AMERICAN
JOURNAL OF BOTANY

VOL. VI DECEMBER, 1919 NO. 10

INFLUENCE OF SUGARS ON THE GROWTH OF ALBINO PLANTS

L. KNUDSON AND E. W. LINDSTROM

In the course of investigations on the influence of carbohydrates on plants by the senior writer (1), the occurrence of albino seedlings of timothy was occasionally noted when germinating the seed. The question then arose, What would be the influence of carbohydrates on these plants? Can an albino plant exist and develop when it is entirely dependent on organic material derived externally, as is the case with species of Monotropa and with other non-chlorophyllous plants?

It is true that experiments have been made in which corn and other plants have been grown in the dark with sugars or other organic substances supplied, and that under these conditions plants have maintained themselves for some time and have shown an increase over the original dry weight. The abnormality of the growth in the dark, however, is such, and the augmentation in weight is so slight, that one cannot draw conclusions as to the ability of phanerogamic plants to maintain themselves when the process of photosynthesis is not active.

There is only one way of determining whether or not a phanerogamic plant can develop at the expense of organic matter derived externally, and that is to use albino plants. It might be suggested that one might grow green plants in the entire absence of atmospheric carbon dioxide, but this would not prevent entirely the process of photosynthesis, since the carbon dioxide produced in respiration and retained within the plant would be re-utilized in photosynthesis.

The experiments with albino corn were made possible by the inheritance studies with corn by the junior writer (3), who obtained during his investigations a hybrid that produced albino corn plants in a simple mendelian ratio. The albino seedlings used were all from self-pollinated ears of green plants. The green plants were heterozygous only for the factor that determines the production of white seedlings. No other visible abnormalities were present in this stock. Such stock had been tested against other albinistic seedlings and had always remained free from any tendency to develop plastids and chlorophyll such as other albino seedlings are known to do. In other words, the albino progeny (approximately 25 percent of the total) from the

[The **Journal** for November (6: 357–400) was issued Dec. 18, 1919.]

heterozygous green plants used in the experiment were remarkably uniform in nature.

In addition to determining the growth of albino corn when supplied with carbohydrates, it was believed that the results obtained might be significant with respect to the question whether or not chloroplasts arise *de novo* or arise only from preexisting plastids.

Methods. The plants were grown either in large culture tubes on agar or in water cultures. In the former type of culture the entire plant was maintained in the absence of all microorganisms, while in the water cultures the tops of the plants were exposed to the atmosphere. The seeds were first weighed and then sterilized by the use of calcium hypochlorite (4). For this purpose 10 grams of calcium hypochlorite was added to 140 cc. of tap water, and this solution was shaken for a few minutes and then filtered. The filtrate alone was used for sterilizing the seed. From the sterilizing solution the seeds were transferred directly to the small culture tubes for germination. When the seeds were germinated and it became apparent which seedlings were albino, they were transferred to the large culture tubes or flasks. For the culture tube experiments the procedure was the same as that employed by the senior writer (1), and for the water cultures the method was the same as that used by Knudson and Smith (2).

The nutrient solution used was that of Pfeffer, with the substitution of dibasic phosphate for monobasic phosphate. The solution under the conditions of the experiment caused some inversion of the sucrose, due probably to the interaction between $Ca(NO_3)_2$ and K_2HPO_4 with the production of a small amount of HNO_3.

Experiment 1. In this experiment the influence of sucrose and glucose was to be determined. The plants were grown in large culture tubes 50 cm. x 6 cm., and 200 cc. of the culture solution was used to which was added 1 percent of agar. The concentration of the sugar was 0.10 gram molecular (weight normal), and, for controls, plants were grown in Pfeffer's solution alone. For comparative purposes chlorophyll-bearing plants were also grown, these being grown from seed derived from the same ear that produced the seed yielding albino plants.

The seedlings were transferred to the culture tubes on March 3 and the tubes were then placed in the greenhouse. On April 18 the leaves of one of the albino plants growing in the absence of sugar were dead, but on the remaining albino plants, death of leaves occurred between May 1 and May 4. The duration of the experiment was then approximately 58 days. The results follow in table 1.

Examination of the data reveals the fact that neither glucose nor sucrose permits an increase in dry weight over the original weight of the seed. In fact, there is a decrease in weight, but the decrease is less with sugar than without. The green plants, however, all show a marked increase in weight.

Experiment 2. In this experiment the conditions were essentially the

TABLE 1

Culture Solution	Culture No.	Original Dry Weight (Milligrams)	Total Yield, Dry Weight (Milligrams)	Gain or Loss (Milligrams)
Pfeffer's solution	1	164	92.5	− 71.5
" "	2	175	98	− 77
" "	3	180	97	− 83
" "	4	137	69	− 68
" "	5*	185	531	+346
Pfeffer's solution + 0.10 mol. sucrose	6	175	125	− 50
" " " " "	7	177	153	− 24
" " " " "	8	197	138	− 59
" " " " "	9*	188	696	+508
Pfeffer's solution + 0.10 mol. glucose	10	171	136	− 35
" " " " "	11	164	136	− 28
" " " " "	12	188	158	− 30
" " " " "	13*	193	1,056	+863

* Green plants.

same as those in experiment 1. In cultures 21 to 25 and 31 to 35, inclusive, the nitrates of calcium and potassium were replaced by the chlorides, and

TABLE 2

Culture Solution	Culture No.	Original Dry Weight of Seed (Milligrams)	Weight of Tops and Roots (Milligrams)
Pfeffer's solution	15	171	25
	16	153	31
	17	162	47
	18	162	49
	19	185	37
	20*	149	217*
Ave. for albino plants			37.8
Pfeffer's solution minus nitrate but with asparagin	21	171	46
	22	163	47
	23	173	32
	24*	165	325*
	25*	138	280*
Ave. for albino plants			41.7
Pfeffer's solution + 0.10 mol. sucrose	26	158	120
	27	162	144
	28	171	86
	29	174	80
	30*	146	615*
Ave. for albino plants			107.5
Pfeffer's solution minus nitrate but with asparagin and sucrose	31	179	110
	32	155	115
	33	180	123
	34	153	97
	35*	162	510*
Ave. for albino plants			111.2

* Green plants.

nitrogen was supplied at the rate of 1.7 grams of asparagin for each 5 liters of culture solution. The seedlings were transplanted to the culture tubes on June 12 and the tubes were placed in the greenhouse. The experiment was concluded on July 30, at which time all the seedlings were dead. Very little difference was noted in the time of death of the seedlings. The data follow in table 2.

In the preceding table the yield is given as dry weight of tops and roots. The residual seed remains were detached from the plant and not included in the weight. It is at once apparent that the addition of sugars makes for an increase in weight, but the substitution of asparagin for nitrates, while permitting equally good growth, apparently does not make conditions more favorable than they are in the solutions with nitrates. As noted by others, asparagin is a favorable source of nitrogen.

Experiment 3. The culture conditions remained similar to those of experiment 1, but the plants were grown in the dark. The data follow in table 3. When supplied with sugars, the plants practically maintained their original weight, while the plant supplied with nutrients alone lost in weight, the loss being about 50 percent of the original dry weight of the seed.

TABLE 3

Culture Solution	Original Weight of Seed (Milligrams)	Total Dry Weight of Plant (Milligrams)	Gain or Loss (Milligrams)
Sucrose 1 percent	133	138	+ 5
Sucrose 1 percent	121	118	− 3
Glucose 1 percent	132	120	−12
Pfeffer's	164	80	−84

Experiment 4. The plants were grown in water culture. For this purpose 500-cc. Erlenmeyer flasks were employed and the volume of solution used was 500 cc. In addition to cultures with sucrose, cultures were also prepared in which a mixture of sugars was used composed of 0.10 mol. glucose, 0.10 mol. sucrose, and 0.01 mol. arabinose. These latter cultures became contaminated near the close of the experiment, but the plants were much like those grown with 0.20 mol. sucrose. The seedlings were transplanted to the culture flasks on March 1 and the experiment was concluded on April 25. The detailed data follow in table 4.

TABLE 4

Culture Solution	Culture No.	Original Dry Weight of Seed (Milligrams)	Dry Weight of Tops (Milligrams)	Dry Weight of Roots (Milligrams)	Dry Weight of Seed Residuum (Milligrams)	Total Dry Weight (Milligrams)	Gain or Loss (Milligrams)
Pfeffer's	35	133	45	7	27	79	− 54
Pfeffer's	36	123	54	7	18	79	− 44
Pfeffer's + 0.2 mol. sucrose	37	129	170	60	27	257	+128
Pfeffer's + 0.2 mol. sucrose	38	126	80	50	26	156	+ 30

In this experiment the plants supplied with sugar showed a very appreciable gain in weight, while those grown in Pfeffer's solution alone showed the usual loss. Furthermore, the leaves of albino plants supplied with sugar lived until April 25, while the plants without sugar showed death of leaves on March 25.

General Discussion. In view of the fact that glucose or sucrose is generally considered to be the first sugar product in photosynthesis, it seemed reasonable to expect that the addition of one of these sugars to the culture solution would permit a considerable growth of the albino seedlings. The expectations were, however, in no way realized. An appreciable increase in growth was noted when sugar was available to the plant, and the albino plants supplied with sugar produced from five to seven leaves each, while the check plants possessed only two or three leaves each. Furthermore, in the water-culture experiments the plants supplied with sugar lived about a month longer than did the plants not supplied with sugar. In the tube-culture experiments there was little difference in the duration of life of different cultures.

The difference in length of life between the sugar and the non-sugar cultures in the two types of cultures is explainable in part by the higher concentration of sugar in the water cultures and by the higher temperatures prevailing in the greenhouse at the time when the water-culture experiments were made. In tube cultures, furthermore, the rate of growth is relatively slower than in water cultures.

The failure of albino plants to make a sustained growth and to show marked increase in weight when supplied with sugar is probably explainable by the inability of the plant to absorb sugar rapidly, and in part also by the relatively slow rate of conduction. This hypothesis is strengthened by the fact that even after the leaves are dead the roots may continue to live, and that, if supplied with sugar, the roots may be alive several months after the roots of the check plants are dead. It is possible that if a greater concentration of sugar be used, more beneficial results may be obtained; but certainly it is not possible greatly to exceed the concentration employed in the experiment, which was 0.20 gram molecular.

LABORATORY OF PLANT PHYSIOLOGY,
CORNELL UNIVERSITY

LITERATURE CITED

1. **Knudson, L.** Influence of certain carbohydrates on green plants. Cornell Univ. Agr. Expt. Sta. Mem. 9: 1–75, 1916.
2. **Knudson, L., and Smith, R. S.** On the secretion of amylase by plant roots. Bot. Gaz. 58 (not yet in print). 1919.
3. **Lindstrom, E. W.** Chlorophyll inheritance in maize. Cornell Univ. Agr. Expt. Sta. Mem. 13: 1–68. 1918.
4. **Wilson, J. K.** Calcium hypochlorite as a seed sterilizer. Amer. Journ. Bot. 2: 420–427. 1915.