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VARIATIONS IN THE ORGANIC RESERVES IN UNDERGROUND PARTS OF FIVE PERENNIAL WEEDS FROM LATE APRIL TO NOVEMBER

A. C. Arny

INTRODUCTION

Quack grass, *Agropyron repens,* and Canada thistle, *Circium arvense,* have been serious weed pests in Minnesota for a long time. The knowledge that these two weeds have been gaining ground and that several new perennial weeds have established themselves in the state on a fairly extensive acreage emphasized the wisdom of learning more about these plant pests and methods of eradicating them. One part of a plan completed early in 1928 provided for a study of the organic reserves in the underground parts of perennial weeds. It was thought that if the organic reserves, carbohydrates and nitrogen, in the storage organs of perennial weeds reach low levels at certain stages in their development, this would be a strategic time to start eradication operations.

The results reported in this paper give differences in the dry weight and the carbohydrate and nitrogen reserves in the underground parts of five perennial weeds in an effort to obtain information of practical value in their eradication and at the same time to extend the knowledge on this subject.

ACKNOWLEDGMENTS

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PREVIOUS WORK

The dry matter, ash, and carbohydrate reserves of the underground parts of Canada thistle were investigated by Rogers (5). He found that the percentage of total carbohydrates was lowest during the latter part of June, at the time of beginning to bloom.

Data from investigations in Ohio by Welton, Morris, and Hartzler (8) on reserves in the roots of Canada thistle, calculated on the basis of green weights, tend to confirm the findings of Rogers for carbohydrates. In addition, their data show that the nitrogen content of the roots tends to decrease to about July and then to increase again. Reserves in the roots of plants the tops of which had been clipped reached lower levels than in roots in the tops of which had not been clipped.

Aldous (1) working with buckbrush, *Symphoricarpos vulgaris;* sumac, *Rhus glabra;* vervain, *Verbenia stricta;* and iron weed, *Vernonia baldwini,* weeds in Kansas pastures, found reduction of the reserves in the roots from spring to the time of budding or flowering and then an increase to the close of the season. Cutting when the reserves in the roots were low was more effective than at other times.

From studies of Johnson grass, Stukie (6) found that cutting for hay in immature stages weakened the plants. Cutting only once a year, when the plants were relatively mature and the seeds in the milk stage resulted in the development of 40 per cent more rootstocks than by the practice of continuous cutting in immature stages. The next season such plants produced 50 per cent more tops and more new rootstocks than plants that were cut in immature stages the previous year and therefore had poorly developed rootstocks in the spring.

Investigations conducted with several crop plants to learn the best practices in maintaining vigorous stands rather than to kill them are of considerable interest and value in this connection.

Trowbridge, Haigh, and Moulton (7) found under Missouri conditions that the weight per acre of the reserve food storage organs (bulbs) in timothy and their nitrogen content were lowest in early spring and increased rapidly to the early bloom stage and then less rapidly to maturity. Late cutting resulted in the most vigorous stand of timothy. On the other hand, Wiggans (9) found, in New York, that cutting timothy before or at bloom, produced considerably higher average yields than cutting at later stages of development. The reason for this was that early cutting killed weeds that crowded out the timothy in the later cuttings. Climatic conditions apparently account to a considerable extent for the different results obtained in the two states.

Graber and his co-workers (4) found that the organic reserves in the roots of alfalfa plants were reduced to low levels by frequently cutting the tops in early stages of development. When cutting was deferred until more mature stages, the reserves in the roots that were depleted in making early vegetative growth were replenished. Many of the plants with low reserves in their roots either died before winter or were killed by freezing during the winter.

Cutting sweet clover for hay in September of the same year it was sown was found by Willard (10) to reduce materially the storage of reserves in the roots. In the spring of the second year, as new growth of tops progressed the weight of the roots decreased rapidly at first and then more slowly.

Crop plants utilize reserve foods in making their early growth. Cutting these crops at immature stages of development prevented them from replenishing these supplies of reserve foods in the underground parts. When tops were repeatedly cut in early stages of development, the plants were weakened most. The results of these investigations with crop plants are in most respects similar to the more limited results available for weeds.

MATERIALS AND METHODS

Annual Growth Cycle of the Five Weeds

A low growth of tops of quack grass, *Agropyron repens* (L), lives over winter above ground, and growth continues early in spring. Seeds mature in late June and July. The numerous wiry rhizomes of well established undisturbed stands of this weed grow largely in the upper two to three inches of the soil. No vertical portions penetrate deeply in the subsoil.

The stems of leafy spurge, *Euphorbia esula* (L), are killed in the fall and numerous large buds are formed at the crowns just underneath the soil, ready to push through as soon as the frost goes out of the ground in spring. Early growth is rapid and by the middle of May blooming usually begins and continues practically throughout the summer. An abundance of seed is produced. The horizontal roots usually are from 4 to 6 inches below the surface of the soil and numerous vertical roots extend downward from 8 to 10 feet or more into the subsoil. The mature portions of the roots of leafy spurge are woody in texture, similar to the roots of shrubs.

Austrian field cress, *Nasturtium austriacum* (Crantz), belongs to the mustard family. This weed is somewhat similar to and the roots very much like horse-radish, *Amoracia amoracia* (L), in appearance but all parts of the plant are much smaller. The plants usually reach the blooming stage about the latter part of May. No seed formation has been observed, but in all probability under favorable weather conditions some might be produced. The old stems die down during the latter part of summer and a vigorous new growth is made. The plants form only rosettes of leaves in autumn and pass through the winter in that stage, hence they are ready to make rapid growth early in spring. The horizontal creeping roots grow at a depth of from 3 to 6 inches and numerous lower vertical roots penetrate the subsoil to depths of from 6 to 10 feet.

The tops of sow thistle, *Sonchus avensis* (L), die down in late summer and fall and new growth does not appear above ground until about the latter part of April or in May. Blossoming usually begins during the latter part of June and in July. Seed ripens in late July and August. In well established, undisturbed stands of this weed, the horizontal thickened roots are mostly in the upper 2 to 4 inches of the soil with an occasional vertical root penetrating from 5 to 10 feet into the subsoil.

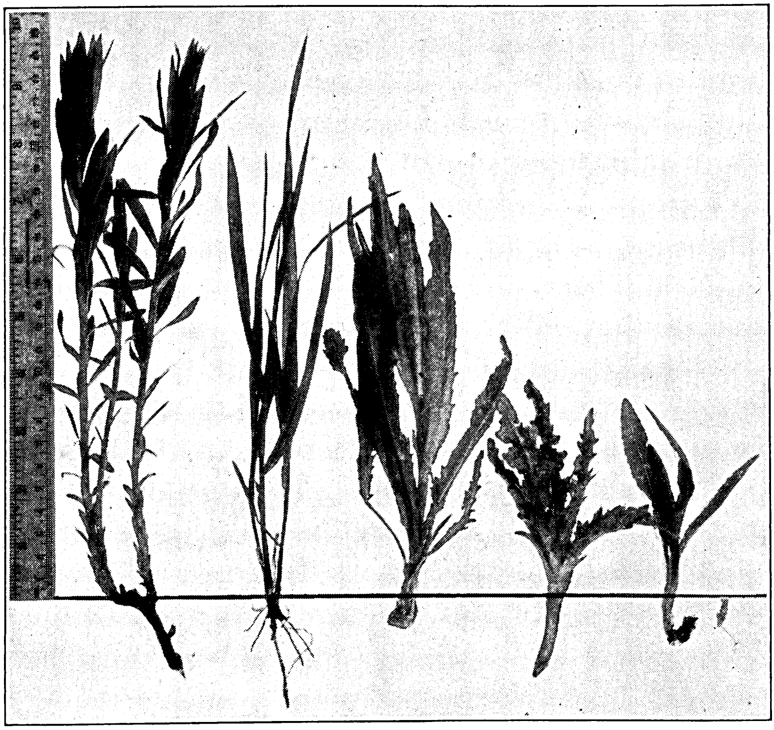

Fig. 1. Stages of Development of Each of Five Weeds on April 28, the First Date of Sampling
From left to right: leafy spurge, quack grass, Austrian field cress, Canada thistle, and sow thistle. Leafy spurge was nearly 10 inches and quack grass and Austrian field cress about 8 inches tall; Canada thistle and sow thistle were just well above ground.

The stems of Canada thistle, *Cirsium arvense* (L) Scop., die down in the fall but in some locations plants pass through the winter with leaves in the rosette stage. It is usually the middle of April or the first part of May before many plants appear above ground. Blooming usually begins in the latter part of June, and seed matures in July and later. The majority of the white fleshy horizontal creeping roots of this weed grow 8 to 12 inches below the surface and some to a depth of 16 inches. The lower vertical roots are similar to the horizontal and reach depths of from 6 to 10 feet. Stems may grow to the surface from either the horizontal or the vertical thickened roots.

Gathering and Preparing the Materials

The area of leafy spurge selected was in Washington County, 14 miles south of University Farm; that of Austrian field cress in Olmstead County, 90 miles southeast. More time necessarily intervened between the digging and weighing of the samples of the Austrian field cress, particularly, then of the other three weeds that were on tracts of land not far from University Farm.

Underground parts of quack grass and leafy spurge were dug on November 11, 1927, and of all five weeds at approximately 10-day intervals during the period April 26 to November 5, 1928. The first Austrian field cress was dug on May 11 and the last on October 25.

Previous work with quack grass (2) had shown that it was possible to secure, rapidly, practically all the rhizomes from square-yard areas. Therefore, in order to be able to compare variations in the percentages and pounds per acre of the various constituents it was decided to determine at each 10-day period in 1928 total weight of rhizomes from six systematically distributed square-yard areas. No attempt was made to obtain all the underground parts from definite areas of the other four weeds. However, care was exercised to include in the 500- to 700-gram representative samples gathered each time all of the underground parts to a depth of approximately 10 inches. For Canada thistle, the major portion of each sample consisted of the horizontal and vertical thickened roots.

Previous to digging the underground parts of the quack grass, the stems and leaves were removed from the measured areas by clipping very close to the surface. For each of the weeds the parts were placed in a closed container as soon as removed from the soil to minimize the loss of moisture.

The underground parts were washed thoroly and moved continually as the surface moisture was removed by drying in a current of heated air. As soon as the surface moisture had disappeared, the total green weight of the quack grass rhizomes recovered from the square-yard areas was determined and a portion was retained for sampling. The underground parts were cut in lengths averaging one-half inch or less, thoroly mixed, and samples taken as follows: (a) duplicates of approximately 10 grams for determination of percentage dry weight, and (b) duplicates of exactly 50 grams for preservation in alcohol for determination of reducing and total sugars, dextrins, and water soluble starches, true starch, hemicelluloses, and total and amino nitrogen. The samples for dry weight determinations were held at 102° C. to constant weight. The 50-gram samples were placed in jars containing boiling 95 per cent alcohol and one gram of pure calcium carbonate in each jar. The covers were put on lightly and the boiling continued for 30 minutes, after which the jars were sealed.

Analytical Procedure

The contents of each jar, after pouring off the alcoholic solution, were further extracted with alcohol in Lansiedl extractors for 36 hours over a steam bath. Tests showed that after 24 hours further extraction was equal to a blank.

The alcohol-soluble extract was made up to volume and treated with chloroform to separate the lipoid material. Aliquots of the alcohol phase were used for determinations of reducing sugars, total sugars, and amino nitrogen, the alcohol being removed in Claissen flasks under reduced pressure at a temperature of 40-60° C.

Carbohydrate Analyses

In the determination of reducing sugar according to the Munsen and Walker method, the volumetric thiosulfate method of Peters was used to estimate the precipitated cuprous oxide.

Total sugars and alcohol-soluble carbohydrates were determined by adding 5 cc. concentrated hydrochloric acid to 50 cc. of the clarified solution and allowing it to stand 24 hours at room temperature for inversion to take place.

The alcohol-insoluble residue was dried to constant weight at 102° C. and ground for use in the determination of dextrins and water-soluble starches, true starch, hemicelluloses, and total nitrogen.

In determining dextrins and soluble starches, 4 grams of the dried alcohol-insoluble fraction was placed in 100 cc. of cold water and allowed to stand 12 hours at room temperature, when it was filtered and washed. The filtrate was acidified to a concentration of 2.5 per cent hydrochloric acid and hydrolyzed 2.5 hours on a steam bath. The solution was neutralized, diluted to volume, and the reducing power of an aliquot determined as glucose.

True starch was determined in the water-soluble residue using taka-diastase, made up to 250 cc. volume, filtered, and an aliquot taken for reducing sugars; washed five times with hot water and the residue taken for hemicellulose determination.

In the determination of hemicelluloses, the residue was boiled in 2.5 per cent hydrochloric acid for 2.5 hours, neutralized, diluted to volume of 250 cc., and filtered. An aliquot was taken for reducing sugars.

Nitrogen Analyses

In the determination of total organic nitrogen, the Kjeldahl method was used.

Amino nitrogen was determined by the Van Slyke method. The mixture of glacial acetic acid, sodium nitrite, and the solution of the sample was shaken for 5 minutes.

All analyses were made in duplicate according to the official methods of the Association of Official Agricultural Chemists (1925).

VARIATIONS IN RESERVE MATERIALS IN THE UNDERGROUND PARTS

One of the functions of the thickened roots of sow and Canada thistle, leafy spurge, Austrian field cress, and the rhizomes of quack grass is the storage of reserve foods. Into the living cells of these organs, surplus foods synthesized by the leaves of the plants are moved, often changed to forms more suitable, and finally stored as reserves. While the plants use relatively small amounts of these reserve products in their life processes during the winter, by far the major portions remain unused until the critical time arrives when large amounts are needed. This critical time comes in spring and early summer, when considerable new growth of stems and leaves is necessary before the weeds can again synthesize all the materials they need. Part of the reserve material used during this time is needed for respiration.

Dry Weight

The percentages of dry weight for the underground storage organs of the five weeds and the dry weight in pounds per acre for rhizomes

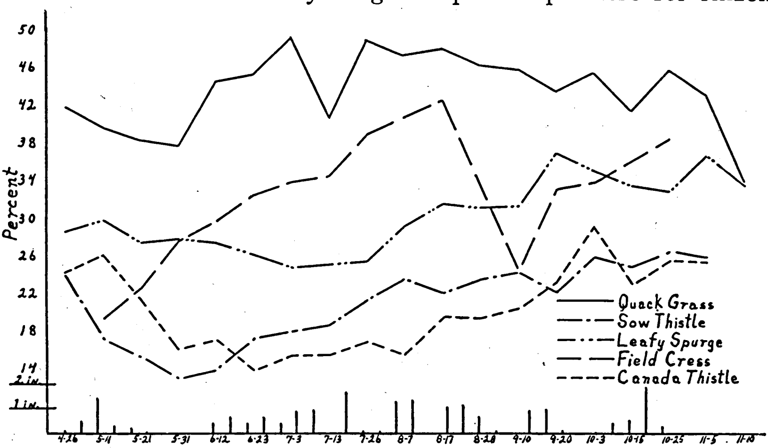

Fig. 2. Upper: Variations in the Percentage of Total Dry Material in the Underground Parts of Five Perennial Weeds at Approximately Ten-Day Periods
Lower: Rainfall, in Inches, at St. Paul, by Approximately Five-Day Periods, April 26 to November 5, 1928

of quack grass are given in Table 1. Curves for the percentages of dry weight are presented in Figure 2. The percentages of dry weight, with those determined on November 10, 1927, at the extreme right, are also shown in Figure 2. In the lower part of Figure 2 is shown the rainfall at approximately five-day period from April 26 to November 5, 1928.

Table 1

Variations in the Percentages of Dry Weight in Underground Storage Organs of Five Perennial Weeds. and in the Pounds per Acre of Dry Weight in the Rhizomes of Quack Grass

Common names of weeds	Dates of sampling								
	4-26	5-11	5-21	5-31	6-12	6-23	7-3	7-13	7-26
	%	%	%	%	%	%	%	%	%
Sow thistle	24.29	17.16	15.28	12.86	13.94	12.39	17.97	18.48	21.44
Leafy spurge	28.55	29.77	27.48	27.70	27.48	26.03	24.78	25.15	25.57
Austrian field cress	....	19.27	22.38	27.76	29.78	32.31	33.83	34.28	38.62
Canada thistle	24.11	26.07	21.36	16.02	17.17	13.76	15.34	15.49	16.75
Quack grass	41.72	39.61	38.18	37.86	44.63	45.27	49.11	40.44	48.94
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	4552	4505	4509	4332	4992	5024	4845	4631	5282

Common names of weeds	Dates of sampling									
	8-7	8-17	8-28	9-10	9-20	10-3	10-15	10-25	11-5	11-10
	%	%	%	%	%	%	%	%	%	%
Sow thistle	23.79	22.01	23.65	24.20	22.08	25.93	24.98	26.49	25.92	....
Leafy spurge	29.35	31.52	31.19	31.34	36.95	34.91	33.58	32.80	36.75	33.49
Austrian field cress	....	42.68	....	24.18	32.98	33.90	....	38.31	....	....
Canada thistle	15.49	19.63	19.48	20.35	23.22	29.39	23.04	25.63	25.59	....
Quack grass	47.52	48.01	46.17	45.95	43.58	45.55	41.44	45.80	43.10	33.87
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	5392	5770	5961	6903	6423	6658	6166	6634	6479	....

Rapid movement, particularly early in the season, of the reserve materials out of the storage organs should result in lowering the dry weight of these organs. The percentage of dry weight in the rhizomes of quack grass was considerably higher than in the underground storage organs of the other four weeds at all times during the season.

In the storage roots of sow and Canada thistle there were declines in the percentage of dry weight to the last part of May and to June 23, respectively, and then gradual and fairly steady increases up to the close of the season. For leafy spurge this decline was gradual during the first part of the season, indicating that the rapid decrease had probably taken place earlier. The decline continued until July and from then on there was a general gain to the close of the season. On November 10, 1927, the percentage of dry weight in the storage organs of leafy spurge was slightly lower than on November 5, 1928. There was a moderate lowering of the dry-weight percentage in the rhizomes of quack grass after the last part of April, followed by a rapid rise and a high level during the rest of the season. The dry-weight percentage in the roots of Austrian field cress rose steadily from the time the first sample was taken to the middle of August. No sample was taken on August 28 and by September 10 the percentage declined materially, after which there was a rise to the close of the season. The decline in late August and early September may have been occasioned, at least in part, by root extension and the formation of leaves above ground in preparation for the following year.

The dry-weight percentages in the underground storage organs of quack grass and Austrian field cress reached their highest levels earlier in the season than in the other weeds. This is probably because each formed a considerable leaf area the previous season, which lived over winter and hence was ready to synthesize food as soon as conditions were favorable in spring.

The dry weight per acre of the rhizomes of quack grass increased from 4,552 to 6,579 pounds, or approximately a ton, per acre from spring to the close of the season.

Carbohydrates

Data for carbohydrates are given in Tables 2, 3, and 4 with the data for the samples taken November 11, 1927, following those for November 5, 1928. The percentages are graphed in Figures 3 to 10, inclusive, with the data for the samples taken on November 11, 1927, plotted at the extreme right.

Total Sugars

Sharp declines in percentages of total sugar initiated earlier in the season continued in the underground storage organs of sow and Canada thistles, Austrian field cress, and leafy spurge during the first part of the period of sampling. The declines continued on a more gradual scale to midsummer or later. This is shown in Table 2 and the percentages are graphed in Figure 3. There was only a slight decline in the total sugar content of the rhizomes of the quack grass during this early period, followed by a rise to the end of May, and a lower level throughout the summer. The percentage of total sugars averaged lower in the rhizomes of quack grass than in the storage organs of any of the other four weeds. There was some increase in total sugars in the storage organs of each of the weeds during the cool weather of fall. In Austrian field cress this increase was slight.

Reducing Sugars

The percentages and pounds of reducing sugars are given in Table 2, part 2, and the percentages are shown graphically in Figure 4.

The common storage form of sugar in underground parts of plants is the non-reducing sucrose, or cane sugar. Sucrose is changed to simpler reducing forms before it is used by plants. Hence the presence of reducing forms of sugar in any amounts usually indicates activity in the moving and use of that reserve product.

Table 2

Variations in the Percentages of Alcohol-Soluble Carbohydrates Calculated on the Dry-Weight Basis in the Underground Storage Organs of Five Perennial Weeds, and Pounds per Acre in the Rhizomes of Quack Grass

Common names of weeds	Dates of sampling								
	4-26	5-11	5-21	5-31	6-12	6-23	7-3	7-13	7-26
					(1) Total sugars				
	%	%	%	%	%	%	%	%	%
Sow thistle	49.50	36.38	28.93	32.66	30.06	22.55	24.93	18.80	21.40
Leafy spurge	19.68	11.03	10.02	12.25	9.77	8.35	8.78	8.04	6.88
Austrian field cress	....	16.86	7.35	5.83	4.05	3.16	2.11	2.10	3.47
Canada thistle	26.68	10.54	12.00	11.57	10.07	8.32	8.27	6.15	7.40
Quack grass	5.70	4.74	6.71	8.65	4.89	4.82	2.84	4.26	3.69
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	259.5	213.5	302.6	374.7	244.1	242.2	137.6	197.3	193.9
					(2) Reducing sugars				
	%	%	%	%	%	%	%	%	%
Sow thistle	6.18	6.78	9.83	...	8.34	2.79	2.51	2.93	2.70
Leafy spurge	3.94	2.87	3.78	4.00	3.95	3.09	3.02	3.13	2.42
Austrian field cress	...	9.18	4.35	1.72	2.95	0.96	0.67	0.81	1.84
Canada thistle	6.37	2.03	3.10	3.79	4.04	2.91	2.00	1.92	2.06
Quack grass	1.59	1.68	1.65	1.67	1.01	0.99	0.65	1.21	1.00
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	72.4	75.7	74.4	72.3	50.4	49.7	31.5	56.0	52.8

Common names of weeds	Dates of sampling									
	8-7	8-17	8-28	9-10	9-20	10-3	10-15	10-25	11-5	11-10
					(1) Total sugars					
	%	%	%	%	%	%	%	%	%	%
Sow thistle	20.82	20.65	19.19	13.98	10.38	7.87	11.49	11.89	22.56	....
Leafy spurge	5.43	5.30	7.22	7.28	6.13	9.32	9.08	14.09	18.48	20.74
Austrian field cress	....	3.37	....	2.45	3.95	5.96	....	4.47	....	....
Canada thistle	....	5.70	6.45	8.06	6.37	9.39	9.87	11.39	11.16	....
Quack grass	2.69	2.67	2.83	2.88	2.99	4.39	3.85	3.96	5.46	8.38
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	145.0	154.1	168.7	198.8	192.0	292.3	237.4	262.7	353.8	....
					(2) Reducing sugars					
	%	%	%	%	%	%	%	%	%	%
Sow thistle	1.57	2.55	2.80	2.66	2.33	0.85	1.20	1.19	3.81	....
Leafy spurge	1.80	1.53	2.34	2.13	2.00	2.38	1.86	2.31	3.94	3.78
Austrian field cress	....	1.77	....	1.77	1.44	1.99	....	1.86	....	....
Canada thistle	3.56	1.41	1.34	1.50	1.93	2.33	2.60	2.58	3.30	....
Quack grass	0.65	0.57	1.00	1.08	1.45	1.32	1.41	1.39	1.93	2.92
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	35.0	32.9	59.6	74.6	93.1	87.9	86.9	92.2	125.0	....

Table 3

Variations in the Percentages of the Alcohol-Insoluble Acid-Hydrolizable Carbohydrates Calculated on the Basis of Dry Weight in the Underground Parts of Five Perennial Weeds, and in the Pounds per Acre of These Materials in the Rhizomes of Quack Grass

Common names of weeds	Dates of sampling								
	4-26	5-11	5-21	5-31	6-12	6-23	7-3	7-13	7-26
(1) Dextrins and soluble starches									
	%	%	%	%	%	%	%	%	%
Sow thistle	5.07	7.27	8.02	6.42	5.06	8.39	8.54	7.98	8.56
Leafy spurge	5.33	4.94	3.23	3.92	4.85	6.31	5.00	4.17	4.62
Austrian field cress	....	7.79	4.73	7.27	4.26	3.87	3.26	3.11	2.95
Canada thistle	10.12	6.66	9.35	9.54	9.68	5.59	6.76	4.39	4.73
Quack grass	7.59	10.86	9.72	9.03	10.28	8.86	11.89	13.08	12.15
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	345.5	489.2	438.3	391.2	513.2	445.1	576.1	605.7	641.8
(2) True starch									
	%	%	%	%	%	%	%	%	%
Sow thistle	0.58	1.17	0.56	1.09	2.19	3.88	4.12	5.04	5.09
Leafy spurge	4.04	3.89	4.41	5.44	12.06	9.78	8.03	9.13	13.17
Austrian field cress	....	13.06	12.02	14.69	28.74	29.08	32.58	34.37	31.65
Canada thistle	1.77	0.74	0.96	1.27	1.40	2.60	2.16	4.87	5.40
Quack grass	0.67	0.62	0.48	0.21	0.45	0.46	0.59	0.57	0.29
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	30.5	27.9	21.6	9.1	22.5	23.1	28.6	26.4	15.3
(3) Hemicelluloses									
	%	%	%	%	%	%	%	%	%
Sow thistle	4.90	6.13	4.99	5.59	6.46	6.99	8.07	10.92	10.78
Leafy spurge	12.66	14.57	14.57	13.50	13.40	13.99	14.23	16.91	17.34
Austrian field cress	....	11.78	16.77	14.17	17.74	19.05	21.93	21.20	20.39
Canada thistle	7.46	7.85	9.76	12.16	11.61	14.73	13.11	15.36	16.09
Quack grass	11.12	10.24	13.83	18.47	16.21	16.18	13.76	16.80	15.14
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	506.2	461.3	623.6	800.1	809.2	812.9	666.7	778.0	800.7

Common names of weeds	Dates of sampling									
	8-7	8-17	8-28	9-10	9-20	10-3	10-15	10-25	11-5	11-10
(1) Dextrins and soluble starches										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	8.27	8.90	9.69	9.23	7.12	7.81	7.73	9.10	9.17	....
Leafy spurge	5.55	4.24	4.62	4.66	4.93	4.24	5.77	5.95	3.36	3.92
Austrian field cress	....	3.43	....	3.67	2.98	3.79	....	6.42	....	....
Canada thistle	....	5.23	5.75	4.93	3.60	3.97	6.31	3.01	6.09	....
Quack grass	12.78	12.31	10.44	11.19	10.99	10.91	8.87	8.20	8.82	8.83
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	689.1	710.3	622.3	772.4	705.9	726.4	546.9	544.0	571.4	....
(2) True starch										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	6.01	5.54	4.83	9.52	15.00	19.52	14.20	10.05	6.97	....
Leafy spurge	18.83	18.05	19.98	21.07	23.61	20.60	20.57	18.83	13.68	8.01
Austrian field cress	....	31.39	....	28.05	28.43	27.32	....	30.02	....	....
Canada thistle	5.97	11.41	9.51	14.39	11.97	16.34	8.36	6.02	9.56	....
Quack grass	0.47	0.08	1.00	0.64	0.74	0.80	1.32	0.56	1.34	1.27
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	25.3	4.6	59.6	44.2	47.5	53.3	81.4	37.2	86.8	....
(3) Hemicelluloses										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	9.35	8.49	9.66	8.70	7.62	5.58	4.77	4.64	4.74	....
Leafy spurge	16.13	15.78	15.53	15.59	14.16	16.04	17.40	13.69	15.09	12.96
Austrian field cress	....	18.92	....	19.53	17.51	10.92	....	12.23	....	....
Canada thistle	14.87	13.51	12.54	10.31	11.34	9.19	9.47	8.68	9.18	....
Quack grass	16.55	15.83	17.59	17.31	16.65	16.81	17.51	16.94	15.61	13.48
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	892.4	913.4	1048.5	1194.9	1069.4	1119.2	1079.7	1123.8	1011.4	....

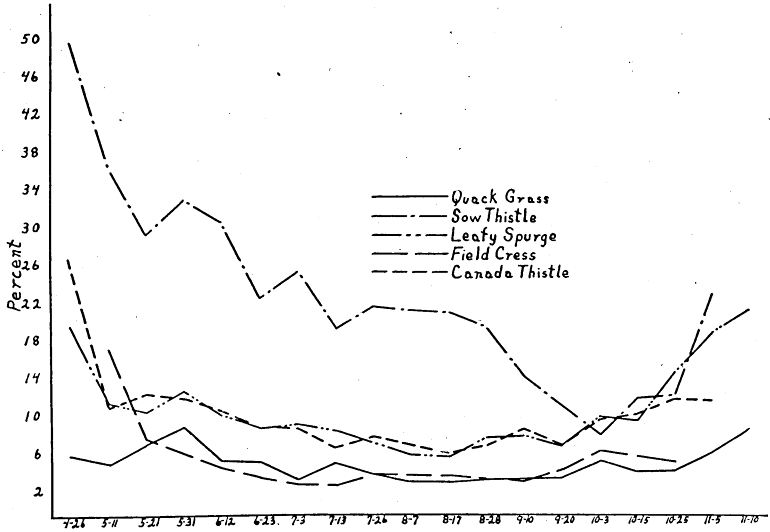

Fig. 3. Variations in the Percentages of Total Sugars Based on Dry Weight in the Underground Parts of Five Perennial Weeds

In the storage roots of sow thistle there was some increase in percentage of reducing sugars during late April and the first part of May, followed by a decrease to low points during the summer and early fall. In the storage roots of Austrian field cress, Canada thistle, and leafy spurge there were decreases during the first part of the sampling

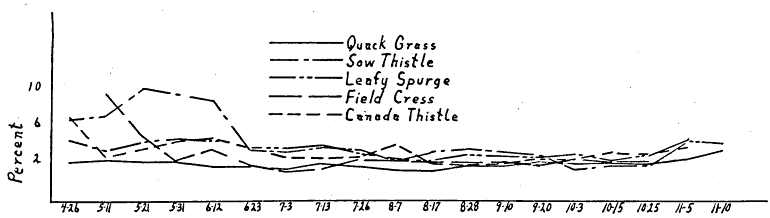

Fig. 4. Variations in the Percentages of Reducing Sugars Based on Dry Weight in the Underground Parts of Five Perennial Weeds

period and declines to low points in summer. The low point for reducing sugars in the rhizomes of quack grass was in summer. There were moderate increases in the percentages of reducing sugars during fall.

Dextrins and Soluble Starches

The results for dextrins and soluble starches are given in the third part of Table 2 and the percentages are shown graphically in Figure 5. These are transition products between starch and sugar readily soluble in water.

Except for quack grass and on the first two dates for sow thistle, there was a lowering of the percentages of dextrins and soluble starches during the early part of the season. For Canada thistle, leafy spurge, and Austrian field cress the decline continued. For sow thistle there was some rise in the percentages of these constituents during the summer. The rhizomes of quack grass contained a relatively high percentage of dextrins and soluble starches on the first sampling, and showed a considerable rise throughout July and the first part of August and then a

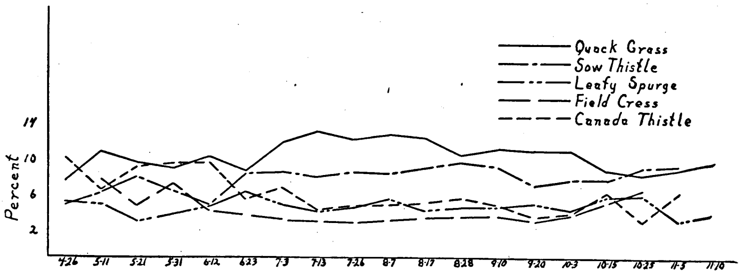

Fig. 5. Variations in the Percentage of Dextrins and Water-Soluble Starches Based on Dry Weight in the Underground Parts of Five Perennial Weeds

gradual decline. Dextrins and soluble starches apparently make up the bulk of the readily available carbohydrates in the rhizomes of quack grass. Earlier sampling was necessary in order to learn whether there was a decrease in these materials as quack grass resumed active growth in spring.

True Starch

The results of the analyses for this material are given in the fourth part of Table 2 and the percentages are shown graphically in Figure 6.

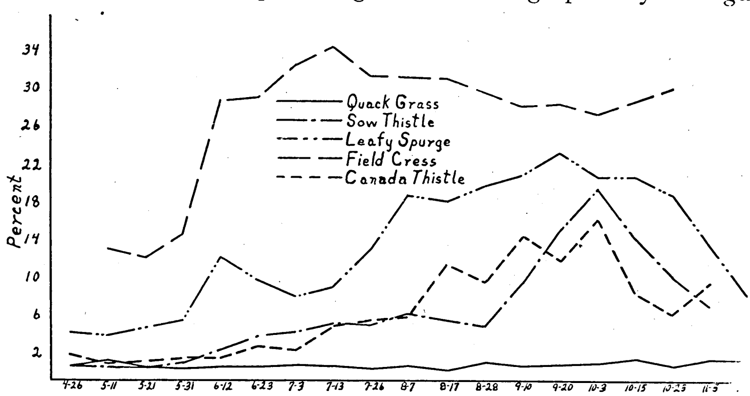

Fig. 6. Variations in the Percentage of True Starch, Based on Dry Weight in the Underground Parts of Five Perennial Weeds

The percentages of true starch were low during the early part of the season in the storage roots of leafy spurge, sow and Canada thistle. There were gradual increases in this carbohydrate to the highest points in September and early October, then marked declines as the temperature decreased. Referring to Figure 2, marked rises in the percentage of total sugars will be noted for leafy spurge, sow and Canada thistle during the same time that the declines in starch percentages occurred. This change in the carbohydrate reserves from starch to sugar in leafy spurge, sow and Canada thistle as the temperatures decreased is similar to that found for alfalfa (4) and some other perennial plants.

True starch made up approximately one-third of the dry weight of the storage roots of Austrian field cress from June to the end of the season. At the opposite extreme, the rhizomes of quack grass contained less than one per cent of carbohydrates in this form throughout practically the entire season. For neither of these two weeds is there any indication of marked change from starch to sugar as temperatures decreased in the fall.

Hemicelluloses

Percentages of hemicelluloses for the five weeds and pounds per acre in the rhizomes of quack grass are given in Table 2. The percentages are shown graphically in Figure 7.

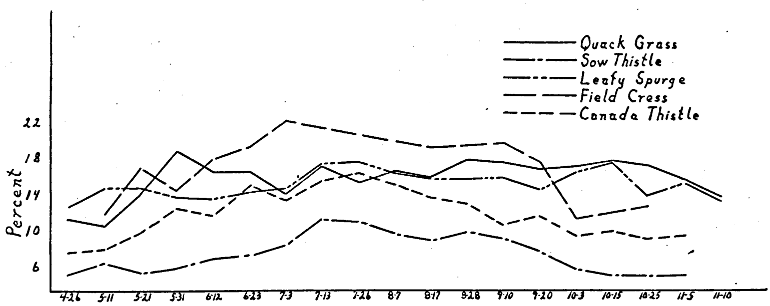

Fig. 7. Variations in the Percentage of Hemicellulose Based on Dry Weight in the Underground Parts of Five Perennial Weeds

Hemicelluloses were less abundant in the storage organs of sow and Canada thistle than in those of the other three weeds. Reserves in the form of hemicelluloses are relatively more stable than the other carbohydrate reserves, hence are drawn on as the supply of the more labile materials becomes low. As the more soluble materials were moved out of the storage organs, the hemicelluloses made up an increasing percentage of the dry weight, altho their total amount did not necessarily increase. Rising percentages of hemicelluloses during the early part and lowering during the latter part of the sampling period was the trend. This, in general, was the opposite of what occurred for the more readily available carbohydrates. In the rhizomes of quack grass, there was a fairly rapid increase in the number of pounds of hemicelluloses during the early part of the period of sampling and a further increase during the latter part of the season.

Total Readily Available Carbohydrates

The percentages of total readily available carbohydrates, as given in Tables 2 and 3, are summarized in the first part of Table 4. As has been stated, hemicelluloses are more stable materials than the other reserve carbohydrates, hence they are not included. The pounds per acre of readily available carbohydrates in the rhizomes of quack grass are also included in the first part of Table 4. The summarized percentages are shown graphically in Figure 8.

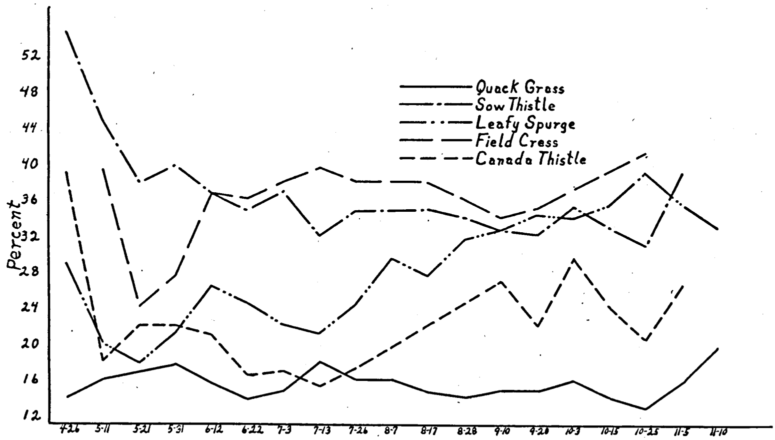

Fig. 8. Variations in the Percentages of Total Readily Available Carbohydrates Based on Dry Weight in the Underground Parts of Five Perennial Weeds

The underground storage organs of sow thistle and Austrian field cress had relatively large amounts of reserve food in readily available form throughout the season and leafy spurge during the latter part of the season. The rhizomes of quack grass were relatively low in percentages of these materials at all times.

For each of the weeds except quack grass, where the decline probably came earlier, there were sharp reductions in total readily available carbohydrates during the latter part of April and the first part of May. The total readily available carbohydrates in the storage organs of leafy spurge and Austrian field cress were at their lowest point during the season at this time. These weeds start early. Altho the sharpest lowering of readily available carbohydrates in the storage organs of sow and Canada thistle occurred at this early period, further moderate declines took place in July.

For each of the five weeds, there was an increase in total readily available carbohydrates during the latter part of the season.

The results for total readily available carbohydrates in the storage roots of Canada thistle are similar to those obtained in Ohio by Welton, Morris, and Hartzler (8).

The low points for readily available carbohydrates in the underground parts of each of the weeds except quack grass occurred at the stage of beginning bloom. For leafy spurge and Austrian field cress this stage of development, as shown in Figure 1, was reached in May at about the time the sharp decline in readily available carbohydrates ceased and storage began. Sow and Canada thistles did not reach this stage of development at the time of the low points in the rapid decline in percentages of readily available carbohydrates in May, but during the first part of July after further more moderate reductions had taken place.

Starting eradication operations against these weeds as they reach the beginning bloom stage appears to be an opportune time so far as readily available carbohydrates are concerned. Cutting the tops close to the ground at that stage compels the building up of new sets of aerial organs, which involves additional drafts on the reserves in the underground parts. Cutting the tops of the weeds at the beginning bloom stage has the additional advantage of preventing seed formation.

Total Carbohydrates

In the second part of Table 4 are given the percentages of total carbohydrates except cellulose accumulated in the underground storage organs of each of the five weeds. These are the sums of the percentages or pounds on each sampling date of total readily available carbohydrates as given in the first part of Table 4 and the hemicelluloses given in the last part of Table 3. The percentages are graphed in Figure 9.

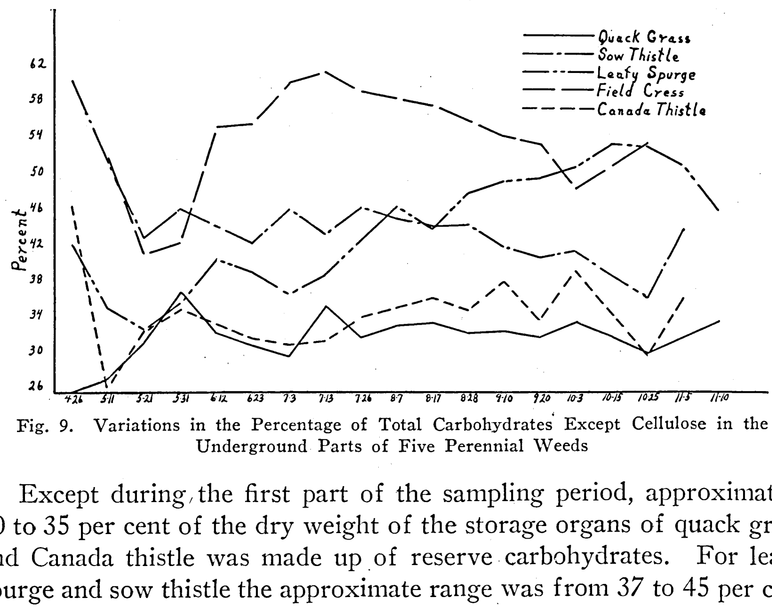

Fig. 9. Variations in the Percentage of Total Carbohydrates Except Cellulose in the Underground Parts of Five Perennial Weeds

Except during the first part of the sampling period, approximately 30 to 35 per cent of the dry weight of the storage organs of quack grass and Canada thistle was made up of reserve carbohydrates. For leafy spurge and sow thistle the approximate range was from 37 to 45 per cent

Table 4

Variations in the Percentage of Total Readily Available and Total Reserve Carbohydrates Except Cellulose on the Dry-Weight Basis in the Underground Storage Organs of Five Perennial Weeds, and in the Pounds per Acre of These Materials in the Rhizomes of Quack Grass

Common names of weeds	Dates of sampling								
	4-26	5-11	5-21	5-31	6-12	6-23	7-3	7-13	7-26
(1) Total readily available carbohydrates (sum of 1 of Table 2; 1 and 2 of Table 3)									
	%	%	%	%	%	%	%	%	%
Sow thistle	55.15	44.82	37.51	40.17	37.31	34.82	37.59	31.82	35.05
Leafy spurge	29.05	19.86	17.66	21.67	26.68	24.44	21.81	21.34	24.67
Austrian field cress..	....	39.71	24.10	27.79	37.05	36.11	37.95	39.58	38.07
Canada thistle	38.57	17.94	22.31	22.38	21.15	16.51	17.19	15.41	17.53
Quack grass	13.96	16.22	16.91	17.89	15.62	14.14	15.32	17.91	16.13
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	635.5	730.6	762.5	775.0	779.8	710.4	742.3	829.4	851.0
(2) Total carbohydrates (sum of Part 1 of Table 4 and Part 3 of Table 3)									
	%	%	%	%	%	%	%	%	%
Sow thistle	60.05	50.95	42.50	45.76	43.77	41.81	45.66	42.74	45.83
Leafy spurge	41.71	34.43	32.23	35.17	40.08	38.43	36.04	38.25	42.01
Austrian field cress..	....	51.49	40.87	41.96	54.79	55.16	59.88	60.78	58.46
Canada thistle	46.05	25.79	32.07	34.48	32.76	31.24	30.30	30.77	33.62
Quack grass	25.08	26.46	30.74	36.36	31.83	30.32	29.08	34.71	31.27
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	1141.7	1191.9	1386.1	1575.1	1589.0	1523.3	1409.0	1607.4	1651.7
(3) Total readily available carbohydrates expressed in per cent of total reserve carbohydrates except cellulose									
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Sow thistle	91.84	87.97	88.26	87.78	85.24	83.28	82.33	74.45	76.48
Leafy spurge	69.65	57.68	54.79	61.62	66.57	63.60	60.52	55.79	58.72
Austrian field cress...	....	77.12	58.97	66.23	67.62	65.46	63.38	65 12	65.12
Canada thistle	83.76	69.56	69.57	64.91	65.56	52.85	56.73	50.08	52.14
Quack grass	55.66	61.30	55.01	49.20	49.07	46.64	52.68	51.60	51.58

Common names of weeds	Dates of sampling									
	8-7	8-17	8-28	9-10	9-20	10-3	10-15	10-25	11-5	11-10
(1) Total readily available carbohydrates (sum of 1 of Table 2; 1 and 2 of Tables 3)										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	35.10	35.09	33.71	32.73	32.50	35.20	33.42	31.04	38.70	....
Leafy spurge	29.81	27.59	31.81	33.01	34.67	34.16	35.42	38.87	35.52	32.67
Austrian field cress...	....	38.19	....	34.17	35.36	37.07	....	40.91	....	....
Canada thistle	....	22.34	21.71	27.38	21.94	29.70	24.54	20.42	26.81	....
Quack grass	15.94	15.06	14.27	14.71	14.72	16.10	14.04	12.72	15.62	19.48
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	859.5	869.0	850.6	1015.4	945.5	1071.9	865.7	843.8	1012.0	....
(2) Total carbohydrates (sum of 1 of Table 2; 1 and 2 of Table 3)										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	44.45	43.58	43.37	41.43	40.12	40.78	38.19	35.68	43.44	....
Leafy spurge	45.94	43.37	47.34	48.60	48.83	50.20	52.82	52.56	50.61	45.63
Austrian field cress...	....	57.11	....	53.70	52.87	47.99	....	53.14	....	....
Canada thistle	....	35.85	34.25	37.69	33.28	38.89	34.01	29.10	35.99	....
Quack grass	32.49	30.89	31.86	32.02	31.37	32.91	31.55	29.66	31.23	32.96
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	1751.9	1782.4	1899.1	2210.3	2014.9	2191.1	1945.4	1967.6	2023.4	....
(3) Total readily available carbohydrates expressed in per cent of total reserve carbohydrates except cellulose										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	78.97	80.52	77.73	79.00	81.01	86.32	87.50	86.99	89.09	....
Leafy spurge	64.89	63.62	67.19	67.92	71.00	68.05	67.06	73.95	70.18	76.53
Austrian field cress...	....	66.87	....	63.63	66.88	77.25	....	76.99	....	....
Canada thistle	....	62.32	63.39	72.65	65.93	76.37	72.16	70.17	74.49	....
Quack grass	49.06	48.75	44.79	45.94	46.92	48.92	44.50	42.89	50.02	....

and for Austrian field cress still higher. In the fall there was approximately a ton per acre of total carbohydrates in the rhizomes of quack grass. This was about twice the amount present at the first date of sampling in spring.

The percentage of total carbohydrates was at a low point in the underground parts of Canada thistle during the last part of June and the first part of July. This confirms the results of Rogers (5) and of Welton, Morris, and Hartzler (8) for total carbohydrates. The percentages of total carbohydrates in the underground parts of sow thistle were relatively low at this time also, but continued to fall gradually until the latter part of October. Leafy spurge and quack grass show increases in these materials from early spring to the latter part of May. From then on there is a fairly rapid and constant increase for leafy spurge; for quack grass there was some decrease throughout June and then not much change to the close of the season.

Relation of Readily Available Carbohydrates to Total Carbohydrates

The relation of readily available carbohydrates to the total carbohydrates except cellulose is shown on a percentage basis in the third part of Table 4 and graphed in Figure 10.

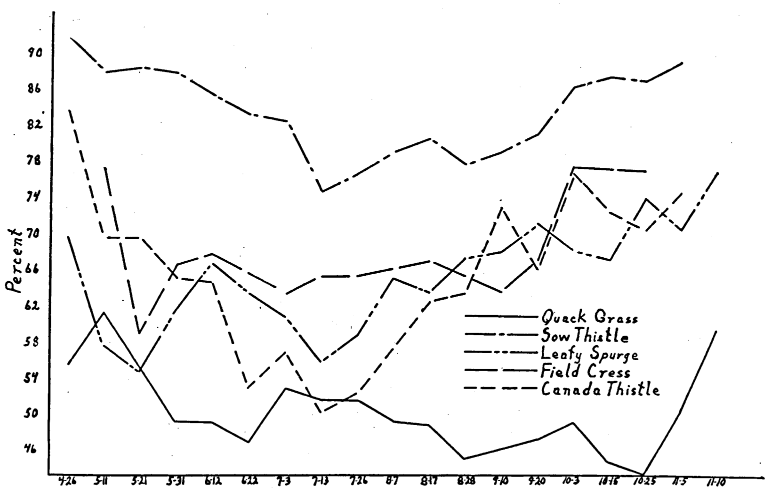

Fig. 10. Readily Available Carbohydrates in per Cent of Total Carbohydrates in the Underground Parts of Five Perennial Weeds

In the spring and fall, about 90 per cent of the total carbohydrates except cellulose in the storage roots of sow thistle was in readily available form; in summer only about 75 per cent was in this condition. The rhizomes of quack grass, at the opposite extreme, had only about 60 per cent of the total carbohydrates in readily available form in spring and fall and in early fall the low point reached less than 45 per cent.

The percentage of total carbohydrates in readily available form for the other three weeds ranged in between those of quack grass and sow thistle and during July they reached points nearly as low as in early spring or lower.

This relation of the readily available carbohydrates to the total carbohydrates in the underground parts of each of the four weeds except quack grass during the first part of July indicates another favorable time at which to begin eradication operations.

Nitrogenous Materials

Data for the nitrogenous materials are presented in Table 5 and graphed in Figures 11 and 12. Data for the samples taken on November 11, 1927, are given at the extreme right in both the table and the graphs.

Total Organic Nitrogen

The percentages of total organic nitrogen in the underground storage organs of the five weeds, graphed in Figure 11, were very materially lower than those for carbohydrates graphed in Figure 9.

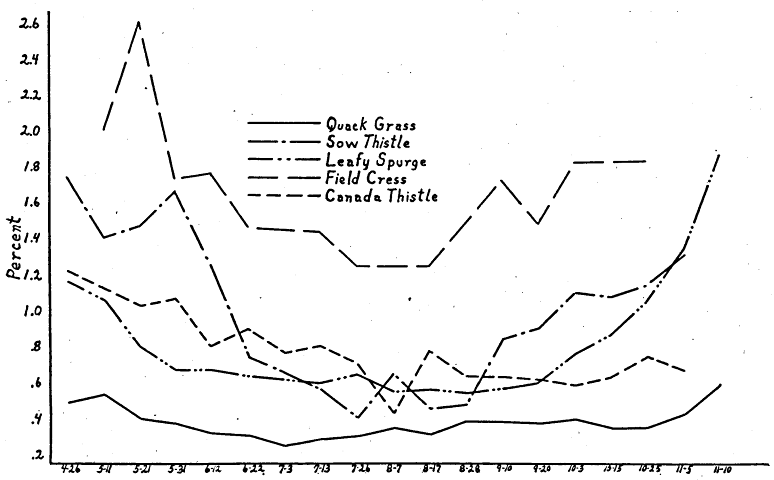

Fig. 11. Variations in the Percentage of Total Organic Nitrogen Based on Total Dry Weight in the Underground Parts of Five Perennial Weeds

Altho present in relatively small amounts, nitrogenous reserves are of great importance at all times, particularly when rapid building up of new plant tissues is occurring in early spring. The storage organs of Austrian field cress were highest in total organic nitrogen, ranging from 2.6 per cent in May to about 1.25 per cent in late July and early August. At the opposite extreme the rhizomes of quack grass contained at no time during the season more than 0.55 per cent of total nitrogen with the low point at 0.24 per cent in early June. The other three ranged between these two, reaching low levels in late July and early August. In percentage of total nitrogen, the underground storage organs of the five weeds showed, during the season, variations in the same general directions as were shown in the readily available carbohydrate reserves. As new plant tissue was built up rapidly in spring the reserve proteins were drawn on heavily. In the underground parts of Austrian field cress the percentage of total organic nitrogen was lower at the first than at the second sampling. The low points occurred in early summer, after which time the amount of protein reserves increased.

In the rhizomes of quack grass, the number of pounds per acre of total organic nitrogen decreased from approximately 20 in spring to half that amount in July and from then on increased to slightly more than in spring.

The curve for the percentage of total organic nitrogen in the underground storage organs of Canada thistle for the season is similar to those obtained by Welton, Morris, and Hartzler (8) for this weed under Ohio conditions.

The period of low nitrogenous reserves in the underground storage organs of leafy spurge, Austrian field cress, sow and Canada thistle coincides fairly well with that of low, readily-available carbohydrates in relation to total carbohydrates in early July.

Amino Nitrogen

During late summer and early fall, when reserve nitrogenous material was being moved into the storage organs and in early spring as it was being moved out rapidly, are when the percentages of amino nitrogen would be expected to be relatively high. As shown in Figure 12, the curves for amino nitrogen in the storage organs of sow and Canada thistle show a rise during the early part of May followed by a decline

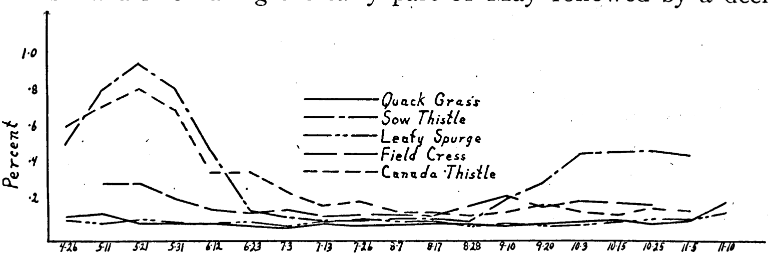

Fig. 12. Variations in the Percentage of Amino Nitrogen Based on the Total Dry Weight in the Underground Parts of Five Perennial Weeds

in the latter part of May and in June. These two weeds are late in starting in spring. If similar trends occurred in the amino nitrogen content of the storage organs of the other three weeds, they took place before the sampling was started. During July and August the amino

Table 5

Variations in the Percentages of Nitrogen Calculated on the Dry-Weight Basis in the Underground Parts of Five Perennial Weeds, in the Tops of Canada Thistle, and in the Pounds of Nitrogen per Acre in the Rhizomes of Quack Grass

Common names of weeds	Dates of sampling								
	4-26	5-11	5-21	5-31	6-12	6-23	7-3	7-13	7-26
(1) Total organic nitrogen									
	%	%	%	%	%	%	%	%	%
Sow thistle	1.77	1.41	1.48	1.68	1.26	0.73	0.65	0.57	0.39
Leafy spurge	1.18	1.13	0.79	0.68	0.68	0.63	0.62	0.59	0.64
Austrian field cress	....	2.02	2.62	1.74	1.77	1.44	1.45	1.42	1.24
Canada thistle roots	1.22	1.07	1.02	1.06	0.81	0.91	0.78	0.80	0.70
Quack grass	0.49	0.55	0.40	0.38	0.32	0.31	0.24	0.29	0.30
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	22.30	24.78	18.03	16.46	15.97	15.57	11.63	13.43	15.85
(2) Amino nitrogen									
	%	%	%	%	%	%	%	%	%
Sow thistle	0.496	0.791	0.932	0.801	0.454	0.117	0.091	0.076	0.075
Leafy spurge	0.082	0.059	0.079	0.055	0.049	0.059	0.035	0.066	0.081
Austrian field cress	....	0.271	0.278	0.197	0.136	0.107	0.125	0.098	0.100
Canada thistle	0.597	0.704	0.801	0.676	0.335	0.339	0.231	0.152	0.177
Quack grass	0.089	0.102	0.052	0.052	0.050	0.034	0.024	0.048	0.037
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	4.05	4.60	2.34	2.25	2.50	1.71	1.16	2.22	1.95
(3) Amino nitrogen expressed in per cent of total nitrogen									
	%	%	%	%	%	%	%	%	%
Sow thistle	28.02	56.10	62.97	47.68	36.03	16.03	14.00	13.33	19.23
Leafy spurge	6.95	5.22	10.00	8.09	7.21	9.37	5.65	11.19	12.66
Austrian field cress	....	13.42	10.61	11.32	7.68	7.43	8.62	6.90	8.06
Canada thistle	48.93	65.79	78.53	63.77	41.36	37.25	29.62	19.00	25.29
Quack grass	18.16	18.55	13.00	13.68	15.63	10.97	10.00	16.55	12.33

Common names of weeds	Dates of sampling									
	8-7	8-17	8-28	9-10	9-20	10-3	10-15	10-25	11-5	11-10
(1) Total organic nitrogen										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	0.66	0.46	0.48	0.86	0.90	1.16	1.12	1.17	1.27	....
Leafy spurge	0.52	0.55	0.53	0.57	0.60	0.76	0.86	1.04	1.35	1.87
Austrian field cress	....	1.26	....	1.72	1.48	1.82	....	1.81	....	....
Canada thistle roots	0.43	0.77	0.62	0.61	0.60	0.59	0.64	0.76	0.66	....
Quack grass	0.36	0.31	0.38	0.38	0.37	0.38	0.35	0.34	0.41	....
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	19.41	17.88	22.65	26.23	23.77	25.30	21.58	22.56	26.56	....
(2) Amino nitrogen										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	0.087	0.084	0.066	0.198	0.277	0.433	0.442	0.459	0.425	....
Leafy spurge	0.072	0.071	0.050	0.053	0.037	0.050	0.073	0.080	0.079	0.129
Austrian field cress	....	0.098	....	0.202	0.144	0.174	....	0.165	....	....
Canada thistle	0.115	0.112	0.099	0.116	0.158	0.110	0.101	0.138	0.117	....
Quack grass	0.042	0.050	0.053	0.040	0.056	0.064	0.072	0.056	0.077	....
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Quack grass	2.26	2.88	3.16	2.76	3.60	4.26	4.44	3.72	4.99	....
(3) Amino nitrogen expressed in per cent of total nitrogen										
	%	%	%	%	%	%	%	%	%	%
Sow thistle	13.18	18.26	13.75	23.02	30.78	37.33	39.46	39.23	33.46	....
Leafy spurge	13.85	12.91	9.43	9.30	6.17	6.58	8.49	7.69	5.85	6.90
Austrian field cress	....	7.78	....	11.74	9.73	9.56	....	9.12	....	....
Canada thistle	26.74	14.55	15.97	19.02	26.33	18.64	15.78	18.16	17.73	....
Quack grass	11.67	16.13	13.95	10.53	15.14	16.84	20.57	16.47	18.78	....

nitrogen content of the storage organs of each of the weeds was low. A rise in amino nitrogen took place in the storage organs of sow thistle during the fall.

Relation of Amino Nitrogen to Total Nitrogen

In the third part of Table 5 is given the relation of the amino nitrogen to the total nitrogen. In the underground parts of sow thistle, quack grass, and Austrian field cress the amino nitrogen was high in relation to total nitrogen during the spring and fall and low during the summer; for leafy spurge the relation was the opposite. The amino nitrogen was high in relation to total nitrogen in the underground parts of Canada thistle in spring, low during the summer, and gained only slightly during fall.

EFFECT OF CUTTING THISTLES ONCE AT FULL BLOOM

The idea that cutting Canada thistles once in the full-bloom stage of development will result in complete eradication appears to be fairly prevalent. In Table 6 are given the percentages of dry matter, carbohydrates, and nitrogen reserves in the storage organs of thistles that grew undisturbed throughout the season and similar data for thistles cut once at full bloom. Cutting thistles at full bloom resulted in later development the following season. Therefore, the higher percentages of total readily available carbohydrates for the cut as compared with the uncut thistles on May 11 as given in the seventh part of Table 6 does not mean that this relationship held the previous fall or earlier in the spring. By May 11 the percentage of total readily available carbohydrates in the underground storage organs of the undisturbed thistles had declined markedly and further decline was more gradual; the rapid decline for the cut thistles was taking place up to June 12. In total nitrogen content, the underground storage organs of the cut thistles were considerably higher than the undisturbed ones at each sampling date. Welton, Morris, and Hartzler (8) found the percentages of readily available carbohydrates in the storage roots of thistles cut once in July about the same during the early part of the following season as for those left uncut. During the latter part of the season, the uncut thistles were higher in carbohydrate reserves than the cut ones. In nitrogenous reserves they were approximately the same. They found that more frequent cutting, three times at monthly intervals over a three-year period, practically eliminated thistles. Gilchrist (3) found that cutting Canada thistle tops when they were from 4 to 6 inches tall and following with two additional cuttings each of two years, successfully eliminated the weed.

Table 6

Comparison of the Percentages of Dry Weight and Chemical Constituents in the Roots of Canada Thistle (a) Undisturbed and (b) Cut Once in Full Bloom the Previous Year

	Dates of sampling											
	5-11	5-21	5-31	6-12	6-23	7-3	5-11	5-21	5-31	6-12	6-23	7-3
	(1) Percentage dry weight						(2) Total sugars					
Undisturbed	26.07	21.36	16.02	17.17	13.76	15.34	10.54	12.00	11.57	11.07	8.32	8.27
Cut at full bloom previous year....	19.79	17.82	12.61	10.90	10.04	10.54	20.57	14.36	11.03	5.52	5.03	9.28
	(3) Reducing sugars						(4) Dextrins and soluble starches					
Undisturbed	2.03	3.10	3.79	4.04	2.91	2.00	6.66	9.35	9.54	9.68	5.59	6.76
Cut at full bloom previous year....	5.04	3.45	4.24	2.06	1.61	2.41	13.44	8.54	5.84	4.15	5.34	4.10
	(5) True starches						(6) Hemicelluloses					
Undisturbed	0.74	0.96	1.27	1.40	2.60	2.16	7.85	9.76	12.10	11.61	14.73	13.11
Cut at full bloom previous year....	0.18	1.84	1.10	0.58	0.84	1.21	13.00	15.44	20.58	21.80	21.11	16.54
	(7) Total readily available carbohydrates (Sum of 2, 4, and 5)						(8) Total reserve carbohydrates (Sum of 6 and 7)					
Undisturbed	17.94	22.31	22.38	21.15	16.51	17.19	25.79	32.07	34.48	32.76	31.24	30.30
Cut at full bloom previous year....	34.19	24.74	17.97	10.25	11.21	14.59	47.19	40.18	38.55	32.05	32.32	31.13
	(9) Total nitrogen						(10) Amino nitrogen					
Undisturbed	1.07	1.02	1.06	0.81	0.91	0.78	0.704	0.801	0.676	0.335	0.339	0.231
Cut at full bloom previous year....	1.38	1.77	2.14	1.89	1.78	1.29	1.160	1.235	0.763	0.513	1.228	0.260

CONCLUSIONS

Readily available and total carbohydrates reached low points in the underground storage organs of leafy spurge, Austrian field cress, sow and Canada thistles at about the time these weeds reached the beginning bloom stage of development. Also, there was some lowering in the total organic nitrogen percentages in the underground storage organs of each of these weeds except Austrian field cress to that stage of development. This appears to be an opportune stage of development at which to begin eradication operations against these weeds.

The time at which the weeds reach the beginning bloom stage of development varies considerably. Leafy spurge and Austrian field cress ordinarily reach this stage of development by about the middle of May; sow and Canada thistles ordinarily do not begin to bloom until the latter part of June or the first part of July.

During the first part of July the readily available carbohydrates were low in relation to total carbohydrates in the underground storage organs of each of the weeds except quack grass. At this time the readily available carbohydrates reached their lowest levels in the underground storage organs of sow and Canada thistles. Also the total organic nitrogen was nearly at its lowest point in the underground parts of each of the five weeds at this time. Another factor aside from the state of the reserves in the underground parts of the weeds is the generally more favorable weather conditions for weed eradication, particularly by tillage methods, during July and August than earlier or later in the season.

During the first part of July appears to be a second opportune time to begin eradication operations against leafy spurge and Austrian field cress. If the beginning of eradication operations is delayed until July, seed formation by these weeds may be avoided by mowing the tops during the latter part of May.

As far as reserve foods in their underground parts are concerned, the first part of July appears to be the most desirable time to begin the eradication of sow and Canada thistles. Mowing the tops at this time prevents seed formation.

Less variation occurred during the season in the percentage of reserve foods in the rhizomes of quack grass than in the underground storage organs of the other four weeds. Carbohydrate reserves in the rhizomes were lower up to the first part of July than at any time later, and organic nitrogen was at its lowest point at that time. Considering all the factors favorable to the eradication of quack grass, the first part of July appears to be the opportune time to begin.

The state of the reserve foods in the underground parts of perennial weeds is probably of greater importance when eradication is planned by cutting the tops or by tillage than when the plan of killing is through chemical means.

SUMMARY

1. The carbohydrate and nitrogenous reserves in the underground storage organs of the five weeds varied during the season in both form and total amounts.

2. There were sharp declines from late April through the first part of May in the percentages of total sugars and total readily available carbohydrates in the underground storage organs of each of the weeds except quack grass.

3. The total readily available carbohydrates in the storage roots of leafy spurge and Austrian field cress, two weeds that resume growth very early in spring, reached low points for the season by the middle of May. At this time they were beginning to bloom. Rapid storage of these materials followed for a time and continued at more moderate rates to the close of the season.

4. For sow and Canada thistles, two weeds that usually do not appear above ground until late April, the declines in total readily available carbohydrates were very rapid at first and continued at more moderate rates to the first part of July, when the plants were in bloom. Reserves accumulated from that time to the close of the season.

5. The rhizomes of quack grass were lower in both percentage and pounds per acre of total readily available carbohydrates at the time the first determinations were made than on any later sampling date.

6. The readily available carbohydrates in the underground storage organs of each of the weeds except quack grass were low in relation to the total reserve carbohydrates during the middle of July.

7. There were marked decreases in the percentages of true starch and increases in sugars in the underground storage organs of sow and Canada thistles and leafy spurge as the temperature lowered in fall. The indications are that this change did not take place in the underground storage organs of Austrian field cress and quack grass.

8. Rapid declines in total organic nitrogen occurred in the underground storage organs of sow thistle and Austrian field cress and less marked declines in those of Canada thistle, leafy spurge, and quack grass during the early part of the season. These declines continued at more moderate rates to August, after which increases occurred.

9. Cutting Canada thistles close to the ground once in full bloom delayed growth the following year as compared with those not cut but did not result in marked lowering of the reserves in the storage roots.

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