.46	
Sept	1		8.33	7.46		911[illegible]	10.80
"	9		10.65	8.83	11.73	10.48	10.71
"	18		6.52	6.31	11.19	10.73	9.30
O"	30		8.63	8.63	10.77	10.73	
Oct	9			6.60			

TABLE III

FOOD RESERVES IN ROOTS OF SOW THISTLE LEFT UNDISTURBED

FORT GARRY, 1932.

Date Dug	Ash %	Protein %	Reducing Sugars (Dextrose)	Sucrose (Invert)	Starch (Dextrose)	Total Carbohydrates.
Old Roots						
May 17	4.86	7.83	11.07	34.27	8.72	54.06
June 6	3.80	2.72	3.34	23.55	20.84	47.73
June 13	....	7.23	3.89	29.41	10.70	44.00
" 21	5.60	4.82	7.66	25.38	14.90	48.14
" 28	6.56	3.96	3.75	28.90	23.90	56.55
July 13	7.64	3.64	10.02	37.12	21.12	68.26
" 20	....	4.68	2.27	20.06	26.28	48.61
" 26	....	....	2.03	24.74	21.88	48.65
New Roots						
June 13	....	....	3.20	27.20	8.18	38.58
" 21	....	9.82	1.80	32.45	10.36	48.61
" 28	3.68	4.57	2.28	34.27	26.92	63.47
July 5	6.00	4.32	3.42	27.78	30.00	61.20
" 13	....	4.38	2.43	29.79	35.60	67.82
" 20	....	6.99	3.25	26.85	34.26	63.36
" 26	....	6.36	3.00	38.43	35.72	77.15
Aug. 2	4.44	5.60	6.51	37.07	20.40	63.93
" 9	3.55	9.64	5.67	39.52	29.20	74.39
" 16	2.84	9.24	2.06	41.79	28.90	72.75
" 23	....	8.27	2.23	27.10	40.40	69.73
Sept. 1	....	9.49	3.24	24.50	37.60	65.34
" 7	3.88	8.83	4.90	20.23	23.80	58.03
" 14	4.30	8.19	2.03	27.60	38.72	68.35
" 24	4.95	9.60	2.13	31.00	34.80	67.93
Oct. 1	4.46	10.14	1.36	28.60	34.80	64.76
" 8	3.40	10.52	3.00	31.50	31.20	65.70

Note:-

Thistle started to bloom June 26th.

" " to seed July 20th.

Crude protein in sow thistle seed 21.06%.

TABLE V.

MOISTURE IN ROOTSTOCKS OF COUCH GRASS, 1931.

Date		New Sod		Alfalfa Sod		Roadside Sod	
		Old	New	Old	New	Old	New
April	15	57.26	%		%		%
"	30	68.58					
May	7	64.78					
"	14	63.28					
"	23	65.46					
"	29	66.53					
June	3	61.71					
"	12	62.83	76.69				
"	16	63.38	78.21	46.66			
"	25	57.82	66.00				
July	9	56.44	68.72			47.43	56.25
"	18	56.10	72.31	56.70	75.79	46.00	52.04
"	26	64.34	74.68	54.46	61.05	45.00	48.28
Aug.	5	66.21	74.32	52.94	58.79	46.02	51.35
"	10	78.84	75.52	54.27	52.68	43.55	49.64
"	17	53.55	70.29	49.24	49.61		46.86
"	31	63.63	59.94	50.66	50.00		52.43
Sept.	8	63.80	63.09	47.28	52.00		42.00
"	14	64.60	68.97	60.10	59.69		46.45
"	30	73.05	67.42	59.10	58.37		47.78
Oct.	9	67.12	62.47	56.35	57.61		49.22
"	16	60.14	58.50	49.25	52.06		44.84
Nov.	17		57.93	56.34	52.34		

TABLE VI

FOOD RESERVES IN ROOTSTOCKS OF COUCH GRASS, 1931

Date		Protein %	Reducing Sugars (Dextrose) %	Sucrose (Invert) %	Starch (Dextrose) %	Total Carbo-hydrates %
Old Rootstocks						
April	30	10.00	1.06	16.82	16.36	35.70
May	7	10.29	2.20	23.50	16.50	42.60
"	15	9.52	1.52	18.42	12.98	32.92
"	23	9.91	1.29	18.24	13.62	33.15
"	29	7.31	1.92	26.88	12.86	41.66
June	3	6.55	1.62	31.30	14.56	47.48
"	12	8.53	1.86	29.53	14.18	45.60
"	18	7.72	1.72	34.30	15.56	50.99
"	25	7.54	1.70	31.04	16.00	48.75
July	9	8.67	2.46	35.41	14.46	52.33
"	18	9.47	3.20	36.35	13.07	52.62
"	26	8.00	3.83	22.40	16.00	44.23
Aug.	4	5.76	6.18	29.34	13.81	49.33
"	10	7.47				
"	17	9.17	2.62	22.97	15.82	41.41
"	30	9.87	3.29	18.02	16.60	37.91
Sept.	6	8.75	1.55	18.18	17.24	36.97
Nov.	17		.90	26.53	12.12	39.51
New Rootstocks						
June	12		1.28	13.44	11.70	26.42
"	18		1.90	19.01	17.36	38.27
"	25		1.90	21.06	17.36	40.92
July	9	14.35	1.63	23.46	16.62	41.71
"	18	13.31	1.70	19.71	14.74	36.15
"	25	15.14	1.61	19.84	22.60	44.05
Aug.	10	15.21	2.48	22.97	14.20	37.17
"	17	13.14	1.52	23.07	15.48	38.55
"	30	12.08	2.62	23.86	12.42	37.82
Sept.	6	11.17	3.44	26.36	17.88	47.88
"	14	12.61	1.50	34.36	12.36	48.31
"	29	10.81				
Oct.	8	9.65	4.16	39.68	13.03	56.87
"	16	9.84	1.76	43.46	19.52	64.74
Nov.	17	8.05	1.56	45.54	12.91	60.01

Note:- Material represented in the table above was obtained from new invasion at the edge of an old established alfalfa field.

TABLE VII

FOOD RESERVES IN ROOTSTOCKS OF COUCH GRASS

From Alfalfa Field 1931.

Date		Protein %	Reducing Sugars (Dextrose) %	Sucrose (Invert) %	Starch (Dextrose) %	Total Carbo-hydrates %
Old Rootstocks						
June	18	7.40				
July	19	7.65				
"	27	6.46	2.65	21.31	16.50	40.16
Aug.	4	8.38				
"	10	5.07				
"	17	6.06				
"	30	6.42				
Sept.	8	8.33				
"	14	9.09				
"	29	6.78				
Oct.	8	6.10				
"	16	6.57				
Nov.	17	6.78				
New Rootstocks						
July	27	12.25	1.94	16.41	15.68	34.03
Aug	4	10.60				
"	11	7.18	2.42	35.74	16.40	54.56
"	17	6.46				
"	30	8.25				
Sept	8	9.20				
"	14	9.34				
"	29	6.57	4.29	24.70	15.14	44.13
Oct.	8	5.90				
"	16	6.94	.50	33.86	18.22	52.58
Nov.	17	7.08	1.81	27.84	13.19	42.84

Note:-

The above material was subject to considerable competition from alfalfa and meadow fescue. All material collected was not analyzed owing to lack of time.

TABLE VIII

FOOD RESERVES IN ROOTSTOCKS OF COUCH GRASS 1932

Date	Protein %	Reducing Sugars (Dextrose) %	Sucrose (Invert) %	Total Carbo-hydrates %
Old Rootstocks				
May 23	5.71	1.76	32.16	33.92
June 6	3	3.20	30.84	34.04
" 11	2.37	1.25	39.01	40.26
" 21	2.96	1.66	36.99	38.65
" 28	2.48	3.52	26.75	30.27
July 7		.09	30.36	30.43
" 12	6.48	.80	38.11	38.91
" 19	3.00	1.85	30.47	32.32
Aug. 6	9.04	1.70	51.55	53.25
" 16	3.86	1.11	44.32	45.43
" 23	3.81	1.28	45.18	46.96
Sept.1	4.68	2.09	42.37	44.46
New Rootstocks				
June 11	5.50	3.37	19.71	23.08
" 21	4.59	2.34	26.81	29.15
" 28	4.23	4.37	17.52	21.91
July 7	3.09	2.09	26.14	28.23
" 12	3.90	2.80	25.38	28.18
" 19	3.07	3.99	29.28	33.27
" 26	4.14	1.97	30.69	32.66
Aug. 6	3.09	2.43	41.54	43.97
" 9	3.22	2.19	32.90	35.09
" 16	3.19	1.36	29.38	30.74
" 23	3.36	.58	33.82	34.40
Sept. 1	5.24	.50	49.50	50.00
" 7	6.80	1.30	29.60	29.99
" 13	4.40	.48	39.36	39.84
" 22	4.12	1.95	43.30	45.25
" 29	3.97	1.70	32.48	34.18
Oct. 7	1.58	3.52	34.02	37.54
" 15	4.37	.35	36.70	37.05
Nov. 4	4.13	1.35	26.91	28.26

Note:-

The above material was obtained from an area of new development where it had unrestricted room for expansion.

CHANGES TAKING PLACE IN AGROPYRON repens DURING THE GROWING SEASON.

MORPHOLOGICAL CHANGES.

As there was no area easily accessible to the college on which couch grass was being summerfallowed, observations were confined to the effect of competition and type of soil on the development of the plant.

The same areas were available both years and in addition an area of entirely new sod was utilised for observation under conditions in which competition was practically eliminated. This new area became established in the weed garden where six single cuttings of grass from different areas in the province, had been planted for observation respecting morphological characteristics. The cuttings were planted about a rod apart in all directions and did not get established till July, but they had formed a solid mat between themselves and for four or five feet beyond the edges of the plot, by the time growth stopped in the autumn. Seed was also produced but not ripened. This proved to be a very useful plot in 1932, supplying all the material for analytical samples as well as for planting in the soil zone tanks. The growth in the older established stands may be considered more characteristic of the species and in general these areas have supplied most of the information regarding habits of growth. Spring development is much earlier in couch grass than in sow thistle, due to the overwintering of leaf crowns established the previous autumn. About April 15th, 1931, conditions were such that it was possible to get out into the field and there was already a good growth of leaf material and new shoots had reached the surface from rootstocks that had been plowed down to a depth of ten or twelve inches. These new shoots are distinguished from the early development of new rootstocks more by the way in which they originate and the direction of their growth than by any morphological characteristic. Whereas the new rootstock invariably develops at the crown or at one of the nodes between the crown and the old rootstock, the new leafshoot buds out from a node on the rootstock itself and grows straight up to the surface. The direction taken by the new rootstock is horizontal and parallel to the surface of the ground. There is some difference in structure but not as much as might be expected, due to the fact that growth between the parent rhizome and the point where the crown develops is rhizoid in character. When the ground level is reached a leaf crown is developed and it is from these crowns or the nodes directly below them that most of the new rootstocks develop. The production of shoots to the surface in the early summer is much more common in sod bound areas than where the plant has room to develop. Under the latter condition new rootstocks develop early and branch profusely, sending numerous branches to the surface and examination shows that in a newly developing sod a large part of the green growth is made up of single culmns. Possibly the most noticable effect that competition has on the habits of couch grass is the extent to which it retards the development of the new rootstocks. In 1932 there was a difference of over a month in the date at which new material was started and after the new rootstocks have started they develop very slowly. When samples were taken during 1931 a progress of development was followed by determining the relative proportion of new material in the newly developing sod and that taken from the adjoining part of the field which was also growing alfalfa. On June 18th when new rootstocks had been noticable for 20 days, out of 31.65 grams dug out of a 6 inch square there was not enough new material to weigh, but from the edge of this same plot where the land was cultivated the new growth amounted to 32.5%. June 25th the amounts were respectively: 17% and 83%, and by July 18th 30% and 94%, and if it had not been for old roots that were plowed down 10 or 12 inches, there would have been no old roots remaining in the newly developing sod.

A difficulty which developed with couch grass that was not encountered with sow thistle was the separating of the new and old material. When the new material consists of a single stem with a definite growing point or when the scales at the nodes are still intact it is comparatively easy, but when there are numerous branches developed the growing points are broken off and the oldest of the rhizomes become dark in color with the scales often completely removed from the nodes. It is probable that there was a certain amount of mixing of new and old rootstocks in 1931, and the probability is much greater in 1932, due to the rapid and very extensive development of new material on the new plot in the weed garden. New rootstocks began to develop at a very early date on this plot and from previous experience it would seem probable that the old material would be dead before the end of July. Pressure of other work prevented the writer from taking the samples personally and the conditions of growth made it almost impossible for inexperienced help to distinguish the earliest development of the current year's growth from that developed the previous year. The foregoing is advanced as an explanation of the erratic results that were obtained, but it has not been definitely determined whether the rootstocks of couch grass may not live more than one year. In this respect some information has been obtained. In 1931 material that had been plowed very deeply into the ground was still viable and in a good state of preservation when the growth had finished for the season. Reference to Table 6, will show that food reserves were not lacking, but in the spring of 1932 all this material was dead and decaying.

When material was obtained from a piece of roadside sod it was found that all the old rootstocks had disappeared by August.

Ecological conditions possibly have a greater effect on the persistence of couch grass than is generally realized. In 1927 Prof. T. J. Harrison established some soil tanks in the agronomy plots in which was placed three feet of soil from the principal soil zones in Manitoba. Couch grass has been planted and grown in these tanks during the summers of 1930, 31, 32. The most striking thing about this experiment was the persistence with which some of the tanks produced more growth than others. During the summer of 1932, weekly moisture samples were taken and the moisture equivalent determined at 3 inch depths, on all the tanks. The moisture equivalent is theoretically, the amount of water that a soil will hold against the power of gravity and the ratio of this figure to the actual moisture content is a measure of the moisture available to the plant at the time. With the assistance of the Soil Division this determination was made on all the weekly samples to endeavor to determine if extent of growth was correlated with either soil texture or moisture. In general the soils of a low M. Eq. i.e. light or sandy soils favored growth when it held abundant moisture but there was no definite correlation and the soil tank that has been outstanding in the production of new growth, producing two or three times as much as the next largest in all the three years, was neither the lightest soil nor did it retain moisture better than some of the others. The conditions within these tanks were not the natural conditions of the soil within the areas from which they were obtained but the data obtained may give some indication as to why couch grass is so much more prevalent and harder to eradicate in some areas than others.

The main change taking place in couch grass during the fall is the development of winter crowns which are established where the single culms have penetrated above ground earlier in the season. The following year these and the crowns previously described which develop in early spring are the main source of seed stocks later in the summer. The previous establishment of a system of roots stocks and leaf crowns is not necessary for seed production as seed is commonly found on material that has developed from small cuttings. In 1929 a few three inch squares of sod of a lawn type of grass produced flowers after being transplanted in July and in 1931 several single nodes produced flower heads together with considerable rootstocks, one node producing 270 feet of rootstock weighing 393 grams and spreading over a radius of 5 or 6 feet.

The later developed series of rhizomes seemed the most active and often the primary does not produce any leaf cro n before the point where the last secondary was developed.

ILLUSTRATION VIII.

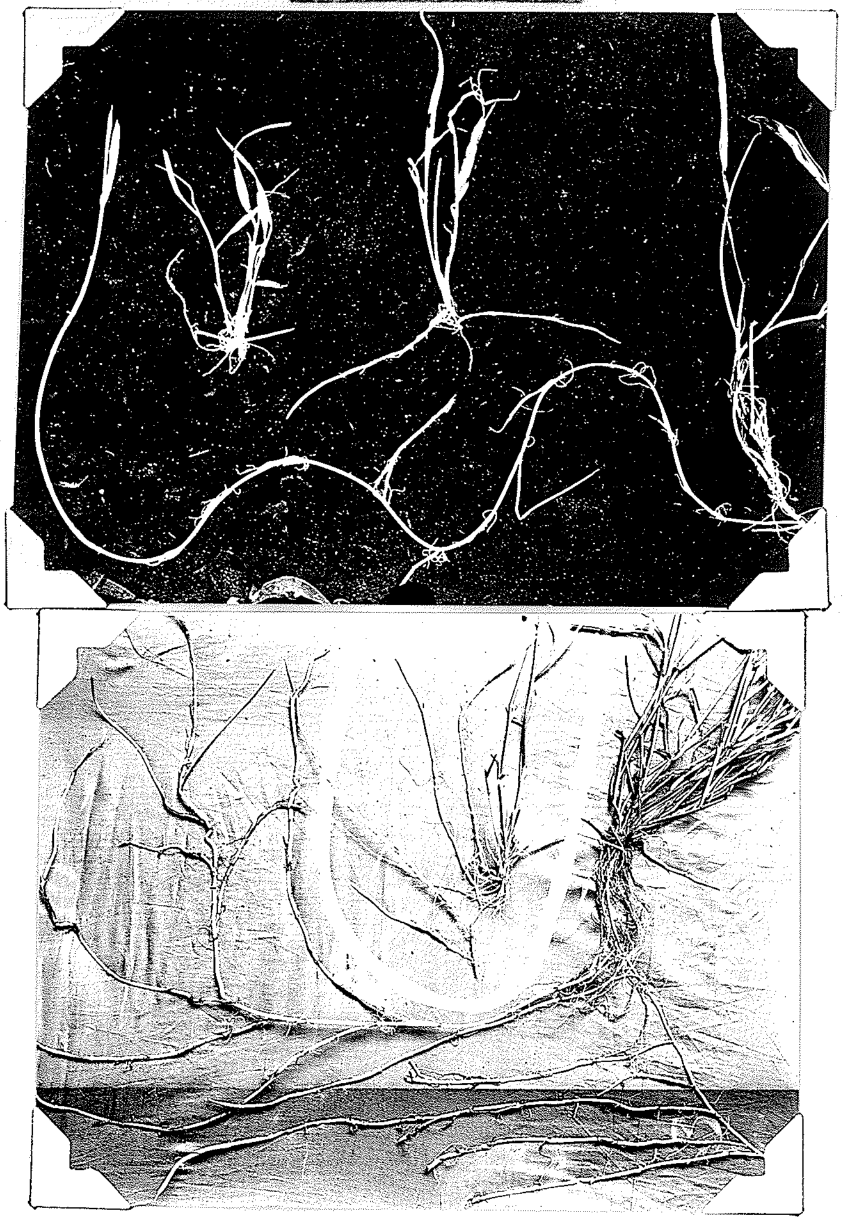
Spring growth from rootstocks, which is mostly directed straight to the surface as illustrated in the upper photograph.

The lower photograph shows the development of a new rootstock later in the summer.

The development of a new rootstock is progressive from the time the bud develops at the crown of the seed plant and is not related in any manner to the progress of the seed producing plant. In both 1931 - 32 the development of new rootstocks had barely started in the alfalfa field when the plants came into head, whereas on the newly developing sod new rootstocks had progressed far enough in development to have produced three new series out of the primary rhizomes. One is illustrated which was dug when the plants were in bloom on July 9th, which has five series and at that time growth had not progressed far enough for a sample of new rootstocks to be obtained in the alfalfa field which was only a few feet distant.

The development of couch grass rhizomes as storage tissues is necessarily different from that of sow thistle roots. Being a monocot there is very little enlargement after the structure is established and the elongation takes place directly behind the needle pointed growing tip. As each internode is produced it is structurally fully developed so that when elongation ends the tissue at the origin is much more mature than that which has just pushed its way above ground and as storage tissue it has probably progressed correspondingly. From the point of view of weed control this question is possibly merely academic but it would be quite interesting to examine critically the various parts of the underground system in relation to their stage of development.

ILLUSTRATION IX



Both the above photographs illustrate the effect of competition on rootstock development, the inset short rootstocks being material from a hay meadow dug at the same time as the better developed rootstocks and only a few feet distant.

stage of development.

PHYSIOLOGICAL CHANGES.

A somewhat different procedure was followed in 1932 than in 1931, in analyzing these rootstocks. The methods used were the same but as there was no evidence of the presence of starch or dextrin in the samples when tested with iodine it was decided to dispense with the starch determination. As the curve for starch in 1931 was practically a straight line it was considered that this would not alter the contour of the total carbohydrates curve to any appreciable extent. An examination of Table 6, will show that there is invariably a rise in "starch" accompanying a drop in sugars and if a large proportion of this fraction is made up of cellulose and related products that are not available as food materials to the plant their inclusion in the totals would lead to as much inaccuracy as the exclusion of the total "starch" fraction. In this regard Arny's (2) figures are of interest as he ran a pure starch fraction, and the resulting curve was almost a straight line at a little less than one percent.

Table No. 5, shows that there is a gradual drop in the moisture content throughout the season and although the moisture content of the soil affects the total amount of moisture in the rootstocks the same relative decrease takes place under all conditions examined. This decrease in moisture content would emphasize the increase in food material during the latter part of the season if this was expressed as percentage of green weight but as there is no way of determining the actual amount of rootstock represented by the sample taken for analysis, it is impossible to say if there is any actual increase other than that shown by the table. On well established sod there is very little variation in the amount of rootstocks per acre when expressed by weight. By taking square foot sods at various times throughout the year, and weighing up all the rootstock material a comparison was obtained and it was found that only enough new material was produced to replace that which died and the actual weight of roots remained fairly constant throughout the season. The old rootstocks retained a fairly constant moisture, the difference between samples taken from various locations, being due to a variation in the moisture content of the soil.

Table No. 6, shows there is an increase of sucrose in the old roots up to the time of maximum seed setting and from then till fall there is a decrease in sucrose accompanied by an increase in reducing sugars which indicates the movement of carbohydrates to the other parts of the plant. Neither of these movements are as emphatic in the new rootstocks and there is a general building up of sucrose from August till fall.

The noticable point in the trend of carbohydrate storage in old roots is the relatively high quantity present in the material that has evidently finished its useful function.

if the amount of food present in old roots, when they are at the point of decay, is compared with the new roots of June when new growth is vigorous and capable of unlimited expansion, it is found that the new rootstocks show less actual food material than the almost dead old roots.

The trend of protein as shown in Table 6, is gradually down in both old and new rootstocks. In the old material this is probably due to the use of part of the reserve for new growth and seed development but the loss in the new rootstocks from August onward may be due to the increased rate of sucrose storage.

Comparing the proteins in tables 6 and 8, there is a noticeable difference in the quantity present throughout the season. The small amount in the 1932 material may be partly due to the phenomenal growth that took place in this area demanding a continual supply for new construction.

After June 28th, it is very probable that the material shown of old rootstocks was actually the earliest developed of the 1932 material. Until such time as there is definite information regarding possible variations in the food content of rootstocks in various stages of growth it would probably be better to ignore the erratic curves obtained from the new material rather than theorize without adequate information. That this abnormality may be due to mixtures of varying amounts of very young and rapidly developing material with more fully developed and comparatively mature rootstalks of the same years growth is offered as possibility.

CONCLUSIONS

In discussing the foregoing data we will confine ourselves as far as possible, to the application of them to the elimination of the plant.

The remarkable regenerative ability of both plants through their underground parts, is clearly shown and a point that might be emphasized is the difference in the reproductive capabilities between the old and new roots of sow thistle. The main function of the old roots is the production of new growth and the establishment of a seed plant. During this process it deteriorates and eventually dies, but this process of deterioration is hastened by the continued elimination of new growth before green leaves are produced and the process may be prolonged if the new growth is not cut until after producing substantial leaf growth.

The production of a new system of thickened roots is the plant's most efficient method of continuance and the main function of these newly produced roots is to build up a food reserve. The depletion of this reserve by inducing new growth is much more difficult as they are not inclined to bud and send out new shoots as freely as the old roots. These new roots are also capable of living through protracted periods of adverse conditions in a state of dormancy. The occurrence of these new roots is not correlated with any particular period in the development of the upper plant only as far as it is necessary to have green leaves to manufacture food for storage, the ecological conditions surrounding the plant and the previous condition of the parent plant determine at what time and to what extent this new system is developed. Where a heavy reserve of food has been stored and an extensive crown is developed, the production of a new system is much earlier than where there is competition and this probably also applies where moisture is at a premium.

Two very definite conclusions may be arrived at from the above, first, that the growth period of the plant above ground is no indication of the progress of the below ground parts, secondly, that the establishment of a new system of thickened roots beyond their very earliest stages, increases enormously the ability of the plant to persist. Therefore it would be advisable to watch the underground parts of sow thistle rather than the top, to determine at what time it would be best to start cultivation with a view to killing the plant. The time nearest that at which the new system is started should be the most effective time to commence cultivation.

Cutting or pasturing sow thistle when carried on intermittently, leads to an increase in the number of new roots but as persistent cutting induced the new roots to produce seed stalks and flower heads, it may be concluded that while cutting down the plants once or twice is of no benefit, persistent cutting will weaken the system to some extent.

When the root material has been entirely eliminated from the upper few inches of soil there is still left a number of vertical roots which were previously attached to the laterals. These vertical roots are very persistent and by their habit of producing a crown of several branches from the cut surface they are able to establish an enormous leaf area and they also produce a new crop of laterals at greater depths than normal. It is these vertical roots which make it necessary to continue cultivating when all signs of lateral roots have disappeared from the field and the thoroughness with which this growth is kept down is often the measure of success or failure of the control.

In analysing the roots of sow thistle the separating of the material into old and new does not alter the curves representing storage trends to any appreciable extent in the present study, but it gives us a little more information which can be used to fairly good advantage. The usual conclusions arrived at when this type of analysis has been carried out before, is that there is a low point in the storage trend when the plant is in a weakened condition and would be vulnerable to attack. If the previous conclusion that it is necessary to attack the plant before a new system is established it is conceivable that the low point in storage might not be reached till after the new root system is well established. It is fairly certain that new roots, even if the concentration of food is not very high, require much more work to eradicate than a larger number of old roots containing a fairly high concentration of food.

The data obtained regarding couch grass need very little discussion. The variability in the dates at which new growth commenced in the various fields under observation, was particularly noticable. It would seem from these data that couch grass would be more easily eradicated when the field was in a heavy sod which had not been cultivated for several years. This is no doubt the reason underlying success often observed where abandoned fields have been recultivated with the proper implements, after remaining in sod for several years. It might be concluded from the above that cultivation could be delayed on this type of field. There are other factors which affect this which do not come within the scope of this paper, therefore, will not be discussed.

The production of new rootstocks immediately below the crown of the plant, tends to concentrate the rootstocks within the first few inches of soil when left undisturbed. This is a further advantage when fields are left in pasture sometime previous to cultivation. It should be noted that the above only applies where fields are thoroughly infested and the extent to which infestation has been observed to spread from the edges of established patches make it very evident that small infestations are extremely dangerous and should be eliminated at any cost. The production of extensive growth from a single node gives us some valuable information on the reason why cultivators that cut the roots rather than pull them out of the ground, have not proven very successful. In this respect it may be noted that in general new rootstocks are much more viable than old.

Determining the relative percentage of old and new rootstocks present in the 1931 sod, gave an opportunity to study what effect separating the new and old rootstocks had on the amounts of the various constituents reported in the tables. A comparison is given below on the difference there would have been if the sample had been reported without separating.

June 18	Red.Sugars	Sucrose	Starch	Total
Old Roots	1.72	34.30	15.58	50.99
New Roots	1.28	13.44	11.70	26.42
70% old 30% new	1.60	28.01	14.39	43.62
July 18				
Old Roots	3.20	36.35	13.07	52.62
New Roots	1.70	19.71	14.74	36.15
30% old 70%new	2.15	24.70	14.24	41.09

When the variation in the percentage of new rootstocks developed under different conditions is considered the possibility of a composite sample giving reliable information regarding progress of development is rather remote.

The above conditions obtained where the edge of a very old infestation had been cultivated the year before and would be similar to a field cultivated for crop but not summerfallowed. Under these conditions the food material in the rootstocks, taken as a whole, were lower on July 18th than on June 18th. On July 18th, 70% of the material in the sod was young, vigorously growing rootstocks which it would have been almost impossible to eradicate by cultivation. This together with the general trends shown in the tables leads to the conclusion that the low point in food storage does not always mark the low point in the plant's resistence.

The production of a vigorous growth of new rootstocks, each node of which is capable of producing hundreds of feet of new growth, is the greatest single factor in persistence of couch grass.

Environmental conditions determine the time at which rootstocks begin to grow and the extent to which they develop.

New rootstocks are produced at or near the crown of the plant. When undisturbed this factor tends to concentrate them near the surface. Cultivation disturbs these conditions and rootstocks were found to be plentiful in the six to ten inches of cultivated fields.

Old rootstocks when transplanted did not produce new growth readily nor extensively.

Taking the above points into consideration it is to be expected that creating conditions adverse to early or extensive production of new rootstocks and the concentration of those present near the surface of the soil, would reduce the time and labor required to eradicate them.

SUMMARY.

Studies of the life histories of sow thistle (Sonchus arvensis L.) and couch grass (Agropyron repens (L) Beauv) are described.

These studies are divided into two parts:

(a) The morphological changes taking place during the growing season.

(b) The physiological changes taking place as reflected in the storage of food reserves.

Sow Thistle

(a) New growth originates either from buds on the roots or the frozen surface of previous year's shoots.

Seed plants die down in the fall and rot.

Shoots produced from old roots developed into seed plants if left undisturbed.

New thickened roots developed at the base of above plants between the old root and the surface of the ground.

A considerable portion of their lateral development took place before thickening began.

New roots are not developed at any particular period in the life cycle of the flowering portion of the plant.

The time and extent of their development depends on the environment and condition of the parent plant.

Vertical branches are produced from the laterals, usually after rosettes of leaves have been produced.

Thickened lateral roots die out in their second year.

Vertical roots are much more persistent than laterals and often develop a new lateral system deeper in the ground than normal.

The development of a new system of lateral thickened roots increases the difficulty of control.

Competition in the field retards development of new roots.

(b) Total nitrogen and reducing sugars in the old roots were higher in the early spring than any other time till they died.

Percentage of protein was maintained at a higher level in roots from cultivated ground.

Sucrose and starch (by acid hydrolosis) declined in the early spring but increased slightly till just previous to their disappearance when there was a very sharp decline.

Total carbohydrates declined in early spring, increased gradually and just previous to dying decreased very rapidly.

New roots showed a slight increase in protein from spring to fall.

Reducing sugars maintained about the same level.

Sucrose increased rapidly as the new roots developed, later it was replaced by starch, but as cold weather approached sucrose again increased at the expense of starch.

Total carbohydrates increased rapidly in the early stages of development.

The high point was reached about midsummer and maintained till fall.

Couch Grass.

(a) New rootstocks developed at the base of the crown of seed plants and very seldom directly from the old rootstock.

Great variation was found between the dates that new rootstocks started to be produced.

Competition delayed development of new rootstocks.

No case was found where rootstocks persisted longer than their second year.

Single nodes of new rootstocks planted in July, produced hundreds of feet of secondary growth with several seed plants by October.

Old material did not produce new rootstocks readily when transplanted.

Winter leaf crowns are developed in the fall and persist all winter. These are the common source of seed plants.

Certain soils were found to favor the growth of couch grass more than others under the same conditions.

(b) The percentage of food reserves was found to be lower in rapidly growing rootstocks than in the old rootstocks that had begun to deteriorate.

The amount of food material contained in rootstocks is not a measure of their vitality.

Crude protein in the old rootstocks remained fairly constant. In new roots it was considerably higher in their early stages but declined to about the same level by the end of the season.

Reducing sugars remained fairly constant in both old and new material.

Sucrose increased in old rootstocks till midsummer, then declined to about 20%.

Old rootstocks which persisted till frost in 1931, still contained over 20% of sucrose.

New rootstocks that produced enormous quantities of material from single nodes contained less than 20% sucrose and as little other reserves as the old rootstocks that died.

The percentage of sucrose increased fairly steadily from the first development of new rootstocks till frost.

Acid hydrolosis gave a fraction that was practically constant and dextrins or starch could be detected in the samples by the iodine test. This fraction was not determined on the 1932 material.

Dividing the material into current and previous year's growth gave more information on the trend of food storage than analysing samples composed of old and new material as they were removed from the soil.

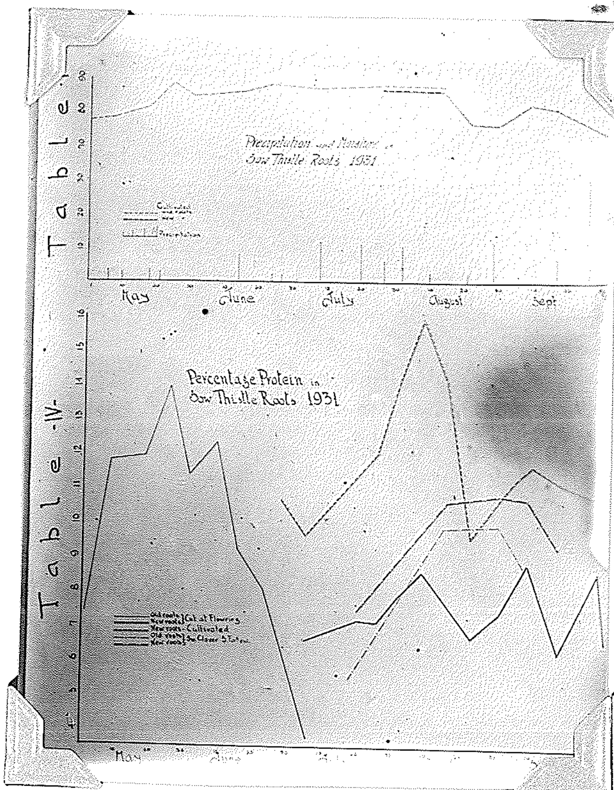


Table -IV-
Precipitation and Moisture in Sow Thistle Roots 1931
Precipitation
Percentage Protein in Sow Thistle Roots 1931
May
June
July
August
Sept.

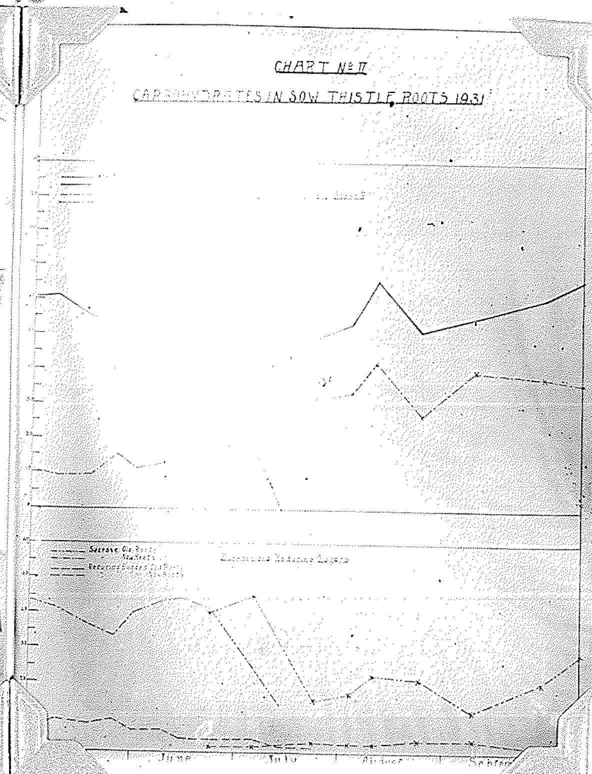


CHART No II
June
July
August

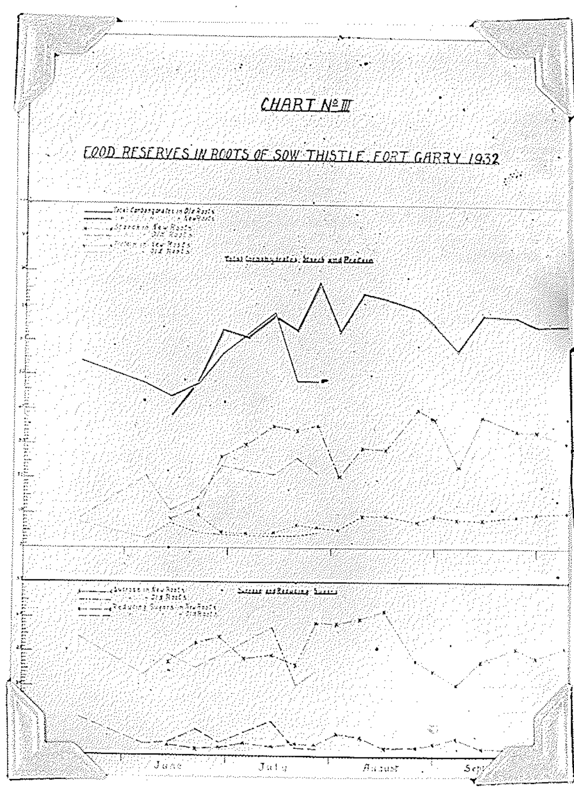


CHART No III
FOOD RESERVES IN ROOTS OF SOW THISTLE, FORT GARRY 1932
June
July
August

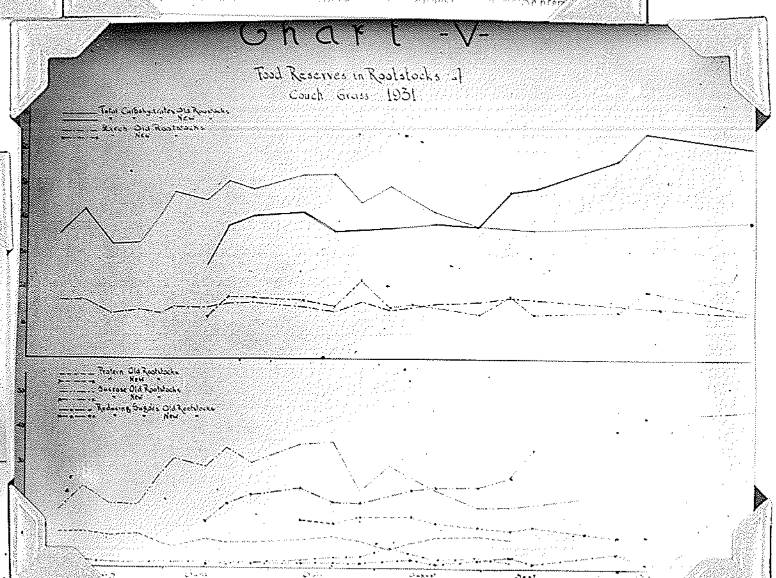


Chart -V-
Food Reserves in Rootstocks of Couch Grass 1931

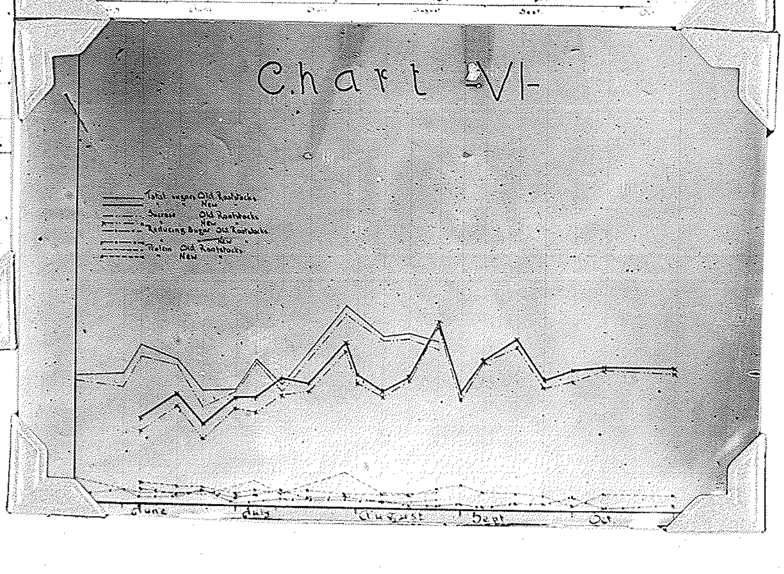


Chart -VI-
June
July
August
Sept.
Oct.

ILLUSTRATION X

SPRING TYPES OF GROWTH IN SOW THISTLE

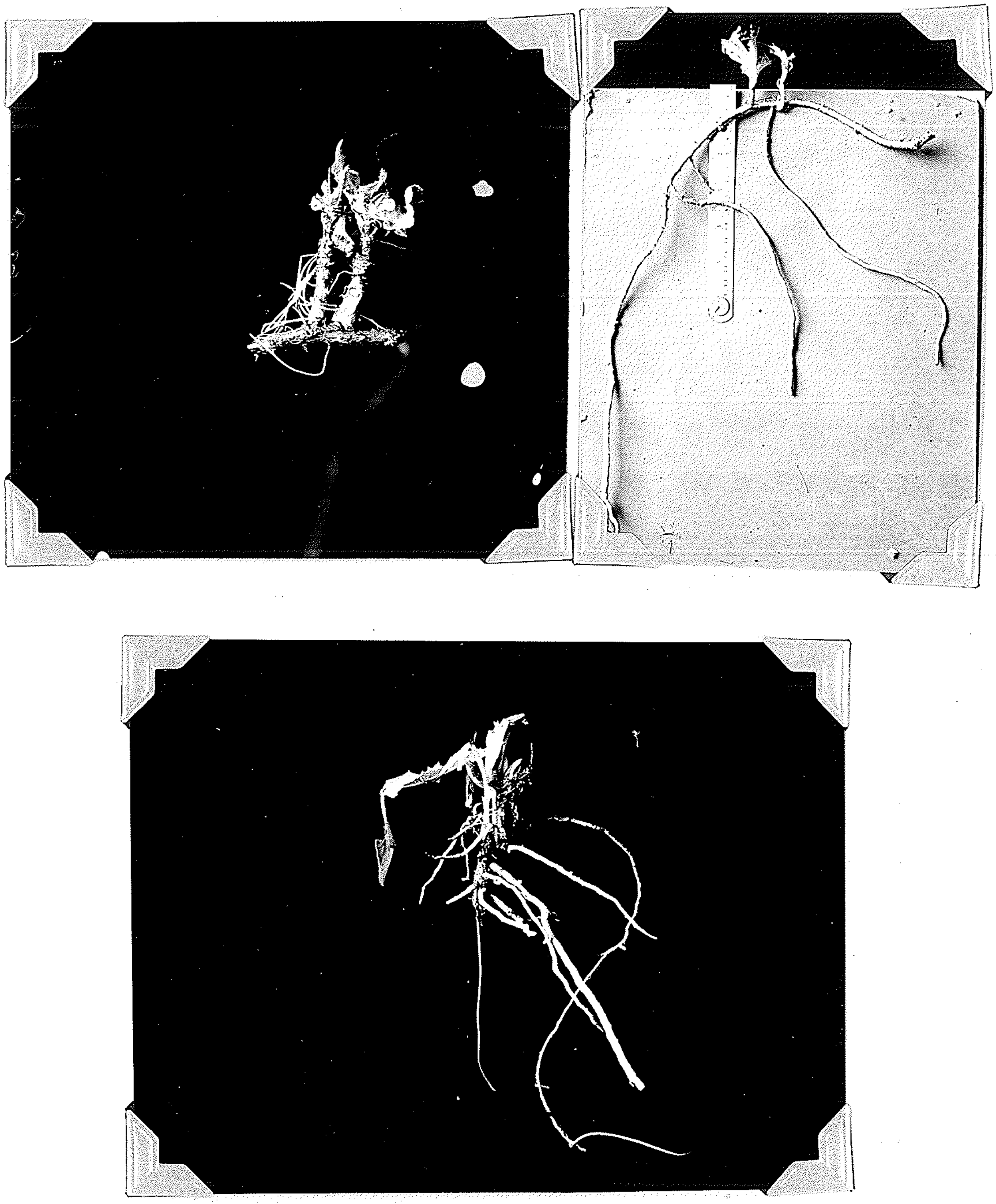


ILLUSTRATION XI

TYPES OF ROOTSTOCK GROWTH IN COUCH GRASS

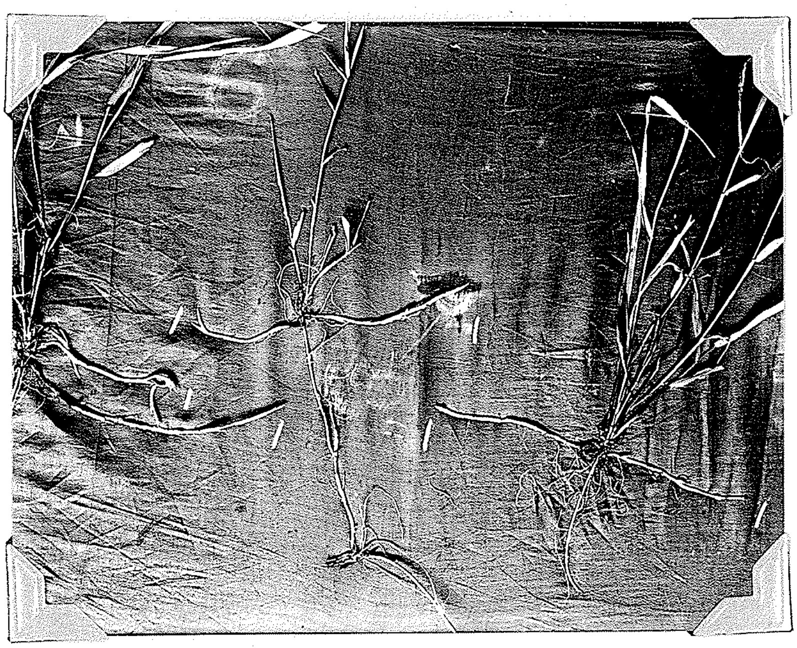
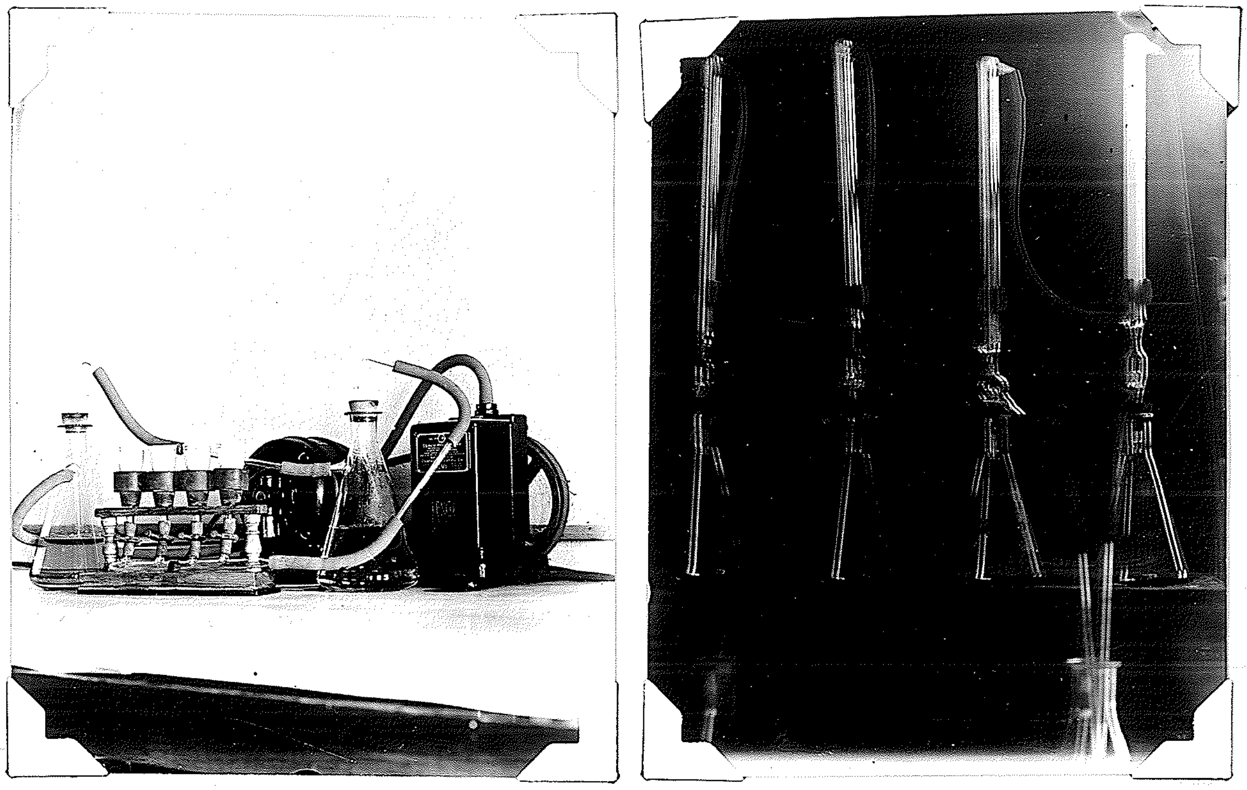


ILLUSTRATION XII



(a) (b)

(a). Battery of Gooch crucibles set on one stand and requiring only one pump to operate.

(b). Illustrates the combined reflux condenser and still used for preparing sample and collecting alcohol residue.

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