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Organic Food Reserves in Relation to the Eradication of Canada Thistles

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ORGANIC FOOD RESERVES IN RELATION TO THE ERADICATION OF CANADA THISTLES

F. A. WELTON, V. H. MORRIS, AND A. J. HARTZLER

INTRODUCTION

The Canada thistle, *Cirsium arvense* Tourn., is generally distributed thruout Ohio, particularly in the northern and central parts of the State. The disadvantages of Canada thistles are so generally recognized that the plant is now rated by law in Ohio and other states as a noxious weed. The deep, creeping, branching rootstock, with its food reserves stored within thus insuring perennial life; the prickly leaves which militate against grazing; the longevity of the seeds and the ease with which they may be disseminated—these are the principal characteristics which have caused it to be so rated. The chief agricultural interest in the plant, therefore, centers in the finding of feasible ways and means by which the pest may be economically eradicated.

True it is, there are many who claim to have been able to kill Canada thistles by a single mowing, and the numerous claims of this kind seem to have given rise to the idea in the minds of many people that there is a certain day, related in some mysterious way to the phases of the moon or the signs of the Zodiac, on which wholesale destruction of these plants can be wrought. A roll call of these individuals (3), however, seems to indicate about as many fatal days as there are days in the growing season.

Spraying with herbicides, cultivating, hoeing, excessive grazing often induced by sprinkling dry salt over the leaves, and mowing, are the chief methods usually employed to kill Canada thistles. The results obtained by different workers from the use of any of these methods have been so diverse as to suggest that the seeming inconsistencies may be due to the stage of growth at which the thistles were attacked.

The creeping rootstock, as indicated in Figure 1, probably serves not only as an organ of absorption and translocation, as in the fibrous rooted plants, but also as an organ of storage of food reserves. Moreover it is likely that on these reserves depends largely the quantity of top and root growth, and that on the depletion of these, thru early and continued mowing of the tops, death of the plants ultimately results.

Waters (5) noted the importance of the storage of food reserves in the bulbs of timothy, *Phleum pratense*, and found that if the timothy was cut early the culms were imperfectly developed and the meadow became thin and was short-lived. On the other hand if the timothy was allowed to stand to maturity or at least until the heads were formed then well filled and well matured bulbs were developed and this condition was associated with permanence of stand.

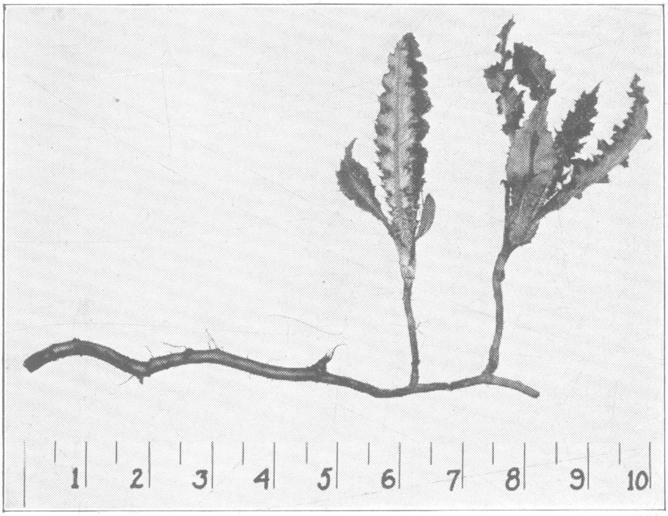

Fig. 1.—Showing manner of growth

In connection with their investigations of the tomato plant, Kraus and Kraybill (4) found, among many other things, that, "Stems without storage starch at the base when cut off close to the surface of the soil, fail to sprout but decay quickly, whereas those with large storage produce new shoots. Accompanying such growth there is a total or complete disappearance of the starch, depending upon the relative amount of growth made and the available nitrogen supply. If the latter is abundant vegetative extension is relatively great; if not, such extension soon ceases and starch is again stored in the new growth."

As a result of field observation and chemical and physiological investigations of alfalfa, *Medicago sativa*, and certain grasses, Graber, Nelson, Luekel, and Albert (2) found that early and frequent cutting caused a decrease in the growth of both tops and roots and among other things they concluded that "The retardation of root and top growth of alfalfa plants and their ultimate death from cutting frequently and at immature stages is due, primarily, to the inability of the plants to elaborate organic food reserves thru photosynthetic activity in sufficient quantities to provide for adequate translocation to and storage of such reserves in the roots for the future development of the roots, as well as that of the tops.

"Frequent and immature cuttings of alfalfa plants in contrast with mature cuttings, lowered the percentage and amount of dry matter; of total available carbohydrates, and of total nitrogen in the roots during the growing season, to such a degree that most pronounced differences, especially in the amounts of these reserves occurred at the time of winter dormancy.

"The susceptibility of the alfalfa plant to winter injury is increased by low percentages of dry matter and low concentrations of carbohydrates and nitrogen reserves in the roots at winter dormancy."

If a situation obtains in Canada thistle plants like that which has been shown to exist in timothy and alfalfa plants, that is, that the top growth, especially that made in the early part of the season, is initiated and developed at the expense of organic reserves elaborated and deposited the preceding year, and that such reserves are replenished later in the year providing the plants are allowed to grow without interruption to maturity, then it would appear that there must be some time in the season at which the reserves reach a minimum point. If such a point is reached then it would seem that this condition would mark a stage in the life history of the Canada thistle at which the plants would be especially vulnerable.

OBJECT

The purpose of the work reported in this paper was to find out if there is a rather definite period in the life cycle of the Canada thistle at which the organic food reserves stored in the roots are noticeably reduced, and, if so, to find the season of the year at which such period occurs. An effort was made also to determine the effect of one or more mowings per season on the storage of organic food reserves in the roots and to note the effectiveness of such mowings as a means of control or eradication.

In this paper the expression "organic food reserves" means the carbohydrate and nitrogen compounds utilized by the plant itself in the processes of maintenance and growth.

MATERIAL

Rootstocks of Canada thistles were gathered at the Experiment Station farms at Wooster in 1925, 1926, and 1927. In 1925 the samples were taken from a virgin pasture field on the Snyder farm. The soil on this farm is classified as Canfield silt loam. The surface drainage is good. Patches of thistles were scattered thruout the field. The stand of thistles in the various patches was moderately thick, but the size of the individual plants was relatively small, perhaps because the rainfall in every month from January to August, inclusive, was below normal.

In 1926 rootstocks were taken from a pasture field on the Frye farm. The field had been in pasture for many years, both cattle and sheep having access to it. Patches of thistles were scattered thruout the field and the region from which the samples were taken had good surface drainage. The thistles made a normal development. The soil is classified as Wooster silt loam.

In 1926 a series of samples was taken from the East farm thus making a second series in that year. These were not located in a pasture field but in a waste area, a slight depression thru which in times of heavy rain considerable water passed. The soil on this farm is classified as Wooster silt loam. The thistles had been established on this ground for many years. The stand was thick, and the plants were vigorous. For years the plants had been mowed each summer, usually once in the season.

In 1927 rootstocks were again taken from the Frye farm; from the same pasture as in 1926, but from a different location in the pasture. The thistles made a normal growth thruout the season.

In sampling no definite area was taken. This was impractical on account of the unevenness of the stand. Neither was a definite number of plants collected for each sample. This was not feasible, for there is no line of demarkation on the rootstock separating definitely one plant from another. For each sample enough rootstock material was dug up to make approximately 100 grams. Only the more mature part of the rootstocks was included in the samples. Practically all the root hairs were removed. The depth at which the rootstocks were found varied from 6 to 15 inches. After thoroly washing with water the rootstocks were dried between sheets of blotting paper, cut into pieces ½ to 1 inch in length, and finally placed in wide mouthed glass stoppered bottles and heated in 95 percent ethyl alcohol at 78° C. (172° F.) for approximately an hour. The strength of the alcohol including the moisture contained in the samples was approximately 70 percent.

METHOD OF ANALYSIS

Extraction of the samples.—After having stood for several months the samples were transferred to a large soxhlet extractor with approximately 800 cc. of 80 percent alcohol and extracted for 8 hours. The extract, after cooling, was rinsed into a 1-liter flask, made up to volume and passed thru a dry folded filter in order to remove any sand or dust that may have adhered to the sample.

Carbohydrate determinations.—Fifty cc. of the alcoholic extract was placed in a 100 cc. volumetric flask and the alcohol driven off on a steam bath. The cooled solutions were diluted somewhat and cleared by the addition of an excess of neutral lead acetate. After making up to volume the solutions were filtered thru dry folded filters, deleaded with dry potassium oxalate, and again filtered.

Twenty-five cc. of the clear filtrate was used for the determination of the free-reducing power.

For the inverted sugars there was added to another 25 cc. aliquot, 0.5 cc. of convertit, a commercial invertase preparation, and after one-half hour the reducing power of the solution was determined.

To determine the easily hydrolyzable carbohydrates, 2 grams of the dry residue was placed in a 300 cc. Kjeldahl flask to which was added 180 cc. water and 20 cc. of a 25-percent solution of hydrochloric acid. The flask was heated for two hours in a boiling water bath after which the solution was filtered thru a linen disk in a Gooch crucible and the residue washed thoroly with hot water and finally with alcohol. The filtrate was then made up to volume in a 500 cc. flask. One hundred cc. was transferred to a 250 cc. flask, neutralized with sodium hydroxide, and made up to volume. Twenty-five cc. was used for the determination of the reducing power.

The reducing power of the sugar solution was determined as follows:

Twenty-five cc. was placed in a 100 cc. centrifuge tube, to which was added 60 cc. of Fehling's solution. The tube was then heated in an electrically controlled water bath at 80° C. for 30 minutes after which it was centrifuged for 10 minutes and then the

Fehling's solution was poured off. The cuprous oxide was washed with 15-20 cc. freshly boiled distilled water, after which a little powdered talc was added and the mixture again centrifuged for 10 minutes. The supernatant liquid was again poured off, a glass bead added to stir up the cuprous oxide and the amount of copper determined by the Bertrand titration method using N/20 K Mn 0 4.

General statement.—The total reducing power of the extract before inversion is recorded as free reducing sugars. The increase in the reducing power of the extract after inversion represents the inverted sugars. The substances obtained by hydrolysis of the dry residue are recorded as easily hydrolyzable carbohydrates. In all three cases the results are expressed as dextrose.

Dry matter.—The residue was air-dried over a steam plate for several days, and then placed in a vacuum oven for 4 hours at 105° C. (221° F.). The residue, after weighing, was ground fine in a mill and then placed in air-tight containers. In order to determine the quantity of dry matter in the alcohol extract, 50 cc. of the solution was transferred to a platinum dish and then placed first on a steam bath and finally in a vacuum oven at 78° C. until constant weight was attained. The sum of the two gives the total dry weight in 100 grams of fresh sample and hence the percent of dry matter.

Total nitrogen.—In the alcohol extract the total nitrogen was determined by placing 100 cc. of the extract in a Kjeldahl flask, evaporating the alcohol and then proceeding as directed in the official method for total nitrogen including nitrates. In the dry residue the total nitrogen was determined by a modification of the official Kjeldahl method.

Calculations.—All the results are calculated on the basis of the green weights and presented in percentages. On this basis it is, of course, possible that the total quantity of the various constituents might remain unchanged and yet appear to decrease or increase due to the intake of water incident to the processes of growth. To have calculated the actual quantity of the various constituents per plant would have been more desirable but on account of inability to delimit accurately one plant from another, as already stated, and in view of the further fact that the rootstock is an organ for the storage of food reserves, it is altogether probable that the changes in percentages noted were due chiefly, if not wholly, to changes in quantity of storage materials rather than to absorption of water. The results are discussed on the basis of that assumption.

RESULTS

Dry matter.—Altho the dry matter found in the rootstock of Canada thistles contains not only organic food reserves, but also cell-wall materials and other constituents, yet the combined quantity of the latter in contrast to the quantity of the former is so small and so constant that any appreciable change in the quantity of total dry matter may well be attributed to changes in quantity of organic food reserves. A study of the organic food reserves stored in the rootstocks of Canada thistles may, therefore, well begin with an examination of their content of dry matter. The date and place on which samples were taken and the percentage of dry matter found in each sample were as shown in Table 1.

TABLE 1.—Dry Matter in Rootstocks of Canada Thistles

1925 Snyder farm		1926 Frye farm		1926 East farm		1927 Frye farm	
Date	Dry matter	Date	Dry matter	Date	Dry matter	Date	Dry matter
	Pct.		*Pct.*		*Pct.*		*Pct.*
		Mar. 31	15.36	Mar. 31	16.87	Mar. 29	15.82
		April 9	15.25	April 9	16.43	April 6	17.50
		April 16	14.76			April 14	16.55
April 23	14.00	April 23	14.49	April 23	15.35	April 19	15.94
		April 30	16.83			April 28	13.63
May 1	11.85					May 4	12.42
May 9	11.59			May 7	13.59	May 10	12.78
May 16	10.87	May 14	11.05			May 17	11.11
May 22	11.00	May 22	13.66			May 24	10.24
May 28	12.21	May 28	10.66	May 28	9.68	May 31	10.43
June 5	12.76	June 4	10.89			June 9	9.92
June 12	12.19	June 14	14.02	June 14	10.54	June 15	11.17
June 19	13.10					June 22	13.64
June 27	14.46	June 28	16.55	June 28	12.41	June 29	13.80
July 7	14.00	July 6	16.69			July 7	18.64
		July 12	23.43	July 12	11.61	July 12	21.65
		July 19	20.25			July 20	20.95
July 24	19.75	July 26	23.83	July 26	19.97	July 27	20.09
		Aug. 2	19.36			Aug. 3	19.58
						Aug. 10	22.11
Aug. 13	23.53	Aug. 18	20.52	Aug. 18	23.71	Aug. 17	22.18
		Aug. 22	24.16			Aug. 23	25.16
		Aug. 30	22.54	Aug. 30	25.57	Sept. 1	25.58
						Sept. 7	26.54
Sept. 9	24.51	Sept. 13	19.51	Sept. 13	25.83	Sept. 16	26.17
						Sept. 21	28.44
						Sept. 28	26.81
						Oct. 5	27.43
Oct. 21	20.93	Oct. 19	20.19	Oct. 19	25.19	Oct. 21	28.59

The results for each year have two things in common. First, the percentage of dry matter was lower in the spring than it was in the fall, thus indicating that a portion was used up by the plants themselves during the winter. Second, and of much more importance in this connection, the percentage of dry matter, beginning in the spring, gradually decreased, reaching a minimum usually about the first of June and then gradually increasing as the season advanced. This general trend in each series is shown graphically in Figure 2.

Easily hydrolyzable carbohydrates.—A further examination of the dry matter shows that the variations noted in Table 1 were due largely to differences in the group of compounds known collectively as the easily hydrolyzable carbohydrates, for the percentage of these compounds found during the season each year varied in the same general way as did the dry matter. This is shown in Table 2, which gives the percentage of easily hydrolyzable carbohydrates found in the various samples. The general trend, first downward and then upward for each series, is shown graphically in Figure 3. In each series there was a minimum point, which in general occurred about the first of June.

TABLE 2.—Easily Hydrolyzable Carbohydrates in Rootstocks of Canada Thistles

1925 Snyder farm		1926 Frye farm		1926 East farm		1927 Frye farm	
Date	Carbohydrates	Date	Carbohydrates	Date	Carbohydrates	Date	Carbohydrates
	Pct.		*Pct.*		*Pct.*		*Pct.*
		Mar. 31	2.51	Mar. 31	2.44	Mar. 29	3.74
		April 9	3.86	April 9	3.54	April 6	4.92
		April 16	3.83			April 14	4.01
April 23	4.39	April 23	3.75	April 23	4.55	April 19	4.48
		April 30	4.82			April 28	3.52
May 1	2.53					May 4	3.38
May 9	3.28			May 7	3.84	May 10	3.55
May 16	3.01	May 14	2.71			May 17	3.18
May 22	3.70	May 22	3.85			May 24	3.14
May 28	3.26	May 28	2.64	May 28	2.20	May 31	3.57
June 5	4.16	June 4	2.88			June 9	2.26
June 12	2.00	June 14	4.15	June 14	2.43	June 15	2.85
June 19	4.18					June 22	4.82
June 27	5.53	June 28	5.46	June 28	2.84	June 29	5.83
July 7	3.34	July 6	6.26			July 7	8.03
		July 12	10.39	July 12	2.99	July 12	10.03
		July 19	8.59			July 20	9.59
July 24	9.29	July 26	10.52	July 26	7.89	July 27	9.44
		Aug. 2	6.82			Aug. 3	9.39
Aug. 13	13.54					Aug. 10	10.78
		Aug. 18	8.28	Aug. 18	11.45	Aug. 17	11.20
		Aug. 22	12.09			Aug. 23	13.96
		Aug. 30	9.64	Aug. 30	13.29	Sept. 1	13.61
Sept. 9	14.98					Sept. 7	16.03
		Sept. 13	8.58	Sept. 13	11.30	Sept. 16	16.09
						Sept. 21	16.74
						Sept. 28	15.46
						Oct. 5	15.69
Oct. 21	11.45	Oct. 19	8.20	Oct. 19	12.55	Oct. 21	16.05

The chief carbohydrate storage form of the Canada thistle, as shown by microchemical tests, is not starch but inulin. This is a common form of storage in many orders of plants, especially in the compositae family of which the Canada thistle is a member.

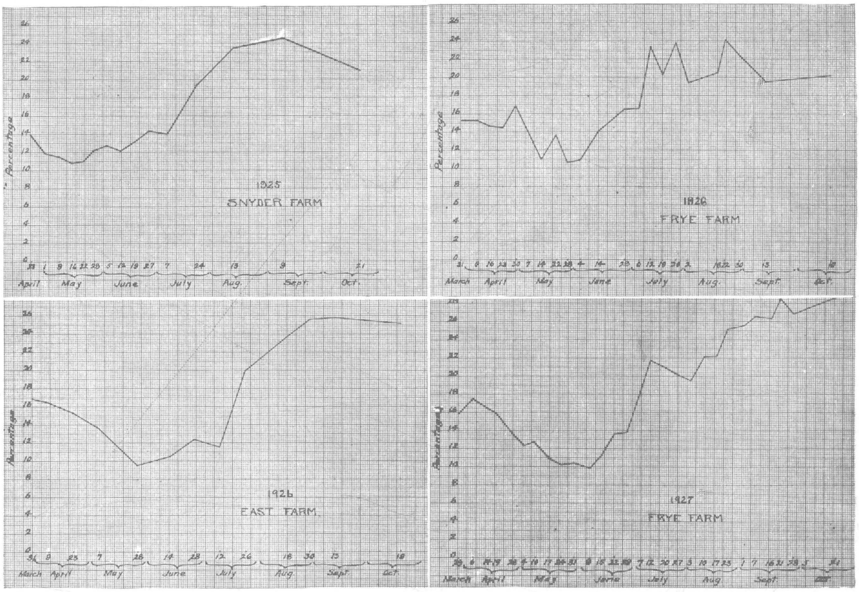

Fig. 2.—Percentage of dry matter, March to October. On Snyder farm, 1925; Frye farm, 1926; East farm, 1926; and Frye farm, 1927

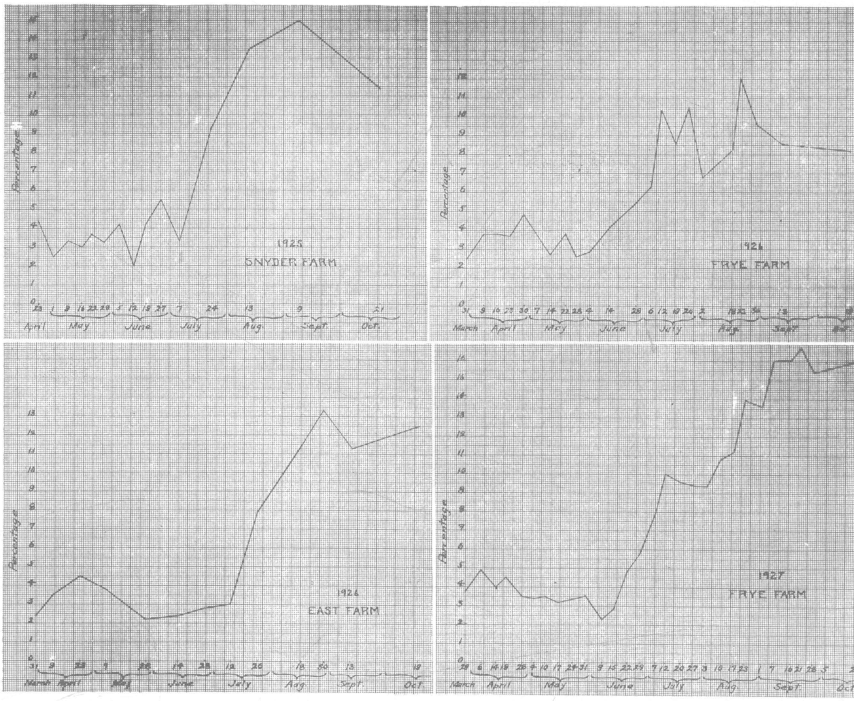

Fig. 3.—Percentage of easily hydrolyzable carbohydrates, March to October. Snyder farm, 1925; Frye farm, 1926; East farm, 1926; and Frye farm, 1927

Inverted sugars.—The percentage of inverted sugars found in the four series of samples was as shown in Table 3. The results for each series are given graphically in Figure 4. In each of the three series where the sampling was started late in March before the thistles had come up the inverted sugars were relatively high, but by the middle or latter part of April they had declined markedly. In one series A 1925, the graph, did not indicate a marked decline in the early part of the year, presumably because the sampling that year was not started until April 23, about three weeks later than in the other three series and at about the time the minimum point occurred in them. With the start of growth processes in the early spring there was for a short time an abundance of inverted sugars, and this condition appeared again in July after the thistles had reached maturity. During the period of rapid development, however, when nutrients were being translocated rapidly to make new growth, the percentage of inverted sugars was low.

TABLE 3.—Inverted Sugars in Rootstocks of Canada Thistles

1925 Snyder farm		1926 Frye farm		1926 East farm		1927 Frye farm	
Date	Inverted sugars	Date	Inverted sugars	Date	Inverted sugars	Date	Inverted sugars
	Pct.		*Pct.*		*Pct.*		*Pct.*
		Mar. 31	3.29	Mar. 31	1.48	Mar. 29	1.75
		April 9	.56	April 9	1.66	April 6	2.30
		April 16	.34			April 14	1.72
April 23	1.40	April 23	.43	April 23	.26	April 19	1.59
		April 30	.68			April 28	.33
May 1	1.01					May 4	.75
May 9	.78			May 7	.16	May 10	.90
May 16	.83	May 14	.87			May 17	.92
May 22	.90	May 22	.94			May 24	1.21
May 28	1.52	May 28	.69	May 28	.23	May 31	.64
June 5	1.02	June 4	.35			June 9	.57
June 12	.86	June 4	1.25	June 14	.03	June 15	1.22
June 19	.83					June 22	1.17
June 27	.86	June 28	1.51	June 28	1.27	June 29	1.57
July 7	1.53	July 6	2.08			July 7	2.14
		July 12	2.15	July 12	1.08	July 12	1.95
		July 19	1.59			July 20	1.67
July 24	1.32	July 26	2.14	July 26	1.81	July 27	1.63
		Aug. 2	1.39			Aug. 3	1.49
Aug. 13	1.59					Aug. 10	1.34
		Aug. 18	....	Aug. 18	1.06	Aug. 17	1.54
		Aug. 22	.83			Aug. 23	1.58
		Aug. 30	1.24	Aug. 30	1.27	Sept. 1	1.40
Sept. 9	1.28					Sept. 7	1.15
		Sept. 13	1.16	Sept. 13	1.46	Sept. 16	1.20
						Sept. 21	.86
						Sept. 28	1.32
						Oct. 5	1.45
Oct. 21	1.75	Oct. 19	1.84	Oct. 19	1.57	Oct. 21	1.31

Free-reducing sugars.—Concomitantly with the decrease in percentage of easily hydrolyzable carbohydrates and of inverted sugars, there was an increase in percentage of free-reducing

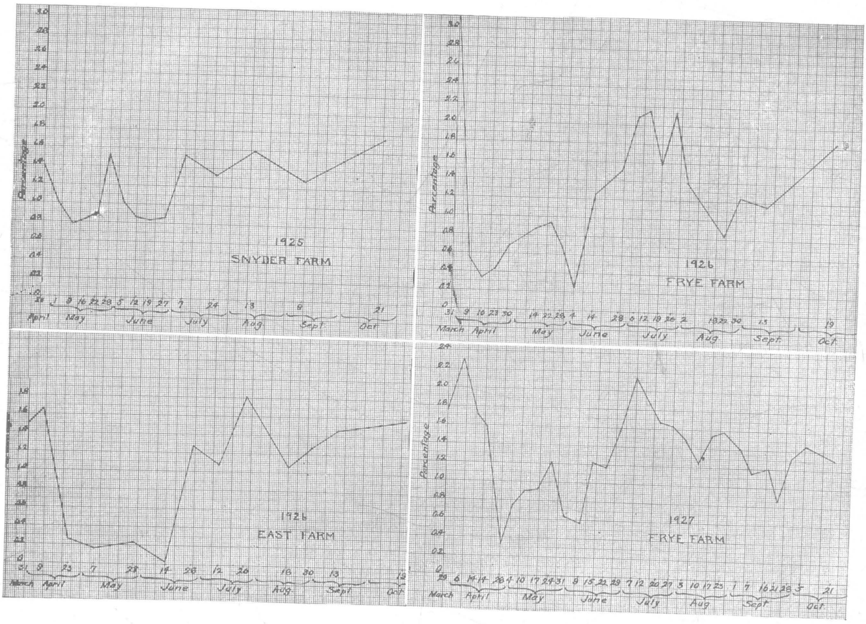

Fig. 4.—Percentage of inverted sugar, March to October. Snyder farm, 1925; Frye farm, 1926; East farm, 1926; and Frye farm, 1927

sugars, simple water soluble substances, into which the more complex compounds would have to be broken up in order that translocation and ultimate combination with nitrogen to form new aerial and underground growth could take place. The percentage of free reducing sugars found in the samples was as shown in Table 4. In general the simple sugars increased quite rapidly in the early part of the year during the period of decrease in easily hydrolyzable carbohydrates, and after reaching a maximum there was a marked tendency for them to fall off rapidly about the last of June. The changes in the percentage of free-reducing sugars in each series noted with the advance of the seasons are shown graphically in Figure 5. The percentages found from time to time were somewhat erratic, especially in 1925, but considering the labile character of the compounds this, perhaps, was to be expected.

TABLE 4.—Free Reducing Sugars in Rootstocks of Canada Thistles

1925 Snyder farm		1926 Frye farm		1926 East farm		1927 Frye farm	
Late	Sugars	Date	Sugars	Date	Sugars	Date	Sugars
	Pct		*Pct*		*Pct.*		*Pct.*
		Mar. 31	0.15	Mar. 31	0.27	Mar 29	0.30
		April 9	.19	April 9	.18	April 6	.32
		April 16	.09			April 14	.34
April 23	0.47	April 23	.39	April 23	.20	April 19	.29
		April 30	.41			April 28	.20
May 1	.18					May 4	.20
May 9	.66			May 7	.44	May 10	.42
May 16	.56	May 14	.29			May 17	.52
May 22	.40	May 22	.48			May 24	.56
May 28	.42	May 28	.43	May 28	.34	May 31	.36
June 5	.62	June 4	.54			June 9	.50
June 12	.48	June 14	.66	June 14	.87	June 15	.45
June 19	.42					June 22	.75
June 27	.24	June 28	.08	June 28	.21	June 29	.08
July 7	.26	July 6	.14			July 7	.08
		July 12	.16	July 12	.36	July 12	.05
		July 19	.12			July 20	.14
July 24	.55	July 26	.25	July 26	.21	July 27	.20
		Aug. 2	.15			Aug. 3	.07
Aug. 13	.39					Aug. 10	.06
		Aug. 18	.16	Aug. 18	.25	Aug. 17	.02
		Aug. 22	.31			Aug. 23	.09
		Aug. 30	.39	Aug. 30	.44	Sept. 1	.08
Sept. 9	.30					Sept. 7	.06
		Sept. 13	.25	Sept 13	32	Sept. 16	.12
						Sept. 21	.25
						Sept. 28	.09
						Oct. 5	.10
Oct. 21	.28	Oct. 19	.14	Oct. 19	.49	Oct. 21	.13

Total nitrogen.—Altho the quantity of total nitrogen in relation to the quantity of total carbohydrates was so very small the utilization of the former had little effect on the depletion of the total dry matter. Nevertheless, on account of the importance of nitrogen in relation to carbohydrates in the processes of growth, it is of importance to note the changes in total nitrogen that occurred,

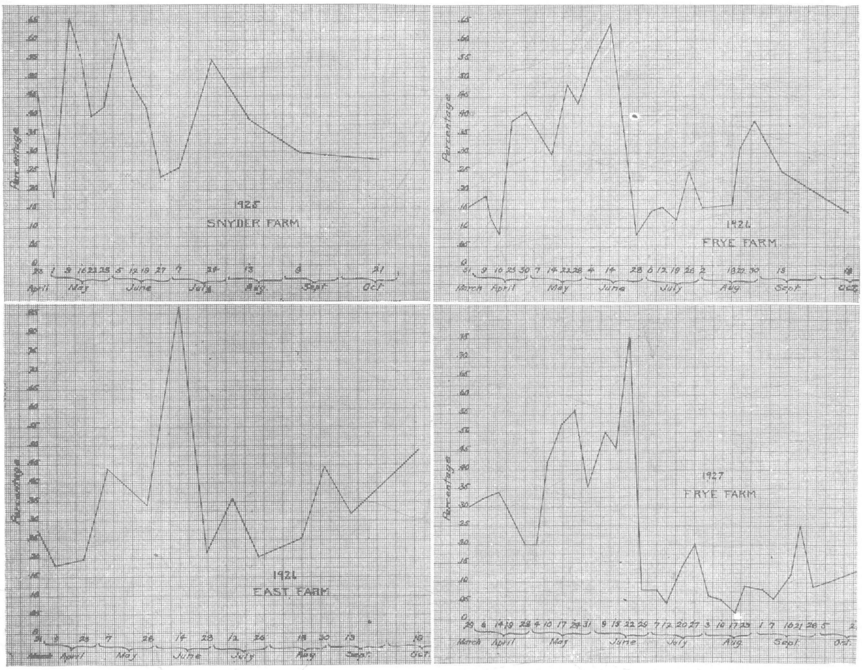

Fig. 5.—Percentage of free reducing sugars, March to October. Snyder farm, 1925; Frye farm, 1926; East farm, 1926; and Frye farm, 1927

during the development of the plants. The percentage of total nitrogen found in the four series of samples was as shown in Table 5.

TABLE 5.—Total Nitrogen in Rootstocks of Canada Thistles

1925 Snyder farm		1926 Frye farm		1926 East farm		1927 Frye farm	
Date	Total nitrogen	Date	Total nitrogen	Date	Total nitrogen	Date	Total nitrogen
	Pct.		*Pct.*		*Pct.*		*Pct.*
		Mar. 31	0.30	Mar. 31	0.31	Mar. 29	0.25
		April 9	.29	April 9	.26	April 6	.26
		April 16	.37			April 14	.21
April 23	0.35	April 23	.13	April 23	.31	April 19	.25
		April 30	.22			April 28	.24
May 1	.32					May 4	.24
May 9	.15			May 7	.26	May 10	.22
May 16	.14	May 14	.22			May 17	.19
May 22	.13	May 22	.30			May 24	.18
May 28	.13	May 28	.14	May 28	.24	May 31	.14
June 5	.10	June 4	.15			June 9	.10
June 12	.12	June 14	.15	June 14	.18	June 15	.10
June 19	.11					June 22	.11
June 27	.11	June 28	.13	June 28	.11	June 29	.09
July 7	.13	July 6	.08			July 7	.10
		July 12	.12	July 12	.08	July 12	.10
		July 19	.10			July 20	.09
July 24	.11	July 26	.13	July 26	.10	July 27	.08
		Aug. 2	.11			Aug. 3	.09
Aug. 13	.11					Aug. 10	.09
		Aug. 18	.11	Aug. 18	.15	Aug. 17	.11
		Aug. 22	.13			Aug. 23	.11
		Aug. 30	.17	Aug. 30	.14	Sept. 1	.12
Sept. 9	.16					Sept. 7	.13
		Sept. 13	.11	Sept. 13	.13	Sept. 16	.17
						Sept. 21	.18
						Sept. 28	.18
						Oct. 5	.20
Oct. 21	.19	Oct. 19	.10	Oct. 19	.14	Oct. 21	.25

In all four series there was a gradual decrease in total nitrogen, reaching a minimum point usually some time in July, which was followed by a gradual increase. With one exception, however, 1926, Frye Farm, the trend upward was not maintained until the end of the season. The changes in percentage of total nitrogen in each series are shown graphically in Figure 6.

Undoubtedly the simple forms of nitrogen, had they been determined, would have been found in abundance during the period of decline in total nitrogen, for at that time vegetative growth was going forward rapidly and the development of the plant is dependent on the presence of simple forms of nitrogen as well as of carbohydrates. The minimum of nitrogen was accompanied or slightly preceded by an abrupt falling off of the simple sugars, and coincident with the marked decline in sugars, it is interesting to note, the thistle heads appeared, thus indicating the end of the period of rapid vegetative development. The growth of aerial parts, stems and leaves, was about completed and the blossoms and

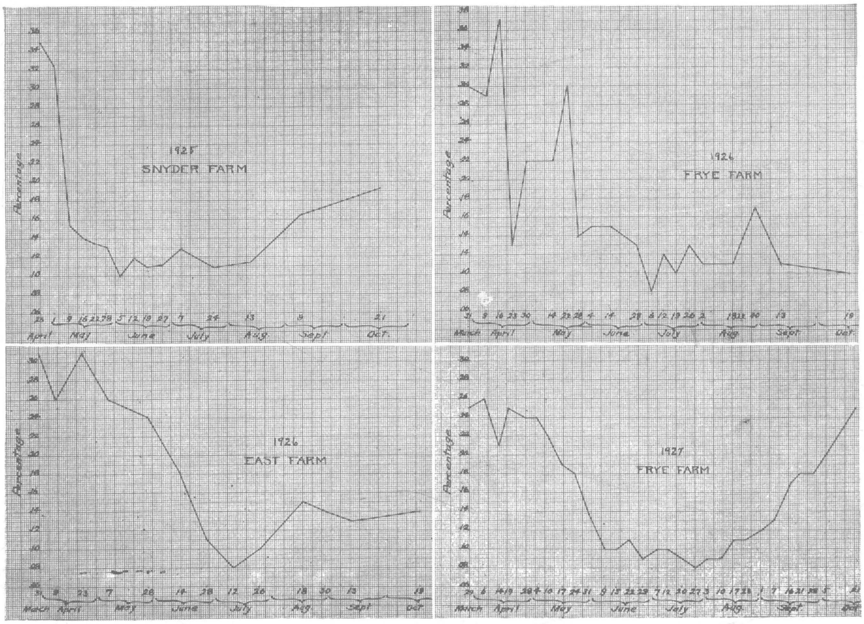

Fig. 6.—Percentage of total nitrogen, March to October. Snyder farm, 1925; Frye farm, 1926; East farm, 1926; and Frye farm, 1927

seeds were beginning to form. The accompanying illustrations, Figure 7, shows the stage of development of the aerial parts of typical plants thru the early part of one season, 1927. On June 28, the date on which the last in the series was photographed, the heads, as may be noted, were beginning to appear. On July 6, eight days later, the heads were well developed and plainly visible.

Effect of mowing on storage of food reserves.—A patch of thrifty Canada thistles on the East farm was laid off into plots 20 by 90 feet in the summer of 1925. The thistles on each were handled as follows:

Plot 1—Unmowed
Plot 2—Cut July 1, Aug. 1 and Sept. 1
Plot 3—Cut June 1, and July 1
Plot 4—Cut July 24 (full bloom)

The mowing test was not started until July 1, 1925, therefore, only one mowing was made on Plot 3 in 1925. In 1926, however, the plots were mowed according to plan. Samples of the rootstocks were taken from time to time from each plot and preserved in alcohol for analysis. The dates of sampling and the percentages of dry matter found on each date are shown in Table 6.

TABLE 6.—Dry Matter in Rootstocks of Canada Thistles, the Tops From a Part of Which Had Been Clipped at Stated Intervals

Date of sampling	Date of clipping			
	Unclipped	July 1 Aug. 1 Sept. 1	June 1 July 1	July 24
	Pct.	*Pct.*	*Pct.*	*Pct.*
April 23	15.35	15.08	20.48	16.27
May 7	13.59	13.40	13.73	14.64
May 28	9.68	9.25	12.10	8.95
June 14	10.54	10.07	10.85	11.02
June 28	12.41	12.55	8.77	15.90
July 12	11.61	....	8.28	17.37
July 26	19.97	9.46	11.74	19.51
Aug. 18	23.71	13.73	12.27	12.50
Aug. 30	25.57	15.39	14.47	12.54
Sept. 13	25.83	20.68	12.31	13.81
Oct. 19	25.19	24.26	19.60	20.58

The percentage of dry matter in the rootstocks was practically the same in mowed and unmowed thistles during the early part of the year, but in the latter part of the season the percentage found in all the mowed thistles was less than in the unmowed. Toward the end of the season, however, the percentage of dry matter in the rootstocks of the mowed thistles increased rapidly, so that by October 19, the last date of sampling, the difference between them

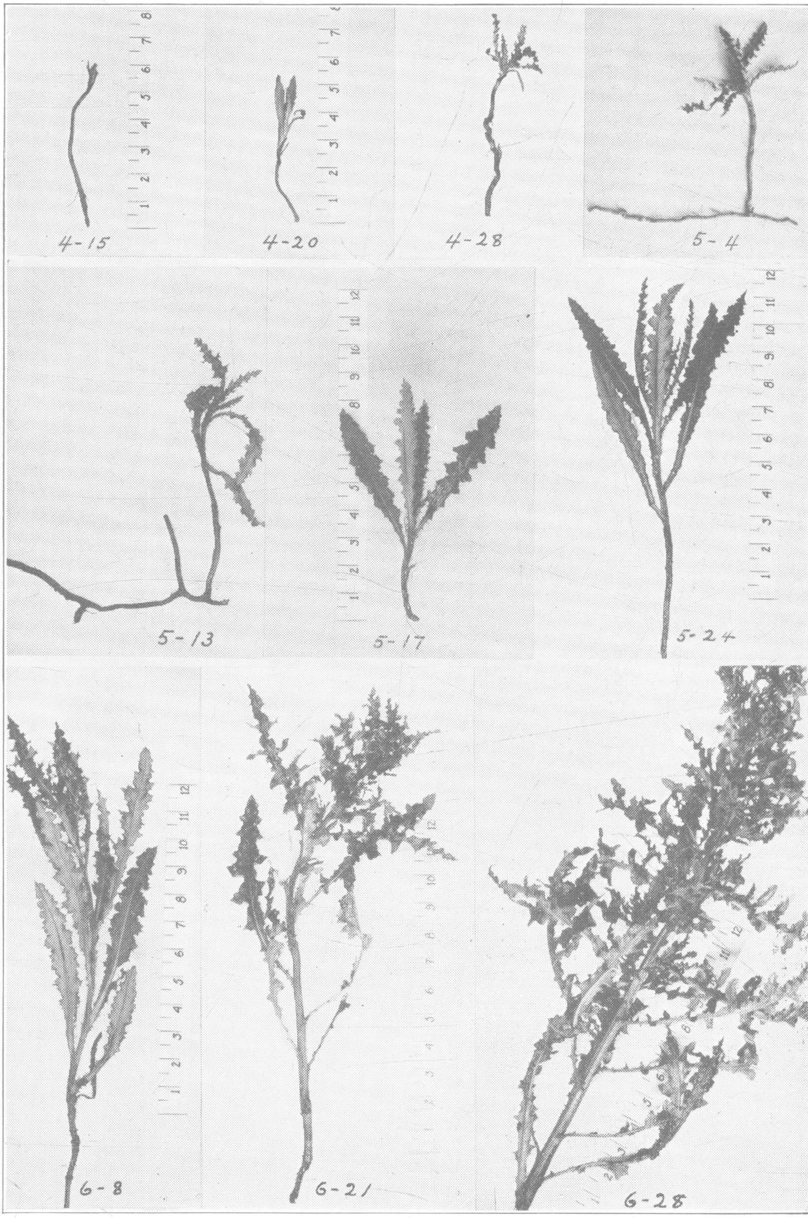

Fig. 7.—Showing the stages of development of the aerial parts of typical plants from April 15 to June 28

and the unmowed was not marked. These results are shown graphically in Figure 8 (above). For the mowed plants to accumulate dry matter more rapidly than the unmowed was, perhaps, to be expected because it is conceivable that in plants that had survived the various mowings the metabolic processes would be somewhat accelerated. Moreover, it is probable that such plants had extraordinary capacity to elaborate and to translocate reserves, otherwise they would have perished before the last samples were taken.

TABLE 7.—Easily Hydrolyzable Carbohydrates in Rootstocks of Canada Thistles, the Tops From a Part of Which Had Been Clipped at Stated Intervals

Date of sampling	Date of clipping			
	Unclipped	July 1 Aug. 1 Sept. 1	June 1 July 1	July 24
	Pct.	*Pct.*	*Pct.*	*Pct.*
April 23	4.55	3.27	5.84	3.74
May 7	3.84	3.08	3.24	3.70
May 28	2.20	1.90	2.81	1.92
June 14	2.43	1.79	2.33	2.47
June 28	2.84	2.84	1.48	3.25
July 12	2.99	....	2.00	6.00
July 26	7.89	1.98	2.29	9.30
Aug. 18	11.45	4.49	3.87	3.08
Aug. 30	13.29	6.23	4.93	2.75
Sept. 13	11.30	11.20	3.76	3.72
Oct. 19	12.55	11.92	7.67	7.45

In the mowed thistles, as already pointed out concerning the unmowed thistles, the changes in dry matter in the rootstocks were due chiefly to changes in the easily hydrolyzable carbohydrates. This was indicated by the percentages of these compounds, which were found to be as shown in Table 7.

TABLE 8.—Total Nitrogen in Rootstocks of Canada Thistles, the Tops From a Part of Which Had Been Clipped at Stated Intervals

Date of sampling	Date of clipping			
	Unclipped	July 1 Aug. 1 Sept. 1	June 1 July 1	July 24
	Pct.	*Pct.*	*Pct.*	*Pct.*
April 23	0.31	0.28	0.48	0.34
May 7	.26	.23	.31	.38
May 28	.24	.12	.21	.23
June 14	.18	.22	.24	.16
June 28	.11	.09	.18	.21
July 12	.08	....	.10	.09
July 26	.10	.13	.14	.09
Aug. 18	.15	.13	.12	.12
Aug. 30	.14	.16	.20	.12
Sept. 13	.13	.13	.23	.16
Oct. 19	.14	.17	.15	.16

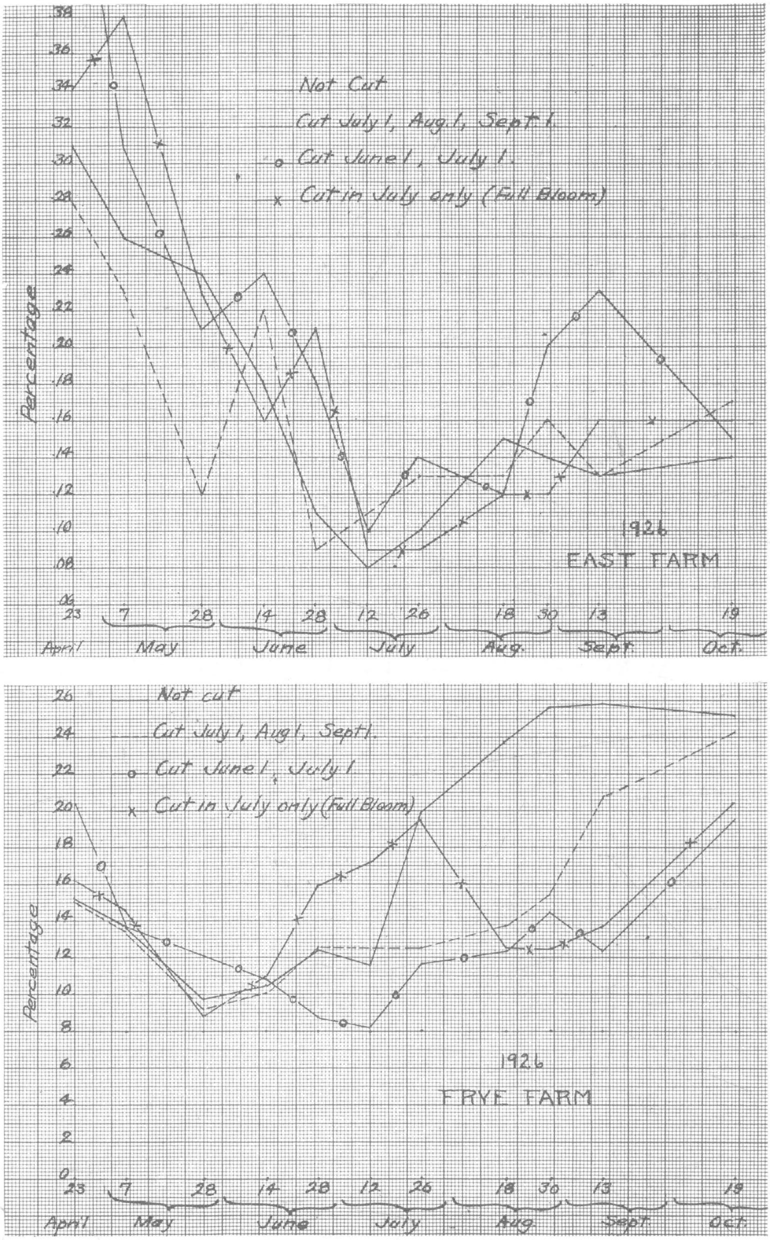

Fig. 8.—Percentage of total nitrogen in cut and uncut thistles on East farm, 1926 (above); percentages of dry matter in cut and uncut thistles on East farm (not Frye farm as lettered in the graph), 1926 (below).

Likewise the percentages of total nitrogen found in the mowed and unmowed thistles were nearly the same, as shown in Table 8 and graphically in Figure 8 (below).

There was a rapid decline during the growing season followed by a gradual increase.

Mowing as a means of eradicating Canada thistles.—To study the effect of systematic cutting as a means of killing Canada thistles, a patch located on the East farm was divided into six plots each 20 by 90 feet. The contour of the land was such that it received the surface drainage from the adjoining territory, so that from the standpoint of moisture and fertility the thistles were favorably located. On a strip about 30 feet wide across the middle of all the plots the stand was thick, but the number thinned out rapidly toward each end. The thistles made a rank growth each season. The land was not in pasture, but for many years the custom had been to mow it once in the middle of the summer when the thistles came into bloom. In the mowing test the plan of cutting was as follows:

Plot 1—Cut June 1, July 1, Aug. 1, Sept. 1
Plot 2—June 1, July 1, Aug. 1
Plot 3—June 1, July 1
Plot 4—July 1, Aug. 1, Sept. 1
Plot 5—July (full bloom)
Plot 6—Unclipped (check)

The test was not started until July 1, 1925, so that all June clippings were omitted the first year. With that one exception, however, the plan has been carried out without interruption thru four summers, 1925-1928, inclusive. From the unmowed or check plot the blossoms only were removed each year. The other plots were cut with a mowing machine, the cutter bar being set to cut as low as possible. Occasionally a leaf or so was left on the stub.

No count of the stand of plants was made from year to year, but the size and number was sufficiently reduced to become noticeable by the third year. In the fourth summer, 1928, the plants on the check plot were rank and vigorous as usual, but those on Plot 5, which had been cut once a year, were not quite so tall and they came into bloom a few days later than their neighbors. Altho at the close of the season of 1928, after four years of clipping, none of the plots were absolutely free from thistles, yet a part of them, Plots 1, 2, and 4 were so nearly cleaned up that the few weak and scattered individuals remaining were of no hindrance from the standpoint of pasturing. Practically all of those found on Plot 1 had encroached from a narrow border which had been allowed to grow along one side of the plot to serve somewhat as a check. A few more were found on Plot 4 than on Plot 2, thus indicating the importance of early mowing when the food reserves were reduced. The plants were quite abundant on Plot 3, thus indicating that early mowing alone is not sufficient, but that it must be followed by several other mowings, otherwise stems and leaves will have opportunity to develop, and if that occurs food materials will be elaborated and stored and the life of the plants prolonged. If the plants had been cut more frequently so that less aerial growth could have taken place between cuttings it is quite probable that the life of the plants would have been materially shortened.

These results are in accord with the work of Gilchrist (1), who reports the eradication of Canada thistles by cutting two and three times a year about three weeks apart, the first mowing being made in June when the thistles were small, not more than 4 to 6 inches tall. In conclusion Gilchrist states, "It has been clearly shown that two years' proper cutting of thistles in a pasture field, or two years' mowing for hay, if mowing is done early and close to the bottom, will practically remove thistles."

SUMMARY

1. The percentage of organic food reserves stored in the rootstocks of Canada thistles varied with the season of the year.

2. The percentage gradually declined during the early part of the year while vegetative growth was going forward rapidly reaching a minimum about the first of June, after which it gradually increased until the end of the season.

3. Mowing the thistles delayed the storage of food reserves and thereby undoubtedly caused the death of many of the weaker plants.

4. Systematic mowings made a month apart and continued thru four seasons removed practically all the thistles. Beginning June 1, four mowings were slightly more effective than three mowings, and three mowings were decidedly more effective than two mowings. Three mowings beginning July 1 were slightly less effective than three mowings beginning June 1, but more effective than two mowings beginning June 1. One mowing made when the plants were in full bloom apparently injured the plants but little.

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