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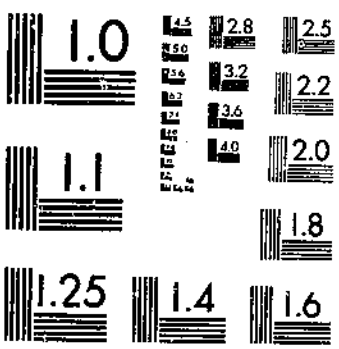

MICROCOPY RESOLUTION TEST CHART
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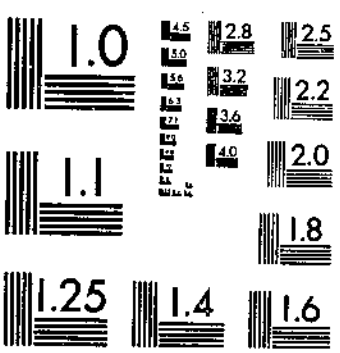

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PHYSIOLOGICAL STUDIES OF JERUSALEM-ARTICHOKE TUBERS, WITH SPECIAL REFERENCE TO THE REST PERIOD [1]

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CONTENTS

INTRODUCTION

Within the last few years the Jerusalem-artichoke (*Helianthus tuberosus* L.) has been given consideration in this country as a possible commercial source of the sugar levulose, of carbohydrates for alcohol manufacture, and to a lesser extent as a vegetable and a food for diabetics. The top of the plant is used to a limited extent as forage and the tubers are used as a feed for hogs. Although this plant is a native of North America and can be found growing wild in many sections of the United States, it has been studied but relatively little. The history, adaptation, and general culture of this crop have been described by Shoemaker (*58*),[3] and results of detailed cultural and varietal studies in the United States have been reported more recently by Boswell et al. (*11*). In the United States the Jerusalem-artichoke is found from the northern tier of States southward as far as Georgia and Arkansas. The crop has been cultivated throughout this range and has been found well adapted to certain regions on the Pacific coast, particularly Oregon. The culture of this plant in the warmer sections of the South has been limited, and in some cases it has been

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[3] Italic numbers in parentheses refer to Literature Cited, p. 48.

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a failure. In at least one report from a tropical region, that of Piper (*53*) in the Philippines, the crop has been reported as a failure. Knowledge of the performance of the crop under hot climatic conditions is very meager. Possibly under such conditions some essential physiological process, such as breaking of the rest period of tubers, is seriously retarded or inhibited. That this may be at least one important factor is suggested by the studies of Boswell (*10*), who noted a remarkably long rest period (over 7 months in some varieties) when tubers of the Jerusalem-artichoke were not exposed to low temperatures such as normally occur under field conditions in regions where the crop is ordinarily grown.

If it is assumed that the general growing conditions of warm regions are favorable to successful growth of the Jerusalem-artichoke, but that an unfavorably long or slowly broken rest period is the chief factor in limiting the production of the crop in such regions, then a knowledge of the nature of the rest period and methods of abbreviating it becomes highly important to the successful culture of the crop. If tubers grown in cooler regions are to be used as seed stock for a winter-grown crop in a warm region, or if tubers from one crop grown in the warm region are to be used as seed stock for a closely following crop, it is essential to know what temperature or chemical treatments may be applied to the resting tubers so that prompt, vigorous, and uniform sprouting of the seed tubers will result.

Although the tubers of the Jerusalem-artichoke resemble, in their general structure, tubers of the potato, on which many dormancy and rest-period studies have been made, the storage carbohydrates in the tubers of these two crops are different. The chief carbohydrate reserve of the potato is in the form of starch, a polysaccharide composed of glucose condensation products, whereas in the Jerusalem-artichoke inulin and closely related inulides made up largely of levulose condensation products are the principal storage forms.

The experimental work reported in this bulletin was designed (1) to find means of abbreviating the long rest period of tubers of the Jerusalem-artichoke; (2) to determine some of the physiological changes occurring during entrance into and emergence from rest; and (3) to correlate, if possible, any changes in composition or physiological activity with the beginning or the termination of the resting condition. Studies were conducted on tubers of two varieties from the beginning of tuberization until the growth of the tops had been terminated by frost (some time after the tubers had gone into the resting condition) and on "mature" tubers of four varieties subjected to numerous chemical and temperature treatments designed to abbreviate the rest period.

REVIEW OF LITERATURE

In spite of the vast extent of the literature on rest period and dormancy, the exact nature of the resting condition and the fundamental causal agencies involved are still largely unknown. No attempt will be made in this bulletin to cover all the literature available on rest-period studies, since excellent reviews of earlier work on the nature of the rest period and possible actions of agents causing termination of rest have been presented by Howard (*36*, *38*) and Appleman (*4*, *6*). Certain of the more recent studies will be mentioned.

Among the suggested methods for terminating the resting condition in various plants or plant organs, exposure to various temperatures and the application, in any of several ways, of various chemicals to the dormant plant materials have been most widely used and most studied. Johannsen (*40*), studying the etherization of plants, was the first to show a growth-inducing effect by chemical treatment. Since that time, numerous workers have reported a large number of chemicals with widely differing properties as being effective in shortening the rest period in a number of different plants. It still remains a matter of conjecture as to just what the common function of these numerous chemical substances with such widely varying properties can be in stimulating the resting organ to growth. Rosa (*55*) thought the action of certain chemicals in breaking the rest period in potatoes was due to their common characteristic of being vigorous oxidizing agents. Boswell (*9*), Jones (*42*), Appleman (*6*), and Schmid (*57*) have also thought that certain cases of stimulation of growth may have been due to the influence of oxygen or oxidizing compounds. However, since not all rest-breaking compounds are oxidizing substances, it appears unlikely that oxidation is the direct controlling factor, but rather that the effect is an indirect one on some other unknown controlling agency.

Just as different chemicals apparently produce the same rest-breaking response, so likewise different temperatures may supply a similar rest-terminating influence. There appears to be only a limited range of temperature, however, that will terminate rest in any one kind of plant, and the effective ranges are not the same for all species.

Among others, Loomis (*45*), Rosa (*56*), Schmid (*57*), Werner (*66*), and Wright and Peacock (*67*) have reported relatively high storage temperatures more effective than lower ones in inducing emergence from dormancy in potato tubers. Similar responses have been reported for gladiolus corms by Loomis (*46*), Loomis and Evans (*48*), and Fairburn (*26*). The many investigators of dormancy in seeds have found, in most cases, a distinct advantage in low temperatures for afterripening. Steinbauer (*59*) and Haber (*31*) have shown low temperatures to be much more effective than high ones in breaking the rest period in tubers of the Jerusalem-artichoke. Loomis (*47*) found temperatures either 15° C. above or 15° below normal (20° considered as normal) to cause a number of plants that he studied to pass through their rest period in minimum time.

Many workers have considered the enzyme-organic-reserve relationships important in the breaking of rest by chemical or temperature treatments. Coville (*16*) considered the main effect of low-temperature treatment (upon the woody plants he studied) to be in changing the permeability of the cells in such a manner as to allow enzymes to come into contact with stored starch. He believed the change of starch to sugar to be intimately associated with a more active metabolism necessary to starting of growth. Howard (*38*) likewise considered the effect of all rest-breaking agents on woody plants to lie in stimulation of enzyme activity. Recent excellent investigations by Denny, Guthrie, Miller, and Stanton (*22, 23, 24, 25, 29, 51*, and others) have added much to the knowledge of the effects of chemical treatments on enzyme activity.

Studies on changes in composition of plants as a result of rest-breaking treatments have been, for the most part, concerned with carbo-

hydrate constituents. An increased sugar content and a decreased starch content as a result of low temperature storage have been reported for potatoes by Müller-Thurgau (*52*), Appleman (*2, 3, 6*), and Hopkins (*35*). Loomis (*47*) found similar chemical responses in storage tissues of a number of plants, whether rest breaking resulted from high or low temperatures. Howard (*37*) and Gardner (*28*) studied the rest period in deciduous fruit trees and noted sugar accumulations accompanying low-temperature exposures, but neither proved these carbohydrate changes to be essential to growth initiation. Some of the effects of low temperature on the composition of Jerusalem-artichoke tubers were described by Traub, Thor, Willaman, and Oliver (*64*), and by Colin (*13*). Traub et al. found a decrease in the ratio of fructose to glucose and of fructose to total water-soluble carbohydrates from maturity in the fall until the end of January, in tubers stored under various temperature and humidity conditions or left in the field. Colin noted a change from a negative to a positive rotation in juice analyzed at intervals during the dormant period, indicating a transformation of inulin to compounds containing more glucose. Denny (*21*) has found in potato tubers treated with various rest-breaking chemicals carbohydrate changes similar to those found in tubers subjected to rest-breaking temperature treatments. He reported a higher sucrose content but no consistent change in reducing sugars upon treating tubers with sodium thiocyanate and ammonium thiocyanate. The sucrose content varied directly with the chemical concentrations employed. However, the actual percentage of sugars or reserve polysaccharides in resting or nonresting plant organs may have nothing to do with rest itself, since Appleman (*3*) has shown that the sugar-starch equilibrium in the potato is one which can be shifted at will by temperature alone whether tubers are resting or not.

Only very small changes in nitrogen fractions have been observed by various workers, Appleman (*4*), Denny (*20*), Combes (*15*), Stuart and Appleman (*61*), Müller-Thurgau (*52*), and others, in plants subjected to rest-breaking agencies.

Practically all of the chemical analyses reported in the literature for materials subjected to rest-breaking agencies have been on twigs, whole tubers, corms, etc., and not on buds alone. This is rather surprising because as early as 1911, Appleman (*2*) indicated that changes peculiar to afterripening might be localized in the buds, and that the metabolism of the tuber as a whole might bear little or no causal relation to these processes. Coville (*16*), in 1920, noted within certain treated branches, a localization of the response of blueberry to low temperature. Perhaps the best proof of rest being localized in buds is that provided by the experiments of Denny and Stanton (*25*). By applying chemical treatments to one bud of each of pairs on the opposite sides of lilac twigs, these investigators were able to force the treated buds into growth while the opposite ones remained dormant.

Increased respiratory activity in material treated to break the rest period has been almost universally noted by those studying the problem. Low temperature, high temperature, and chemicals all seem to have given this response.

No consistent relationship of catalase activity to the resting condition has yet been proved. Appleman (*2, 5*) found a striking correla-

tion of catalase activity with respiratory activity of potato tubers previously held in cold storage where the temperature had not fallen below 3° C. He also found greater catalase activity at the end of the rest period than at the beginning (*1*), and Miller (*51*) has also found this true whether rest was broken naturally or as the result of chemical treatments. Guthrie (*29*) and Miller (*51*) found no significant correlation between the effects of a number of chemical treatments for breaking rest in potato tubers and the changes in catalase activity. Guthrie, Denny, and Miller (*30*) reported increased catalase activity in dormant and nondormant gladiolus corms as a result of ethylene chlorhydrin treatments. Barton (*8*), Crocker and Harrington (*17*), Davis (*18*), and Flemion (*27*) have reported increased catalase activity in various seeds afterripened at low temperatures.

Although the composition of Jerusalem-artichoke tubers has been studied by numerous investigators, most of the analyses have been published without data relative to the age and size of the tubers analyzed. So far as known to the writer, none of these workers have made analyses on tubers of a definite size, the resting or nonresting condition of which was known, or at least reported. Tanret (*62*) was probably the first to make a careful analysis of the reserve carbohydrates present in artichoke tubers harvested in the fall, and to state the properties of the various levulosans he found. His work shows that there is no singled predominating reserve in the Jerusalem-artichoke corresponding to starch, but rather there are inulin and a graded series of levulosans differing in their solubilities and other properties. Colin (*13*), in 1919, presented data on analyses of artichoke tubers dug at intervals between July 28 and November 17. Unfortunately his analyses were made on different sized tubers at the different dates, and no reference is made to the physiological state of the plants at any of the harvests. His data reveal that there were never more than very small amounts of reducing sugars present during the period studied, and that the percentages of sucrose and inulin in the various samples varied but little between these dates. Meyer (*50*), in 1895, reported the young tubers to be rich in "glycose," with the quantity decreasing as inulin increased with growth. Analyses reported by Collins and Gill (*14*) for tubers analyzed during growth on October 2, 30, and December 13 show an increase in both free reducing sugars and free levulose between the first and last dates studied. They suggest that the free levulose really represented the free reducing sugars, since the values for the two fractions were within the limits of experimental error. The experiments of Thaysen, Bakes, and Green (*63*) have confirmed the properties of the levulosans isolated from Jerusalem-artichoke tubers by Tanret, and have shown a definite transformation of inulin and closely related inulides to levulosans containing less levulose during the winter season. They thought the increase in dextrorotation in tubers dug toward spring was at least partially due to sucrose. Traub, Thor, Zeleny, and Willaman (*65*) reported a slightly increased ratio of fructose to glucose and almost no change in the ratio of fructose to total sugars in tubers of four varieties of Jerusalem-artichokes, grown under Minnesota conditions, when analyzed on August 30 and November 3.

ENTRANCE INTO THE REST PERIOD

MATERIALS AND GENERAL METHODS

On April 4, 1933, a row of Jerusalem-artichokes of the variety Chicago was planted from uniform 1-ounce tubers on a gently sloping plot of sandy loam soil at the United States Horticultural Field Station near Beltsville, Md. About April 15, 1934, a similar lot of the variety Chicago and another of Blanc Ameliore were planted from approximately 1-ounce tubers in the same field and about 50 feet distant from the 1933 location.

Beginning on July 19, 1933, and on July 23, 1934, when tuber formation had started, and at approximately 10-day intervals thereafter until early October (also one sample on November 12, 1934, when the plant tops had been killed by frost and the tubers were already dormant), 5 to 18 hills of each variety were dug, the number and weight of stolons [4] and tubers in each of the several size classes were recorded, and samples of tubers, stolons, or buds of tubers over 1.4 cm in diameter were preserved in ethyl alcohol for chemical analyses. In 1934, catalase determinations also were made on stolons, tubers, or buds of tubers in each of the various classes. At each harvest, samples of 5 to 25 stolons or tubers from each class were planted in soil in a shaded greenhouse in which the temperature was kept between 65° and 75° F. at night and between 75° and 85° in the daytime. During July and August it was impossible to keep the maximum temperature down to 85° on some days. Periodic examinations were made of the greenhouse plantings to determine at what time the tubers had entered the resting condition, as judged by failure to sprout after 15 or more days. The sprouting trials in 1933 were conducted partly in the field and partly in a greenhouse similar to that used in 1934, but on a single, composite sample from each digging.

METHODS OF BIOCHEMICAL ANALYSIS

SAMPLING

Each harvest was begun about 9 a. m., and required about 2 hours for completion. During this period harvested tubers were kept in a manila bag in the shade, beneath wet burlap. Immediately after completion of digging, the samples were taken to the laboratory, about 15 miles distant, where the tubers were washed in cool water, dried with towels, and classified as to size. After the tubers or stolons in each class were weighed and counted, a random composite sample was taken from each class, the tubers or stolons cut into slices approximately one-eighth of an inch thick, and duplicate samples of the cut material quickly weighed out and dropped at once into sufficient boiling 95-percent alcohol (in glass-top fruit jars containing 0.2 g of calcium carbonate) to give a final concentration of about 80 percent. After the jars were boiled in a water bath for 15 to 20 minutes, they were sealed and set away until the time of analysis. The total time

[4] Unless specified otherwise, the term "stolon" as used in this bulletin refers to the 2- to 3-inch apical portion of an unthickened stolon. Where definite thickening of this apical portion, as compared with the rest of the stolon, was evident, tuberization was considered to have begun.

from completion of digging until completion of sampling was, for the later, larger samples, about 4 hours. For the earlier harvests with fewer tuber-size classes, the time was somewhat less.

Buds for analysis were removed from tubers over 1.4 cm in diameter with a 9-mm cork borer, and the tissues deeper than one-eighth of an inch below the base of the bud were discarded. The buds, after being cut in two longitudinally, were preserved in alcohol in the same manner as the tuber samples.

EXTRACTING

The entire preserved sample was macerated in a mortar and filtered through a 50-mm Alundum extraction thimble. The alcoholic filtrate was transferred to a 500-ml volumetric flask. The residue was extracted in the Soxhlet apparatus for 16 to 20 hours, starting with 80-percent alcohol in the extraction flask. This extract was added to that in the 500-ml volumetric flask, and the whole made up to volume with 80-percent alcohol.

DRY MATTER

Alcohol-soluble solids were determined on a 50-ml aliquot of the alcoholic extract by evaporating off the alcohol on a water bath at 70° to 80° C. with the aid of an air stream, then drying to constant weight by successive 30-minute dryings at 80° in an oven.

Alcohol-insoluble solids were determined by partially drying the extracted residue, thoroughly mixing, dividing the sample, and drying in an oven one-half of the residue to constant weight at 100° C.

CARBOHYDRATES

One-half of the alcoholic extract was evaporated to a thin sirup free of alcohol in a 400-cc beaker on a water bath at 70° to 80° C. with the aid of an air stream. To this sirup was added the half of the extracted alcohol-insoluble material not previously used for the insoluble-solids determination, and 50 ml of water. The beaker was then placed in a boiling-water bath for 1 hour, after which the aqueous extract was pressed out, while hot, into a 250-ml volumetric flask, using a hydraulic press with a pressure of 3,000 pounds per square inch, the sample being enclosed in a fine linen cloth. The press cake was further washed and pressed three times, using approximately 40-ml portions of boiling water at each wash. The washings were added to the volumetric flask, the flask was cooled, and the contents were made up to volume with water. A 50-ml aliquot withdrawn into a 100-ml volumetric flask was clarified with saturated neutral lead acetate solution, made up to volume with water, and filtered, and the excess lead was removed from the filtrate by precipitating with solid potassium oxalate, and refiltering.

Determinations of free reducing substances were made on aliquots of the cleared filtrate by the Bertrand modification of the Munson and Walker method. Free levulose also was determined on aliquots of the filtrate by the Jackson and Mathews modification of the Nyns method (*39*), using the volumetric permanganate method for determining reduced copper.

To the remaining 200-ml portion of the expressed juice in the 250-ml flask 7.5 ml of 8.12 N hydrochloric acid were then added, and the flask was placed in a water bath at 70° to 80° C. for 35 minutes, after which the flask was cooled, the contents were neutralized with anhydrous sodium carbonate, then cleared as outlined above. This procedure is a slight modification of that used by Traub et al (*64*). Suitable aliquots of the final filtrate were used in determining total levulose by the Jackson and Mathews modification of the Nyns method (*39*). Total reducing substances from the water extraction were determined on the filtrate by the Lane and Eynon volumetric method (*44*).

An aliquot of the alcoholic extract was evaporated on a water bath, clarified as outlined above for free reducing substances, then hydrolyzed with 10 ml hydrochloric acid (sp. gr. 1.125) per 100 ml of solution hydrolized. After neutralizing with anhydrous sodium carbonate total reducing substances in the alcoholic extract were determined by the Bertrand modification of the Munson and Walker method.

The press cake remaining after expression of the aqueous extract was dried, ground in a small Wiley-type mill to pass a 60-mesh screen, and extracted for 8 hours in a Soxhlet extractor, starting with 80-percent alcohol in the extraction flask. After the residue was dried overnight at 55° C., it was transferred to a wide-mouthed 500-ml Erlenmeyer flask. 100 ml of water and 10 ml of hydrochloric acid (sp. gr. 1.125) were added, and the sample was refluxed for 2½ hours. After the mixture was cooled and neutralized, it was transferred to a 250-ml volumetric flask, made up to volume with water, and filtered. Suitable aliquots of the filtrate were used for determination of reducing substances by the Bertrand modification of the Munson and Walker method (*7*). This fraction will be designated in this bulletin as "acid-hydrolyzable hot-water-insoluble polysaccharides."

In all determinations of reducing power, dilutions were varied to suit the size of the original samples and their carbohydrate contents.

CATALASE

Bud samples for catalase determinations were taken by first quickly removing the outer bud scales and the epidermis at the base of the buds with a scalpel (to avoid introduction of foreign matter), removing the buds from the tubers with a 9-mm cork borer, and discarding that portion of the cylinder of tissue below the base of the bud lying deeper than one-eighth of an inch. Stolon samples consisted of those portions of the stolons lying within one-half inch of the apical end. In making determinations on tubers less than 0.9 cm in diameter halves of whole tubers were used; on all tubers larger than this only the halves of the terminal buds were used. The corresponding halves of these tubers or buds were used in dry-matter determinations. Dry-matter samples of stolon tissue were made up of an equal number of stolons comparable in size with those used in the catalase determinations. Composite samples consisted of 10 to 30 stolons or 5 to 20 buds or tubers except where the limited number of tubers in a few of the large-sized-tuber classes of later harvests made necessary the

use of 2 to 4 buds per sample. Comparisons of 5- and 10-tuber composite samples showed the former gave practically the same catalase results as the latter. Determinations were made with the apparatus described and illustrated by Pope (*54*). The technique used, except for minor modifications, was also that described by Pope. In all cases determinations were made at 24.5° C.

PRESENTATION OF RESULTS

TUBER DISTRIBUTION DURING THE PERIOD OF TUBERIZATION AND ENTRANCE INTO REST

In tables 1 and 2 data are presented showing the distribution in number and weight of tubers and stolons produced by the varieties Blanc Ameliore and Chicago during the period of tuber growth in the 1934 season.

TABLE 1.—*Number and weight distribution* [1] *of Jerusalem-artichoke tubers of the variety Blanc Ameliore during the period of tuber development in the field, season of 1934*

DISTRIBUTION OF NUMBERS

Diameter of tubers (centimeters)	Data for tubers harvested—								
	July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10	Nov. 12
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nontuberized stolons	45.0	54.2	52.3	53.7	37.4	29.8	14.0	10.8	1.7
Less than 0.9	22.1	17.9	19.7	16.3	23.8	12.3	11.9	9.7	11.0
0.9 to 1.4	27.4	16.6	15.9	18.3	13.2	19.9	15.5	8.2	11.3
1.4 to 1.9	5.5	9.8	10.3	9.4	17.2	16.4	21.3	11.4	8.2
1.9 to 2.4		1.5	1.9	2.3	8.3	15.8	23.8	22.1	15.1
2.4 to 2.9						5.7	11.3	24.2	24.3
2.9 to 3.4							2.1	12.6	20.5
Over 3.4								.9	7.9

DISTRIBUTION OF WEIGHTS

Nontuberized stolons	11.6	8.9	8.8	9.6	3.9	1.1	0.3	0.1	0.0
Less than 0.9	13.4	8.0	9.5	7.6	5.7	1.4	.6	.2	.2
0.9 to 1.4	48.7	31.3	29.5	34.9	11.6	8.5	2.9	.7	.9
1.4 to 1.9	26.4	39.8	40.4	33.9	38.9	21.5	12.0	3.5	1.5
1.9 to 2.4		12.0	11.8	14.0	39.9	42.4	37.9	17.8	6.9
2.4 to 2.9						25.1	36.1	38.0	23.7
2.9 to 3.4							10.3	35.1	40.4
Over 3.4								4.5	26.5

MEAN NUMBERS AND WEIGHTS OF TUBERS AND STOLONS PER HILL

	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Stolons	10.5	19.1	22.5	31.7	15.2	13.2	5.5	5.7	1.0
Tubers	12.8	16.2	20.5	27.3	25.5	31.1	33.7	40.8	57.4
Total	23.3	35.3	43.0	59.0	40.7	44.3	39.2	52.5	58.4
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Stolons	3	5	7	14	6	2	1	1	0
Tubers	25	48	68	127	140	209	342	816	1,067
Total	28	53	75	141	146	211	343	817	1,067

[1] Leaders indicate that no tubers were found in the size class designated.

TABLE 2.—*Number and weight distribution* [1] *of Jerusalem-artichoke tubers of the variety Chicago during the period of tuber development in the field, season of 1934*

DISTRIBUTION OF NUMBERS

Diameter of tubers (centimeters)	Data for tubers harvested—								
	July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 28	Oct. 12	Nov. 12
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nontuberized stolons	40.3	36.7	59.6	49.0	31.0				
Less than 0.9	21.4	27.7	17.9	32.3	32.8	4.0	3.8	2.7	6.0
0.9 to 1.4	31.0	23.1	15.1	15.3	27.8	25.5	10.1	12.4	20.1
1.4 to 1.9	7.3	12.6	7.4	3.4	8.4	39.5	19.6	7.4	30.1	
1.9 to 2.4						25.8	26.8	12.4	28.5
2.4 to 2.9						5.2	32.8	33.4	8.5
2.9 to 3.4							6.9	29.6	.7
Over 3.4								5.0	

DISTRIBUTION OF WEIGHTS

Nontuberized stolons	7.4	4.7	16.4	16.7	9.4				
Less than 0.9	12.8	10.5	16.6	18.6	20.7	0.2	0.1	0.1	0.4
0.9 to 1.4	55.1	38.1	34.3	46.1	44.8	6.6	.8	.6	4.5
1.4 to 1.9	24.7	46.7	32.6	18.5	25.1	33.1	5.8	1.0	22.0
1.9 to 2.4						44.9	20.2	5.6	43.5
2.4 to 2.9						15.0	54.4	29.6	26.5
2.9 to 3.4							18.7	48.4	3.0
Over 3.4								14.8	

MEAN NUMBERS AND WEIGHTS OF STOLONS AND TUBERS PER HILL

	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Stolons	10.0	14.3	28.0	29.1	13.6	0.0	0.0	0.0	0.0
Tubers	14.8	24.7	20.0	30.3	30.3	41.1	78.9	88.6	162.2
Total	24.8	39.0	48.0	59.4	43.9	41.1	78.9	88.6	162.2
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Stolons	3	3	14	10	7	0.0	0.0	0.0	0.0
Tubers	38	65	73	87	68	406	1,451	2,147	1,402
Total	41	68	87	97	75	406	1,451	2,147	1,402

[1] Leaders indicate that no tubers were found in the size class designated.

These data show that, in general, during the period of tuber growth there was an increase in both the total number and total weight of tubers and stolons produced per plant. As the season advanced, a progressive decrease in the proportion of the total number and weight of tubers and stolons in the smaller-sized-tuber classes and a corresponding increase in the proportion in the larger-sized-tuber classes were observed. These changes in number and weight did not, however, progress at the same rate. A more rapid shift toward the larger sizes in the total weight of tubers than in their total number suggests that the earlier-formed tubers may be physiologically dominant to later-formed ones and may have a "first call" on elaborated storage and growth materials. This supposition of physiological dominance appears to be supported by the catalase data presented later (see tables 5 and 6). Clark (*12*) has reported for potatoes a similar case of a failure of later-formed tubers to develop at as fast a rate as those formed earlier.

The data for the mean numbers and weights of stolons and tubers produced per plant, given at the bottom of each table, show that the mean total number per plant did not increase regularly from the first to last harvests. The total number increased from July 23 to August 23, then a decided drop is evident in the September 4 harvest. There was little change in this total number for approximately a month,

after which a noticeable increase in the total number again occurred for the remainder of the season. A study of the data for stolons and tubers separately reveals that the decrease in numbers occurred largely in the stolon class. The maximum stolon number was reached at the August 23 harvest, and there was a steady decline thereafter. The fact that the mean tuber number per plant increased more rapidly than the stolon number decreased during the period from September 4 onward indicates that stolon formation had not stopped. Clark (*12*), studying tuber formation in potatoes, found actual shrinkage and disintegration of smaller tubers at certain periods during tuber development. It seems quite possible that the apparent losses in total numbers found in the present study may have been due to a similar disintegration of stolons and small tubers for a time after August 23 (until about September 20 in the variety Chicago, and about October 1 in Blanc Ameliore).

Both the low total weight and the small size of the November 12 tubers of the variety Chicago suggest that the plants harvested on that date were not comparable with those harvested on the previous dates.

The failure to find any stolons in the harvests of the Chicago plants between September 17 and November 12 may be due to either or both of two factors: (1) This variety has a very spreading habit of tuber placement, and it seems quite likely that some of the stolons may have been broken off and lost in digging; (2) the later formed stolons tended to be more thickened than earlier formed ones and therefore were probably classified as showing some tuberization. This would cause them to be placed in the tuber class less than 0.9 cm in diameter.

TIME OF INITIATION OF REST PERIOD

Data presented in table 3, for the variety Chicago, show the relation of time of harvest in 1933 to the amount and character of sprouting that occurred when representative tuber samples were planted immediately after each harvest. Under the 1933 conditions the immature tubers apparently entered the resting condition some time between August 28 and September 7. The tubers dug on July 25 and August 28 had not entered the resting condition. The reason for the change in type of growth of sprouts from tubers planted from the August 28 harvest is not known but may have been due to a decreasing photoperiod.

TABLE 3.—*Time of entrance into the rest period of Jerusalem-artichoke tubers of the variety Chicago as indicated by the percentage of tubers sprouted on Oct. 25, 1933*

[All tubers planted in the field or greenhouse immediately after being dug]

Date of digging	Place planted	Tubers sprouted, Oct. 25	Character of growth
		Percent	
July 25	Field	20	Normal plants 10 to 16 inches tall.
Aug. 28	do	40	Rosette type of growth; plants 2 to 4 inches tall.
Sept. 7	do	0	No apparent growth.
Sept. 19	do	0	Do.
Do	Greenhouse	0	Buds somewhat swollen, but no evidence of sprouting.
Oct. 3	do	0	No apparent change in the buds.

More extensive sprouting data for the varieties Blanc Ameliore and Chicago in the 1934 season are presented in table 4. These data show very clearly that the larger the tuber size, the later is the time of en-

trance into complete rest. For example, stolons or tubers less than 0.9 cm in diameter (under 1 g in weight) in Blanc Ameliore attained deep rest some time between September 4 and 17, whereas tubers 2.9 to 3.4 cm in diameter (42 to 44 g in weight) did not reach this state until sometime between September 26 and October 10. There is also some evidence from the data that at any date prior to entrance into deep rest, the larger the tubers are the greater is their capacity for sprouting. Thus, for any date of harvest there is a tendency for the percentage of tubers sprouting to increase proceeding from stolons to the largest-size tubers. The data for Blanc Ameliore indicate this somewhat more clearly than the data for Chicago.

TABLE 4.—*Time of entrance into the rest period of tubers of the Jerusalem-artichoke, as indicated by the percentage of tubers sprouted on Oct. 25, 1934*

[Tubers planted in a greenhouse immediately after being dug]

Variety and tuber diameter (centimeters)	Tubers sprouted on Oct. 25 harvested [1]—							
	July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10
Blanc Ameliore:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nontuberized stolons	10	45	40	58	5	0	0	0
Less than 0.9	50	60	70	15	10	0	0	0
0.9 to 1.4	66	90	50	53	0	8	0	0
1.4 to 1.9	100	90	80	70	10	30	10	0
1.9 to 2.4		100	83	80	50	60	20	0
2.4 to 2.9						80	0	0
2.9 to 3.4							20	0
Chicago:								
Nontuberized stolons	50	30	50	60	7	0	[2] 0	[3] 0
Less than 0.9	60	70	75	29	20	0	[2] 0	[3] 0
0.9 to 1.4	100	60	78	40	33	0	[2] 0	[3] 0
1.4 to 1.9	67	50	80	0	25	7	[2] 0	[3] 0
1.9 to 2.4						10	[2] 0	[3] 0
2.4 to 2.9						0	[2] 0	[3] 0
2.9 to 3.4							[2] 0	[3] 0
3.4 to 3.9								[3] 0

[1] Leaders indicate that no tubers were found in the size class designated.
[2] Harvested Sept. 28. [3] Harvested Oct. 12.

It also seems from the data of tables 3 and 4 that the time of initiation of rest in tubers of a variety may vary somewhat from season to season, due, perhaps, to the effects of the date of planting and of various environmental factors, such as temperature and rainfall, on the relative development of the tuber-producing mother plant. Also, varieties may differ even when grown under the same conditions. Rest appears to have been established later in 1934 than in 1933 in the variety Chicago although the planting date was also about 10 days later in 1934. Rest was also established later in the Blanc Ameliore than in the Chicago in 1934. The Chicago has been observed to be an early-maturing variety, the plants tending to drop more of their leaves before frost than plants of Blanc Ameliore.

These sprouting data indicate that entrance into rest in the Jerusalem-artichoke tuber is a process that takes place gradually but one which shows a somewhat more abrupt change as rest is closely approached.

CATALASE ACTIVITY DURING INITIATION OF REST

The apparent correlation of catalase activity with various metabolic processes of a number of plants or plant parts, as reported by Appleman (*1*, *5*), Heinicke (*34*), Harding (*32*), Pope (*54*), and numerous others, suggested the possibility that catalase activity might bear

some relation to the entrance of Jerusalem-artichoke tubers into the rest period. Determinations of catalase activity on stolons and the various size classes of tubers were therefore made at each harvest. Results of these determinations are presented in tables 5 and 6.

TABLE 5.—*Catalase activity during initiation of rest in the developing tubers of Jerusalem-artichokes of the variety Blanc Ameliore, season of 1934*

EXPRESSED AS CUBIC CENTIMETERS OF OXYGEN EVOLVED PER 0.04 G OF FRESH TISSUE IN 5 MINUTES AT 24.5° C.[1]

Tuber diameter (centimeters)	Catalase activity of tubers harvested [1]—								
	July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10	Nov. 12
Nontuberized stolons	11.78	11.95	10.93	11.65	12.08	[3] 4.93	6.83	4.53	9.30
Less than 0.9	9.58	10.18	9.65	8.70	10.38	[3] 10.35	10.70	8.95	9.85
0.9 to 1.4	9.05	8.98	10.43	12.35	11.48	10.90	[3] 10.60	9.65	10.85
1.4 to 1.9	10.48	9.53	-------	11.95	12.80	12.80	12.35	[3] 11.78	10.35
1.9 to 2.4	-------	8.23	-------	11.05	12.83	13.20	12.88	[3] 12.28	9.90
2.4 to 2.9	-------	-------	-------	-------	-------	13.70	[3] 12.88	13.13	10.80
2.9 to 3.4	-------	-------	-------	-------	-------	-------	-------	13.15	[3] 11.53
3.4 to 3.9	-------	-------	-------	-------	-------	-------	-------	-------	11.95

EXPRESSED AS CUBIC CENTIMETERS OF OXYGEN EVOLVED PER CENTIGRAM OF DRY MATTER IN 5 MINUTES AT 24.5° C.[1]

Nontuberized stolons	20.77	27.17	31.33	38.20	35.77	[3] 13.18	14.07	14.52	30.78
Less than 0.9	13.13	18.06	15.90	19.78	18.97	[3] 19.68	17.72	12.41	11.34
0.9 to 1.4	13.40	16.98	20.65	25.11	21.10	20.19	[3] 15.45	13.63	12.05
1.4 to 1.9	16.97	19.53	-------	24.80	25.15	25.34	21.79	[3] 15.79	12.91
1.9 to 2.4	-------	15.36	-------	21.01	25.21	26.72	22.59	[3] 17.49	11.41
2.4 to 2.9	-------	-------	-------	-------	-------	30.18	[3] 22.48	18.87	13.14
2.9 to 3.4	-------	-------	-------	-------	-------	-------	-------	18.37	[3] 13.09
3.4 to 3.9	-------	-------	-------	-------	-------	-------	-------	-------	13.77

[1] Determinations made on terminal buds only, except with stolons and tubers less than 0.9 cm, in which cases the whole stolons or tubers were used. Values are averages of duplicate determinations.
[2] Leaders indicate no material available for determination.
[3] Approximate date of entrance into deep rest as judged by sprouting tests.

TABLE 6.—*Catalase activity during initiation of rest in the developing tubers of Jerusalem-artichokes of the variety Chicago, season of 1934*

EXPRESSED AS CUBIC CENTIMETERS OF OXYGEN EVOLVED PER 0.04 G OF FRESH TISSUE IN 5 MINUTES AT 24.5° C.[1]

Tuber diameter (centimeters)	Catalase activity of tubers harvested [2]—								
	July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 28	Oct. 12	Nov. 12
Nontuberized stolons	15.58	13.98	12.75	11.65	15.75	-------	-------	-------	-------
Less than 0.9	9.95	9.75	10.28	10.25	13.30	[3] 12.28	13.90	15.60	11.03
0.9 to 1.4	9.43	10.78	12.02	10.55	14.40	[3] 12.20	14.38	14.20	12.75
1.4 to 1.9	8.05	11.30	11.70	-------	13.53	13.80	[3] 13.88	12.65	12.83
1.9 to 2.4	-------	-------	-------	-------	-------	14.10	[3] 14.18	14.13	13.78
2.4 to 2.9	-------	-------	-------	-------	-------	[3] 14.63	14.78	14.20	14.25
2.9 to 3.4	-------	-------	-------	-------	-------	-------	[3] 14.75	14.98	15.00
3.4 to 3.9	-------	-------	-------	-------	-------	-------	-------	[3] 15.15	-------

EXPRESSED AS CUBIC CENTIMETERS OF OXYGEN EVOLVED PER CENTIGRAM OF DRY MATTER IN 5 MINUTES AT 24.5° C.[1]

Nontuberized stolons	32.43	32.60	45.20	35.73	28.97	-------	-------	-------	-------
Less than 0.9	12.94	15.20	28.08	29.20	25.38	[3] 16.69	17.19	15.94	11.37
0.9 to 1.4	13.13	15.26	33.76	25.00	28.74	[3] 19.40	20.18	18.28	13.12
1.4 to 1.9	10.97	15.19	29.62	-------	25.03	23.71	[3] 20.50	23.00	14.58
1.9 to 2.4	-------	-------	-------	-------	-------	20.09	[3] 26.16	18.60	14.08
2.4 to 2.9	-------	-------	-------	-------	-------	[3] 31.60	22.02	17.11	16.32
2.9 to 3.4	-------	-------	-------	-------	-------	-------	[3] 24.34	18.31	17.36
3.4 to 3.9	-------	-------	-------	-------	-------	-------	-------	[3] 18.86	-------

[1] Determinations made on terminal buds only, except with stolons and tubers less than 0.9 cm, in which cases the whole stolons or tubers were used. Values are averages of duplicate determinations.
[2] Leaders indicate no material available for determination.
[3] Approximate date of entrance into deep rest as judged by sprouting tests.

It can be seen from the tables that in general catalase activity reaches a maximum value at the time of or prior to entering rest, and that it shows a rather consistent decrease thereafter for the remainder of the developmental period.

It seems significant that in both varieties studied the catalase values for the successively larger tuber size classes, when expressed on a dry-weight basis, form a regular ascending series at the time of or immediately preceding the time of entrance into complete dormancy. Only one exception to this generalization can be noted, that of the size class 1.9 to 2.4 cm in the variety Chicago, and even this value might be found to be in the proper relation to the others if it could be known exactly when entrance into the rest period occurred. Further examination of these data shows that in most cases this greater activity of the larger tubers continues to the end of the period studied.

These catalase results seem important when considered in connection with the more rapid increase in the proportion of total weight of tubers than in their total numbers, represented by the larger-sized tubers (tables 1 and 2), and with the delayed entrance into rest by larger sizes of tubers as compared with smaller tubers (tables 3 and 4). The data taken together suggest a physiological dominance of the first formed tubers (the larger ones later on) over later formed tubers, a first call on carbohydrates and other substances used for growth and storage, and a delayed rest period because of this more active metabolism.

It is interesting that the variety Chicago, which is the earlier "maturing" variety of the two studied, is also the one to show the earlier decline in catalase activity.

CHANGES IN CARBOHYDRATE COMPOSITION

It was believed that since the rest period has been shown by other investigators to be confined to buds in other plants and is not systemic in nature, analyses of buds of Jerusalem-artichoke tubers might give some significant information on carbohydrate changes occurring during the entrance into rest. In order to find what changes occur in whole tubers during the same period, tubers of the largest-size class for which a fairly complete series was available were analyzed. The results for the 1934 season of chemical analyses of terminal buds from tubers over 1.4 cm in diameter of the varieties Blanc Ameliore and Chicago and of tubers 1.9 to 2.4 cm in diameter of the variety Blanc Ameliore are given in table 7.

The most striking feature of the data is the much greater changes in composition of terminal buds than of the whole tubers during the period studied. It will be noted that the content of hot-water-soluble reducing substances, levulose, and dry matter were lower and that the amount of free reducing substances and alcohol-soluble reducing substances were higher in buds than in tubers during the early stages of development. Toward the end of the period studied the percentages of the various constituents in the buds tend to approach those of the whole tubers, particularly when expressed on the dry-weight basis.

Acid-hydrolyzable hot-water-insoluble polysaccharides form a small part of the dry matter with nonsignificant changes, and this is practically the same in both buds and whole tubers.

TABLE 7.—*Chemical composition of terminal-buds and tubers of Jerusalem-artichokes during the period of tuber development in 1934*

[Dry-weight basis]

Date of harvest	Dry matter	Free levulose	Free reducing substances	Total levulose	Total hot-water-soluble reducing substances (as glucose)	Total alcohol-soluble reducing substances (as invert sugar)	Acid-hydrolyzable hot-water-insoluble polysaccharides (as glucose)	Ratios: Alcohol-soluble reducing substance / Hot-water-soluble reducing substance	Ratios: Free reducing substances / Alcohol-soluble reducing substance	Ratios: Total levulose / Hot-water-soluble reducing substance
BLANC AMELIORE—BUDS FROM TUBERS OVER 1.4 CM IN DIAMETER										
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*			
Aug. 14	11.46	0.71	8.33	10.85	41.36	35.35	4.76	0.855	0.230	0.262
Aug. 23	12.20	.10	6.35	15.97	41.35	32.78	4.46	.793	.194	.386
Sept. 4	13.27	.00	1.26	33.45	50.15	29.94	3.24	.597	.042	.667
Sept. 17	12.17	.00	2.76	22.76	51.57	30.81	2.89	.772	.089	.441
Sept. 26	15.25	.00	.32	45.85	65.21	36.54	3.18	.560	.009	.749
Oct. 10 [1]	18.16	.00	.05	53.10	72.49	41.06	2.20	.566	.001	.733
Nov. 12	23.12	.00	.00	50.79	72.22	44.60	2.70	.618	.000	.703
BLANC AMELIORE—TUBERS 1.9 TO 2.4 CM IN DIAMETER (APPROXIMATELY 15 G)										
Aug. 2	15.46	0.00	1.60	52.13	65.29	27.10	3.90	0.415	0.059	0.798
Aug. 14	16.69	Tr	1.61	51.19	68.22	28.30	3.81	.415	.057	.750
Aug. 23	15.45	Tr	1.44	53.31	69.62	30.85	4.24	.443	.047	.766
Sept. 4	13.00	Tr	1.40	51.37	68.17	30.45	4.58	.447	.046	.754
Sept. 17	13.41	.00	1.45	50.48	69.94	35.70	3.61	.510	.040	.722
Sept. 26	15.65	Tr	.25	54.39	74.56	33.24	3.12	.446	.007	.730
Oct. 10 [1]	18.33	Tr	.04	57.90	75.99	33.34	2.12	.439	.001	.762
Nov. 12	21.76	.00	.12	51.30	70.86	44.35	2.81	.626	.003	.724
CHICAGO—BUDS FROM TUBERS OVER 1.4 CM IN DIAMETER										
Sept. 17	13.99	0.00	1.32	47.56	61.83	38.47	3.46	0.622	0.034	0.769
Sept. 28 [1]	16.07	.00	.29	47.52	64.24	34.18	2.78	.532	.008	.740
Oct. 12	20.39	.00	.00	38.55	63.51	37.31	2.80	.587	.000	.705
Nov. 12	24.98	Tr	.00	44.59	65.76	34.68	2.92	.527	.000	.678

[1] Approximate date of entrance into deep rest as judged by sprouting tests.

Some interesting relationships are shown by the ratios of the various fractions to each other given in table 7. The ratio of alcohol-soluble substances (dextrose, free levulose, sucrose, and the more labile, higher-dextrose-containing inulides) to hot-water-soluble substances (the alcohol-soluble materials, the less labile inulides, and inulin) is high in terminal buds early in the season and shows a progressive decrease until the time the resting condition is reached. Such is not the case in whole tubers. In the latter this ratio is at a minimum during the early part of the season. Early in the season the ratio of total levulose to hot-water-soluble substances is low in buds and high in tubers and bears a reciprocal relation with that of alcohol-soluble substances to hot-water-soluble substances. This suggests that the tubers begin storing reserves in the form of inulin and the higher inulides very early in the season, but that buds, while retaining the capacity for active growth, instead of storing carbohydrates as levulose condensation products tend to keep a greater proportion of the total in the form of glucose or glucose containing compounds. This is suggested further

by the relative magnitude of the ratios of reducing sugars to alcohol-soluble reducing substances in the two cases.

Although it is impossible to point to any abrupt or large change or changes among the fractions studied that might account for entrance of buds into the resting condition, a noticeable change occurred in most fractions around September 20. The data point toward a greater accumulation of the less labile reserve substances, such as inulin or the higher inulides, bearing a high degree of association (but not necessarily a causal relationship) with the resting condition.

Inasmuch as the Blanc Ameliore whole-tuber analyses reported in table 7 were for only the tuber-size class, 1.9 to 2.4 cm in diameter, it seemed desirable to ascertain whether the composition of tubers of the other size classes might exhibit changes at successively later harvests similar to the tubers of this one class. It was not practicable, however, to make complete analyses of all samples. Examination of the results shown in table 7 indicated that the alcohol-soluble reducing-substance fraction showed a fairly consistent trend over the period studied; therefore analyses of this fraction were made on samples of the other Blanc Ameliore tuber sizes. Results of the latter are presented in table 8, together with similar analyses for the variety Chicago.

TABLE 8.—*Dry-matter and total alcohol-soluble reducing-substance contents of Jerusalem-artichoke tubers of different sizes harvested during the period of tuber development in 1934*

Tuber diameter (cm)	Dry-matter content on harvest date—						
	Aug. 2	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10	Nov. 12
Blanc Ameliore:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nontuberized stolons	12.83	8.33	9.26	[1] 12.60			
Less than 0.9	16.26	13.81	13.89	[1] 16.55	18.47		
0.9 to 1.4	16.42	14.77	16.16	14.76	[1] 16.98	19.92	19.36
1.4 to 1.9	15.66	15.50	16.31	14.43	17.29	[1] 18.11	20.68
1.9 to 2.4	15.46	15.45	13.00	13.47	15.65	[1] 18.33	21.76
2.4 to 2.9				13.32	[1] 16.37	19.44	23.79
2.9 to 3.4					16.74	[1] 18.59	23.56
3.4 to 3.9						18.33	22.72
Chicago:							
Nontuberized stolons	14.16	8.53	13.06				
Less than 0.9	17.86	12.13	12.40				
0.9 to 1.4	20.15	16.52	14.90	[1] 17.70	[2] 20.23	[3] 21.82	24.76
1.4 to 1.9	21.00	18.21	13.16	17.07	[1] [2] 18.25	[3] 21.90	26.72
1.9 to 2.4				17.83		[3] 23.91	27.34
2.4 to 2.9				[1] 17.91	[2] 20.82	[3] 22.61	26.58
2.9 to 3.4					[1] [2] 21.27	[3] 23.05	28.05
3.4 to 3.9						[1] [3] 23.43	

Tuber diameter (cm)	Alcohol-soluble reducing substances (dry-weight basis) on harvest date—						
	Aug. 2	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10	Nov. 12
Blanc Ameliore:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nontuberized stolons	23.90	30.89	29.30	[1] 19.48			
Less than 0.9	19.81	28.50	28.62	[1] 32.79	28.60		
0.9 to 1.4	26.05	27.40	27.53	34.40	[1] 30.32	30.77	45.78
1.4 to 1.9	23.87	27.35	24.52	32.01	30.31	[1] 34.01	44.32
1.9 to 2.4	27.10	30.85	30.45	35.70	33.24	[1] 33.34	44.35
2.4 to 2.9				30.63	[1] 27.18	29.09	40.05
2.9 to 3.4					24.86	[1] 26.21	42.01
3.4 to 3.9						26.87	42.73
Chicago:							
Nontuberized stolons	20.21	31.78	29.87				
Less than 0.9	15.90	23.00	34.18				
0.9 to 1.4	15.53	15.74	24.90	[1] 27.69	[2] 28.46	[3] 26.01	27.42
1.4 to 1.9	13.43	12.63	30.44	27.10	[1] [2] 29.20	[3] 27.24	28.25
1.9 to 2.4				27.45		[3] 25.26	20.80
2.4 to 2.9				[1] 29.01	[2] 20.31	[3] 26.14	39.85
2.9 to 3.4					[1] [2] 18.80	[3] 22.83	53.07
3.4 to 3.9						[1] [3] 23.86	

[1] Approximate date of entrance into deep rest as judged by sprouting tests.
[2] Harvested Sept. 28. [3] Harvested Oct. 12.

There are some fluctuations in the actual percentages of alcohol-soluble reducing substances and dry matter in the various samples on any one harvest date, but the same general seasonal trends can be noted in all size classes. It seems likely, therefore, that if analyses had been made for the various other fractions reported in table 7, the trends for all tuber sizes probably would have been found similar. Further study of the data of table 8 makes it appear unlikely that there is any definite threshold value of alcohol-soluble reducing substances associated with the beginning of deep rest, since a given value associated with rest in tubers of one size class is not associated with the resting condition in tubers of other size classes.

DISCUSSION

Results of this study show that the degree of development (size) of tubers bears a fairly definite relationship to the time of initiation of rest. This relationship, however, is the opposite of what might be expected in that the data show rest to be established first in stolons and smaller younger tubers rather than in the larger and older ones. The latter class of tubers would ordinarily be considered more mature.

In the Jerusalem-artichoke full maturity is commonly considered as that condition existing in tubers when the tops of the plants are fully developed (usually dead because of senescence). Fully mature tubers make no further increase in size and have attained a composition characterized by a maximum content of the less labile carbohydrate reserves. More specific definition of the mature condition has not yet been accomplished. It is certain that in the present study full maturity, as here defined, was not essential to entrance of tubers into the resting condition, since rest was established in stolons and tubers long before frost stopped the maturation process. If, however, in developing tubers there is some particular stage or degree of maturity characterized by definite chemical relationships that is responsible for cessation of bud growth and entrance into rest, then such chemical relationships must be concerned with substances or enzyme systems that have not yet been studied. While it appears that the constituents thus far investigated are not the ones directly involved in the cessation of growth or entrance into rest, nevertheless, some interesting associations are found in the data.

The capacity for active growth in buds appears to be closely associated with a low ratio of levulose to total hot-water-soluble carbohydrates and a correspondingly high ratio of alcohol-soluble to hot-water-soluble reducing substances. The high proportion of levulose in the reserve substances when rest is attained might be assumed to indicate inactivation of inulase and other enzymes by accumulation of higher levulosans, or it might mean that synthesis of the latter proceeds at so fast a rate that insufficient simpler carbohydrates are available for growth. On the other hand, the observed relation of carbohydrate changes to initiation of rest may be merely a coincidence bearing no causal relation to the real regulator of growth, whatever it may be.

Chemical analyses show that changes in tubers of the same size harvested at intervals do not fluctuate as widely in the carbohydrate fractions studied (except in the alcohol-soluble reducing-substance

fraction) as do changes in the terminal buds of tubers. The relatively small changes in tubers corroborate the findings of Colin (*13*) that the composition of tubers is almost the same throughout the period of development. The much greater changes occurring in buds than in whole tubers may explain why other investigators, practically all of whom analyzed only whole tubers, twigs, etc., have failed to correlate chemical differences with differences in rest, if there really are any such relations. Hope of finding significant relationships in this regard in any future studies appears to lie in intensive studies of buds rather than whole tubers, or other organs.

These data do not support the statement of Meyer (*50*) that young tubers are rich in glucose, nor the findings of Collins and Gill (*14*) that there is an increase in both free reducing sugars and free levulose during tuberization. The supposition of the latter workers that free levulose constitutes the free reducing sugars is likewise not borne out in this study (table 7).

EMERGENCE FROM THE REST PERIOD

MATERIALS AND METHODS

The phase of the problem dealing with emergence from rest was conducted in the laboratories and greenhouses of the Bureau located at the Arlington Experiment Farm, Arlington, Va., at the United States Horticultural Station, Beltsville, Md., and at Washington, D. C.

All tubers used in the experiments in any one year were from plants of uniform age, grown on the experimental plots at Arlington Farm (1931 and 1932), and at the United States Horticultural Station near Beltsville (1933 and 1934). Tubers were dug during November or the first week in December of each season, after the tops of the plants had been killed by frost, but before freezing of the soil had occurred (one very slight surface freezing of the soil occurred before digging was completed in 1933). Tubers (in most cases 1 ounce) were selected by weight within ±8 g of the desired size, then kept in a cool (about 60° to 70° F.) greenhouse head-house during the short period that the various experiments were being started.

PROCEDURE FOR CHEMICAL TREATMENTS TO HASTEN EMERGENCE OR SPROUTING

In the 1931 tests 1- and 2-ounce tubers of four varieties (Blanc Ameliore, Chicago, Waterer, and Tait) were used. Immediately before treatment the 2-ounce tubers were cut longitudinally into two pieces weighing approximately 1-ounce each. In the 1932 tests only 1-ounce whole tubers of the varieties Blanc Ameliore and Chicago were used, since the 1931 work had indicated a very similar response to the treatments by both cut and whole tubers, except that when any treatment was toxic it was more so to the cut tubers.

Three types of treatment were used to hasten emergence: (a) The dip method, in which the tubers were dipped into the chemical solution, removed immediately and planted, or in some cases placed in 2-quart screw-top fruit jars for a given period before planting to allow vapors from the chemicals to act on the tubers; (b) the vapor method, in which tubers were placed in a metal container, the chemical placed in a shallow vessel on top of the sample and the can sealed for given periods, after which the tubers were removed and planted; and (c) the soak method, in which tubers were submerged for given periods in a

treating solution, then removed and either planted at once, or placed in covered 2-quart fruit jars for given periods of time before planting. All treatments were made at room temperature, approximately 70° F.

After treatment the tubers were planted in flats of damp peat moss. In the 1931–32 work all flats were kept in a cool greenhouse (45° to 55° F.) during the winter and spring months. In the 1932–33 investigations, in addition to the lots kept in the cool house, a duplicate lot for each treatment was kept in a warm greenhouse (65° to 75°) in order to determine whether the low sprouting temperature was the cause of the abnormally slow development of plants observed with many treatments in 1931. Near the end of the experimental periods in both seasons it was impossible to keep the day temperatures from going somewhat higher than desired.

Samples consisted of 25 to 30 cut or whole tubers, and controls contained a like number of tubers planted at the time of making chemical treatments, and in the same manner as the treated lots.

At 15-day intervals from the time of treating, the tubers of each lot were removed from the peat, examined as to the amount of sprout growth, root development, and extent of rotting, and the sound tubers were then carefully replanted. Such examinations were continued until all sound tubers had sprouted.

PROCEDURE FOR TEMPERATURE TREATMENTS

In the 1931 experiments 35 samples, of 25 to 30 1-ounce tubers each, were selected from each of the 4 varieties, Blanc Ameliore, Chicago, Waterer, and Tait. Of these samples, 14 were put in ordinary manila-paper bags, and of the 14, 7 were placed at 36° F. (relative humidity 77 to 97 percent), and the other 7 at 50° (relative humidity 69 to 88 percent) in constant-temperature chambers of the cold-storage laboratory at Arlington Farm. The tubers of each of the other 21 samples were carefully packed in damp clay in manila-paper bags to retard water loss and the latter placed inside snug-fitting cloth bags. Seven of these clay-packed samples were then placed in each of three constant-temperature chambers held at 18° (very low humidity), 32° (relative humidity 76 to 99 percent), and 32° (relative humidity 50 to 75 percent), respectively. An additional sample of about 250 untreated tubers of each variety was placed in a well-drained pit covered with about 8 inches of soil in an open field, care being taken to keep layers of tubers separated by thin layers of soil. No records were taken as to temperatures existing in the field pits. At successive intervals of approximately 15 days each, after the beginning of the treatments, samples of each variety were removed from the constant-temperature chambers and the field pits, planted in flats of moist peat and sprouting tests conducted the same as for the chemically treated samples mentioned above. At each interval of planting a sample of five to eight tubers from each of the various lots planted was taken for chemical analysis.

In the 1932 studies 1-ounce tubers of two varieties, Blanc Ameliore and Chicago, were used. All tubers stored at 32°, 36°, and 50° F. were kept in manila-paper bags. Tubers stored at 15° were packed in damp clay similar to the 18° samples of 1931. One lot of each variety was placed in a field pit similar to that used in 1931, and a continuous thermographic record was kept of soil temperature at the average depth of the pit. Thirty-tuber samples were removed at 15-day

intervals and sprouting tests were conducted in moist peat in the cool greenhouse in the same manner as with the chemically treated samples. At each planting date 20 to 25 tubers were removed from each storage lot for chemical analysis of the buds.

In 1933, samples of the variety Blanc Ameliore were stored at 32° with high humidity and at 50° F. Sprouting tests were conducted at 15-day intervals by planting 15 tubers from each temperature in moist sand in the bench of a greenhouse kept at 65° to 75° F. during the first 30 days of the experiment and at 55° thereafter. At each removal from storage, samples of tubers were taken for catalase determinations.

The 1934 studies were similar to those of 1933 except that two varieties, Blanc Ameliore and Chicago, were treated and that respiration determinations were made on each lot removed from the storage chambers.

METHODS OF BIOCHEMICAL ANALYSIS

Sampling

In 1931–32 the whole tubers were carefully washed in cool water, dried at once with a towel, and ground through the fine knife of a food chopper. This material was thoroughly mixed, and a 100-g sample was quickly weighed out, and preserved in alcohol as described on page 6.

In 1932–33 the bud samples of 15 or 25 g were taken and preserved as previously described.

Extracting, Dry Matter, Carbohydrate Fractions

The procedures previously outlined (pp. 7, 8) were used.

Nitrogen

Total alcohol-soluble and alcohol-insoluble organic nitrogen determinations were made on aliquots of the alcoholic extracts and alcohol-insoluble residues by the Kjeldahl-Gunning-Arnold method (7).

Catalase

Catalase determinations were made on terminal buds, pith, and cortex separately. Bud samples were taken as described on page 7. Pith samples were obtained by cutting a cylinder of tissue from the center of the tuber along the main longitudinal axis with a 6-mm cork borer. Approximately one-fourth inch was discarded from each end of the cylinder. Cortex, as here used, refers to that portion of the tuber lying between the epidermis and the pith. Samples of cortex were obtained with a 6-mm cork borer by cutting a cylinder of tissue through the tuber near the center at right angles to the longitudinal axis (avoiding inclusion of any bud tissue), discarding the epidermis and pith, and using the two intervening portions of the cylinder for the determination. The same apparatus and technique previously mentioned (p. 9) were used in making the determinations.

Respiration

The tubers used in the respiration studies were counted and weighed at the time they were put in storage at 32° and at 50° F., at the time they were removed from storage, and again immediately before the respiration determinations were begun.

Determinations were made at a common temperature of 77° F. on comparable samples from the two storage chambers.

Upon removal from the storage chambers the samples were transferred to a constant-temperature room at 70° F. to allow them to approach the temperature at which the respiration determinations were to be made. (A 77° chamber was not available for this purpose.) After 72 hours the samples were removed to the room in which the respiration determinations were to be made and they were kept there at room temperature (about 70° to 77°) until the following morning when the determinations were begun.

An apparatus patterned after that described by Harding, Maney, and Plagge (*33*) was found well suited to the needs of this study. In the apparatus used, duplicate Truog towers were connected in each system to facilitate periodic titration of samples without stopping the continuous air flow through the system.

In making determinations the samples were placed in separate systems set up side by side, with the respiration chambers placed in the same water bath the temperature of which was thermostatically controlled at 77° F. At the beginning of a determination the system was swept free of carbon dioxide by drawing carbon-dioxide-free air through it for 1 to 1½ hours before beginning absorption of carbon dioxide in the Truog towers. The rate of air flow through the chambers was so regulated as to change the air in the chambers approximately once each 30 minutes. Composite moisture samples were taken for each treatment at the beginning of each determination. With one or two exceptions the total period during which carbon-dioxide evolution was measured was 9 or 12 hours. The size of samples used varied between 33 and 107 approximately 1-ounce tubers, but most of the samples contained 45 or more tubers.

Excess barium hydroxide in the Truog towers at the end of a determination was titrated with 0.2 N hydrochloric acid.

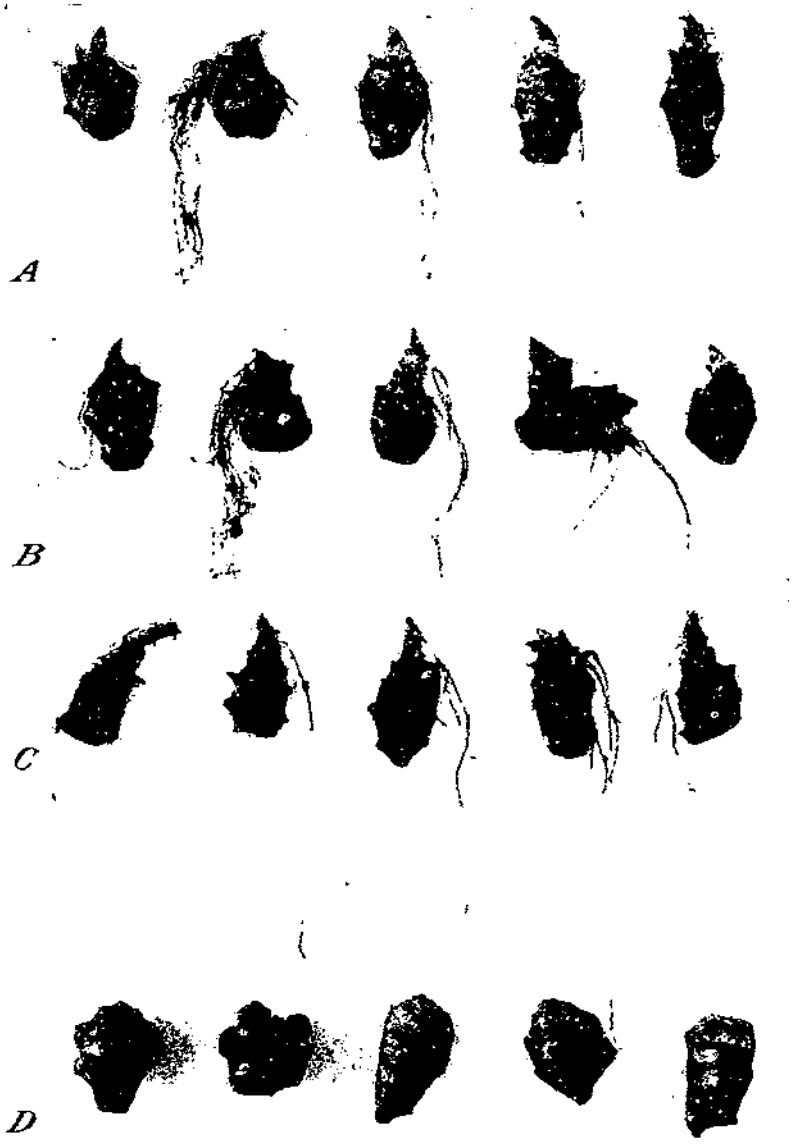
PRESENTATION OF RESULTS

EFFECT OF CHEMICAL TREATMENTS

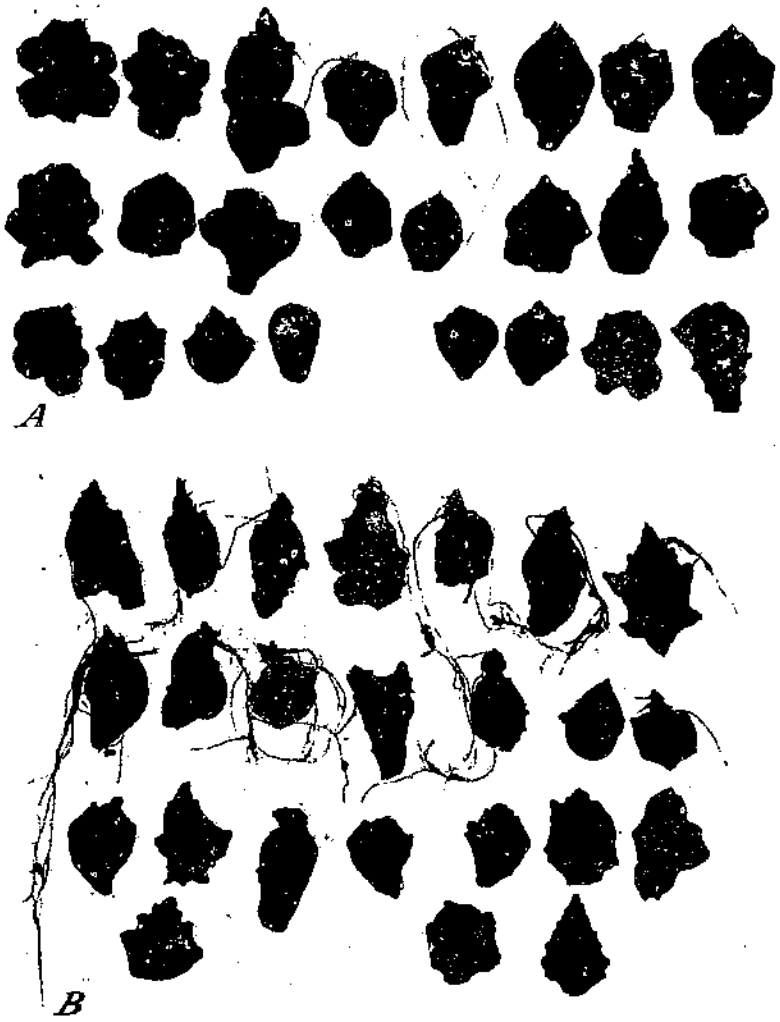
In this investigation a considerable number of chemicals previously found more or less successful in breaking the rest period of other plants or plant parts (*19* and others) were applied to Jerusalem-artichoke tubers. None of the chemicals or methods are new, but as far as known to the writer none of them had been used on Jerusalem-artichoke tubers prior to the time the present investigations were started. A brief report of this work was published by Steinbauer (*60*) in 1933. Haber (*31*) has since (1934) also reported chemical treatments of Jerusalem-artichoke tubers. He found that ethylene chlorhydrin, thiourea, and sodium thiocyanate were somewhat effective, but sodium nitrate gave no response.

It will not be practicable to present all the detailed observations made as to the effectiveness or toxicity of the various chemicals used. Results of the various treatments for 1931–32 and 1932–33 are presented in tables 9, 10, and 11. The data in these tables show the effectiveness of the treatments in shortening the rest period, as indicated by the time elapsing to the first-evident sprout growth and the time when 50 percent of the tubers showed evidence of sprouting. The toxicity of certain treatments is indicated in the values for per-

centage of tubers rotting. Sprouting was considered to have occurred when the bud scales were definitely elongating and spreading away from the bud proper. In most samples more or less swelling of the buds and often root growth occurred, but unless the changes in bud scales were evident growth was not recorded as having occurred. It is not to be interpreted, however, that because a treatment stimulated bud activity in a single bud, or even in 50 percent or more of the buds, that normal plant development followed. As early as 1909, McCallum (*49*) noted that some substances used on potatoes stimulated buds quite vigorously but at the same time killed tissues of the tuber. In the present studies it was found that many treatments that caused breaking of rest in buds of Jerusalem-artichokes caused only a temporary stimulation, in most cases followed by a period, often of considerable length, when little further development took place. This was particularly true in the 1931–32 work. (See pl. 1. Note that although the tubers were planted early in December 1931 and growth was soon stimulated, very little actual sprout growth had occurred by March 15, 1932.)



Effect of various chemical treatments in breaking the rest period in Jerusalem-artichoke tubers, variety Blanc Ameliore, in 1931-32. All lots photographed March 15, 1932. *A*, Tubers soaked in 20-percent ethyl alcohol 1 hour, removed and stored in a closed container for 24 hours. Planted December 3, 1931. *B*, Same as *A* but treated with 20-percent acetone instead of alcohol. *C*, Tubers exposed to carbon disulphide vapors at 1 cc per 35-liter space for 24 hours. Planted December 3, 1931. *D*, Control, untreated tubers planted November 25, 1931.



Untreated control tubers of Jerusalem-artichoke, variety Blanc Ameliore. *A*, planted in a cool greenhouse (45° 55° F.) December 3, 1932, and photographed January 11, 1933; *B*, tubers similar to those of *A* but planted in a warm greenhouse (65°–75°). (Compare with lots shown in pls. 3 and 4.)

TABLE 9.—*Effect of various chemical treatments on the length of rest period in Jerusalem-artichoke tubers of the varieties Blanc Ameliore and Tait in 1931–32*

Treatment	Blanc Ameliore						Tait					
	Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 1		Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 1	
	Whole[1]	Halves[1]	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves
	Days	*Days*	*Days*	*Days*	*Percent*	*Percent*	*Days*	*Days*	*Days*	*Days*	*Percent*	*Percent*
Control	135	150	150	165	0	0	135	150	150	165	0	0
Soaked 1 hour in 1-percent sodium thiocyanate	135	150	165	195	0	0						
Tubers split twice at right angles across basal end, parallel to main axis; soaked 1 hour in 1-percent sodium thiocyanate	135		165		3.4							
Soaked 1 hour in 3-percent sodium thiocyanate	135	150	180	180	3.4	0						
Soaked 1 hour in 1-percent ammonium thiocyanate	135	150	180	180	3.3	3.1	150	150	165	165	0	9.7
Soaked 1 hour in 2-percent ammonium thiocyanate	165	135	180	180	3.1	3.3	150	150	165	165	11.5	20.7
Soaked 1 hour in 3-percent ammonium thiocyanate	30	150	180	180	13.3	28.1	150	150	165		12.3	78.6
Dipped in 0.5-molar sodium nitrate	135	135	135	150	0	0	135	135	150	150	0	0
Dipped in 1-molar sodium nitrate	135	135	150	135	0	0	135	135	150	150	0	0
Soaked 1 hour in 5-percent ethyl alcohol; subjected to vapors 24 hours	30	15	150	150	6.7	0	120	15	135	150	0	0
Soaked 1 hour in 20-percent ethyl alcohol; subjected to vapors 24 hours	15	15	30	30	0	32.3	15	15	15		36.7	40.0
Soaked 1 hour in 50-percent ethyl alcohol; subjected to vapors 24 hours	30				90.0	100.0	75				96.7	100.0
Soaked 1 hour in 70-percent ethyl alcohol; subjected to vapors 24 hours	30				93.3	100.0						
Soaked 1 hour in 95-percent ethyl alcohol; subjected to vapors 24 hours					100.0	100.0						
Soaked 1 hour in 5-percent acetone; subjected to vapors 24 hours	135	150	150	165	0	0	135	150	150	150	0	0
Soaked 1 hour in 20-percent acetone; subjected to vapors 24 hours	15	15	30	150	35.6	42.8	30	30	60	150	17.9	46.7
Subjected to ether vapors, 1 part in 50, 200, 400, or 1,000, for 24 hours					100.0	100.0					100.0	100.0
Subjected to ether vapors, 1 part in 2,000, for 24 hours							60				66.7	
Subjected to chloroform vapors, 1 part in 50 or 400, for 24 hours					100.0	100.0					100.0	100.0
Subjected to carbon tetrachloride vapors, 1 part in 14,000, for 24 hours	30	15	165	165	10.0	0	135	135	150	150	0	0
Subjected to carbon disulphide vapors, 1 part in 17,500, for 24 hours	15	15	15		33.3	71.4	15	15	15	15	50.0	36.0
Subjected to carbon disulphide vapors, 1 part in 35,000, for 24 hours	15	15	15	15	20.0	6.7	15	15	150	90	3.8	11.5
Subjected to ethyl bromide vapors, 1 part in 5,400, for 24 hours	15	15	15		41.7	66.5	15	15	15		45.0	56.0
Subjected to ethyl bromide vapors, 1 part in 8,000, for 24 hours	15	15	15	150	20.0	15.4	15	15	15	15	20.0	20.0
Subjected to ethyl iodide vapors, 1 part in 48,500, for 24 hours	135	135	165	150	4.8	8.3	15	135	150	135	4.2	20.0
Subjected to ethyl iodide vapors, 1 part in 97,000, for 24 hours	135	135	150	150	4.2	3.8	135	135	150	135	6.3	50.0
Subjected to ethylene chlorhydrin vapors at 0.75 cc (40 percent) per liter space 24 hours	15	30	135	180	11.5	20.8	120	135	135	135	4.2	25.0
Soaked 2 hours in 0.2-percent ethylene chlorhydrin	15	15	150	135	0	4.3	105	15	150	135	0	8.3
Dipped in 6-percent ethylene chlorhydrin; subjected to vapors 24 hours	30				80.0	100.0	15				81.8	100.0
Dipped in 2-percent ethylene chlorhydrin; subjected to vapors 24 hours	15	15	30		42.1	81.5	15	135	30		31.6	83.3
Soaked in 3-percent thiourea for 1 hour	120	135	150	150	0	3.8	65	120	165	150	4.3	3.6
Soaked in 1-percent thiourea for 1 hour	120	120	150	150	0	0	120	120	135	135	4.0	7.7
Wrapped in cotton batting saturated with 10-percent hydrogen peroxide; unwrapped after 7 days	135		165		40.0		150				70.0	

[1] Whole=1-ounce whole tubers; halves=1-ounce halves from 2-ounce whole tubers.

TABLE 10.—*Effect of various chemical treatments on the length of rest period in Jerusalem-artichoke tubers of the varieties Chicago and Waterer in 1931–32*

Treatment	Chicago						Waterer					
	Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 1		Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 1	
	Whole[1]	Halves[1]	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves
	Days	*Days*	*Days*	*Days*	*Percent*	*Percent*	*Days*	*Days*	*Days*	*Days*	*Percent*	*Percent*
Control	150	150	150	150	0	0	180	180	195	195	0	0
Soaked 1 hour in 1-percent ammonium thiocyanate	150	165	180	-------	4.2	59.4	-------	-------	-------	-------	4.0	27.6
Soaked 1 hour in 2-percent ammonium thiocyanate	165	150	180	180	16.0	37.5	-------	-------	-------	-------	15.6	4.0
Soaked 1 hour in 3-percent ammonium thiocyanate	-------	-------	-------	-------	100.0	100.0	-------	-------	-------	-------	36.0	100.0
Dipped in 0.5-molar sodium nitrate	150	135	150	165	0	0	165	165	-------	-------	32.0	80.0
Dipped in 1-molar sodium nitrate	150	150	150	150	0	0	150	120	-------	-------	0	0
Soaked 1 hour in 5-percent ethyl alcohol; subjected to vapors 24 hours	15	15	150	135	4.1	6.5	135	150	-------	-------	8.3	3.1
Soaked 1 hour in 20-percent ethyl alcohol; subjected to vapors 24 hours	15	15	15	15	4.3	0	30	45	135	90	26.9	13.8
Soaked 1 hour in 5-percent acetone; subjected to vapors 24 hours	120	135	135	165	4.3	0	150	135	-------	-------	68.0	6.3
Soaked 1 hour in 20-percent acetone; subjected to vapors 24 hours	15	15	165	-------	47.8	66.7	135	135	-------	-------	28.0	85.7
Subjected to ether vapors, 1 part in 1,000 or 2,000, for 24 hours	-------	-------	-------	-------	100.0	-------	-------	-------	-------	-------	98.0	-------
Subjected to ether vapors, 1 part in 10,000, for 24 hours (tubers dug Dec. 21)	15	-------	45	-------	0	-------	-------	-------	-------	-------	-------	-------
Subjected to ether vapors, 1 part in 10,000, for 24 hours (tubers dug in November)	120	-------	135	-------	4.5	-------	-------	-------	-------	-------	-------	-------
Subjected to ether vapors, 1 part in 20,000, for 24 hours (tubers dug in November)	120	-------	135	-------	4.2	-------	-------	-------	-------	-------	-------	-------
Subjected to ether vapors, 1 part in 20,000, for 24 hours (tubers dug Dec. 21)	45	-------	75	-------	0	-------	-------	-------	-------	-------	-------	-------
Subjected to chloroform vapors, 1 part in 400, 1,000, 2,000, or 10,000, for 24 hours	-------	-------	-------	-------	100.0	100.0	-------	-------	-------	-------	100.0	100.9
Subjected to chloroform vapors, 1 part in 20,000, for 24 hours	105	-------	105	-------	37.5	-------	-------	-------	-------	-------	-------	-------
Subjected to chloroform vapors, 1 part in 100,000, for 24 hours	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	23.1	-------
Subjected to carbon tetrachloride vapors, 1 part in 14,000, for 24 hours	120	120	150	150	0	0	120	120	180	180	10.0	10.0
Subjected to carbon disulphide vapors, 1 part in 17,500, for 24 hours	-------	-------	-------	-------	100.0	100.0	65	135	-------	-------	50.0	92.9
Subjected to carbon disulphide vapors, 1 part in 35,000, for 24 hours	15	15	150	150	0	0	135	135	180	180	12.5	0
Subjected to ethyl bromide vapors, 1 part in 5,400, for 24 hours	15	15	-------	-------	60.0	58.6	-------	-------	-------	-------	100.0	100.0
Subjected to ethyl bromide vapors, 1 part in 8,000, for 24 hours	15	15	15	15	16.7	46.9	15	15	-------	-------	56.0	70.0
Subjected to ethyl iodide vapors, 1 part in 48,500, for 24 hours	15	15	150	165	8.3	0	135	135	-------	-------	29.2	90.0
Subjected to ethyl iodide vapors, 1 part in 97,000, for 24 hours	15	15	150	165	4.0	6.7	150	-------	-------	-------	8.3	64.3
Subjected to ethylene chlorhydrin vapors at 0.75 cc (40 percent) per liter space 24 hours	15	15	150	165	16.0	16.7	150	150	-------	180	8.7	3.1
Soaked 2 hours in 0.2-percent ethylene chlorhydrin	30	15	165	150	13.0	6.7	120	120	180	165	16.0	40.6
Dipped in 6-percent ethylene chlorhydrin; subjected to vapors for 24 hours	15	30	-------	-------	56.5	93.3	30	-------	-------	-------	95.8	100.0
Dipped in 2-percent ethylene chlorhydrin; subjected to vapors for 24 hours	15	15	75	75	13.0	17.2	135	-------	135	-------	50.0	100.0
Soaked in 3-percent thiourea for 1 hour	30	15	-------	-------	65.4	83.9	165	165	-------	-------	24.0	22.2
Soaked in 1-percent thiourea for 1 hour	30	150	150	150	4.1	3.2	150	165	-------	-------	8.0	3.6
Wrapped in cotton batting saturated with 10-percent hydrogen peroxide; unwrapped after 7 days	30	-------	180	-------	30.0	-------	-------	-------	-------	-------	90.6	-------

[1] Whole = 1-ounce whole tubers; halves = 1-ounce halves from 2-ounce whole tubers.

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TABLE 11.—*Effect of various chemical treatments on the length of rest period in Jerusalem-artichoke tubers of the varieties Blanc Ameliore and Chicago in 1932–33*

Treatment	Blanc Ameliore						Chicago					
	Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 10		Time until first sprouting		Time until 50 percent of tubers sprouted		Tubers rotted (before sprouting) prior to June 10	
	Cool [1]	Warm [1]	Cool	Warm	Cool	Warm	Cool	Warm	Cool	Warm	Cool	Warm
	Days	*Days*	*Days*	*Days*	*Percent*	*Percent*	*Days*	*Days*	*Days*	*Days*	*Percent*	*Percent*
Control	120	45	[2] 135	75	66.7	37.5	60	45	135	120	20.0	21.3
Soaked 2 hours in 3-percent sodium thiocyanate	60	30			83.3	68.0	90	30	150	90	48.0	42.3
Soaked 1 hour in 5-percent sodium thiocyanate	30	30			88.0	92.3	60	30			72.0	92.6
Soaked 1 hour in 5-percent ethyl alcohol; subjected to vapors 24 hours	60	15	105	75	24.0	40.0	30	30	90	75	0	8.0
Soaked 1 hour in 20-percent ethyl alcohol; subjected to vapors 24 hours	15	15	90	15	15.4	40.0	15	15	75		0	60.0
Soaked 1 hour in 20-percent acetone; subjected to vapors 24 hours	15	15	90	45	24.0	42.3	45	15	90	45	20.0	48.0
Subjected to ether vapors, 1 part in 2,000, for 3 hours							45	15	90		50.0	70.0
Subjected to ether vapors, 1 part in 2,000, for 6 hours							90	15			85.7	100.0
Subjected to ether vapors, 1 part in 2,000, for 24 hours											100.0	100.0
Subjected to ether vapors, 1 part in 10,000, for 24 hours	90	30	120	60	25.0	33.3	75	60	135	90	44.4	4.2
Subjected to chloroform vapors, 1 part in 10,000, for 3 hours							75	30	135	60	44.4	0
Subjected to chloroform vapors, 1 part in 10,000, for 6 hours							60	15			87.5	88.9
Subjected to chloroform vapors, 1 part in 10,000, for 24 hours							30	30		90	92.3	12.0
Subjected to chloroform vapors, 1 part in 20,000, for 24 hours	30	15	75	30	36.0	4.0	15	15	135	60	16.7	16.0
Subjected to carbon disulphide vapors, 1 part in 32,000, for 24 hours	15	15			92.3	76.9	15	15			56.0	62.5
Subjected to ethyl bromide vapors, 1 part in 8,000, for 24 hours	60	15			88.0	76.0	15				87.5	87.0
Subjected to ethyl bromide vapors, 1 part in 5,400, for 24 hours	15				92.3	100.0					100.0	100.0
Dipped in 2-percent ethylene chlorhydrin; subjected to vapors 24 hours	15	15	15	15	10.0	0	15	15	30	30	0	15.4
Dipped in 6-percent ethylene chlorhydrin; subjected to vapors 24 hours	15	15	15	15	22.7	25.0	15	15	30	30	20.0	20.0
Subjected to vapors of ethylene chlorhydrin at 0.75 cc (40 percent) per liter space 24 hours	30	15	120	60	19.2	4.0	60	30	135	90	4.0	12.0
Soaked 2 hours in 5-percent thiourea	30	30	30	30	28.0	8.0	30	30	30	30	12.0	0

[1] Cool=planted in 45° to 55° F. greenhouse; warm=planted in 65° to 75° F. greenhouse.
[2] Days until 50 percent of tubers that were sound at the previous examination sprouted.

The data for 50 percent of tubers sprouting are probably a better index of the effectiveness of a treatment in breaking the rest period of a lot of tubers than the data for either first sprouting or for 100-percent sprouting. Often one tuber in a sample may start to sprout, but a considerable time may elapse before any more tubers show any evidence of growth. Incidence of rots and toxicity of treatments make the 100-percent-sprouted basis inaccurate and misleading.

Tables 9, 10, and 11 show that depth of rest and ease of breaking of rest varied from season to season even within the same variety, and also between varieties in the same season. Whole tubers and half tubers, in general, were stimulated much alike by chemical treatments. Injury by toxic treatments, however, was generally greater with cut tubers. The data in table 11 indicate that there was a greater, or at least more readily observed, stimulation by effective treatments at the higher temperatures than at the lower sprouting temperatures employed. The lower temperatures were chosen in 1931 because, under field conditions, sprouting usually occurs while the soil temperature is still quite low. It appears, however, that for tests of efficacy of a chemical in breaking rest the higher temperatures may be better. (Compare illustration of similarly treated tubers sprouted under the two temperature conditions shown in pls. 2, 3, and 4.)

The following classification according to the effects of the treatments summarizes, in a general manner, the results secured over the 2-year period on the four varieties, with cut and uncut tubers, and at two sprouting temperatures. The classification is based on the data of tables 9 to 11, and on other data and observations not presented herein.

A. Treatments producing some shortening of the rest period and having little or no deleterious effect on the tubers:

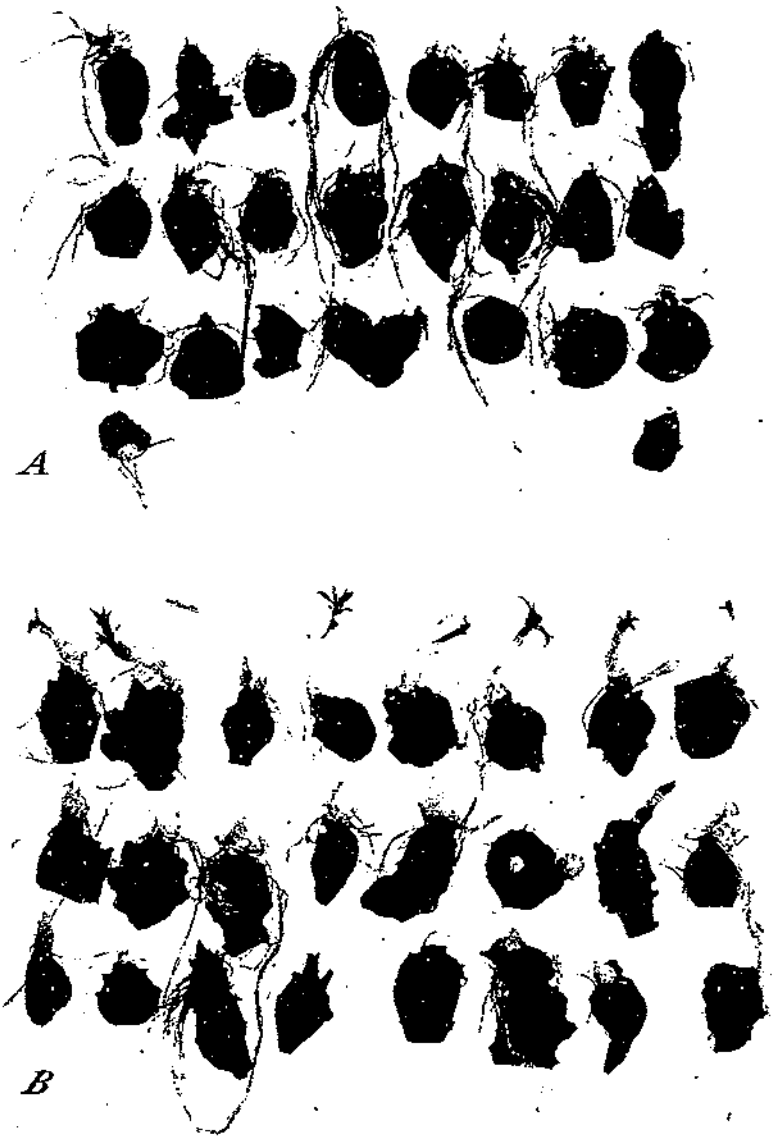
Soaking in 20-percent ethyl alcohol for 1 hour, followed by exposure to vapors for 24 hours.
Soaking in 5-percent thiourea for 2 hours and planting at once.
Dipping in 2-percent ethylene chlorhydrin solution, followed by exposure to vapors for 24 hours.
Exposing to vapors of carbon disulphide, 1 part in 35,000 of air, for 24 hours.

B. Treatments producing some shortening of the rest period but with noticeable toxic effects on the tubers:

Soaking in 20-percent acetone 1 hour, followed by exposure to vapors for 24 hours.
Dipping in 6-percent ethylene chlorhydrin solution, followed by exposure to vapors for 24 hours.
Exposing to ethyl bromide vapors, 1 part in 8,000 of air, for 24 hours.
Exposing to carbon disulphide vapors, 1 part in 32,000 of air, for 24 hours.
Exposing to chloroform vapors, 1 part in 20,000 of air, for 24 hours.

C. Treatments definitely toxic and not shortening the rest period or so toxic that the extent of shortening could not be determined:

Soaking in 50-, 70-, or 95-percent ethyl alcohol 1 hour, followed by exposure to vapors for 24 hours.
Soaking in 3-percent sodium thiocyanate for 2 hours and planting at once.
Soaking in 5-percent sodium thiocyanate for 1 hour and planting at once.
Exposing to ether vapors, 1 part in 2,000 of air, for 3, 6, or 24 hours.
Exposing to ether vapors, 1 part in 50, 200, 400, 1,000, or 2,000 of air, for 24 hours.
Exposing to chloroform vapors, 1 part in 50, 400, 1,000, or 2,000 of air, for 24 hours.
Exposing to chloroform vapors, 1 part in 10,000 of air, for 3, 6, or 24 hours.
Exposing to ethyl bromide vapors, 1 part in 5,400 of air, for 24 hours.



Jerusalem-artichoke tubers, variety Blanc Ameliore. *A*, Soaked in 20-percent ethyl alcohol 1 hour, removed and stored in closed container 24 hours. Planted in a cool greenhouse (45°–55° F.) December 13, 1932; photographed January 12, 1933. *B*, Tubers treated the same as those of *A* except that they were planted in a warm greenhouse (65°–75°). (Compare with lots shown in pl. 2.)

Jerusalem-artichoke tubers, variety Blanc Ameliore. *A*, Dipped in 2-percent ethylene chlorhydrin, removed and stored in closed container 24 hours. Planted in a cool greenhouse (45°–55° F.) December 16, 1932; photographed January 12, 1933. *B*, Similar tubers treated the same as those of *A* except that they were planted in a warm greenhouse (65°–75°). (Compare with lots shown in pl. 2.)

Exposing to carbon disulphide vapors, 1 part in 17,500 of air, for 24 hours.
Wrapping tubers in cotton batting saturated with 10 percent solution of commercial hydrogen peroxide, removing the cotton after 7 days.

D. Treatments not toxic to tubers, but shortening the rest period only a little or not at all:

Soaking in 1- or 3-percent sodium thiocyanate 1 hour, and planting at once.
Soaking in 1- or 2-percent ammonium thiocyanate 1 hour, and planting at once.
Soaking in 5-percent ethyl alcohol 1 hour, followed by exposure to vapors for 24 hours.
Soaking in 5-percent acetone 1 hour, followed by exposure to vapors for 24 hours.
Soaking in 1- or 3-percent thiourea 1 hour, and planting at once.
Dipping in 0.5- or 1.0-molar sodium nitrate, and planting at once.
Exposing to carbon tetrachloride vapors, 1 part in 14,000 of air, for 24 hours.
Exposing to ether vapors, 1 part in 10,000 or 20,000 of air, for 24 hours.
Exposingto ether vapors, 1 part in 100,000 of air, for 16 hours.
Exposing to chloroform vapors, 1 part in 100,000 of air, for 16 hours.
Exposing to ethylene chlorhydrin vapors, 1 cc 40-percent solution in 1,300 cc space, for 24 hours.
Exposing to ethyl iodide vapors, 1 part in 48,500 or 97,000 of air, for 24 hours.

Photographs of a few of the chemically treated lots are reproduced in plates 1 to 4.

Although considerable shortening of the rest period was found with some of the chemical treatments, subsequent growth and development in all cases was much slower than that induced when the rest period was terminated by the low-temperature treatments described on page 19. The large number of chemicals, concentrations, and periods of exposure tried are only a very small proportion of the almost infinite combinations of these factors that could be used. It seems possible that certain combinations, not yet found, may induce as good response as the temperature treatments.

EFFECT OF TEMPERATURE TREATMENTS

Sprouting

Results of sprouting tests for the four seasons and four varieties of Jerusalem-artichokes studied are presented in tables 12 and 13. It is clearly evident from the data that there is, in general, a consistent decrease in the length of the rest period as the temperature of storage is decreased from 50° to 32° F., not only when the time until 50 percent sprouting is considered but also when the time for production of first sprouts is the measure; storage at 36° was only slightly less effective than that at 32° in reducing the sprouting time, but at 50° it was markedly less effective than at the lower temperatures. Since the data on the extent of sprouting were recorded only at 15-day intervals, they cannot show abbreviations of the rest period to less than 15 days. Other unrecorded observations, however, showed that treatment at the lower temperatures, particularly at 32°, continued to shorten the sprouting time until by the time the trials were terminated, 50-percent sprouting was occurring in less than 7 days from planting. There were only minor differences in sprouting periods between tubers stored under the two conditions of humidity at 32°.

TABLE 12.—*Effect on length of rest period of temperature conditions to which dormant Jerusalem-artichoke tubers of 4 varieties were exposed, 1931*

DAYS FROM PLANTING TO FIRST EVIDENT SPROUTING

Period of exposure (days)	Blanc Amelíore						Chicago						Waterer						Tait					
	18° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit	18° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit	18° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit	18° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit
0	150	150	150	150	150	150	150	150	150	150	150	150	180	180	180	180	180	180	150	150	150	150	150	150
15	120	60	45	45	75	75	90	30	30	45	135	75	120	45	45	45	120	120	105	60	60	60	75	60
30	120	30	30	30	75	45	30	30	30	30	120	30	60	30	30	30	120	30	120	30	30	45	45	30
45	45	15	15	15	45	15	45	15	15	15	75	15	(1)	15	15	15	45	30	90	15	15	15	15	15
60	105	15	15	15	15	15	30	15	15	15	45	15	15	15	15	15	45	15	90	15	15	15	15	15
75	30	15	15	15	15	15	15	15	15	15	30	15	(1)	15	15	15	30	15	45	15	15	15	15	15
90	75	15	15	15	15	15	60	15	15	15	30	15	(1)	15	15	15	30	15	30	15	15	15	15	15
105	60	15	15	15	15	15																		

DAYS FROM PLANTING UNTIL 50 PERCENT OF TUBERS SPROUTED [2]

0	150	150	150	150	150	150	150	150	150	150	150	150	195	195	195	195	195	195	150	150	150	150	150	150
15	165	75	60	60	135	105	120	45	45	75	135	90	135	90	105	120	135	135	120	60	60	60	105	75
30	120	30	30	30	90	75	120	30	30	30	135	45	135	45	45	30	150	105	120	30	45	45	75	30
45	120	30	30	15	105	45	105	15	15	15	90	30	(1)	15	15	15	90	45	120	15	30	30	45	30
60	105	15	15	15	75	15	90	15	15	15	45	15	105	15	15	15	60	15	105	15	15	15	30	15
75	90	15	15	15	30	15	60	15	15	15	45	15	(1)	15	15	15	30	15	60	15	15	15	15	15
90	75	15	15	15	15	15	60	15	15	15	30	15	(1)	15	15	15	30	15	45	15	15	15	15	15
105	60	15	15	15	15	15						15												

PERCENTAGE OF TUBERS ROTTED PRIOR TO JUNE 1

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	88	0	0	9	4	0	5	0	0	0	19	0	15	0	12	19	29	0	54	0	0	0	8	4
30	84	0	0	0	4	0	10	0	0	0	63	0	17	0	0	0	48	29	52	12	0	0	0	0
45	73	23	0	0	5	0	33	0	0	0	0	0	63	0	0	0	50	0	42	0	0	0	0	0
60	87	0	0	0	32	0	19	5	0	0	15	0	33	0	0	0	36	0	50	0	0	0	4	0
75	77	0	0	0	4	0	35	0	0	0	5	0	67	9	0	0	19	0	76	6	0	0	0	0
90	91	5	0	0	72	0	20	0	0	0	7	0	100	0	0	0	0	0	77	27	0	0	5	0
105	92	0	0	0	72	0																		

[1] All tubers rotted without sprouting.

[2] Percentage based on number of sound tubers at preceding examination.

TABLE 13.—*Effect on length of rest period of temperature conditions to which dormant Jerusalem-artichoke tubers of 2 varieties were exposed, 1932–34*

Period of exposure (days)	Blanc Ameliore, 1932						Chicago, 1932						Blanc Ameliore, 1933		Blanc Ameliore, 1934		Chicago, 1934	
	15° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit	15° F.	32° F., low humidity	32° F., high humidity	36° F.	50° F.	Field pit	32° F., high humidity	50° F.	32° F., high humidity	50° F.	32° F., high humidity	50° F.
DAYS FROM PLANTING TO FIRST EVIDENT SPROUTING																		
0	120	120	120	120	120	120	60	60	60	60	60	60	120	120	15	15	60	60
15	15	15	15	30	60	30	30	30	15	30	45	45	30	60	15	15	15	75
30	15	15	15	15	30	15	15	15	15	15	45	15	15	30	15	15	15	15
45	15	15	15	15	15	15	15	15	15	15	30	15	15	15	15	15	15	60
60	15	15	15	15	15	15	15	15	15	15	30	15	15	15	15	15	15	30
75	(1)	15	15	15	15	15	(1)	15	15	15	15	15	15	15	15	15	15	15
90							(1)	15	15	15	15	15			15	15	15	15
DAYS FROM PLANTING UNTIL 50 PERCENT OF TUBERS SPROUTED [2]																		
0	135	135	135	135	135	135	135	135	135	135	135	135	135	135	60	60	135	135
15	45	60	45	45	90	60	105	60	60	45	120	75	75	90	30	45	45	90
30	60	15	15	30	45	15	45	15	15	30	90	30	30	45	15	60	15	105
45	30	15	15	15	30	30	45	15	15	15	75	15	30	30	15	45	15	90
60		15	15	15	15	15	15	15	15	15	60	15	15	15	15	15	15	30
75	(1)	15	15	15	15	15	(1)	15	15	15	30	15	15	15	15	15	15	30
90							(1)	15	15	15	15	15			15	15	15	15
PERCENTAGE OF TUBERS ROTTED PRIOR TO JUNE 1																		
0	67	67	67	67	67	67	18	18	18	18	18	18	0	0	20	20	15	15
15	65	5	0	0	16	10	32	0	4	0	0	0	0	0	20	15	0	15
30	70	0	0	0	6	0	32	0	0	0	4	0	0	0	0	35	0	58
45	75	0	0	0	0	0	70	0	0	0	0	0	0	0	5	45	0	55
60	92	6	0	0	25	0	64	0	0	0	0	0	0	0	0	40	0	10
75	100	25	0	0	25	0	100	9	0	5	0	0	0	0	0	5	0	20
90							100	0	0	0	0	0			0	53	0	25

[1] All tubers rotted without sprouting.
[2] Percentage based on number of sound tubers at preceding examination.

Sprouting tests on tubers stored in field pits, where the temperature was subject to fluctuations between about 30° and 40° F., showed that such tubers were intermediate in their sprouting response between the 36° and 50° constant-temperature treatments. The two temperatures below 32° that were used (18° in 1931–32, and 15° in 1932–33) did not give as prompt sprouting as might have been expected. It is important to note, however, that at both these low temperatures freezing injury occurred, in most cases followed by more or less break-down of tissues of the tubers, the pith in particular quickly decomposing. Although several attempts were made to gradually thaw tubers frozen at these low temperatures, by bringing them from the low to successively higher temperatures for periods of about 1 day each, none were successful.

The 50° F. treatment was markedly inferior to the 32°, 36°, or field-pit treatments, not only in its effect on the sprouting time but also in the type of growth obtained after sprouting had begun. This inferiority is apparent in the photographs of the 1934–35 experiments shown in plate 5. It can be seen that while the 50° samples are less vigorous in their growth throughout the series of both varieties studied, the longer the period of exposure the more nearly the growth approaches that of the 32° samples. In determining what storage treatments are most effective for breaking rest, it therefore seems necessary to distinguish between those that break rest and those that not only break rest but also induce normal subsequent plant development.

Since the publication of a preliminary report (*59*) on the author's 1931 experiments, Haber (*31*) has drawn essentially the same conclusions as those discussed herein and in the preliminary report relative to the shortening of the rest period by low-temperature storage.

Another factor that must be taken into account in determining any practical method of breaking the rest period of Jerusalem-artichokes is that of susceptibility of tubers to diseases during or following treatment. The data given in tables 12 and 13 show that, in general, a much greater percentage of the tubers stored at 50° F. rotted after planting than of those stored at any of the lower temperatures (above freezing) employed. Johnson (*41*) concluded from a study of storage rots of the Jerusalem-artichoke that high temperature and comparatively low relative humidity seem to be the conditions most favorable for development of such rots, while temperatures near the freezing point were the only means of keeping the tubers free of rot.

From the standpoint of more rapid breaking of rest, inducing normal plant development, and in keeping down the amount of rotting, it is evident that the 32° and 36° F. temperature treatments are far superior to the 50° treatment.

Catalase Activity

Results of catalase determinations made on terminal buds, pith, and cortex of Blanc Ameliore and Chicago tubers exposed at 32° and 50° F. for the various periods in 1933–34 and in 1934–35 are given in figures 1, 2, and 3. There were noticeable fluctuations in the moisture content of tubers stored for the different periods and under different temperature conditions; therefore, it was thought desirable to present data on the dry-weight as well as on the fresh-weight basis.

Critical examination of these results fails to reveal any consistent relation of catalase activity, when expressed on the fresh or on the dry basis, to the sprouting response. In Blanc Ameliore the terminal-

Relative sprout development of Blanc Ameliore and Chicago Jerusalem-artichoke tubers when planted in sand after storage at 50° or at 32° F. and high humidity for various periods. Tubers placed in storage November 16, 1934; photographed March 4 and 5, 1935. *A*, Variety Blanc Ameliore: *c*, Unstored control planted November 17, 1934; lot 1, 32° storage, and lot 2, 50° storage, for 15 days before planting; lot 5, 32° storage, and lot 6, 50° storage, for 30 days before planting; lot 9, 32° storage, and lot 10, 50° storage, for 45 days before planting; lot 13, 32° storage, and lot 14, 50° storage, for 60 days before planting; lot 17, 32° storage, and lot 18, 50° storage, for 75 days before planting; lot RC1, 32° storage, and lot RD1, 50° storage, for 90 days before planting. *B*, *C*, and *D*, Variety Chicago: *c*, Unstored control planted November 17, 1934; lot 1, 32° storage, and lot 2, 50° storage, for 15 days before planting; lot 3, 32° storage, and lot 4, 50° storage, for 30 days before planting; lot 5, 32° storage, and lot 6, 50° storage, for 45 days before planting; lot 7, 32° storage, and lot 8, 50° storage, for 60 days before planting; lot 9, 32° storage, and lot 10, 50° storage, for 75 days before planting; lot RC11, 32° storage, and lot RD11, 50° storage, for 90 days before planting.

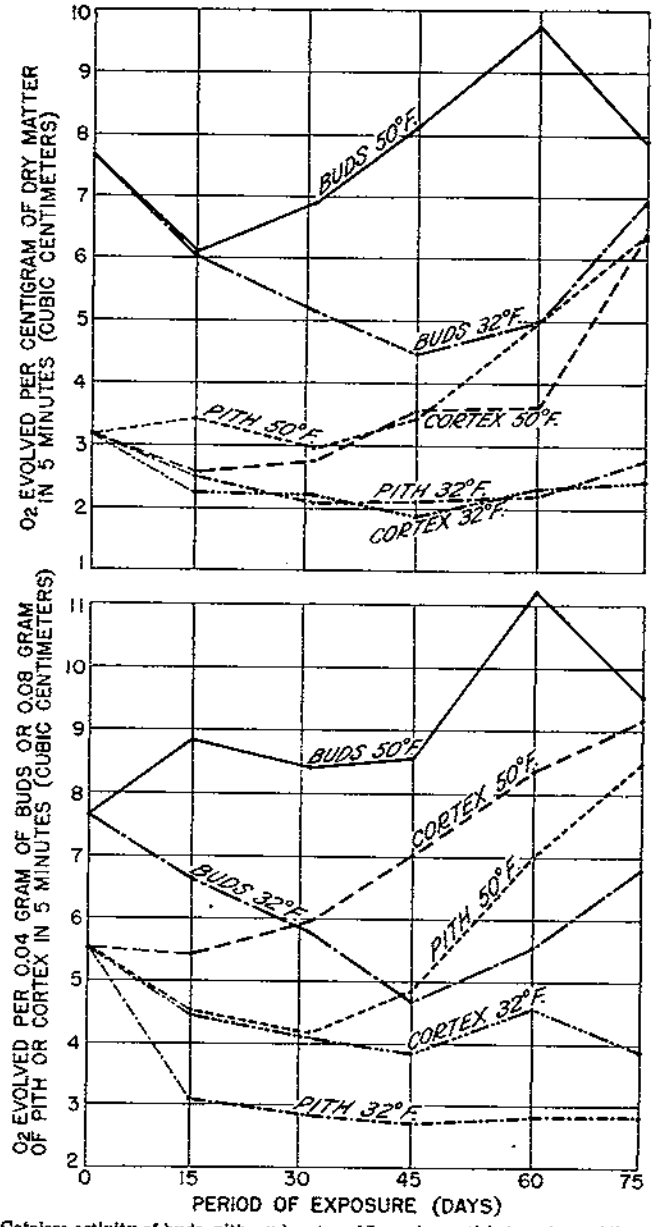


FIGURE 1.—Catalase activity of buds, pith, and cortex of Jerusalem-artichoke tubers of the variety Blanc Ameliore stored at 32° and 50° F. for different periods in 1933–34.

bud catalase values of the two temperature treatments show similar relationships in the two seasons, but only when expressed on the fresh-weight basis. That is, the tubers of the 50° F. treatment showed greater activity per unit of fresh weight than the corresponding tubers of the 32° treatment on any date, although the values are much more nearly alike for the two treatments in 1934–35 than in 1933–34. The trends in catalase activity over the whole period studied are quite

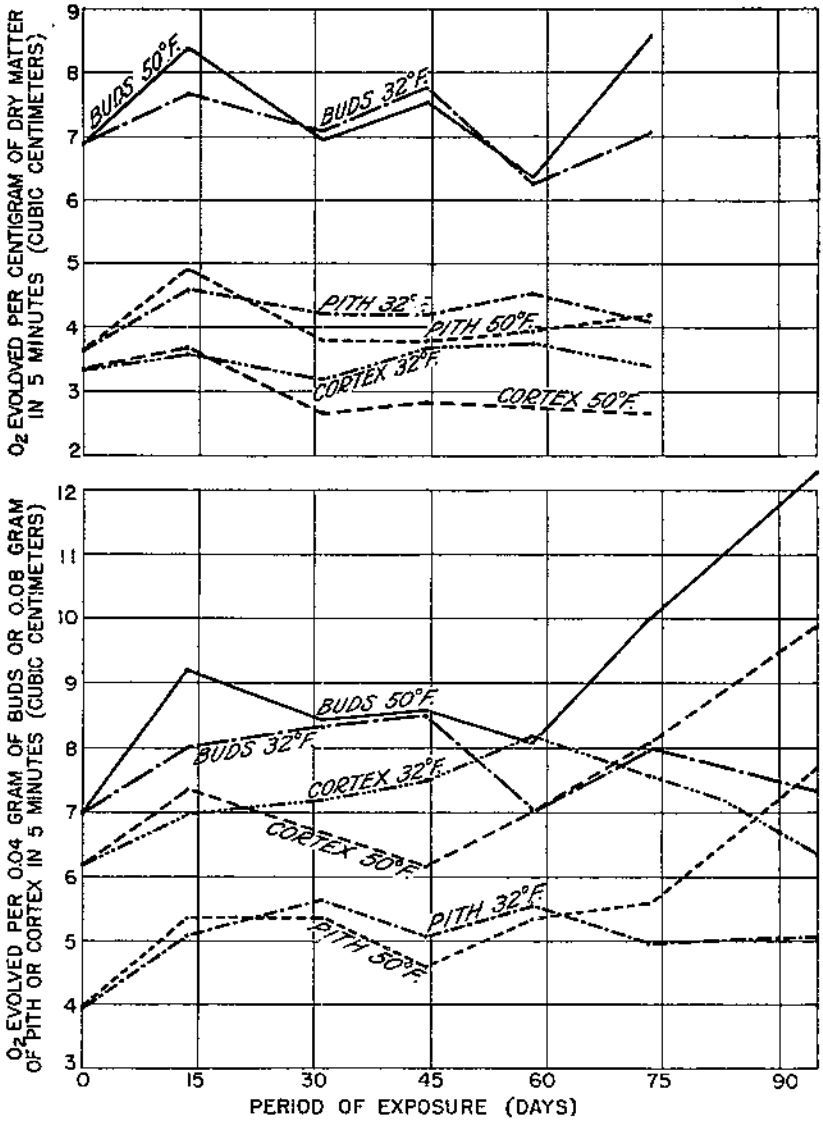


FIGURE 2.—Catalase activity of buds, pith, and cortex of Jerusalem-artichoke tubers of the variety Blanc Amellore stored at 32° and 50° F. for different periods in 1934–35.

dissimilar in the two seasons, especially for the buds of the 32° exposures. In 1933–34 the latter showed a tendency for a decreased catalase activity until the tubers had been exposed for almost 45 days, after which there was a slightly increased activity; in 1934–35 the activity showed an increase until the 45-day storage period, after which there was a decline for the next 15 days followed by a second period of increase. It is puzzling that the catalase values for the 32° and 50° exposures should have been so much more widely divergent in the 1933–34 season, when growth was more nearly alike in these

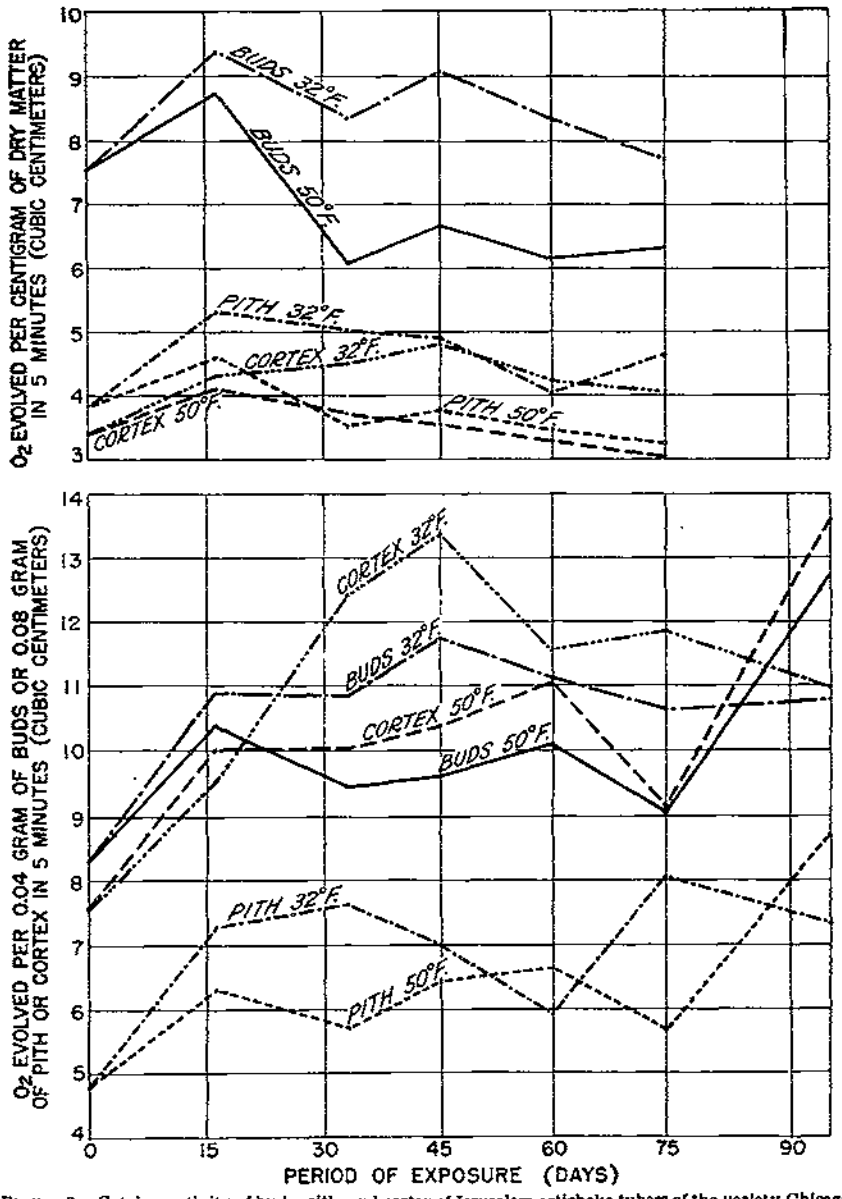


FIGURE 3.—Catalase activity of buds, pith, and cortex of Jerusalem-artichoke tubers of the variety Chicago stored at 32° and 50° F. for different periods in 1934–35.

samples (as judged by the time to 50-percent sprouting), than in 1934–35, when the sprouting responses were not so similar.

In Blanc Ameliore the relationships between the cortex catalase values of the 32° F. treatments and of the 50° treatments are different in the two seasons. The same is also true for the pith catalase values for the two temperature treatments.

Not only were the catalase values and trends different in Blanc Ameliore in the two seasons, but those of Chicago were quite different

from those of Blanc Ameliore in the same season; in fact, the relative catalase activity per unit of fresh weight in the two treatments was just reversed. In Chicago the tissues of 32° F. tubers exhibited considerably greater activity than the corresponding tissues of 50° tubers; in Blanc Ameliore the tissues of 32° tubers had less activity than the 50° tissues.

An attempt to find a definite catalase activity associated with the nonresting condition (immediately following breaking of rest) irrespective of the previous treatment was unfruitful. It was thought possible that the catalase value for a 32° F. sample at the time rest is broken, say at 30 days' exposure, might be of the same order of magnitude as that of a 50° sample of the same variety when rest terminated at perhaps 60 days' exposure. The data do not indicate that such a value exists.

Respiration

Results of the respiration determinations conducted in the 1934–35 season on the two varieties, Blanc Ameliore and Chicago, are presented in table 14. The relative losses in weight during the storage period at 32° and 50° F. and during the 72-hour period at 70° immediately following removal from the 32° and 50° storage conditions can be noted from the data of table 15. The respiration data are expressed on three different bases. Probably the best measure of respiratory activity and that used in discussing the results, is that given on the per-tuber basis, since tubers were of uniform size in all lots. The data show that in this study the relative respiratory values for different treatments are practically the same regardless of the manner of expression used. Only in the 45- and 60-day lots of Chicago and the 75-day lot of Blanc Ameliore are the relationships between the 32° and 50° treatments reversed when expressed on the fresh-weight basis, as compared with the dry weight or per-tuber methods of expression.

Table 14.— *Rates of respiration of Jerusalem-artichoke tubers stored Nov. 16, 1934, at 32° and 50° F. for various periods*

EXPRESSED AS MILLIGRAMS OF CARBON DIOXIDE EVOLVED PER AVERAGE TUBER PER HOUR AT 77° F.[1]

Period of exposure (days)	Blanc Ameliore		Chicago		Period of exposure (days)	Blanc Ameliore		Chicago	
	32° F.	50° F.	32° F.	50° F.		32° F.	50° F.	32° F.	50° F.
0 [2]	0.889	0.889	0.617	0.617	45	1.032	1.045	1.325	1.299
15	.998	.786	1.158	.807	60	.934	[3] 1.003	1.422	1.384
30	1.977	1.044	[3] 1.175	1.106	75	1.378	1.329	1.607	1.262

EXPRESSED AS MILLIGRAMS OF CARBON DIOXIDE EVOLVED PER KILOGRAM OF FRESH WEIGHT PER HOUR AT 77° F.[1]

0 [2]	35.48	35.48	24.79	24.79	45	51.66	53.76	64.19	78.08
15	40.50	34.26	51.81	42.52	60	49.50	[3] 49.87	68.26	75.49
30	[3] 42.22	48.10	[3] 55.22	53.25	75	63.89	74.02	79.91	75.00

EXPRESSED AS MILLIGRAMS OF CARBON DIOXIDE EVOLVED PER KILOGRAM OF DRY MATTER PER HOUR AT 77° F.[1]

0 [2]	138.88	138.88	81.47	81.47	45	176.42	178.24	175.87	170.58
15	177.70	131.11	152.64	124.70	60	149.20	[3] 165.60	188.23	166.64
30	[3] 154.56	167.27	[3] 178.24	136.69	75	220.93	238.86	227.04	157.79

[1] Based on 4- to 8-hour runs after the first 3-hour period on all except the untreated samples. Only data for the first 3 hours were taken on the latter samples. Length of run was always the same for corresponding 32° and 50° F. samples.

[2] Samples kept at room temperature (about 68° F.) from Nov. 16 to Nov. 23, before determinations were made.

[3] Time of termination of rest as judged by 50-percent sprouting occurring within 15 days after planting of treated tubers.

TABLE 15.—*Losses in weight of Jerusalem-artichoke tubers during storage at 32° and 50° F. and during a 72-hour period at 70° F. immediately following removal from the 32° and 50° F. storage conditions*

BLANC AMELIORE

Period in storage (days)	Loss in weight during storage at—		Loss of original weight during the 72-hour period at 70° F.		Moisture at the end of 70° F. period	
	32° F.	50° F.	32° F.	50° F.	32° F.	50° F.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0					74.4	74.4
15	2.63	5.99	2.32	3.22	77.2	73.9
30	4.76	11.81	4.15	3.99	72.7	71.2
45	6.07	18.91			70.7	69.8
60	6.85	17.30	4.61	5.93	72.8	69.9
75	11.15	24.27	1.48	2.64	72.2	69.1

CHICAGO

0					69.6	69.6
15	3.69	7.97	4.21	4.72	66.1	65.9
30	6.29	15.39	3.51	3.54	69.0	59.3
45	6.50	21.16	7.28	6.31	63.5	54.2
60	10.20	25.21	4.15	5.64	63.6	54.7
75	12.74	31.32	1.05	.95	64.9	52.5

No very significant correlation is evident in these data between respiratory activity and emergence from rest. If time of emergence from rest be judged by the time required to give 50-percent sprouting within 15 days from planting, the respiratory values for the two treatments are not widely different in either variety (for example, between the 30-day exposure at 32° F. and the 60-day exposure at 50° in Blanc Ameliore), yet the fact that the differences between the two treatments are even smaller at times when the sprouting response is not the same (for example, at the 45-day exposure in Blanc Ameliore) suggests that little importance can be attached to the similarity of these values.

The two varieties studied exhibited differences in the relative respiratory response to the two temperatures. In the Chicago variety the respiratory rate of the 50° F. samples expressed on the per-tuber basis remained lower than that of the 32° lots over the entire period studied, and in Blanc Ameliore it was lower only at the 15- and 75-day periods.

A consistently increasing respiratory rate can be observed in the Chicago data throughout the period studied in both the 32° and 50° F. samples. A similar tendency, though not as consistent, can also be seen for Blanc Ameliore.

The results of this phase of the investigation show that, under the conditions of this experiment, the exact time of emergence from rest resulting from exposures at 32° and 50° F. cannot be determined by the respiratory rate of the whole tubers. Emergence from rest does occur, however, during a rising gradient of respiratory activity.

CHEMICAL COMPOSITION

1931 WHOLE-TUBER SAMPLES

Whole-tuber samples of two varieties from the 1931–32 studies were analyzed. In Blanc Ameliore, dry matter, alcohol-soluble nitrogen, alcohol-insoluble nitrogen, total hot-water-soluble reducing sub-

stances, and total levulose (levulosans determined as levulose) determinations were made. Although attempts were made to determine free levulose on several samples, none of those analyzed showed more than traces, consequently no determinations were made on the remaining samples. Data for Blanc Ameliore are given in table 16. Determinations of dry matter, free levulose, free reducing substances, total levulose (levulosans determined as levulose), total alcohol-soluble reducing substances, total hot-water-soluble reducing substances, and acid-hydrolyzable hot-water-insoluble polysaccharides were made for the Tait series, and the results are presented in table 17.

TABLE 16.—*Chemical composition of Jerusalem-artichoke tubers of the variety Blanc Ameliore subjected to different temperature conditions for various periods in 1931–32*

[Dry-weight basis]

DRY MATTER (FRESH-WEIGHT BASIS)

Treatment [1] (°F.)	Chemical composition after treatment for—						
	15 days	30 days	45 days	60 days	75 days	90 days	105 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Control [2]	24.20	24.20	24.20	24.20	24.20	24.20	24.20
32 LH	24.43	23.86	36.36	[3] 34.99	29.67	32.61	----------
32 HH	22.97	24.87	27.41	[3] 24.78	24.17	25.58	----------
36	25.56	25.44	[3] 24.62	23.18	24.37	25.61	27.46
50	26.31	26.92	27.22	27.29	30.91	[3] 36.72	32.15
Field pit	22.35	22.44	22.20	[3] 20.89	21.47	20.52	19.75

ALCOHOL-SOLUBLE NITROGEN

Control	1.07	1.07	1.07	1.07	1.07	1.07	1.07
32 LH	.84	.79	.72	[3] .94	1.07	.92	----------
32 HH	.85	.95	1.03	[3] 1.01	1.10	.96	----------
36	.94	.87	[3] .92	1.08	1.00	.93	.99
50	.86	.88	.95	1.00	1.06	[3] 1.09	1.29
Field pit	1.03	----------	.90	[3] 1.14	1.06	1.03	1.27

ALCOHOL-INSOLUBLE NITROGEN

Control	0.85	0.85	0.85	0.85	0.85	0.85	0.85
32 LH	.87	.82	.87	[3] .88	.80	.98	----------
32 HH	.84	.87	.88	[3] .81	.82	.84	----------
36	.83	.79	[3] .87	.70	.82	.78	.79
50	.85	.77	.81	.80	.74	[3] .93	.80
Field pit	.75	.80	.74	[3] .83	.76	.83	.84

TOTAL NITROGEN

Control	1.92	1.92	1.92	1.92	1.92	1.92	1.92
32 LH	1.71	1.61	1.59	[3] 1.82	1.87	1.90	----------
32 HH	1.69	1.82	1.91	[3] 1.82	1.92	1.80	----------
36	1.77	1.66	[3] 1.79	1.84	1.82	1.71	1.73
50	1.71	1.65	1.76	1.80	1.80	[3] 2.02	2.00
Field pit	1.78	----------	1.64	[3] 1.97	1.82	1.88	2.11

TOTAL HOT-WATER-SOLUBLE REDUCING SUBSTANCES

Control	60.61	60.61	60.61	60.61	60.61	60.61	60.61
32 LH	60.92	61.92	53.58	[3] 59.67	65.91	58.55	----------
32 HH	61.67	60.22	60.96	[3] 60.45	61.84	58.56	----------
36	65.10	62.72	[3] 65.75	62.53	60.69	63.55	62.02
50	63.25	67.38	63.11	62.72	59.78	[3] 58.99	60.73
Field pit	62.61	63.90	60.53	[3] 59.04	60.83	60.27	60.32

See footnotes at end of table.

TABLE 16.—*Chemical composition of Jerusalem-artichoke tubers of the variety Blanc Ameliore subjected to different temperature conditions for various periods in 1931–32*—Continued

[Dry-weight basis]

TOTAL LEVULOSE

Treatment (° F.)	Chemical composition after treatment for—						
	15 days	30 days	45 days	60 days	75 days	90 days	105 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Control	52.20	52.20	52.20	52.20	52.20	52.20	52.20
32 LH[1]	48.71	49.77	44.53	[3] 46.48	52.31	45.45	----------
32 HH	48.37	45.60	48.08	[3] 47.69	47.96	47.29	----------
36	55.20	50.31	[3] 49.05	50.78	45.17	50.57	53.84
50	57.37	57.25	55.81	49.48	48.80	[3] 48.29	46.30
Field pit	52.87	53.89	49.82	[3] 45.71	47.50	48.12	47.82
HOT-WATER-SOLUBLE REDUCING SUBSTANCES OTHER THAN LEVULOSE							
Control	8.41	8.41	8.41	8.41	8.41	8.41	8.41
32 LH	12.21	12.15	9.05	[3] 13.19	13.60	13.10	----------
32 HH	13.30	14.62	12.88	[3] 12.76	13.88	11.27	----------
36	9.90	12.41	[3] 15.80	11.75	16.52	12.98	8.18
50	5.88	10.13	7.30	13.24	10.98	[3] 10.70	14.43
Field pit	9.74	10.01	10.71	[3] 14.23	13.33	12.15	12.50

[1] LH=low humidity; HH=high humidity.
[2] Original tubers at harvesttime.
[3] Time of termination of rest as judged by 50-percent sprouting occurring within 15 days after planting of treated tubers.

TABLE 17.—*Chemical composition of Jerusalem-artichoke tubers of the variety Tait subjected to different temperature conditions for various periods in 1931–32*

[Dry-weight basis]

DRY MATTER (FRESH-WEIGHT BASIS)

Treatment[1] (° F.)	Chemical composition after treatment for—					
	15 days	30 days	45 days	60 days	75 days	90 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Control[2]	24.34	24.34	24.34	24.34	24.34	24.34
32 LH	21.43	24.33	[3] 28.55	28.13	30.62	30.65
32 HH	22.04	22.33	21.78	[3] 22.70	24.26	23.01
36	23.97	29.11	25.13	[3] 24.61	27.81	26.15
50	30.51	25.69	28.67	29.11	[3] 28.34	30.12
Field pit	17.27	22.19	20.82	[3] 18.02	21.18	21.17
FREE LEVULOSE						
Control	0.05	0.05	0.05	0.05	0.05	0.05
32 LH	2.46	1.20	[3].84	.46	.78	.86
32 HH	1.35	.52	.59	[3].70	.53	.35
36	1.00	----------	.38	[3].39	.29	.49
50	.04	.28	.12	.50	[3].99	.29
Field pit	.42	.05	.05	[3].09	.03	.08
FREE REDUCING SUBSTANCES (AS DEXTROSE)						
Control	0.13	0.13	0.13	0.13	0.13	0.13
32 LH	3.37	2.15	[3] 1.84	1.34	1.84	1.68
32 HH	2.30	1.43	1.41	[3] 1.88	1.48	----------
36	1.46	.87	1.09	[3] 1.36	1.43	1.31
50	.71	1.08	.89	1.23	[3] 2.00	1.09
Field pit	1.82	.81	.72	[3] 1.03	.40	.86

See footnotes at end of table.

TABLE 17.—*Chemical composition of Jerusalem-artichoke tubers of the variety Tait subjected to different temperature conditions for various periods in 1931–32*—Con.

[Dry-weight basis]

TOTAL LEVULOSE

Treatment (° F.)	Chemical composition after treatment for—					
	15 days	30 days	45 days	60 days	75 days	90 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Control	47.18	47.18	47.18	47.18	47.18	47.18
32 LH	39.38	36.13	[3] 34.15	34.24	35.19	34.39
32 HH	37.27	38.79	33.53	[2] 34.89	38.16	34.66
36	39.36	40.03	32.00	[3] 37.13	36.14	37.29
50	41.05	38.61	33.17	35.97	[4] 37.72	35.95
Field pit	35.98	35.65	31.91	[2] 32.88	34.21	34.54

TOTAL ALCOHOL-SOLUBLE REDUCING SUBSTANCES (AS INVERT SUGAR)

Control	34.33	34.33	34.33	34.33	34.33	34.33
32 LH	41.87	39.16	[3] 41.09	41.57	40.88	38.10
32 HH		40.40	40.62	[2] 42.99	43.35	41.73
36	40.89	39.66	37.86	[3] 43.08	41.38	40.45
50	35.26	40.10	37.21	40.11	[4] 40.08	39.12
Field pit		39.73	38.71	[3] 41.63	38.43	

TOTAL HOT-WATER-SOLUBLE REDUCING SUBSTANCES (AS LEVULOSE)

Control	67.02	67.02	67.02	67.02	67.02	67.02
32 LH	69.02	62.13	[3] 68.73	62.53	65.70	56.66
32 HH	62.95	63.08	61.36	[2] 63.06	61.03	60 80
36	58.04	62.75	58.62	[3] 65.35	55.50	61.14
50	63.68	65.32	59.28	63.03	[4] 63.57	61.92
Field pit	63.93	64.40	59.76	[2] 61.60	57.84	57.16

ACID-HYDROLYZABLE HOT-WATER-INSOLUBLE POLYSACCHARIDES (AS DEXTROSE)

Control	3.45	3.45	3.45	3.45	3.45	3.45
32 LH	3.50	3.88	[3] 3.58	3.88	3.80	1.88
32 HH	3.56	4.35	3.91	[2] 3.99	4.22	4.32
36	3.46	2.60	3.76	[3] 3.74	3.88	4.26
50	3.61	3.40	3.36	3.64	[4] 3.73	3.69
Field pit	3.86	3.72	3.77	[2] 3.98	4.41	3.89

[1] LH=low humidity; HH=high humidity.
[2] Original tubers at harvesttime.
[3] Time of termination of rest as judged by 50-percent sprouting occurring within 15 days after planting of treated tubers.

The data reveal no consistent relation of alcohol-soluble nitrogen, alcohol-insoluble nitrogen, or total nitrogen either to the temperatures of exposure used or to termination of the resting condition as judged by sprouting tests.

Total hot-water-soluble reducing substances showed considerable fluctuation during the period studied. In both varieties there was less fluctuation under the 32° F. high-humidity exposure than under any of the others used, and the data show that this treatment also exhibited the most consistent dry-matter content. In Blanc Ameliore the 50° treatment exhibited a considerably larger content of hot-water-soluble reducing substances than either of the 32° treatments during

the first 60 days of the experiment. The Tait variety did not show this. A much greater loss of hot-water-soluble reducing substances occurred with all exposures in Tait than in Blanc Ameliore during the experimental period.

The total levulose content (levulosans determined as levulose) underwent a more consistent change than hot-water-soluble reducing substances, apparently as a result of the differences in temperature. Throughout most of the period studied and particularly during the first 60 days with Blanc Ameliore and the first 15 days with Tait, the total levulose content (on the dry-weight basis) was much higher with the 50° F. exposure than with the lower temperature treatments. This suggests that a larger proportion of the reserves at 50° are in the form of inulin or closely related higher-levulose inulides than at the lower temperatures. This contention is supported by the values for percentage of alcohol-soluble reducing substances and free reducing substances in Tait, which show, in general, a lower content of these substances at 50° than at lower constant-temperature exposures, and consequently a higher percentage of the alcohol-insoluble substances, largely inulin or higher inulides. Further, the data show that of this alcohol-soluble fraction, a smaller proportion is present in the form of free reducing substances, the most labile form of carbohydrates. The maximum free reducing substance and free levulose contents occurred at 15 days' exposure for all temperatures below 50°, but not until 75 days' exposure at 50°.

The reducing substances other than levulose in the total hot-water-soluble fraction (largely glucose) in Blanc Ameliore also indicate that at 50° F. a smaller proportion of the hot-water-soluble reducing substances are in the form of the more labile (higher-dextrose-containing) substances than at 32° exposures, particularly during the first 45 days of treatment. Since no analyses were made on this variety, there is no justification for assuming that the free reducing-substance content of the 50° samples was different from that of samples treated at lower temperatures. This is particularly true in view of the fact that almost no free levulose was found and that analyses of certain bud samples, given later in this bulletin (p. 41), showed no free reducing substance where no free levulose could be detected.

A higher free levulose content during the first 45 days of exposure at 32° F. than at 50° is observed in table 17. It appears, however, that this is not of universal occurrence under these conditions, since the free levulose content was either nonexistent or so small as to be unmeasurable in the variety Blanc Ameliore.

The acid-hydrolyzable hot-water-insoluble polysaccharide fraction formed a slightly higher percentage of the dry matter from the 30- to 75-day lengths of exposure at 32° F. than at 50°. The differences are not large, however, and are probably of little significance.

1932 BUD ANALYSES

Tables 18 and 19 give data on the composition of buds of the Blanc Ameliore and Chicago tubers.

TABLE 18.—*Chemical composition of buds from Jerusalem-artichoke tubers of the variety Blanc Ameliore previously subjected to different temperature conditions for various periods in 1932–33*

[Dry-weight basis]

DRY MATTER (FRESH-WEIGHT BASIS)

Treatment [1] (° F.)	Chemical composition after treatment for—				
	15 days	30 days	45 days	60 days	75 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Control [2]	28.45	28.45	28.45	28.45	28.45
32 LH	31.29	[3] 34.48	34.21	36.29	41.29
32 HH	33.10	[3] 27.66	28.62	30.61	33.36
36	31.77	30.42	[3] 29.81	30.53	30.31
50	32.42	32.84	31.85	[3] 32.75	37.11
Field pit	27.58	[3] 25.10	----	23.19	22.91

FREE LEVULOSE

Control	0	0	0	0	0
32 LH	3.27	[3] 2.38	2.52	.78	1.43
32 HH	2.09	[3] 2.28	1.43	----	1.19
36	1.80	1.78	[3] 1.54	.67	.43
50	.28	.71	.33	[4]	.60
Field pit	.52	[3] .08	----	.05	0

FREE REDUCING SUBSTANCES (AS DEXTROSE)

Control	1.06	1.06	1.06	1.06	1.06
32 LH	3.83	[3] 3.99	4.47	1.83	2.61
32 HH	2.40	[3] 3.85	2.50	2.20	2.19
36	2.46	2.88	[3] 2.64	1.75	1.61
50	.84	1.74	1.10	[4]	1.47
Field pit	1.61	[3] 1.38	----	1.05	1.07

TOTAL LEVULOSE

Control	51.42	51.42	51.42	51.42	51.42
32 LH	51.86	[3] 49.18	47.75	47.13	44.35
32 HH	50.60	[3] 46.17	44.87	47.34	46.69
36	50.45	48.11	[3] 48.62	47.44	46.55
50	51.66	53.28	50.67	[3] 54.54	49.29
Field pit	47.09	[3] 47.54	----	44.65	43.13

TOTAL ALCOHOL-SOLUBLE REDUCING SUBSTANCES (AS INVERT SUGAR)

Control	48.84	48.84	48.84	48.84	48.84
32 LH	50.53	[3] 62.03	60.39	56.05	58.04
32 HH	60.31	[3] 61.79	58.88	62.06	60.13
36	61.93	64.26	[3] 62.70	58.44	61.53
50	49.36	57.45	57.43	[3] 61.25	55.84
Field pit	57.04	[4]	----	55.72	57.36

TOTAL HOT-WATER-SOLUBLE REDUCING SUBSTANCES (AS LEVULOSE)

Control	74.60	74.60	74.60	74.60	74.60
32 LH	75.16	[3] 83.24	76.26	71.60	70.71
32 HH	78.40	[3] 72.92	61.83	73.50	73.97
36	79.30	75.62	[3] 74.59	73.96	73.35
50	74.30	76.11	74.16	[3] 81.78	75.69
Field pit	74.49	[3] 68.53	----	67.70	63.89

See footnotes at end of table.

TABLE 18.—*Chemical composition of buds from Jerusalem-artichoke tubers of the variety Blanc Ameliore previously subjected to different temperature conditions for various periods in 1932–33*—Continued

ACID-HYDROLYZABLE HOT-WATER-INSOLUBLE POLYSACCHARIDES (AS DEXTROSE)

Treatment (° F.) [1]	Chemical composition after treatment for—				
	15 days	30 days	45 days	60 days	75 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Control	3.07	3.07	3.07	3.07	3.07
32 LH	2.97	[3] 3.93	3.40	3.95	4.35
32 HH	3.01	[3] 3.65	3.70	4.33	3.82
36	2.70	3.60	[3] 3.23	3.84	4.18
50	3.56	3.35	3.64	[3] 3.54	3.36
Field pit	3.65	[3] 3.59		4.19	4.00

[1] LH=low humidity; HH=high humidity.
[2] Original tubers at harvesttime.
[3] Time of termination of rest as judged by 50-percent sprouting occurring within 15 days after planting of treated tubers.

TABLE 19.—*Chemical composition of buds from Jerusalem-artichoke tubers of the variety Chicago previously subjected to different temperature conditions for various periods in 1932–33*

[Dry-weight basis]

DRY MATTER (FRESH-WEIGHT BASIS)

Treatment [1] (° F.)	Chemical composition [2] after treatment for [3]—				
	15 days	30 days	45 days	60 days	75 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Control [4]	34.65	34.65	34.65	34.65	34.65
32 LH	34.33	[5] 34.04	35.65	34.74	38.11
32 HH	34.57	[5] 32.88		31.25	34.86
36	33.70	33.11	(6)	32.30	30.02
50	37.89	31.28	28.66	29.13	34.98
Field pit	30.70	24.20	[5] 23.99	23.13	23.90

TOTAL LEVULOSE

Control	48.53	48.53	48.53	48.53	48.53
32 LH	45.28	[5] 46.19	40.67	39.24	41.35
32 HH	43.88	[5] 43.21		37.25	42.22
36	43.77	43.14	(6)	46.13	37.08
50	46.27	45.20	44.54	42.45	44.02
Field pit	45.34	41.43	[5] 43.12	39.85	42.66

TOTAL ALCOHOL-SOLUBLE REDUCING SUBSTANCES (AS INVERT SUGAR)

Control	45.39	45.39	45.39	45.39	45.39
32 LH	47.87	[5] 46.93	46.01	40.00	45.07
32 HH	43.98	[5] 47.04		44.80	47.43
36	47.50	44.46	(6)	44.98	42.74
50	37.18	41.39	42.44	40.80	38.90
Field pit	49.90	46.06	[5] 48.36	46.66	48.64

TOTAL HOT-WATER-SOLUBLE REDUCING SUBSTANCES (AS LEVULOSE)

Control	70.58	70.58	70.58	70.58	70.58
32 LH	66.78	[5] 69.50	63.34	61.50	62.76
32 HH	64.00	[5] 62.57		60.58	62.40
36	65.53	60.26	(6)	63.54	55.78
50	64.64	65.07	64.68	61.32	62.71
Field pit	67.74	63.39	[5] 63.59	60.19	61.85

See footnotes at end of table.

TABLE 19.—*Chemical composition of buds from Jerusalem-artichoke tubers of the variety Chicago previously subjected to different temperature conditions for various periods in 1932–33*—Continued

ACID HYDROLYZABLE HOT-WATER-INSOLUBLE POLYSACCHARIDES (AS DEXTROSE)

Treatment (° F.)	Chemical composition after treatment for—				
	15 days	30 days	45 days	60 days	75 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Control	4.05	4.05	4.05	4.05	4.05
32 LH	3.57	[5] 4.48	4.85	4.58	4.82
32 HH	3.84	[5] 4.36	----	4.78	4.83
36	4.07	4.83	(3)	4.40	5.23
50	4.00	4.46	4.43	4.48	4.06
Field pit	4.10	5.17	[5] 4.56	4.58	4.65

[1] LH=low humidity; HH=high humidity.
[2] No free reducing substances nor free levulose were found under any temperature treatment or period of storage.
[3] Leaders indicate that no analyses were made due to loss of the chemical samples.
[4] Original tubers at harvesttime.
[5] Time of termination of rest as judged by 50-percent sprouting occurring within 15 days after planting of treated tubers.

Large fluctuations in the content of total hot-water-soluble reducing substances are again observed in the variety Blanc Ameliore. The percentages in Chicago are much less variable. No consistent effect of temperature on the magnitude of this fraction is evident from the data. Larger differences are shown by samples stored under the two conditions of humidity at 32° F. than exist between either of these and the 50° exposure.

The total levulose content of the 50° F. samples is generally higher in both varieties, and total alcohol-soluble reducing substances lower than those of either 32° treatment.

No free reducing substances or free levulose were found in any samples of Chicago. This is a very striking fact when the data for Blanc Ameliore at the same time show up to 4.5 percent of the dry matter to be in the form of free reducing substances and almost 3.3 percent of the dry matter to be present, in one case, as free levulose. Moreover, the excellent correlation of the temperature of constant-temperature exposures with the content of both these fractions in Blanc Ameliore gives a strong suggestion of some importance of free levulose and free reducing substances to the general regularity of the rest breaking response to temperature. However, since these changes do not occur, or at least are not apparent, in all varieties, it must necessarily be concluded that any suspected relationship probably does not really exist. It will be recalled that only traces of free levulose could be found in the 1931 whole-tuber samples of Blanc Ameliore, yet the buds of similar tubers in the same variety showed considerable amounts of free levulose in 1932.

The content of acid-hydrolyzable hot-water-insoluble polysaccharides in both varieties was lower at the lower temperatures of exposure than at 50° F. at the end of the first 15-day period of exposure, but thereafter the lower temperatures generally gave somewhat higher values than the 50° treatment.

It is difficult to see any correlation of time of emergence from rest with chemical data obtained on the whole tubers or on buds of such tubers in any of the three varieties. There is no conclusive evidence

that any particular percentage value of the various constituents studied or of ratios of these constituents to each other determines the time of termination of the resting condition. Comparisons of results of sprouting tests, given in tables 12 and 13, with these chemical analyses do show, however, that growth of buds occurs at a time when the total levulose content is at or near a minimum and the more soluble carbohydrate constituents are at a correspondingly high value.

DISCUSSION

It appears that the factor releasing first growth of buds is entirely separate from those changes in composition that allow later growth to attain normal expression. In practice, treatments are required that not only break the rest period but promote normal growth as well. The low-temperature treatments apparently influence both responses favorably, whereas higher ones may affect neither response very much, or possibly only the second.

Although a few chemical treatments of these experiments were found effective in breaking rest, it is significant that very few of them gave subsequent normal growth such as resulted with low-temperature treatments. Apparently, at least some of the effective chemical treatments influence the first of these responses favorably, but not the second. Since no determinations were made of the chemical composition of tubers subjected to chemical treatments, it is impossible to tell whether lack of normal development of sprouts after rest had been broken was determined by or related to changes in composition.

While discussing the matter of inferior growth following certain treatments, it seems a justifiable criticism of certain investigations of the rest period, at least one of which included the Jerusalem-artichoke (*31*), that the time of breaking of rest was measured by the time when sprouts were visible above ground. In reports of the investigations referred to, no mention was made of the depth of planting in soil, and it is assumed therefore that it was probably at least one-half inch. It is obvious that while rest was broken in some of the tubers illustrated in the plates (for example, lots c, 1, 2, 6, and 10 in plate 5, *A*), no sprout growth would be visible above ground for some time if the tubers were planted at any ordinary planting depth (the tubers illustrated in plate 5 were purposely kept just at the soil surface). An investigator might thus conclude that certain lots of tubers were still in a resting condition when as a matter of fact they might already be out of rest but incapable of making normal growth. Such a method of judging termination of rest seems to confuse the matter of rest with that of normal growth. The evidence from both chemical and temperature treatments in this study indicates that the two conditions are regulated by entirely different agencies (at least directly), and that care must be taken to differentiate between them.

Denny (*21*) has reported increases in the sucrose content of potatoes treated with ethylene chlorhydrin, sodium thiocyanate, and thiourea, similar to the changes resulting from exposures to low temperatures as reported by Appleman (*3, 4, 6*) and others. Denny suggests that in judging the effectiveness of a chemical in breaking rest the sucrose changes may be better evidence than the changes in reducing sugars. In the present Jerusalem-artichoke experiments in some varieties

fairly large and apparently significant differences were noted in the free reducing substance and free levulose fractions of samples treated differently to break the rest period, yet in tubers of other varieties these fractions were not evident in amounts large enough to be measurable. This makes it seem highly dubious that any great significance in the breaking of rest can be attached to these fractions. Sucrose was not isolated and determined, as such, in these experiments, but the data do show that the total alcohol-soluble reducing-substance fraction, which includes sucrose, was at a high value at the time active growth of buds resulted.

That changes in the chemical constituents studied are not directly associated with termination of rest is further evident from comparisons of the composition and behavior of field-pit tubers or buds of such tubers with those of the samples treated at 50° F. Sprouting tests show that rest is broken considerably sooner in the field pit than at 50°, yet some of the carbohydrate fractions of field-pit tubers that might otherwise be suspected of being important to growth release, show more similarity to the 50° samples than to any other treatment used. Obviously, if the composition of the tubers or buds determined the resting or nonresting condition, then samples as unlike in sprouting response as the field-pit and 50° samples ought to be more dissimilar in composition than lots showing more similar sprouting responses, for example, the field-pit and 36° or 32° samples.

The main effect of the effective temperature treatments upon the chemical constituents analyzed appears to have been in making available the more labile materials necessary for normal growth independent of some other, as yet unknown, controlling factor (possibly something of the nature of a hormone) that was activated or set in motion by the exposure, thus making growth possible. These experiments were not designed to ascertain the relationship between composition and normal growth. It appears, however, from the analyses of buds and observations on the character of growth obtained in the sprouting trials that for normal growth of buds to occur, once rest is broken, a relatively large amount of the more labile alcohol-soluble materials must be available. With storage temperatures as high as 50° F. the process of transformation of the more stable reserves to the more labile forms is apparently retarded, and more of the labile forms are used up in respiration than with lower storage temperatures. There are consequently less of the readily usable materials available, and a more or less stunted growth results. However, with the lapse of a sufficiently long time, apparently enough of the required materials are accumulated to permit normal sprout development even at 50° F.

No consistent relation was evident in these studies between catalase activity and respiration of buds and tubers of the two varieties studied in two seasons, or between these factors separately and the sprouting response.

The catalase values of cortex, pith, and terminal buds at each temperature exposure in each season showed a fairly consistent tendency to exhibit parallel variations. This suggests that catalase activity measures a general systemic response to the treatments, and not necessarily a response in the bud alone, in which rest-period changes are thought to be localized.

That the terminal-bud catalase values for the 50° F. exposures are, in general, higher than those for the corresponding 32° samples in the variety Blanc Ameliore is a somewhat puzzling result. Just the opposite might be expected, since the 32° samples were the ones showing the growth response first and in a more vigorous manner. If catalase measures the relative metabolism, then the 32° samples would be expected to show the greater magnitude of catalase values. From an examination of the data for the variety Chicago in 1934, it is found that the catalase values are higher with the 32° treatment, not only in the buds but also in the cortex and pith. It is possible that in these experiments the catalase determinations were made too soon (the next day) after removal from constant temperature storage to allow the 32° samples to attain their maximum catalase activity, while the 50° samples may have already reached the maximum. There is another possibility—that catalase activity of Jerusalem-artichoke tubers is gradually reduced with storage at 32° in a manner similar to that found in potatoes by Appleman (*2*), who suggested that the reduction might be due to accumulation of organic acids at the low temperature. If such were the case, why did the variety Chicago show higher values in 1934 with 32° storage than with the 50° treatment?

It is surprising that the differences between the respiratory rates of the 32° and 50° F. lots were not larger than the data show them to be. Table 15 shows that the 50° samples suffered much greater losses in weight during storage than the 32° samples, and that a much greater amount of the weight loss was due to loss of substances other than water. Since the necessarily higher respiratory rate of the 50° samples during storage must have occurred at the expense of the simpler reserve substances and since there is a larger proportion of the more labile carbohydrates in the 32° samples, one would expect a much higher respiratory rate in the 32° samples than in those at 50° upon removal to the 77° temperature. Kimbrough (*43*), working with potatoes, found a much higher respiratory rate to occur for a period after removal from low-temperature storage than in potatoes stored continuously at higher temperatures.

Regardless of whether the storage temperature employed in the present studies was 32° or 50° F., the data show that in general the longer the tubers were stored at either of these temperatures the higher was the respiratory activity upon removal of the tubers to a temperature of 77°. The respiratory rate observed at the latter temperature continued to increase with the duration of storage at 32° or 50° up to the time the studies were terminated (after over 10 weeks of such storage). In the case of the potato, Kimbrough (*43*) found that the maximum respiratory rate at 72° was obtained after only about 3 weeks of storage at 36°.

Although this study was concerned primarily with the rest-period problem, it has supplied considerable data with regard to storage of the crop and also methods of handling required where the tubers are to be utilized in various industrial processes such as levulose production or alcohol manufacture. The data have confirmed the recommendations of others that temperatures slightly above freezing and high humidities are essential to maintenance of the tubers in good condition and reasonably free from storage rots. The results of the chemical analyses show clearly that if the maximum inulin or levulose

content is desired in any manufacturing process, tubers must be used when they have reached their greatest development and before they have been stored for any appreciable length of time. Delaying the time of utilization beyond this period will invariably result in lowered percentage and absolute yields of levulose and other carbohydrates.

It seems desirable also to point out that this study has been largely an exploratory one. Very little was known about the rest period of the Jerusalem-artichoke when this study was started; in fact, a single short paper by Boswell (*10*) then comprised the entire literature on the subject. The first attack on the problem was a practical one—finding means of terminating the resting condition. Although the results of chemical treatments were on the whole rather disappointing, those with temperature treatments have been very gratifying. Subsequent studies on initiation of rest, catalase activity, respiration, and chemical composition have only opened up starting points for more intensive studies of the fundamentals underlying the whole rest-period problem in this crop. In conducting these investigations it might have been desirable to have used but a single variety for all studies. It is felt, however, that it has been helpful rather than detrimental to have used several varieties, not always the same in all seasons. This course has, for instance, proved the universality of the sprouting response to low-temperature exposures, and at the same time it has prevented drawing of erroneous conclusions concerning composition and physiological behavior. The responses of a single variety in a single season may or may not be that of all varieties in the same or different seasons.

SUMMARY AND CONCLUSIONS

Changes in size, number, and composition of tubers of two varieties of Jerusalem-artichokes were studied during the period of tuber formation and entrance into the rest period in the field. Catalase activity of stolons, tubers, and buds was measured to determine the relation between entrance into rest (as indicated by sprouting tests) and the metabolic conditions of the organs.

Of the total weight of tubers and stolons, during the period of tuber formation, the proportion represented by the larger tubers increased more rapidly than the proportion of these larger tubers in the total number of tubers and stolons produced. This is interpreted as indicating a physiological dominance of the large (first-formed) tubers, which apparently gives them a first call on elaborated growth and storage materials.

Time of entering rest varied with the tuber size. The largest tubers were the last to become dormant.

Sprouting tests indicate that entrance into rest is a quite gradual process—not an abrupt change, regardless of the tuber size studied.

Catalase activity of stolons and terminal buds of tubers reached a maximum value at, or a short time preceding, the entrance into complete rest. Catalase values for terminal buds of tubers at the time the largest tubers entered complete rest formed an ascending series corresponding to the increasing sizes of tubers from which the bud samples were taken. Although catalase activity decreased from this time onward, in most cases the larger-sized tubers continued to have the higher catalase activity.

Chemical analyses of tubers 1.9 to 2.4 cm in diameter and of buds of tubers over 1.4 cm in diameter showed the latter to exhibit much greater changes in composition during the period of tuber development in most of the carbohydrate fractions than the whole tubers. The percentage of total hot-water-soluble reducing substances, total levulose, and dry matter were lower, and the percentages of free reducing sugars and total alcohol-soluble reducing substances higher in the buds than in the whole tubers during the early stages of development. As compared with buds, only relatively small changes occurred in the whole tubers during the period studied. There was a tendency for the percentages of the various constituents in the buds to approach those of the whole tubers toward the end of the period studied (around October 10).

The available data indicate that an accumulation of the less labile reserve carbohydrates such as inulin and the higher inulides bears a high degree of association (but not a causal relation) to the resting condition.

About 50 different treatments involving 15 different chemical compounds, applied in different ways and in varying concentrations, were used on four varieties of Jerusalem-artichoke tubers during two seasons. Only four of the chemical treatments tried were found consistent in giving sufficient shortening of rest and worthy to be recommended for further use, without having noticeable toxic effects on the tubers. Other treatments were found which shortened the rest period but which were decidedly injurious to the tubers. None of the chemical treatments tried were entirely satisfactory in giving rapid sprout development after the rest period was broken.

The effects of holding four varieties of Jerusalem-artichokes in cold-storage rooms at 15°, 18°, 32°, 36°, and 50° F., and in field pits for various periods, on the sprouting response, catalase activity, respiratory rate, and chemical composition of the tubers were studied.

The sprouting response was poor from the lots held at 15°, 18°, and 50° F. Freezing injury occurred at the two lowest temperatures. The sprouting response was very prompt and vigorous from tubers stored at 32° and 36° and in field pits, and was best at 32°. The period of exposure required for good responses at the 32° and 36° and field-pit exposures varied somewhat between seasons and between varieties, but 30 to 45 days' exposure gave good sprouting and good subsequent growth in all varieties and seasons studied.

The data secured showed no conclusive evidence of any correlation of chemical composition of tubers, or buds of tubers, with time of emergence from the rest period. The data did show, however, a gradual attainment of a low value of total levulosans and of a correspondingly high value for the more soluble carbohydrate constituents from harvest up to the time growth of buds occurred.

Although the content of free reducing substances and that of free levulose showed excellent inverse relationships with temperature of exposure in some varieties, none of either of these fractions could be detected in tubers of other varieties subjected to the same conditions. It is concluded, therefore, that these substances cannot be important in the growth-release process.

There was a tendency for both the whole tubers and buds of tubers subjected to 50° F. exposures to be higher in levulose and the ratio of levulose to hot-water-soluble reducing substances, and lower in

alcohol-soluble reducing substances than those exposed at lower temperatures.

In the single variety and season in which certain nitrogen fractions were determined there was not a good correlation of the nitrogen fractions either with the temperature of exposure or with breaking of the rest period.

The chemical constituents studied in the variously exposed tubers or buds of tubers do not appear to control or be related to breaking of rest, although at least some of the constituents seem important in determining the vigor of sprout growth following termination of rest.

No consistent relation was found between catalase activity of buds and tubers and respiration of tubers of the two varieties studied in two seasons, or between either of these factors and the sprouting response after storing the tubers at 50° and 32° F.

These investigations have provided considerable evidence suggesting that breaking of rest in buds is governed by an entirely different agent from that governing subsequent development of the activated buds. The two factors have apparently been confused in the past, and it is pointed out that termination of the rest period, at least in some plant materials, cannot be judged with certainty by the time sprouts appear above ground in sprouting tests.

The chemical analyses of tubers stored under the various conditions indicate that where tubers are to be used for manufacturing purposes requiring a high inulin or levulose content, it is essential that they be used immediately after harvest, or after only relatively short periods of storage. Prolonged storage results in marked reductions in both the percentage and absolute yields of levulose.

Large losses due to rotting of tubers occurred during storage at 50° F. Storage temperatures slightly above freezing are essential in reducing such losses to a minimum.

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