ORGANIC RESERVES IN THE ROOTS OF BINDWEED [1]

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INTRODUCTION

Organic reserves in the roots of perennial weeds are closely associated with their persistence. Earlier work on bindweed control involved mainly the study of the effect of herbicides and the development of control methods by cultivation or smother crops with little consideration of the physiology of the weed. In 1936 work was undertaken at this station to study the carbohydrate reserves in bindweed roots and their role in growth and regeneration. The experiments reported in this paper relate to the effect of various cultural practices and chemical treatments on the trend of organic reserves in the roots of bindweed (*Convolvulus arvensis* L.).

MATERIALS

The study of the root reserves of bindweed is one phase of a larger program of weed investigations being carried on at the Colorado Agricultural Experiment Station. A 10-acre field of bindweed-infested land is under lease, and various cultural and chemical methods of weed control are in progress. The general plan of this part of the study involved the cultivation of plots at various intervals after emergence of the bindweed following each cultivation. Cultivations during the season of 1936 were (1) at emergence, (2) 3, (3) 6, (4) 9, (5) 12, and (6) 15 days after emergence. In addition to the clean cultivation and chemical tests, various cropping practices are being carried out.[3]

The study of the root reserves consisted essentially in determining the trend of the carbohydrates in the roots of plants under various treatments in comparison with undisturbed plants. Four separate types of collections were made:

1. Root samples collected at biweekly intervals from April 25 to October 30. Two series of plots were sampled—one in which the plants were undisturbed throughout the season, and the other in which the plants were clean-cultivated all season at 9-day intervals after emergence of the bindweed. First emergence of plants commonly occurred about 6 days after cultivating. Therefore cultivating 9 days after emergence is comparable to cultivation once every 2 weeks.
2. Root samples collected at 4-day intervals for a period of 24 days after a single cultivation at various dates during the season.
3. Root samples collected from plots treated on various dates with dry sodium chlorate at the rate of 3 pounds per square rod. Root

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[3] Under the supervision of Bruce J. Thornton.

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samples were taken June 1, July 1, August 1, and September 1 at time of treatment, and also 1 month after treatment. Checks were run on untreated plots.

4. Root samples were collected at the end of the growing season near October 1 from plots as follows:

(1) Uncultivated; (2) cultivated at emergence to depth of 3 inches, April to October; (3) cultivated 3 days after emergence, April to October; (4) cultivated 6 days after emergence, April to October; (5) cultivated 9 days after emergence, April to October; (6) cultivated 12 days after emergence, April to October; (7) cultivated 15 days after emergence, April to October; and (8) cultivated to a depth of 6 inches 9 days after emergence, April to October.

METHOD OF SAMPLING

Root samples were obtained by sifting the soil containing bindweed roots and placing the roots with some soil, in quart mason fruit jars for transport to the laboratory. A post-hole digger which made a hole 6 inches in diameter was used in digging the roots. By making four adjacent holes in the pattern of a square a hole was produced 1 foot square and as deep as required. For the work on bindweed, root samples were taken from the first foot level only. Five cubic feet of soil from five different locations in the plot were taken as a standard composite field sample.

The roots were taken to the laboratory as soon as possible after digging, the soil and sand removed, and the roots washed with cold water. The excess water was removed by blotting with cheesecloth. Duplicate 50-gm. samples were weighed to ± 0.05 gm. on a torsion balance. These were cut into pint mason fruit jars containing 200 ml. of boiling 95-percent alcohol, sealed, and allowed to simmer in a boiling water bath for 45 to 60 minutes. The samples were then stored until they could be conveniently extracted and analyzed.

METHODS OF ANALYSIS

The preserved root material was extracted by decantation with 80-percent boiling alcohol until reducing substances had been removed from the sample as determined by tests. From 12 to 15 extractions were required. The extract from each sample was collected in a volumetric flask and the extracting liquor made to volume after completion of the extraction. Two-hundred-milliliter portions of this liquor were used for the sugar determinations. The alcohol was removed by evaporation and the resulting water solution cleared with neutral lead acetate. Reducing substances were determined by the Munson-Walker (*22*)[4] method for the precipitation of the cuprous oxide. A modification of the Bertrand (*7*) method was used for the estimation of copper. The residue, after the removal of the soluble carbohydrates, was dried to constant weight at 100°C., ground to suitable fineness, and analyzed for starch and acid-hydrolyzable materials separately.

One-gram samples of the residue were gelatinized and digested with undiluted taka-diastase until negative iodine tests for starch were obtained. The digest was then filtered, the filtrate cleared with neutral lead acetate, and the glucose equivalent after hydrolysis was determined on aliquots. The starch fraction included small amounts

[4] Italic numbers in parentheses refer to Literature Cited, p. 412.

of other substances which might be brought into solution by the gelatinizing process and the taka-diastase digestion. Evidence for this is the fact that appreciable values for starch were obtained on samples from fallowed plots when iodine failed to give positive tests for starch. No important reserve material remained in the residue after the alcohol extraction and diastase digestion. This is shown by the uniformly low acid-hydrolyzable values.

The term "readily available carbohydrates," as used in this paper, includes the total sugars and starch only, since acid-hydrolyzable substances probably do not serve as a readily available reserve.

The acid-hydrolyzable fraction is shown in the tables, however, for the convenience of readers who desire to estimate the total carbohydrates. The reducing sugars are necessarily a part of the total sugars as determined after invertase hydrolysis. Results shown in all the tables are expressed on the basis of both fresh and dry weight. The graphs show the data on the basis of fresh weight.

PRESENTATION AND DISCUSSION OF RESULTS

Reserve food in the bindweed roots studied in these experiments occurred chiefly in the form of sucrose and starch. Although the reducing-sugar content was low, approximately 0.50 to 2.00 percent, the total sugars varied from about 2.00 to 7.00 percent. In a recent paper Bakke, Gaessler, and Loomis (*4*) showed that reserves in the bindweed roots of their experiment consisted largely of sucrose and a dextrinlike compound or group of compounds. They showed also that reducing sugars and true starch played less important roles.

TABLE 1.—*Seasonal variations in the carbohydrate content (percent) of cultivated and of undisturbed bindweed roots expressed on fresh-weight and dry-weight bases 1936*

Date	Basis	Undisturbed plants—					Cultivated plants—				
		Reducing sugars	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates	Reducing sugars	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates
Apr. 25	Fresh weight	0.53	2.44	1.80	3.12	4.24	------	------	------	------	------
	Dry weight	3.16	14.60	10.81	18.70	25.41	------	------	------	------	------
May 9	Fresh weight	.51	1.91	.93	3.10	2.84	------	------	------	------	------
	Dry weight	3.30	12.36	6.00	19.95	18.36	------	------	------	------	------
May 25	Fresh weight	.66	2.25	1.65	2.50	3.90	0.53	1.50	2.01	2.89	3.51
	Dry weight	4.48	15.13	11.28	16.92	26.41	3.09	8.68	11.65	16.77	20.33
June 8	Fresh weight	1.07	2.54	3.31	2.37	5.85	.40	1.77	1.40	3.00	3.17
	Dry weight	7.13	17.77	22.09	15.85	39.86	2.48	11.00	8.56	18.70	19.56
June 22	Fresh weight	.84	2.81	2.97	2.98	5.78	.26	1.19	.70	3.69	1.89
	Dry weight	4.85	16.34	15.50	17.30	31.84	1.54	6.94	4.06	21.47	11.00
July 6	Fresh weight	.77	2.66	4.20	3.20	6.86	.03	.82	.97	3.20	1.79
	Dry weight	3.95	13.78	21.03	16.57	34.81	.18	5.02	5.97	19.40	10.99
July 20	Fresh weight	1.31	3.94	4.74	3.15	8.68	.01	.70	.78	3.00	1.48
	Dry weight	6.81	18.93	26.50	15.92	45.43	.09	4.52	5.22	20.17	9.74
Aug. 1	Fresh weight	1.21	3.96	6.21	3.50	10.17	.02	.71	.79	3.33	1.50
	Dry weight	5.24	17.05	26.81	15.10	43.86	.03	4.32	4.87	21.60	9.19
Aug. 17	Fresh weight	1.25	2.79	5.58	3.48	8.37	------	.71	1.00	2.80	1.71
	Dry weight	5.63	12.56	25.15	15.72	37.71	------	4.63	6.81	18.42	11.44
Aug. 31	Fresh weight	1.56	3.97	6.83	3.25	10.80	.20	.98	.98	2.70	1.96
	Dry weight	8.98	22.83	31.44	14.97	54.27	1.29	6.22	6.15	18.35	12.37
Sept. 16	Fresh weight	1.62	4.46	8.28	3.72	12.74	.17	.54	.88	3.60	1.42
	Dry weight	5.40	17.22	32.00	14.40	49.22	.94	3.00	4.90	19.95	7.90
Sept. 29	Fresh weight	1.92	5.77	8.48	4.02	14.25	.11	.80	1.50	3.20	2.30
	Dry weight	7.91	23.69	34.90	16.55	58.59	.06	4.79	9.03	19.45	13.82
Oct. 15	Fresh weight	1.67	5.83	6.61	3.50	12.44	------	.95	.85	2.90	1.80
	Dry weight	9.26	32.22	29.22	15.50	61.44	------	10.45	5.62	19.17	16.07
Oct. 30	Fresh weight	1.00	7.20	5.22	2.93	12.32	------	------	------	------	------
	Dry weight	5.16	36.35	26.81	15.07	63.16	------	------	------	------	------

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In the experiments reported herein no attempt was made to separate the true starch from the dextrin. The values for starch reported, therefore, represent the true starch together with the dextrinlike group of compounds which Bakke, Gaessler, and Loomis discuss.

Table 1 shows the data for total and reducing sugars, starch, acid-hydrolyzable and the readily available carbohydrates for undisturbed plants and plants cultivated 9 days after emergence (biweekly) throughout the growing season of 1936. In most cases dates of sampling are at exactly 2-week intervals.

SEASONAL TREND OF CARBOHYDRATES IN BINDWEED ROOTS

The seasonal trend of the sugars is represented graphically in figure 1. The total sugar content of the undisturbed plants gradually increased from April to the last of October. The reducing sugars in the

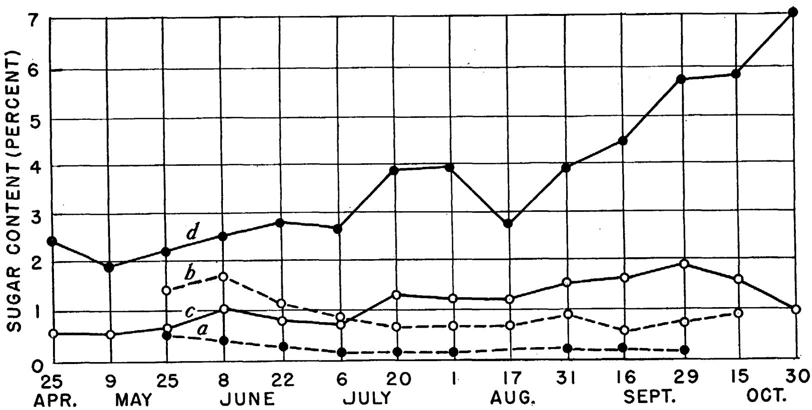

FIGURE 1.—Total and reducing sugar content of bindweed roots, when undisturbed and when cultivated at 2-week intervals, 1936: *a*, reducing sugars, cultivated; *b*, total sugars, cultivated; *c*, reducing sugars, undisturbed; *d*, total sugars, undisturbed.

undisturbed plants showed only slight increase from the beginning to the end of the experiment. Whether reducing sugars are precursors of sucrose or arise as a result of hydrolysis of the sucrose in bindweed is open to question. But in either case great variation in this fraction would not be expected, since in the former case they would rapidly be changed into the disaccharide and in the latter instance they would doubtless be used in general metabolism as rapidly as they were formed, without accumulating.

It has been shown in an earlier paper (*5*) that the total sugars of bindweed are materially depleted and are held at a minimum of about 1 percent of the dry weight by frequent cultivation. The data presented here show that when a cultivation program is started early in the spring the apparent depletion of total sugars is largely the result of a lack of normal accumulation rather than an actual depletion. Compare figure 1. Collection of samples from the cultivated plots was started May 25, 4 weeks after samples were first collected from the undisturbed plants. The total sugar content of the roots from the cultivated plots was 0.75 percent less than from undisturbed plants. Slight depletion occurred, but the significant point seems to be the lack of accumulation in those plants which were repeatedly cultivated Only traces of reducing sugars were found in the roots of cultivated plants.

In the undisturbed series, the starch content showed greater variation than did the total sugars. The minimum values for both starch and total sugars on May 9 may be accounted for by the rapid utilization of carbohydrate material for regeneration and growth in the early spring. Observation of the growth status of the plants showed that four to six leaves had appeared on the young plants before May 5; about May 7 to 9 the plants exhibited much additional growth and marked vining. It seems reasonable to believe that this rapid vegetative growth would be a drain on the reserve foods since the limited photosynthetic area probably could not supply the high sugar requirements for rapid cell division.

The data show relatively more rapid accumulation of starch than sugar before October 1. The September 29 starch value was 471 percent of the value on April 25, while the total sugar for September 29 was about 236 percent of its value on the earlier date. The marked seasonal increase in percentage of starch as compared with the accumulation of total sugars may be interpreted to mean that while sucrose may act as a temporary storage product it is rapidly transformed into the more stable and insoluble polysaccharide material.

TABLE 2.—*Seasonal variations in the carbohydrate content (percent) of cultivated and of undisturbed bindweed roots expressed on fresh-weight and dry-weight bases, 1937*

Date	Basis	Undisturbed plants				Cultivated plants			
		Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates
May 11	Fresh weight					0.95	1.70	3.10	2.65
	Dry weight					5.86	13.02	21.33	18.88
May 30	Fresh weight					1.59	1.74	3.14	3.33
	Dry weight					9.69	11.60	24.18	21.29
June 3	Fresh weight	1.94	1.74	3.76	3.68	2.42	2.44	2.10	4.86
	Dry weight	10.16	9.96	21.20	20.12	13.90	15.75	19.70	29.65
June 17	Fresh weight	1.97	2.83	3.28	4.80	2.15	3.60	3.09	5.75
	Dry weight	10.83	17.00	19.83	27.83	12.38	22.65	19.46	35.03
July 1	Fresh weight	1.97	2.84	3.44	4.81				
	Dry weight	9.96	15.70	21.36	25.66				
July 15	Fresh weight	1.70	3.13	3.07	4.83	1.96	4.05	2.43	6.01
	Dry weight	8.12	10.24	16.71	18.36	9.23	20.36	14.13	29.59
July 29	Fresh weight	3.08	7.50	2.45	10.58				
	Dry weight	12.67	33.82	10.72	46.49				
Aug. 12	Fresh weight	3.85	9.80	2.36	13.65	1.93	3.65	3.30	5.58
	Dry weight	16.90	41.90	10.70	58.80	9.11	17.63	14.15	26.74
Aug. 27	Fresh weight	3.78	8.84	2.91	12.62	3.11	3.88	3.22	6.99
	Dry weight	16.70	23.90	13.40	40.60	1.27	17.69	14.70	18.96
Sept. 11	Fresh weight	3.47	8.04	2.46	11.51	2.98	3.16	3.00	6.15
	Dry weight	13.05	35.10	10.47	48.15	14.14	16.75	15.85	30.89
Sept. 24	Fresh weight	2.75	7.47	3.38	10.22				
	Dry weight	11.14	32.10	15.27	43.24				
Oct. 7	Fresh weight	3.95	5.87	3.08	9.82				
	Dry weight	17.07	28.20	12.70	45.27				
Oct. 28	Fresh weight	5.00	4.63	2.73	9.63				
	Dry weight	22.62	25.30	15.34	47.92				

The change in percentage composition of sugar and starch in the roots of bindweed after about the end of September is interesting. Field notes taken indicate that temperatures had dropped considerably and growth had practically ceased near the end of September. Superficially the plants appeared to be dead and to be going into the usual winter dormant condition. It is a well-known fact that certain plants may be hardened to make them cold and drought resistant. Chemical analysis of such plants shows a marked change in the

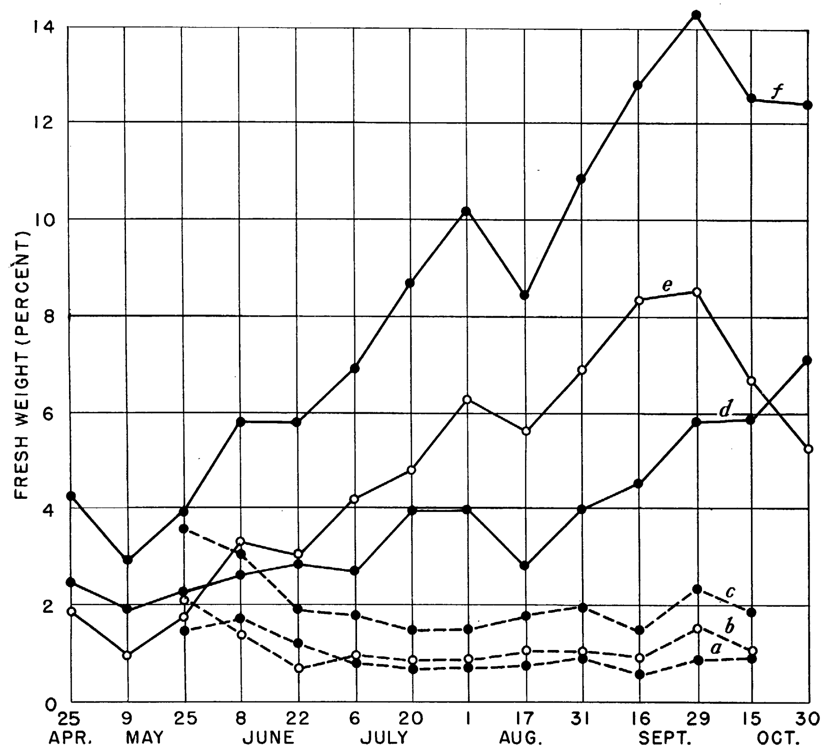

FIGURE 2.—Total sugar, starch, and readily available carbohydrate content of bindweed roots when undisturbed and when cultivated at 2-week intervals, 1936: *a*, Total sugars, cultivated; *b*, starch, cultivated; *c*, readily available carbohydrates, cultivated; *d*, total sugars, undisturbed; *e*, starch, undisturbed; *f*, readily available carbohydrates, undisturbed.

starch-sugar equilibrium. The marked decrease in starch content of bindweed roots accompanied by the increase in sugar percentage is indicative of the transition occurring in the roots with the approach of cold weather. Harvey (*12*) credits Lidforss (*16*) with reporting that a shift from polysaccharides to glucose and sucrose is a common occurrence in plants during the cold season. Hasselbring and Hawkins (*13*) have shown the same shift occurs in sweetpotatoes kept at low temperatures. Harvey (*12*) also has shown that the polysaccharides of hardened cabbages are displaced in the direction of monosaccharides and disaccharides.

Readily available reserves reached a maximum of 14.25 percent in the roots of undisturbed plants and a maximum of 3.51 percent in the cultivated plants.

Sugars, starch, and readily available carbohydrates, are plotted together in figure 2 to show their seasonal trends in undisturbed and cultivated plants. Distinct reductions are observed in each fraction A noteworthy fact which the graph reveals is the marked reduction in the carbohydrates of the cultivated plants.

Investigation of the seasonal trend of the carbohydrates was carried through the 1937 season also. The behavior of the carbohydrate

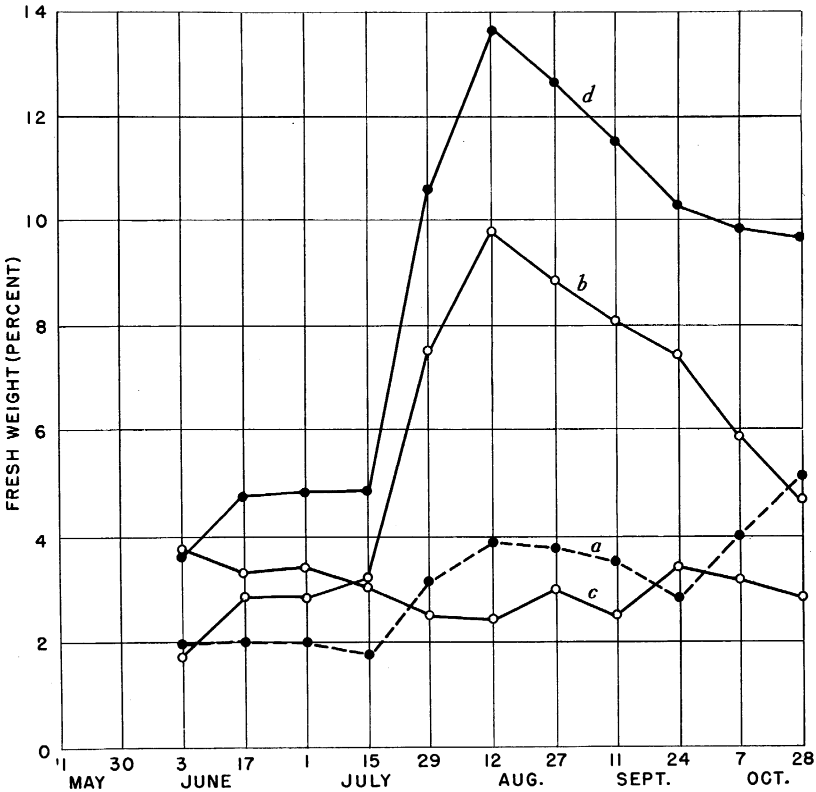

FIGURE 3.—Carbohydrate content of bindweed roots when undisturbed, 1937: *a*, Total sugars; *b*, starch; *c*, acid-hydrolyzable substances; *d*, readily available carbohydrates.

fractions in 1937 was similar to that in 1936 as shown in table 2 and figure 3. There was, however, more rapid accumulation of starch in the undisturbed plants. The data show that very little accumulation of starch occurred before July 15 but that thereafter there was a very rapid increase in the starch content, reaching a maximum of 9.80 percent by August 12th. This date was about 1 month earlier than the time of maximum carbohydrate accumulation in 1936. The data are shown in figure 4.

Weather data for 1937 are incomplete, but it is believed that the local environmental conditions delayed early accumulation and caused the rapid increase in starch between July 15 and August 12, in the undisturbed plants.

It should be pointed out that the samples used to show the seasonal trend of carbohydrates from fallowed plots for the 1937 series were taken from plots which were cultivated irregularly at 3- to 4-week intervals. This may account for the higher values found in the 1937 cultivated plants as compared with those of 1936.

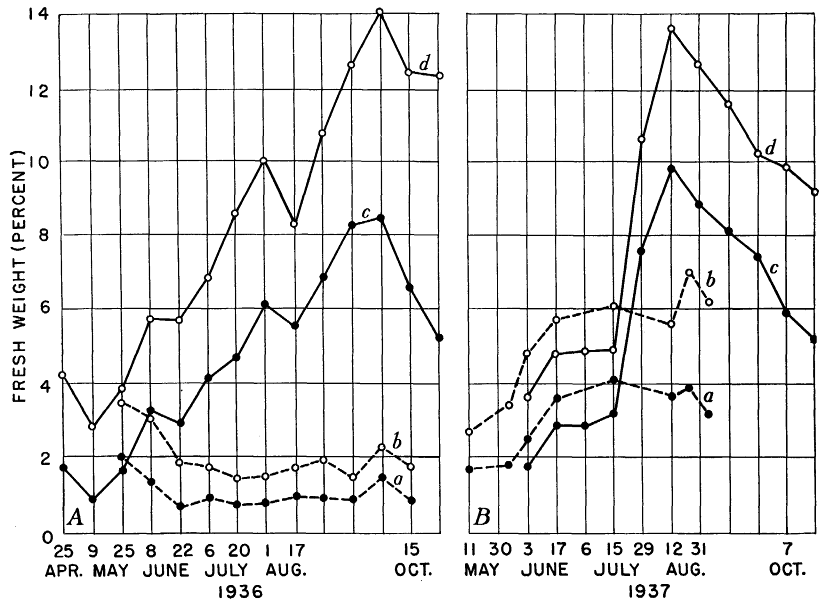

FIGURE 4.—Starch and readily available carbohydrate content of bindweed roots when undisturbed and when cultivated, 1936 (*A*) and 1937 (*B*): *a*, Starch, cultivated; *b*, readily available carbohydrates, cultivated; *c*, starch, undisturbed; *d*, readily available carbohydrates, undisturbed.

TREND OF CARBOHYDRATES IN BINDWEED ROOTS AFTER CROP HARVEST OR CULTIVATION

At the outset it was planned to study the trend of the food reserves in the roots of bindweed at short intervals of sampling after small-grain or other crop harvest and after one cultivation.

Assuming that rapid and important changes might be taking place in the carbohydrate fractions early in the season which could not be detected in the biweekly series, root samples were collected at 4-day intervals from May 2 to May 25, 1936. Analyses showed, however, that reducing sugars, total sugars and acid-hydrolyzable substances remained uniformly constant. The data are given in table 3. There was a moderate decline in the starch content from May 7 to 13 which was recovered by May 17, followed by gradual accumulation until May 25. During the period May 2 to May 25 the total sugar content was about 1 percent higher than the starch content.

Root samples of bindweed were collected at 4-day intervals for a period of 24 days after barley harvest. No unusual relationship was found between the several carbohydrate fractions (table 3), as a result of the grain crop growing with the bindweed, nor did any striking changes take place after the barley was harvested.

TABLE 3.—*Variations in carbohydrate content (percent) of bindweed roots expressed on fresh-weight and dry-weight bases, 1936*

[Plants sampled at 4-day intervals May 2 to 25 and July 8 to August 1 (after barley harvest)]

MAY 2 TO 25

Date	Basis	Reducing sugars	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates
May 2	Fresh weight	0.48	1.90	1.22	3.10	3.12
	Dry weight	3.01	11.87	7.60	19.32	19.47
May 7	Fresh weight	.65	2.19	1.36	3.05	3.55
	Dry weight	4.15	13.98	8.68	19.40	22.66
May 9	Fresh weight	.51	1.91	.93	3.10	2.84
	Dry weight	3.30	12.37	6.00	19.95	18.37
May 13	Fresh weight	.65	2.15	.90	2.80	3.05
	Dry weight	4.43	14.68	6.15	19.08	20.83
May 17	Fresh weight	.59	2.37	1.39	2.97	3.76
	Dry weight	3.75	15.00	8.78	18.78	23.78
May 21	Fresh weight	.60	2.28	1.55	2.71	3.83
	Dry weight	4.24	16.15	10.96	19.17	27.11
May 25	Fresh weight	.66	2.25	1.65	2.50	3.90
	Dry weight	4.48	15.30	11.28	16.92	26.58
JULY 8 TO AUGUST 1 (AFTER BARLEY HARVEST)						
July 8	Fresh weight	1.10	3.33	4.37	3.51	7.70
	Dry weight	5.80	17.63	21.03	16.87	38.66
July 12	Fresh weight	1.06	3.03	3.80	3.51	6.83
	Dry weight	5.39	15.43	19.43	17.92	34.86
July 16	Fresh weight	1.07	3.30	4.75	3.68	8.05
	Dry weight	.49	15.20	21.94	16.95	37.14
July 20	Fresh weight	1.54	4.28	4.74	3.24	9.02
	Dry weight	6.81	18.93	26.50	13.92	45.43
July 24	Fresh weight	2.32	5.14	7.71	3.49	12.85
	Dry weight	9.10	22.33	33.56	13.80	55.89
July 28	Fresh weight	2.14	5.14	7.90	3.85	13.04
	Dry weight	8.02	19.95	29.50	14.35	49.45
August 1	Fresh weight	1.23	3.96	6.22	3.50	10.18
	Dry weight	5.24	18.67	26.81	15.10	45.48

Two series of collections, usually at 4-day intervals, were made in 1937 in an effort to determine the extent of carbohydrate reduction after one cultivation. It was also believed that such a study would throw some light on the problem of carbohydrate relationships in regeneration.

In the first series the plot was cultivated May 4 and sampling was started May 11, upon emergence of the first plants. A marked decline occurred in both the sugar and starch content 4 days after emergence as compared with the values at emergence (table 4 and fig. 5). This decline was followed by a slight increase during the next 11 days. From May 11 to June 3 the starch was 0.2 to 0.8 percent higher than the total sugars. A closer relationship between these two fractions was shown here than at any other place in the study.

The first sample in the second series was collected July 29, when the plot was cultivated. Another sample was taken at emergence, and others (usually at 4-day intervals) thereafter for 24 days. Somewhat the same results were obtained at this time as earlier in the season. The total sugar content was practically the same as in the earlier series but did not show as much fluctuation. The starch content at cultivation was about 234 percent of the early spring value and dropped rapidly until 4 days after emergence and was still declining gradually at the end of the experiment.

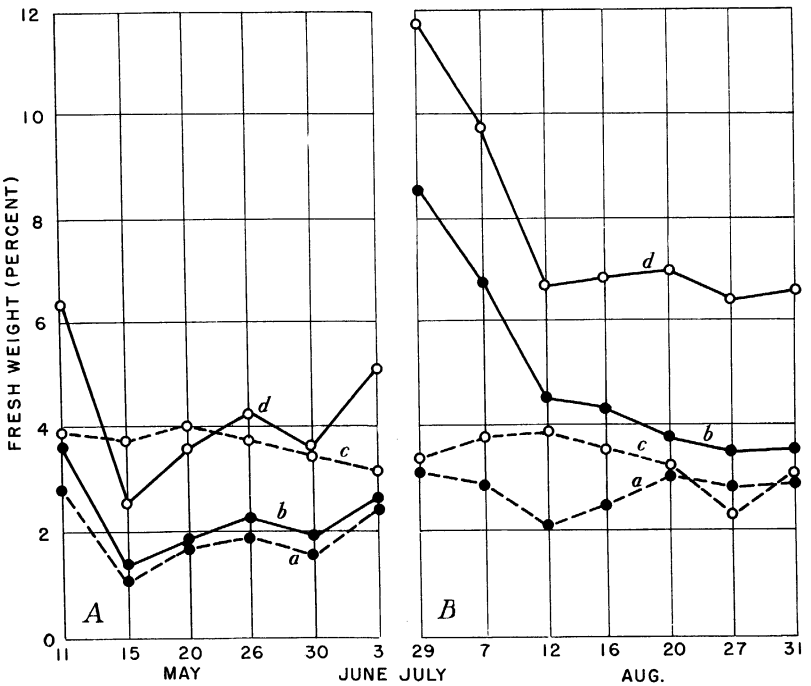

FIGURE 5.—Effect of one cultivation on the carbohydrate content of bindweed roots, 1937: *A*, Experiment performed in May; *B*, experiment performed in July. Sampled at emergence and at 4-day intervals for a period of 24 days: *a*, Total sugar; *b*, starch; *c*, acid-hydrolyzable substances; *d*, readily available carbohydrates.

TABLE 4.—*Carbohydrate content (percent) of bindweed roots after one cultivation expressed on fresh-weight and dry-weight bases, 1937*

MAY SERIES

Date	Basis	Total sugar	Starch	Acid-hydro-lyzable substances	Readily available carbohy-drates
May 11	Fresh weight	2.78	3.61	3.93	6.39
	Dry weight	16.45	18.50	20.10	34.95
May 15	Fresh weight	1.11	1.43	3.79	2.54
	Dry weight	6.97	8.60	20.23	15.57
May 20	Fresh weight	1.72	1.92	4.06	3.64
	Dry weight	8.84	9.93	20.98	18.77
May 26	Fresh weight	1.91	2.33	3.76	4.24
	Dry weight	10.98	13.00	21.07	23.98
May 30	Fresh weight	1.59	1.91	3.43	3.50
	Dry weight	9.74	11.60	24.18	21.34
June 3	Fresh weight	2.42	2.67	3.17	5.09
	Dry weight	14.90	15.75	19.70	30.65
AUGUST SERIES					
July 29	Fresh weight	3.15	8.48	3.42	11.63
	Dry weight	12.24	33.00	13.19	45 24
Aug. 7	Fresh weight	2.95	6.75	3.84	9.70
	Dry weight	12.06	22.62	15.73	34.68
Aug. 12	Fresh weight	2.11	4.58	3.94	6.69
	Dry weight	9.13	17.63	14.15	26.76
Aug. 16	Fresh weight	2.54	4.33	3.50	6.87
	Dry weight	11.45	20.10	17.01	31.55
Aug. 20	Fresh weight	3.11	3.87	3.22	6.98
	Dry weight	1.27	17.69	14.70	18.96
Aug. 27	Fresh weight	2.87	3.52	2.34	6.39
	Dry weight	11.08	32.10	11.75	43.18
Aug. 31	Fresh weight	2.98	3.53	3.13	6.51
	Dry weight	14.14	16.75	15.85	30.89

In general, the trend of the carbohydrates after a single cultivation showed an expected decline 4 to 10 days after cultivation with only moderate change for the rest of the 24-day period. It was concluded, therefore, that 6 intervals of 4 days each was not sufficient time for the plants to recover from the set-back brought about by the cultivation, and that subsequent investigation should be performed in a somewhat different fashion.

The information gathered from the carbohydrate studies of 1935 (*5*), 1936, and 1937 point also to the possibility of making total carbohydrate determinations, in certain studies at least, rather than attempting to fractionate the carbohydrates.

In 1938 the study of the carbohydrate trend after one cultivation was made in the following manner: Samples were collected but instead of being preserved in alcohol, they were dried by forced ventilation in an oven at 70° C. The dry material was then ground to proper fineness and hydrolyzed with 1+20 (i. e., 1 ml. of concentrated hydrochloric acid plus 20 ml. of water) hydrochloric acid at 120° for 1 hour, and determinations were made for reducing substances.

TABLE 5.—*Total carbohydrates (percent) by acid hydrolysis* [1] *in bindweed roots after one cultivation, expressed on fresh-weight and dry-weight bases, 1938*

Date	Total carbohydrates by acid hydrolysis on basis of—		Date	Total carbohydrates by acid hydrolysis on basis of—	
	Fresh weight	Dry weight		Fresh weight	Dry weight
June series			*August series*		
June 29	5. 35	33. 56	Aug. 5	13. 05	43. 62
July 6	2. 82	30. 25	Aug. 26	11. 20	41. 10
July 11	2. 99	32. 82	Sept. 6	9. 84	38. 20
July 19	3. 08	30. 75	Sept. 23	10. 27	38. 05
Aug. 3	3. 42	32. 20	Oct. 1	10. 96	39. 98
Aug. 9	3. 52	33. 90	Oct. 8	11. 84	42. 09

[1] Analysis for total carbohydrates made by acid hydrolysis of dry tissue and determinations made by the ceric sulfate method (*6*).

These data are presented in table 5. In the first series shown in figure 6 *A* the plot was sampled June 29 at the time of cultivation, again at the time of emergence of the bindweed, and at irregular intervals for about 1 month. The second series was started August 5. Cultivation was unavoidably delayed until August 15, and samples were collected at irregular intervals after emergence until October 8. The carbohydrate content at the beginning of the second series in August (Fig. 6 *B*) was 244 percent of that in June. Although a reduction of 47 percent was found in the total carbohydrate content from time of cultivation until emergence in the June series, the total reduction in the August series was but 25 percent. Depletion continued longer, however, at the later date, and the subsequent accumulation of total carbohydrates was relatively more rapid.

The difference in behavior of the reserve food in the two experiments might be explained in the following manner: A certain quantity of reserve food is used for the synthesis of new protoplasts. Removal of food from a low initial reserve caused a greater net effect than later in the season when the reserve was higher. The prolonged reduction after cultivation observed later in the season was probably owing to less favorable growing conditions. The limited growth checked the demand for reserves, and as a consequence the photosynthate accumulated rapidly in spite of the limited photosynthetic area. This accumulation then aided materially in increasing the already relatively large supply of reserve materials in the roots.

NITROGEN VARIATIONS

Studies of the organic reserves in a large number of crop plants and noxious weeds have been made by Aldous (*1*), Arny (*2*), Barr (*5*), Graber et al (*9*), Grandfield (*10*, *11*), McCarty (*19*, *20*), Nelson (*24*),

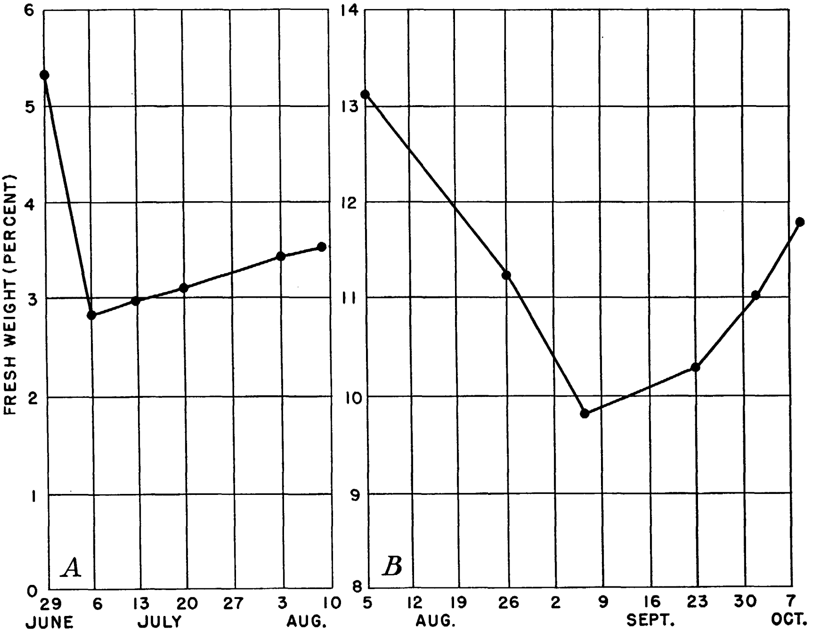

FIGURE 6.—Effect of one cultivation on the total carbohydrate content of bindweed roots, 1938: *A*, Experiment performed in June; *B*, experiment performed in August.

Pierre and Bertram (*25*), Welton, Morris, and Hartzler (*26*), and others. With few exceptions, attention has been directed chiefly to investigations of the carbohydrates. It is well known that the reserve carbohydrates are important factors in plant growth, but our knowledge relative to the several forms of nitrogen as they occur in storage organs of weeds is limited. It seemed, therefore, that a study of the various nitrogen fractions might throw some light on the problem of regeneration and growth in bindweed.

Analyses were made on the 1936 and 1937 root samples for nitrogen content. The dry material was analyzed by the Kjeldahl (*3*) method for colloidal or protein nitrogen. Determinations were made on the alcoholic extract for (1) ammonia and amide nitrogen according to Loomis and Shull (*18*), (2) amino nitrogen by the Van Slyke method, and (3) total nitrogen including nitrates by the modified Kjeldahl-salicylic acid method as described by Loomis and Shull (*18*). The data are given in table 6 and shown graphically in figure 7.

Table 6 and figure 7 show gradual but marked accumulation of colloidal nitrogen in the undisturbed plants from April to October. Cultivation held the colloidal nitrogen around 0.25 percent with very

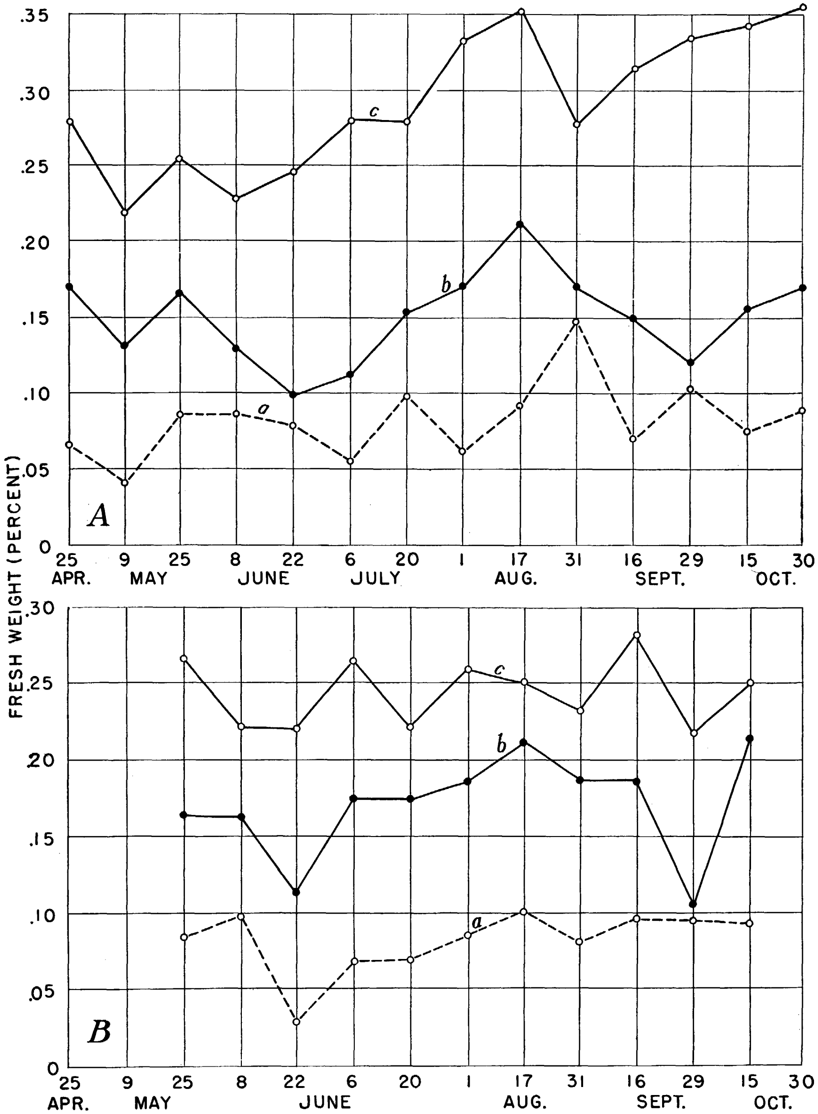

FIGURE 7.—Nitrogen content of bindweed roots when undisturbed (*A*) and when cultivated at 2-week intervals (*B*), 1936: *a*, Amino nitrogen; *b*, soluble nitrogen; *c*, colloidal nitrogen.

little change throughout the season. The data show that cultivation reduced the colloidal-nitrogen content, although frequency of cultivation appeared to have no material effect. No important changes occurred in the soluble-nitrogen content in either cultivated or undisturbed plants. Traces of amide nitrogen and moderate quantities of nitrates and nitrites which showed no consistent variations were found.

TABLE 6.—*Seasonal variations in nitrogen content (percent) of bindweed roots, when undisturbed and when cultivated, expressed on fresh weight and dry weight bases, 1936–37*

Series and date	Basis	Colloidal nitrogen	Total soluble nitrogen	Amino nitrogen
UNDISTURBED, 1936				
Apr. 25	Fresh weight	0.27	0.17	0.067
	Dry weight	1.67	1.04	.40
May 9	Fresh weight	.21	.13	.041
	Dry weight	1.40	.84	.26
May 25	Fresh weight	.25	.16	.086
	Dry weight	1.72	1.14	.29
June 8	Fresh weight	.22	.12	.082
	Dry weight	1.51	.85	.54
June 22	Fresh weight	.24	.09	.076
	Dry weight	1.44	.79	.31
July 6	Fresh weight	.28	.11	.056
	Dry weight	1.51	.59	.29
July 20	Fresh weight	.27	.15	.098
	Dry weight	.94	.65	.43
Aug. 1	Fresh weight	.33	.17	.063
	Dry weight	1.45	.76	.13
Aug. 17	Fresh weight	.35	.21	.087
	Dry weight	1.58	.94	.39
Aug. 31	Fresh weight	.27	.17	.148
	Dry weight	1.27	.81	.68
Sept. 16	Fresh weight	.31	.15	.069
	Dry weight	1.21	.61	.34
Sept. 29	Fresh weight	.33	.12	.102
	Dry weight	1.36	.32	.42
Oct. 15	Fresh weight	.34	.15	.071
	Dry weight	1.54	.67	.31
Oct. 30	Fresh weight	.35	.17	.082
	Dry weight	1.80	.87	.45
CULTIVATED, 1936				
May 25	Fresh weight	0.26	0.16	0.082
	Dry weight	1.53	.98	.48
June 8	Fresh weight	.22	.16	.098
	Dry weight	1.37	1.00	.60
June 22	Fresh weight	.21	.11	.027
	Dry weight	1.27	.65	.15
July 6	Fresh weight	.26	.17	.068
	Dry weight	1.61	1.05	.41
July 20	Fresh weight	.22	.17	.071
	Dry weight	1.48	.59	.33
Aug. 1	Fresh weight	.25	.18	.085
	Dry weight	1.56	1.10	.51
Aug. 17	Fresh weight	.24	.21	.100
	Dry weight	1.63	1.41	.65
Aug. 31	Fresh weight	.22	.18	.083
	Dry weight	1.45	1.07	.52
Sept. 16	Fresh weight	.27	.18	.095
	Dry weight	1.54	1.02	.52
Sept. 29	Fresh weight	.21	.10	.094
	Dry weight	1.30	.60	.28
Oct. 15	Fresh weight	.24	.21	.090
	Dry weight	1.64	1.38	.59

TABLE 6.—*Seasonal variations in nitrogen content (percent) of bindweed roots, when undisturbed and when cultivated, expressed on fresh weight and dry weight bases, 1936–37*—Continued

AFTER ONE CULTIVATION, 1937

Series and date	Basis	Colloidal nitrogen	Total soluble nitrogen	Amino nitrogen
First series:				
May 11	Fresh weight	0.25	0.26	0.089
	Dry weight	.15	1.57	.52
May 15	Fresh weight	.18	.16	.042
	Dry weight	1.16	1.07	.26
May 20	Fresh weight	.25	.25	.077
	Dry weight	1.30	1.29	.39
May 26	Fresh weight	.19	.18	.054
	Dry weight	1.14	1.07	.31
May 30	Fresh weight	.19	.15	.050
	Dry weight	1.16	.97	.30
June 3	Fresh weight	.16	.10	.053
	Dry weight	.95	.60	.31
Second series:				
July 29	Fresh weight	.27	.18	.082
	Dry weight	1.03	.68	.31
Aug. 7	Fresh weight	.22	.14	.057
	Dry weight	.91	.60	.23
Aug. 12	Fresh weight	.21	.10	.051
	Dry weight	.92	.46	.22
Aug. 16	Fresh weight	.19	.11	.046
	Dry weight	.86	.50	.10
Aug. 20	Fresh weight	.21	.14	.049
	Dry weight	.90	.57	.20
Aug. 27	Fresh weight	.20	.10	.046
	Dry weight	.89	.45	.21
Aug. 31	Fresh weight	.19	.12	.062
	Dry weight	.92	.57	.29

The most significant fluctuations were found in the roots collected at 4-day intervals after one cultivation. The soluble nitrogen content of the early-season (first) series (table 6 and fig. 8) was relatively high, having a value at the time of cultivation slightly above the colloidal nitrogen in the residue. The marked drop in both colloidal and soluble nitrogen is important and can be accounted for by the rapid utilization of nitrogenous compounds in the quick growth of the plants at that time of the year. The plot from which these samples were collected was cultivated on May 4 and showed profuse emergence on May 11 when the first sample of the series was collected. The marked fluctuation in percentage of colloidal nitrogen and total soluble nitrogen from May 11 to 20 is not understood. It seems quite probable that the initiation of new shoot growth would stimulate the digestion of stored proteins and thus reduce the percentage of these materials in the root tissue. Loomis (*17*) has shown that in woody plants initiation of shoot growth is correlated with a relatively high concentration of organic nitrogen compounds.

If soluble organic nitrogenous compounds are related to shoot growth in bindweed, the transition of stored proteins to soluble nitrogen would account for the rapid drop in protein after cultivation. Continued reduction of protein nitrogen for the next 10 to 15 days would be expected since considerable vegetative growth occurred during that period. This behavior is also in harmony with the trends of the sugar and starch which suggest that photosynthesis after the new plants were well established was adequate to supply the carbohydrate needs for regeneration but not sufficient to allow for any accumulation.

THE EFFECT OF SODIUM CHLORATE ON THE ORGANIC RESERVES IN BINDWEED

Observations made by a number of investigators (*8*, *14*, *15*, *21*, *23*, *27*) have shown that sodium chlorate is generally more effective as a weed killer when applied late in the summer and fall than at any time earlier in the growing season. Unpublished results of experiments at this station with whiteweed suggested the possibility that the effect of sodium chlorate could be increased by making applications subsequent to cultivation. It was assumed that the stimulation of physiological activities by cultivation would have an initial effect of reducing the reserve food. If, then, sodium chlorate were applied, the net result

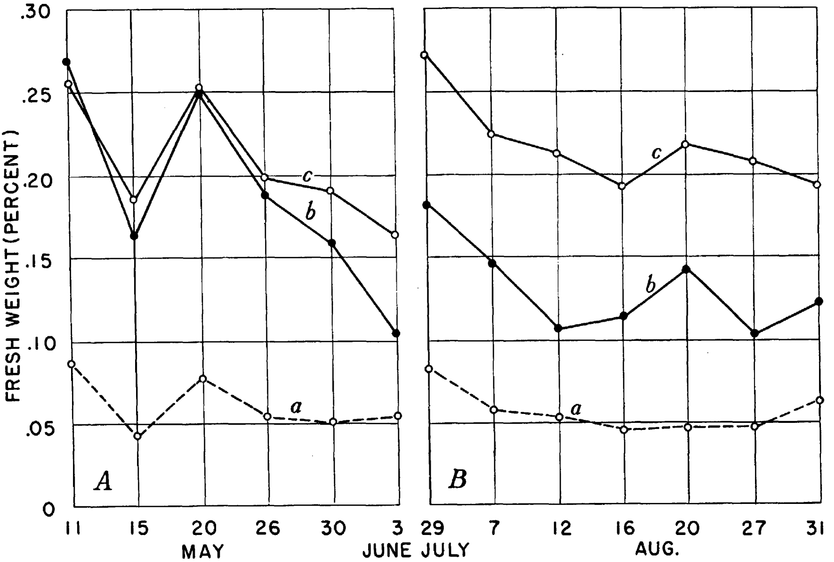

FIGURE 8.—Effect of one cultivation on the nitrogen content of bindweed roots 1937: *A*, Experiment performed in May; *B*, experiment performed in July: *a* Amino nitrogen; *b*, soluble nitrogen; *c*, colloidal nitrogen.

should be greater than either treatment alone. It was further believed that the application of sodium chlorate previous to cultivation probably caused the plant to become temporarily dormant which accounted for the observation that apparently better results were obtained by the addition of sodium chlorate subsequent to cultivation.

It seemed, therefore, that experiments designed to study the root reserves as affected by sodium chlorate applied to cultivated plants at various dates through the year might yield results which would be of value in developing a plant of control.

Several plots were selected which were uniformly infested with bindweed. A series of treatments was arranged so that sodium chlorate was applied to one plot June 1; another plot was treated July 1; another August 1, and so on until the middle of September. A similar series of chlorate treatments was made on plots cultivated at weekly intervals during the same period. Samples were taken when the chlorate was applied and also 1 month after its application. This arrangement provided a plan for the study of the root reserves as affected by sodium chlorate when applied at various dates during the season and also of the effect of a combined treatment of chlorate and cultivation.

Results of analyses showed that the carbohydrate content was held to a lower value by cultivation alone than by application of sodium chlorate alone. The data of tables 7 and 8 show also that sodium

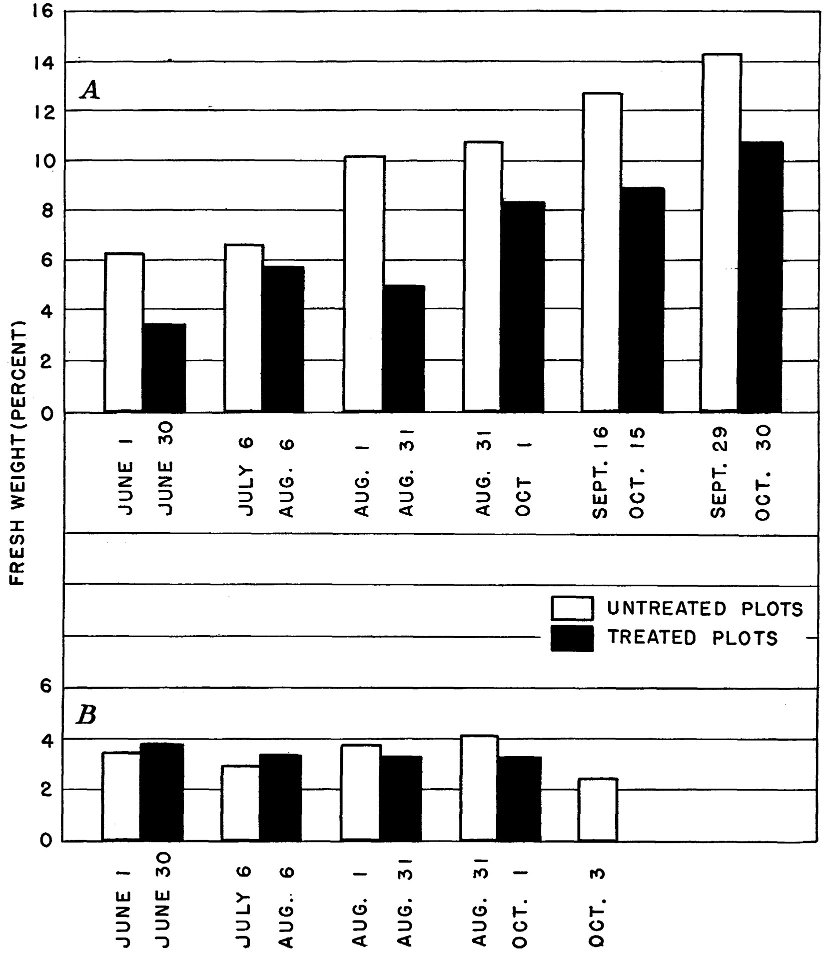

FIG. 9.—Carbohydrate content of bindweed roots as affected by date of application of sodium chlorate to undisturbed and to cultivated plots, 1936: *A*, Undisturbed; *B*, cultivated.

chlorate was relatively less effective (in reducing the carbohydrate reserve) on cultivated plants than on those which were undisturbed. The data are shown graphically in the histogram of figure 9. It may be concluded from these data that the application of sodium chlorate to bindweed under clean cultivation resulted in no important reduction of carbohydrate content beyond the decline obtained by clean cultivation.

TABLE 7.—*Effect of combined treatment with sodium chlorate and cultivation on the carbohydrate content percent of bindweed roots, expressed on fresh-weight and dry-weight bases, 1936*

SAMPLED AT TIME OF TREATMENT

Date	Basis	Undisturbed plants: Total carbohydrates	Undisturbed plants: Readily available carbohydrates	Cultivated plants: Total carbohydrates	Cultivated plants: Readily available carbohydrates
June 1	Fresh weight	9.46	6.06	6.45	3.55
	Dry weight	54.34	34.96	40.57	21.87
July 6	Fresh weight	9.76	6.56	5.27	2.87
	Dry weight	51.39	34.81	35.46	19.01
Aug. 1	Fresh weight	13.66	10.16	6.13	3.73
	Dry weight	60.58	45.48	43.52	26.22
Aug. 31	Fresh weight	13.97	10.77	7.25	4.15
	Dry weight	69.29	54.31	42.36	24.08
Sept. 16	Fresh weight	16.46	12.76		
	Dry weight	63.62	49.22		
Sept. 29	Fresh weight	18.27	14.27		
	Dry weight	75.14	58.59		
Oct. 30	Fresh weight			5.87	2.32
	Dry weight			35.22	13.92
SAMPLED 1 MONTH AFTER TREATMENT					
June 30	Fresh weight	6.52	3.32	6.44	3.74
	Dry weight	39.71	20.76	42.94	24.39
Aug. 6	Fresh weight	8.64	5.74	5.48	3.38
	Dry weight	52.02	34.47	45.31	28.06
Aug. 31	Fresh weight	8.54	4.94	5.52	3.12
	Dry weight	41.99	24.41	46.55	30.63
Oct. 1	Fresh weight	11.55	8.25	5.81	3.01
	Dry weight	55.46	39.69	38.94	20.12
Oct. 15	Fresh weight	12.52	8.82		
	Dry weight	59.01	42.06		
Oct. 30	Fresh weight	13.52	10.82		
	Dry weight	73.05	58.15		

TABLE 8.—*Effect of combined treatment with sodium chlorate and cultivation on the nitrogen content (percent) of bindweed roots, expressed on fresh-weight and dry-weight bases, 1936*

SAMPLED AT TIME OF TREATMENT

Date	Basis	Undisturbed plants: Colloidal nitrogen	Undisturbed plants: Soluble nitrogen	Cultivated plants: Colloidal nitrogen	Cultivated plants: Soluble nitrogen
June 1	Fresh weight	0.21	0.20	0.23	0.15
	Dry weight	1.24	.57	1.48	.94
July 6	Fresh weight	.28	.11	.21	.21
	Dry weight	1.51	.59	1.45	1.44
Aug. 1	Fresh weight	.33	.17	.21	.15
	Dry weight	1.45	.76	1.48	1.13
Aug. 31	Fresh weight	.22	.15	.21	.14
	Dry weight	1.26	.71	1.25	.86
Sept. 16	Fresh weight	.31	.15		
	Dry weight	1.21	.61		
Sept. 29	Fresh weight	.33	.07		
	Dry weight	1.36	.32		
Oct. 3	Fresh weight			.24	.16
	Dry weight			1.54	1.00
SAMPLED 1 MONTH AFTER TREATMENT					
June 30	Fresh weight	0.27	0.28	0.23	0.52
	Dry weight	1.61	1.65	1.56	3.74
Aug. 6	Fresh weight	.27	.16	.17	.14
	Dry weight	1.61	.96	1.35	1.19
Aug. 31	Fresh weight	.31	.16	.20	.17
	Dry weight	1.84	.82	1.31	1.12
Oct. 1	Fresh weight	.37	.20	.20	.08
	Dry weight	1.76	.97	1.34	.58
Oct. 15	Fresh weight	.39	.19		
	Dry weight	1.80	.89		
Oct. 30	Fresh weight	.33	.11		
	Dry weight	1.74	.61		

The general trend of the organic reserves in the chlorated and cultivated plants was essentially the same for 1937 as for 1936.

Estimated regrowth based on observations made in June 1939 indicated that from 50- to 75-percent eradication was obtained on uncultivated plots by the application of sodium chlorate in June, July, or August 1938 while 88- to 92-percent eradication was obtained by the September treatments. Approximately 65- to 75-percent eradication was obtained by the application of sodium chlorate in June, July, or August to cultivated plots, and 95 to 97-percent when applied in September.

TABLE 9.—*Effect of combined treatment with sodium chlorate and cultivation on the carbohydrate content (percent) of bindweed roots, expressed on fresh-weight and dry-weight, 1938.*[1]

Date of cultivation and chlorate treatment: Cultivated	Date of cultivation and chlorate treatment: Treated	Date of sampling	Basis	Reducing sugars	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates
			Fresh weight	0.54	1.20	0.61	3.18	1.81
May 10 and June 7	May 10	June 10	Dry weight	3.83	8.40	4.31	22.41	12.71
None	do		Fresh weight	.59	1.69	1.03	3.43	2.74
			Dry weight	3.97	11.34	7.00	22.93	18.34
			Fresh weight	1.17	2.42	.89	3.67	3.31
May 10 and June 7	June 10	July 10	Dry weight	7.27	15.03	5.56	22.80	20.59
None	do		Fresh weight	.52	1.09	1.04	3.77	2.13
			Dry weight	3.25	6.84	6.50	23.60	13.34
			Fresh weight	2.23	10.53	2.01	3.46	12.54
May 10 and June 7	July 9	Oct 15	Dry weight	10.14	47.66	9.12	15.70	56.78
None	do		Fresh weight	2.60	5.00	3.18	3.28	8.18
			Dry weight	11.90	27.98	14.53	14.95	42.51
			Fresh weight	1.86	8.64	2.59	3.22	11.23
			Dry weight	7.54	40.44	12.15	15.07	52.59
May 10 and June 7	Aug. 5		Dry weight	2.14	5.75	1.81	2.99	7.56
None	do		Dry weight	11.31	30.29	9.62	15.82	39.91
May 10 and June 7	Sept. 23	Oct 22	Fresh weight	.83	5.24	1.11	2.73	6.35
None	do		Dry weight	4.18	26.43	5.59	13.75	32.02
			Fresh weight	.96	6.88	.57	1.99	7.45
			Dry weight	5.49	39.31	3.28	11.40	42.59

[1] Carbohydrates determined by use of ceric sulfate (*6*). Samples were taken at the time of treatment and 1 month after treatment for the first 2 months; no samples were taken following the July, August, and September treatments until the end of the season in October.

Table 9 shows the reducing sugars, total sugars, starch, and readily available carbohydrates. It should be noted that samples were taken at the time of treatments and 1 month after treatment for the first 2 months, while no samples were taken following the July, August, and September treatments until the end of the season, in October.

Results of experiments for the 3-year period 1936–38 consistently showed no important reduction of carbohydrates when attempts were made to weaken the plants by pretreatments of cultivation before applying chlorates. This is in accord with the observations made by Crafts (*8*) on resprouting of bindweed after hoeing and various herbicidal spray treatments.

Analysis of the dry residue for total nitrogen and the alcoholic extract for total soluble and amino nitrogen failed to give results indicating that nitrogen was significantly affected by a combined chlorate and fallow treatment.

RESERVES IN BINDWEED ROOTS AT END OF SEASON

In table 10 and figure 10 are shown reducing sugar, total sugar, starch and acid hydrolyzable values of bindweed roots collected at the end of the 1936 growing season from plots which were (1) undisturbed.

(2) cultivated all season at emergence, and (3) cultivated 3, 6, 9, 12, and 15 days after emergence. The starch content of undisturbed plants was over 700 percent of that of plants cultivated at emergence. The sugar content on the other hand in the undisturbed plants was only 360 percent of that found in the plants cultivated at emergence. Cultivation reduced the acid-hydrolyzable substances and hexose sugars only moderately, as would be expected since the acid-hydrolyzable materials do not constitute a readily available reserve and hexose sugars are present only in small quantities. Although more frequent

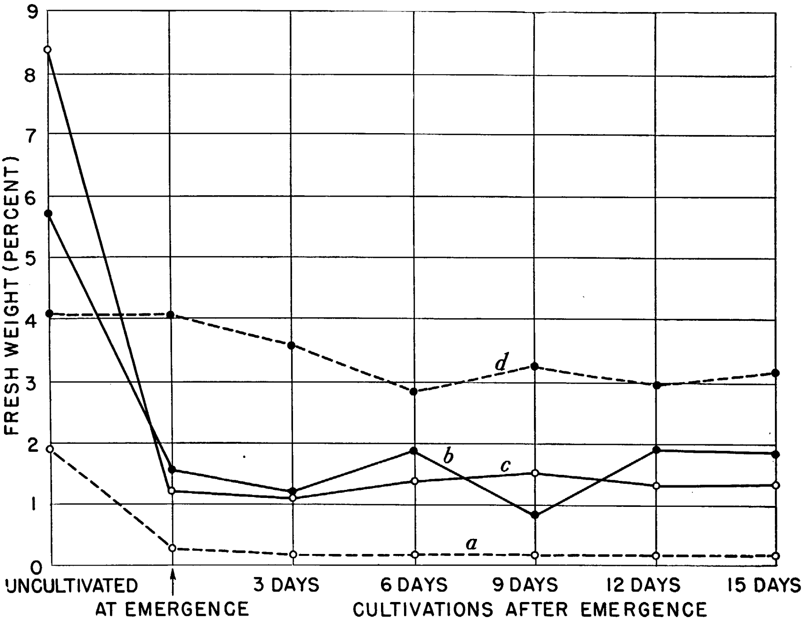

FIG. 10.—Carbohydrate content of bindweed roots when undisturbed and when cultivated at emergence and 3, 6, 9, 12, and 15 days after emergence, 1936, sampled in October: *a*, Reducing sugars; *b*, total sugars; *c*, starch; *d*, acid-hydrolyzable substances.

cultivation aided materially in diminishing the regeneration and persistence of the weed, it seemed to have no practical advantage over the less frequent cultivation (6, 9, 12, or 15 days after emergence) in reducing the values of the various carbohydrate fractions. These results are in close agreement with those reported in an earlier paper (*5*). The carbohydrate content of the roots of plants cultivated to a depth of 6 inches showed no important variation from that of plants cultivated to the depth of 3 inches. Data on this problem are meager, but it would seem that the advantage of deep cultivation for the purpose of reducing root reserves is open to question.

The clean-cultivation program started in 1936 was continued through 1937 and 1938. Emergence of the plants was somewhat retarded, and the time between cultivations increased for all the tests.

By October 1937 only a few scattered plants continued to emerge, and the quantity of roots which could be collected was so small that in some cases analyses could not be made. A small area of bindweed persisted, however, covering portions of two adjoining plots well into the 1938 season after 3 years of clean cultivation at intervals of 6 and 9 days after emergence. Roots were collected, of which the analyses showed that the total sugar content was about 2.5 percent and starch about 1 percent.

TABLE 10.—*Effect of cultivation on carbohydrate and nitrogen content (percent) of bindweed roots, expressed on fresh-weight and dry-weight bases, 1936*

When cultivated	Basis	Reducing sugars	Total sugars	Starch	Acid-hydrolyzable substances	Readily available carbohydrates	Colloidal nitrogen	Total soluble nitrogen	Amino nitrogen
Undisturbed	Fresh weight	1.92	5.77	8.48	4.02	14.25	0.33	0.12	0.102
	Dry weight	7.91	23.69	34.90	16.55	58.59	1.36	.32	.42
At emergence (3 inches)	Fresh weight	.27	1.59	1.19	4.02	2.78	.21	.21	.026
	Dry weight	1.56	9.26	6.90	23.35	16.16	1.27	1.26	.15
3 days after emergence	Fresh weight	.14	1.17	1.15	3.55	2.32	.24	.14	.059
	Dry weight	.86	7.02	6.90	21.30	13.92	1.49	.85	.35
6 days after emergence	Fresh weight	.20	1.89	1.36	2.81	3.25	.19	.14	.085
	Dry weight	1.60	15.23	10.90	19.40	26.13	1.52	.57	.49
9 days after emergence	Fresh weight	.11	.80	1.50	3.24	2.30	.21	.10	.094
	Dry weight	.06	4.79	9.03	19.45	13.82	1.30	.60	.28
12 days after emergence	Fresh weight	.10	1.88	1.27	2.92	3.15	.25	.11	.083
	Dry weight	1.36	25.86	7.00	16.00	32.86	1.38	.65	.45
15 days after emergence	Fresh weight	.10	1.85	1.27	3.12	3.12	.19	.10	.054
	Dry weight	.77	11.50	7.94	19.42	19.44	1.18	.67	.33
9 days after emergence (6 inches).	Fresh weight	.03	1.40	1.05	3.90	2.45	.20	.11	.073
	Dry weight	.17	8.25	5.62	20.80	13.87	1.06	.62	.38

The relatively high carbohydrate content clearly indicates movement of food from the deeper roots, since continued clean cultivation for the 2-year period had allowed no photosynthesis to take place. The results obtained here are not to be confused or, perhaps, even compared with results ordinarily obtained, since this is a single exceptional case of persistent regrowth. The behavior of the plants on this small area was very unusual and unexpected even after one season of clean cultivation. No explanation other than a possible varietal difference or peculiar soil condition can be offered to account for the persistence of the plants on the area in question.

SUMMARY

The carbohydrate and the nitrogen content of the roots of bindweed (*Convolvulus arvensis* L.) as affected by various cultural methods and chemical treatments were studied, and the results of experiments covering 3 years' investigation are reported. Data are presented to show the seasonal trend of the reducing sugars, total sugars, starch, and acid-hydrolyzable substances, for undisturbed plants and for those cultivated 9 days after emergence. The maximum reducing-sugar content did not exceed about 2 percent of the fresh weight of the roots of undisturbed plants. Total sugars reached a maximum of about 7 percent in late October, with a minimum value in May.

The percentage of starch increased gradually, reaching a maximum in August or September, followed by a sharp decline conicident with a rapid increase in percentage of total sugar. This behavior suggests the shift of polysaccharides to soluble carbohydrates which commonly occurs in plants during the cold season. Cultivation of the plants at 2-week intervals held the total sugar and starch content each to about 1 percent. The readily available carbohydrate accumulation in the roots of cultivated plants was reduced to 2.30 percent, which was 16 percent of that of undisturbed plants.

One cultivation the first part of May 1937 reduced the sugar and the starch content to about 2 percent each, while cultivation the latter part of July reduced the starch content almost 50 percent without any important effect on the total sugars. Similar experiments in 1938 showed comparable results, indicating the advantage of early fallowing.

The colloidal nitrogen in the roots of the undisturbed plants showed gradual increase from May until the last of October. Cultivation checked this accumulation. The total soluble, amino, amide, nitrate, and nitrite nitrogen fractions showed no consistent variations. On the basis of the results obtained for total nitrogen and nitrogen fraction determinations it would appear that the importance of nitrogen in a study of root reserves in bindweed is open to question.

The carbohydate content was held to a lower value by cultivation than by application of sodium chlorate.

A combined treatment of sodium chlorate following early-season cultivation did not increase the effectiveness of the chlorate in reducing the carbhoydrate reserve.

Fall applications of sodium chlorate to uncultivated plants were relatively more effective than early applications in reducing the root reserves and in controlling the weed.

Plants cultivated systematically all season at emergence, and 3, 6, 9, 12, or 15 days after emergence were uniformly low in starch content, 1 to 2 percent, as determined by taka-diastase digestion. The data showed that cultivating at emergence had essentially no greater effect than the less frequent cultivations in reducing the carbohydrate content of bindweed roots in the top foot of soil.

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