STUDIES ON THE REST PERIOD OF TUBERS OF THE JERUSALEM ARTICHOKE. (*Helianthus tuberosus*, L.)

By

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A Thesis submitted to the Faculty of the Graduate School
Of the University of Maryland in partial
fulfillmant of the requirements for
the degree of Doctor of
Philosophy

June
1936

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INTRODUCTION.

For many years the rest period of plants and plant organs has been the subject of much speculation, discussion, and experimentation. Many studies concerning this physiological state have practical aspects of considerable economic importance. Among these may be cited the numerous studies on the rest period of tubers of the Irish potato (*Solanum tuberosum*) intended for seed purposes, of flowering shrubs and bulbs intended for forcing purposes, and of fruit trees, such as the peach and pear, which require certain definite intervals of exposure to low temperature during the dormant season for continued normal growth and development. Many plants, some economically valuable, others of scientific interest only, have been used in rest period investigations.

Within the last few years the Jerusalem artichoke (*Helianthus tuberosus*) 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 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. In the United States it 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 in Oregon. The culture of this plant in the warmer regions of the South has been limited, and cases are known where the crop was a failure under such conditions. At least one report from a tropical region, that of Piper (58) in the Philippines, has cited the crop as a failure. Our knowledge of the performance of the crop under hot climatic conditions is very meagre. Possibly under the hot climatic 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 (11) who noted a remarkably long rest period (over seven 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.

Assuming the general growing conditions of warm regions to be favorable to successful growth of the Jerusalem artichoke, but an unfavorably long, or slowly broken rest period to be the chief retarding 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 seedstock for a winter-grown crop in a warm region, or again 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 to apply to the resting tubers so that prompt, vigorous, and uniform sprouting of the seed tubers will result.

The tubers of the Jerusalem artichoke resemble, in their general structure, tubers of the Irish potato on which many dormancy and rest period studies have been made. There are, however, at least two outstanding differences between the tubers of these two crops: (1) the chief storage carbohydrate in the potato is starch, a polysaccharide composed principally of glucose condensation products, whereas that of the Jerusalem artichoke is inulin (and closely related inulides), made up largely of levulose condensation products; (2) the potato tuber has a corky covering or periderm that is resistant to loss of water and wounding whereas the artichoke has no such corky covering. Certain workers have suggested that rest in potato tubers may be due, at least partially, to restriction of gaseous exchange by the corky periderm. It seems that this factor could not be important in the Jerusalem artichoke where the suberized layer is not normally present. In view of these physiological and morphological differences between tubers of the two crops, it seems likely that evidence which has been supplied by rest period investigations on the potato might not be entirely applicable to the Jerusalem artichoke.

STATEMENT OF THE PROBLEM AND ITS APPROACH.

The experimental work reported in this paper was designed, (1), to find means of abbreviating the normally long rest period of tubers of the Jerusalem artichoke when not previously exposed to temperatures much below 50°F., (2), to determine 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 termination of the resting condition. To these ends 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 given numerous chemical and temperature treatments designed to abbreviate the rest period.

Although the studies on entrance into rest were initiated later than those on emergence from rest, the studies on entrance will be presented first in this paper.

REVIEW OF LITERATURE.

A voluminous literature has developed on the general subjects of rest period and dormancy. In spite of its vast extent, however, the exact nature of the resting condition and the fundamental causal agencies involved are still largely unknown. No attempt will be made in this paper to cover all the literature available on rest period studies. Only those papers, available to the writer, which appear pertinent to the present investigations will be cited.

Many theories have been advanced as to the nature of the rest period and some of the possible actions of agents used in breaking rest. Excellent reviews of the literature on these subjects have been presented by Howard (39, 41) and Appleman (5,7). Among the suggested methods for terminating the resting condition in various plants or plant organs, those of exposure to various temperatures, and of application, in any of several ways, of various chemicals to the dormant plant materials, have

been most widely used and most studied.

A very extensive number of chemicals has been reported by numerous workers, which have been used effectively to shorten the rest period in a wide variety of plants. Johannsen (44) working with the etherization of plants was the first to show a growth-inducing effect by chemical treatment. Hempel (37) has since presented a very good summary of the effects of narcotics on plants. The diverse nature of some of the compounds used in breaking rest can be noted in the list, given in the paper of Denny (20), containing some thirty chemical substances reported by various workers as effective on potatoes. Many more substances have been found effective on potatoes and other plants. It still remains a matter of conjecture as to just what the common function of these numerous chemical substances with such very widely varying chemical properties can be in stimulating the dormant plant to growth. Denny (23) has said, "In discussing use of chemical treatments in breaking dormancy the difficulty consists in understanding why so many different kinds of chemicals can produce approximately the same or at least similar results . . . . . It has not been possible at present to find a correlation between results obtained and the chemical characteristics of substances used in treatments."

Rosa (60) in certain of his investigations thought the action of certain chemicals in breaking rest in potatoes was due to their general characteristic of being vigorous oxidizing agents. Boswell (10), Jones (46), and Appleman (7) have also thought that in certain cases stimulation of growth in some resting plants may have been due to the influence of oxygen or oxidizing compounds. However, the fact that all rest breaking

compounds are not oxidizing substances makes it appear unlikely that oxidation is the direct controlling factor, but rather that the effect is an indirect one on some other more fundamental controlling agency. What the latter is has not yet been determined.

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

Among others, Loomis (49), Rosa (61), Schmid (62), Werner (70), and Wright and Peacock (71) have reported relatively high storage temperatures more effective than lower temperatures in inducing emergence from dormancy in potato tubers. Similar responses have been reported for gladiolus corms by Loomis (50), Loomis and Evans (52), Fairburn (27), and others. The many investigators of dormancy in seeds have found in most cases a distinct advantage in low temperatures for after-ripening. Steinbauer (63), and Haber (33) have shown low temperatures to be much more effective than high ones in breaking the rest in tubers of the Jerusalem artichoke. Loomis (51) found temperatures either 15°C. above or 15°C. below normal (normal assumed as approximately 20°C.) to cause a number of plants which 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. Thus Coville (17), with the woody plants which he studied, considered the main effect of low temperature treatment to be in changing the permeability in the plant cells in such a manner as to allow enzymes to get to the

stored starch. According to his reasoning the change of starch to sugar is intimately associated with a more active metabolism necessary to starting of growth. Howard (41) likewise considered the effect of all rest-breaking agents on woody plants to lie in stimulation of enzyme activity, especially by the effect on the relationship of the enzyme to the products of enzyme action. Recent excellent investigations by Denny, Guthrie, Miller, and Stanton (24, 25, 31, 55 and others) at the Boyce Thompson Institute have added much to our knowledge of the effects of chemical treatments on enzyme activity. It is significant that data of Denny (24) support the idea that "the effects of chemicals in inducing sprouting (in potatoes) are indirect, and not due to direct effect upon amylase activity." It seems likely that this is also true with other enzymes active during sprouting.

Studies on changes in composition of plants as a result of rest-breaking treatments have been, for the most part, concerned with carbohydrate constituents. An increased sugar content and a decreased starch content as a result of low temperature storage, have been reported for potatoes by Muller-Thurgau (57), Appleman (3, 4, 7), and Hopkins (38). Loomis (51) found similar chemical responses in storage tissues whether rest breaking resulted from high or low temperatures. In all cases there was an accumulation of available carbohydrates, particularly sucrose, in the treated tissues. Howard (40) and Gardner (29) studied these carbohydrate changes in deciduous fruit trees and noted sugar accumulations with low temperature exposures. Neither of these workers proved these carbohydrate changes essential to growth initiation. Some idea of the effects of low temperature exposures on composition of Jerusalem artichoke

tubers can be gathered from the data of Traub, Thor, Willaman, and Oliver (68), and of Colin (14). 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 (22) has found in potatoes treated with various rest-breaking chemicals, carbohydrate changes similar to those found in tubers subjected to temperature treatments. He reports a higher sucrose content but no consistent change in reducing sugar content upon treating tubers with sodium thiocyanate and ammonium thiocyanate. The sucrose content formed a regular series corresponding with the series of chemical concentrations employed. The actual percentage of sugars or reserve polysaccharides in resting or non-resting plant organs may have nothing to do with rest itself. Appleman (4) 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 the various workers (Appleman (5), Denny (21), Combes (16), Stuart and Appleman (65), Müller-Thurgau (57), 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. As early as 1911, Appleman (3) reported a belief that changes peculiar to after-ripening

might be in the buds, and that the metabolism of the tuber as a whole might bear little or no causal relation to these processes. Howard (42) in 1915, made the statement that "the secret of the rest period lies in the buds rather than in the cambium, roots, or any of the tissues of trunk or branches." Coville (17), in 1920, was able to localize within certain branches, the response of blueberry to low temperature. Perhaps the best proof we have of the rest being localized in buds is that provided by the experiments of Denny and Stanton (26). These workers, by applying chemical treatments to one bud of each pair on the opposite sides of lilac twigs were able to force the treated buds into growth while the opposite ones remained dormant. In the light of the knowledge of this localization of response it is rather surprising that investigators of the rest period problem have not made more analyses of bud tissues.

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. Kimbrough (47) found the respiratory rate of potatoes stored at temperatures between 32°F. and 50°F. to be much higher for a time after removal to a higher temperature than when held continuously at the higher temperature, and the lower the storage temperature, the higher the initial respiratory rate. About three weeks storage at 36°F. was necessary before the maximum respiratory rate was reached upon removal from storage. Appleman (3, 6) found a striking correlation of catalase activity with respiratory activity of potato tubers previously held in cold storage where the temperature had not fallen below 3°C. After storing at 0°C. the catalase activity was less than in tubers in ordinary storage, a fact which Appleman thought due to destruction of

catalase by accumulation of free acids. He also found catalase activity to be greater at the end of the rest period than at the beginning (2).

Denny, Miller, and Guthrie (25) found increases in catalase activity and pH of juices of potatoes treated with ethylene chlorhydrin, sodium thiocyanate, or thiourea to break the rest period. The increases in catalase were not direct effects of chemicals on the enzyme because the activity of the juice was not increased by adding the chemical directly to the juice, but only when the chemical was applied to the tuber. They observed a series of catalase values corresponding to the concentration of chemical used on the tubers. Guthrie (31), using eleven chemicals on potato tubers, was able to find no good correlation between the effects of the chemical treatments on growth and the changes in catalase activity and pH. A similar lack of relation of catalase activity to effectiveness of a number of sulphur compounds in breaking rest of potatoes was also reported by Miller (55). He does point out, however, that when dormancy is broken by chemicals or naturally there is always some increase in catalase activity. Results of Guthrie, Denny, and Miller (32), on gladiolus, show that ethylene chlorhydrin treatments produced increases in catalase and pH with both dormant and non-dormant corms. Barton (9), Crocker and Harrington (18), Davis (19), and Flemion (26) have reported increased catalase activity in various seeds after-ripened at low temperatures. It is apparent from these more or less conflicting reports that no consistent relationship of catalase activity to the resting condition has yet been proven.

Decreased acidity during the dormant period also appears, from the literature, to be quite general in occurrence and occurs even though no artificial treatment be applied to the plant.

Although the composition of Jerusalem artichoke tubers has been studied by numerous investigators, most of the analyses have been published without statements 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 for which the resting or non-resting condition of the tubers was known, or at least reported. Tanret (66) was probably the first to make a careful analysis of the reserve carbohydrates present in tubers harvested in the fall, and to state the properties of the various levulosans he found. His work shows that there is no single, predominating reserve in the artichoke corresponding to starch, but rather inulin and a graded series of levulosans differing in their solubilities and other properties. Colin (14), in 1919, presented data on analyses of artichoke tubers dug at intervals between July 28 and Nov. 17. Unfortunately his analyses were made on different size 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 are never more than very small amounts of reducing sugars present during the period studied, and that the percentage content of sucrose, and inulin in the various samples did not vary much between July 28 and Nov. 17. Meyer (54) 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 (15) for tubers analyzed during growth, on October 2, October 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 (67) have confirmed the properties of the levulosans isolated from 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 due, at least partially, to sucrose. Traub, Thor, Zeleny, and Willaman (69) reported a slightly increased ratio of fructose to glucose in tubers of four varieties of artichokes grown under Minnesota conditions, when analyzed on August 30, and November 3, and almost no change in the ratio of fructose to total sugars in the same period.

PART I.

ENTRANCE INTO THE REST PERIOD

Materials and General Methods

On April 4, 1933, a row of the variety Chicago was planted from uniform one-ounce tubers, on a gently sloping plot of gravelly loam soil at the U. S. 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 one-ounce tubers in the same field and about 50 feet distant from the 1933 location.

Beginning on July 19 in 1933 and on July 23 in 1934 when tuber formation had begun, and at approximately 10-day intervals thereafter until early October (also one sample on Nov. 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[1] and tubers in each of the several size classes recorded, and samples of tubers, stolons, or buds of tubers over 1.4 cm. in diameter, preserved for chemical analyses. In 1934 catalase determinations also were made on composite samples of stolon, tuber, or bud tissues 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°F. in the day time. (During July and August it was impossible to keep the maximum temperature down to 85°F on some days). Periodic

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[1] Unless specified otherwise, the term "stolon" refers in this paper 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.

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 fifteen or more days). The 1933 sprouting trials 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. All diggings were begun about 9:00 A.M., and required about 2 hours for completion. During this period dug tubers were kept in a manila bag in the shade, beneath wet burlap. Immediately after completion of digging, the samples were taken to a Washington, D. C., laboratory of the U. S. Department of Agriculture (about 15 miles distant) where the samples were washed in cool water, dried with towels, and the various tuber sizes classified. After weighing and counting the tubers or stolons in each class, a random composite sample was taken from each class, the tubers or stolons cut into approximately one-eighth inch thick slices, and duplicate samples of the cut material quickly weighed out and dropped at once into sufficient boiling 95% alcohol (in glass-top fruit jars containing 0.2 gram calcium carbonate) to give a final concentration of about 80%. After boiling in a water bath for 15 to 20 minutes, the jars were sealed and set away until the time of analysis. The total time from completion of digging until completion of sampling was, for the later, larger, samples, about 4 hours. For the earlier diggings with fewer tuber-size classes the time was, of course, less than this.

Buds for analysis were removed from tubers over 1.4 cm. in diameter with a 9 mm. cork borer and the tissue deeper than one-eighth inch below

the base of the bud 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 tube. The alcoholic filtrate was transferred to a 500 ml. volumetric flask. The residue was extracted in the Soxhlet apparatus for 16 to 20 hours with 80% alcohol in the extraction flask and this extract was added to that in the 500 ml. volumetric flask, and the volume made to the 500 ml. mark.

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 aid of an air stream, then drying to constant weight by successive 30-minute dryings at 80°C. in an oven. The relatively low temperature and short drying periods were used in order to avoid caramelization of the large quantities of carbohydrates present in the extract.

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

Carbohydrates. Two hundred fifty ml. of the alcoholic extract were evaporated to a thin syrup free of alcohol in a 400 cc. beaker on a water bath at 70° - 80°C. with the aid of an air stream. To this syrup 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 an hydraulic press with a pressure of 3000 lbs. 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 then cooled, the contents made to volume with water. A 50 ml. aliquot withdrawn into a 100 ml. volumetric flask was then clarified with saturated neutral lead acetate solution, made to volume with water, and filtered. 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 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 (43), using the volumetric permanganate method for determining reduced copper.

To the 200 ml. portion of the expressed juice in the 250 ml. flask 7.5 ml. of 8.12 N HCl were then added, and the flask placed in a water bath at 70° ~ 80°C. for 35 minutes, after which the flask was cooled.and cleared with neutral lead acetate. A white precipitate of lead chloride was first formed, followed by precipitating colloidal matter. Contents of the flask were then made to volume, filtered, the filtrate deleaded with solid potassium oxalate, and again filtered. This procedure is a slight modification of that used by Traub, et al (68). Suitable aliquots of the final filtrate were used in determining TOTAL LEVULOSE by the Jackson and Mathews modification of the Nyns Method (43). TOTAL REDUCING SUBSTANCES FROM THE WATER EXTRACTION were determined on the filtrate by the Lane and Eynon Volumetric Method (48). (The latter fraction includes inulin, inulides, sucrose and free reducing substances.)

TOTAL REDUCING SUBSTANCES IN THE ALCOHOLIC EXTRACT (including the

lower, more labile inulides, sucrose, and free reducing substances) were determined by the Bertrand modification of the Munson and Walker Method. 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. HCl (sp. grav. 1.125 or approximately 11 N) per 100 ml. of solution hydrolyzed. Reducing power was determined on the solution after neutralizing the acid with anhydrous sodium carbonate.

The press cake remaining after expression of the aqueous extract was dried, ground in a small Wiley type of mill to pass a 60-mesh screen, and extracted for 8 hours in a Soxhlet extractor (starting with 80% alcohol in the extraction flask). After drying over night at 55°C. the residue was transferred to a wide-mouth 500 ml. Erlenmeyer flask, 100 ml. of water and 10 ml. of HCl (sp. gr. 1.125) added, and the sample refluxed for two and one-half hours on an electric hot plate. After cooling, the contents of the flask were neutralized with anhydrous sodium carbonate, then transferred to a 250 ml. volumetric flask, the volume made up 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 (8). This fraction will be designated in this paper as ACID-HYDROLYZABLE HOT WATER-INSOLUBLE POLYSACCHARIDES.

In all carbohydrate determinations dilutions were varied according to 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 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, but with 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 (60 hour drying at 65° - 75°C). Dry matter samples of stolon tissue was made on an equal number of stolons comparable in size with those used in the catalase determination. 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-size tuber classes of later diggings made necessary the use of 2 to 4 buds per sample). Comparisons of 5- and 10-tuber composite samples showed the 5-tuber size to give practically the same catalase results as the 10-tuber size indicating that while the numbers used were in some cases small, they were large enough to give trustworthy results.

In making a catalase determination the tissues were quickly weighed in a tared weighing bottle, an equal weight of calcium carbonate weighed out, and both placed in a small mortar together with a small quantity of washed quartz sand. The tissues were then quickly ground to a smooth paste, adding a little water from a burette when necessary. The sample was then washed into a beaker with water (from the burette) in an amount sufficient to give a convenient dilution for the determination. For buds a dilution of 1 part (by weight) of tissue to 50 parts of water, and for other tissues 1 part of tissue to 25 parts of water were used in most cases. The apparatus devised by Pope (59), and illustrated in Plate XXIV was used. This apparatus is briefly described by Pope as follows: "...It consists of a square, wooden, motor-driven arm sliding through supports

at either end and carrying a Bunzel tube (22 mm. inside diameter), each arm of which has ample capacity for 4 cc. of liquid. A flexible rubber tube of sufficient length to allow a full excursion of the shaker arm connects the Bunzel tube with a small-bore glass tube. This glass tube is in direct connection through a 3-way glass stopcock with the upper end of a 50 cc. burette, the lower end of which is connected by a thick-wall rubber tube with the lower end of a second burette of the same capacity which may be raised or lowered at will to equalize the water levels in the two burettes. The gas-conducting portions of the apparatus are purposely made of small-bore material to reduce the volume of gas subject to temperature and pressure changes . . . . The Bunzel tube is immersed in a water thermostat electrically heated and controlled. A knife-type heater is used, and the thermoregulator is of the mercury type, sensitive to about $\pm$ 0.02°C., working through a mercury relay in which both poles are permanently bathed in mercury. The water temperature is equalized by a motor-driven stirrer of the turbine type. The Bunzel tube is shaken at the rate of approximately 204 complete excursions per minute, and the thermostat is kept constant at 24.5°C. In starting the shaker motor the switch is thrown one second before the minute, which allows the first mixture to occur approximately on the minute."

After thoroughly stirring the sample to be analyzed, a 2 ml. aliquot was drawn with a pipette and placed in one arm of the reaction tube. Two ml. of 12-volume Dioxogen (H_2O_2) were then pipetted into the other arm of the reaction tube and the tube connected to the apparatus in the water bath. The tubes were allowed to stand two minutes in the water bath before beginning determinations to allow the sample temperature to attain that of

the thermostat. During this two minute period the burettes were adjusted to the same level. At five seconds before beginning the determination the 3-way stopcock was turned so as to close the system, and at one second before start of the determination the motor switch was thrown. During the determination the levels of the burettes were adjusted frequently so that evolution of oxygen would be at approximately atmospheric pressure. The number of cubic centimeters of oxygen evolved at the end of 1, 2, 3, 4, 5, and 10 minutes operation, as well as the time in seconds required to evolve 5 cc. and 10 cc. of oxygen, were recorded.

PRESENTATION OF RESULTS

Tuber Distribution During the Period of Tuberization

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 tuberization in 1934.

These data show that, in general, during this period there is an increase in both the total number and total weight of tubers and stolons produced per plant. As the season advances, a progressive decrease in the proportion of the total number and weight of tubers and stolons in the smaller-size classes and a corresponding increase in the proportion in the larger-size classes is observed. These changes in number and weight do not, however, progress at the same rate. A more rapid shift toward the larger sizes in total weight than in total number of tubers 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 in Tables 5, 6. Clark (13) has reported a

Table 1. — Changes in number and weight distribution of Jerusalem Artichoke tubers during the period of tuber development in the field. Variety Blanc Ameliore. Season of 1934.

Diameter of tubers	Date of harvest: July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10	Nov. 12
	Distribution of numbers in per cent. for each harvest								
Untuberized stolons	45.0	54.2	52.3	53.7	37.4	29.8	14.0	10.8	1.7
Less than 0.9 cm.	22.1	17.9	19.7	16.3	23.8	12.3	11.9	9.7	11.0
0.9 to 1.4 cm.	27.4	16.6	15.9	18.3	13.2	19.9	15.5	8.2	11.3
1.4 to 1.9 cm.	5.5	9.8	10.3	9.4	17.2	16.4	21.3	11.4	8.2
1.9 to 2.4 cm.	----*	1.5	1.9	2.3	8.3	15.8	23.8	22.1	15.1
2.4 to 2.9 cm.	----	----	----	----	----	5.7	11.3	24.2	24.3
2.9 to 3.4 cm.	----	----	----	----	----	----	2.1	12.6	20.5
Over 3.4 cm.	----	----	----	----	----	----	----	0.9	7.9
	Distribution of weights in per cent. for each harvest								
Untuberized stolons	11.6	8.9	8.8	9.6	3.9	1.1	0.3	0.1	0.0+
Less than 0.9 cm.	13.4	8.0	9.5	7.6	5.7	1.4	0.6	0.2	0.2
0.9 to 1.4 cm.	48.7	31.3	29.5	34.9	11.6	8.5	2.9	0.7	0.9
1.4 to 1.9 cm.	26.4	39.8	40.4	33.9	38.9	21.5	12.0	3.5	1.5
1.9 to 2.4 cm.	----	12.0	11.8	14.0	39.9	42.4	37.9	17.8	6.9
2.4 to 2.9 cm.	----	----	----	----	----	25.1	36.1	38.0	23.7
2.9 to 3.4 cm.	----	----	----	----	----	----	10.3	35.1	40.4
Over 3.4 cm.	----	----	----	----	----	----	----	4.5	26.5
	Mean number of tubers and stolons per hill								
Number of stolons	10.5	19.1	22.5	31.7	15.2	13.2	5.5	5.7	1.0
Number of tubers	12.8	16.2	20.5	27.3	25.5	31.1	33.7	46.8	57.4
Total number	23.3	35.3	43.0	59.0	40.7	44.3	39.2	52.5	58.4
	Mean weight of tubers and stolons per hill (grams)								
Weight of stolons	3	5	7	14	6	2	1	1	0
Weight of tubers	25	48	68	127	140	209	342	816	1067
Total weight	28	53	75	141	146	211	343	817	1067

* ----indicates that no tubers were found in the size-class.

Table 2. -- Changes in number and weight distribution of Jerusalem Artichoke tubers during the period of tuber development in the field. Variety Chicago. Season of 1934.

Diameter of tubers	Date of harvest: July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 28	Oct. 12	Nov. 12
Distribution of numbers in per cent. for each harvest									
Untuberized stolons	40.3	36.7	59.6	49.0	31.0	----	----	----	----
Less than 0.9 cm.	21.4	27.7	17.9	32.3	32.8	4.0	3.8	2.7	6.0
0.9 to 1.4 cm.	31.0	23.1	15.1	15.3	27.8	25.5	10.1	12.4	20.1
1.4 to 1.9 cm.	7.3	12.6	7.4	3.4	8.4	39.5	19.6	7.4	36.1
1.9 to 2.4 cm.	----*	----	----	----	----	25.8	26.8	12.4	28.5
2.4 to 2.9 cm.	----	----	----	----	----	5.2	32.8	33.4	8.5
2.9 to 3.4 cm.	----	----	----	----	----	----	6.9	26.6	0.7
Over 3.4 cm.	----	----	----	----	----	----	----	5.0	----
Distribution of weights in per cent. for each harvest									
Untuberized stolons	7.4	4.7	16.4	16.7	9.4	----	----	----	----
Less than 0.9 cm.	12.8	10.5	16.6	18.6	20.7	0.2	0.1	0.1	0.4
0.9 to 1.4 cm.	55.1	38.1	34.3	46.1	44.8	6.6	0.8	0.6	4.5
1.4 to 1.9 cm.	24.7	46.7	32.6	18.5	25.1	33.1	5.8	1.0	22.0
1.9 to 2.4 cm.	----	----	----	----	----	44.9	20.2	5.6	43.5
2.4 to 2.9 cm.	----	----	----	----	----	15.0	54.4	29.6	26.5
2.9 to 3.4 cm.	----	----	----	----	----	----	18.7	48.4	3.0
Over 3.4 cm.	----	----	----	----	----	----	----	14.8	----
Mean number of stolons and tubers per hill									
Number of stolons	10.0	14.3	28.0	29.1	13.6	0	0	0	0
Number of tubers	14.8	24.7	20.0	30.3	30.3	41.1	78.9	88.6	162.2
Total number	24.8	39.0	48.0	59.4	43.9	41.1	78.9	88.6	162.2
Mean weight of tubers and stolons per hill (grams)									
Weight of stolons	3	3	14	16	7	0	0	0	0
Weight of tubers	38	65	73	81	68	406	1451	2147	1402
Total weight	41	68	87	97	75	406	1451	2147	1402

* ---- indicates that no tubers were found in the size-class.

similar case of a failure of later formed tubers of potatoes 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 (13), 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 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 of the November 12 tubers of the variety Chicago, and their lack of tuber size suggest that the plants harvested on that date were not comparable to 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 at least 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 were therefore, probably classified as showing some tuberization. This would automatically place them in the tuber class less than 0.9 cm. in diameter.

Time of Initiation of Rest Period

To study initiation of rest period, a logical approach seemed to lie in the following question: How is the time of harvest and size of tubers related to entrance into the resting condition? 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 secured 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 although it is possible that the actual time may have been a little later than the latter date, since field conditions might not have been conducive to sprouting as late as September 7, whereas under favorable greenhouse conditions sprouting might have occurred. 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 is possibly due to a decreasing photoperiod.

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

Table 3. — Time of entrance into the rest period of tubers of Jerusalem Artichoke (variety Chicago), as indicated by the percentage of tubers sprouted on October 25, 1933. Tubers planted in the field or greenhouse immediately after being dug.

Date of Digging	Place Planted	Per cent. sprouted	Character of growth
July 25	Field	20	Normal plants 10 to 16 inches tall
Aug. 28	Field	40	"Flat" growth; plants 2 to 4 inches tall
Sept. 7	Field	0	
Sept. 19	Field	0	
Sept. 19	Greenhouse	0	Buds somewhat swollen but no evidence of sprouting
Oct. 3	Greenhouse	0	

Table 4. — Time of entrance into the rest period of tubers of the Jerusalem Artichoke as indicated by the percentage of tubers sprouted on October 25, 1934. Tubers planted in a greenhouse immediately after being dug.

Tuber diameter in cm.	Date of harvest: July 23	Aug. 2	Aug. 14	Aug. 23	Sept. 4	Sept. 17	Sept. 26	Oct. 10
Variety Blanc Ameliore								
Untuberized stolons	10	45	40	56	5	0	0	0
less than 0.9	50	60	70	15	10	0	0	0
0.9 to 1.4	60	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
Variety Chicago							(Sept. 28)	(Oct. 12)
Untuberized stolons	50	30	50	60	7	0	0	0
less than 0.9	60	70	75	29	20	0	0	0
0.9 to 1.4	100	60	78	40	33	0	0	0
1.4 to 1.9	67	50	80	0	25	7	0	0
1.9 to 2.4	---	---	---	---	---	10	0	0
2.4 to 2.9	---	---	---	---	---	0	0	0
2.9 to 3.4	---	---	---	---	---	---	0	0
3.4 to 3.9	---	---	---	---	---	---	---	0

* --- Indicates that no tubers were found in the size-class.

entrance into complete rest. For example, we find that for stolons or tubers less than 0.9 cm. in diameter (under 1 gram in weight) in the variety Blanc Ameliore, deep rest was attained some time between September 4 and September 17, whereas for tubers 2.9 to 3.4 cm. in diameter (42 to 44 grams in weight) this state is not reached until some time between September 26 and October 10. There is also some evidence, from the data, that for any date of harvest prior to entrance into definite rest, the larger the tubers the greater their capacity for sprouting. Thus for any date of digging there is a tendency for the percentage of sprouting to increase as we proceed from stolons to the largest size samples. The data on Blanc Ameliore indicate this somewhat more clearly than that of Chicago.

It also seems from the data of Tables 3 and 4 that the time of initiation of rest in 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 and its effect on the tubers), and between varieties grown under the same conditions. Thus rest appears to have been established later in 1934 (planting date April 15) than in 1933 (planting date April 4) with the variety Chicago. Rest was also established later in the variety Blanc Ameliore than in the variety Chicago in 1934. Chicago has been noted to be an "early maturing" variety, tending to drop more of its leaves before frost than the variety Blanc Ameliore.

The relative development of stolons and tubers of the variety Blanc Ameliore (White Improved) used in the 1934 sprouting trials can be readily seen from the photographs in Plates I, II, and III. These photographs

show the development of tops from each tuber size class, as they appeared on November 19, 1934. Not only did the earlier-dug lots produce vigorous sprouts, but the sprouts so formed were, in many cases, able to develop another crop of tubers the same season. No attempt was made to determine whether these "second crop" tubers were dormant, but it would be interesting to know whether this was the case.

Catalase Activity During Initiation of Rest

The apparent correlation of catalase activity with the metabolic state of various plants or plant parts, as reported by many workers dealing with growth and dormancy, suggested the possibility that catalase activity might bear some relation to entrance of Jerusalem artichoke tubers into the rest period. Determinations of catalase activity on stolons, and the various tuber classes were therefore made at each harvest. Results of these determinations are presented in Tables 5 and 6 and Figures 1 and 2.

It can be seen from the data and graphs that, in general, catalase activity reaches a maximum value at the time of entering rest, or at some time prior to this, and that it shows more or less decrease thereafter for the remainder of the developmental period.

It seems of some significance that in both varieties studied, when catalase activity is expressed on a per unit dry weight basis, the values for the successively larger tuber size classes 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 may be in the proper relation to the others if we could know exactly when entrance into rest took place. Further examination of

Table 5. — Catalase activity during initiation of rest in the developing tubers of Jerusalem artichoke. Variety Blanc Ameliore. Season of 1934.

Digging date	Tuber diameter in cm.							
	Untuberized stolons	less than 0.9	0.9-1.4	1.4-1.9	1.9-2.4	2.4-2.9	2.9-3.4	3.4-3.9
	Expressed as cc. O_2 evolved per 0.04 g. fresh tissue in 5 minutes at 24.5°C.*							
July 23	11.78	9.58	9.05	10.48	----**	-----	-----	-----
Aug. 2	11.95	10.18	8.98	9.53	8.23	-----	-----	-----
Aug. 14	10.93	9.65	10.43	-----	----	-----	-----	-----
Aug. 23	11.65	8.70	12.35	11.95	11.05	-----	-----	-----
Sept. 4	12.08	10.38	11.48	12.80	12.83	-----	-----	-----
Sept. 17	4.93	10.35	10.90	12.80	13.20	13.70	-----	-----
Sept. 26	6.83	10.70	10.60	12.35	12.88	12.88	-----	-----
Oct. 10	4.53	8.95	9.65	11.78	12.28	13.13	13.15	-----
Nov. 12	9.30	9.85	10.85	10.35	9.90	10.80	11.53	11.95
	Expressed as cc. O_2 evolved per centigram dry matter in 5 minutes at 24.5°C.							
July 23	20.77	13.13	13.49	16.97	-----	-----	-----	-----
Aug. 2	27.17	18.06	16.98	19.53	15.36	-----	-----	-----
Aug. 14	31.33	16.00	20.65	-----	-----	-----	-----	-----
Aug. 23	38.20	19.78	25.11	24.80	21.01	-----	-----	-----
Sept. 4	35.77	18.97	21.10	25.15	25.21	-----	-----	-----
Sept. 17	13.18	19.68	20.19	25.34	26.72	30.18	-----	-----
Sept. 26	14.07	17.72	15.45	21.79	22.59	22.48	-----	-----
Oct. 10	14.52	12.41	13.63	15.79	17.49	18.87	18.37	-----
Nov. 12	30.78	11.34	12.05	12.91	11.41	13.14	13.09	13.77

* Determinations made on terminal buds only, except with stolons and tubers less than 0.9 cm, where the whole stolons or tubers were used. Figures are averages of duplicate determinations.

** -----No material available for determination.

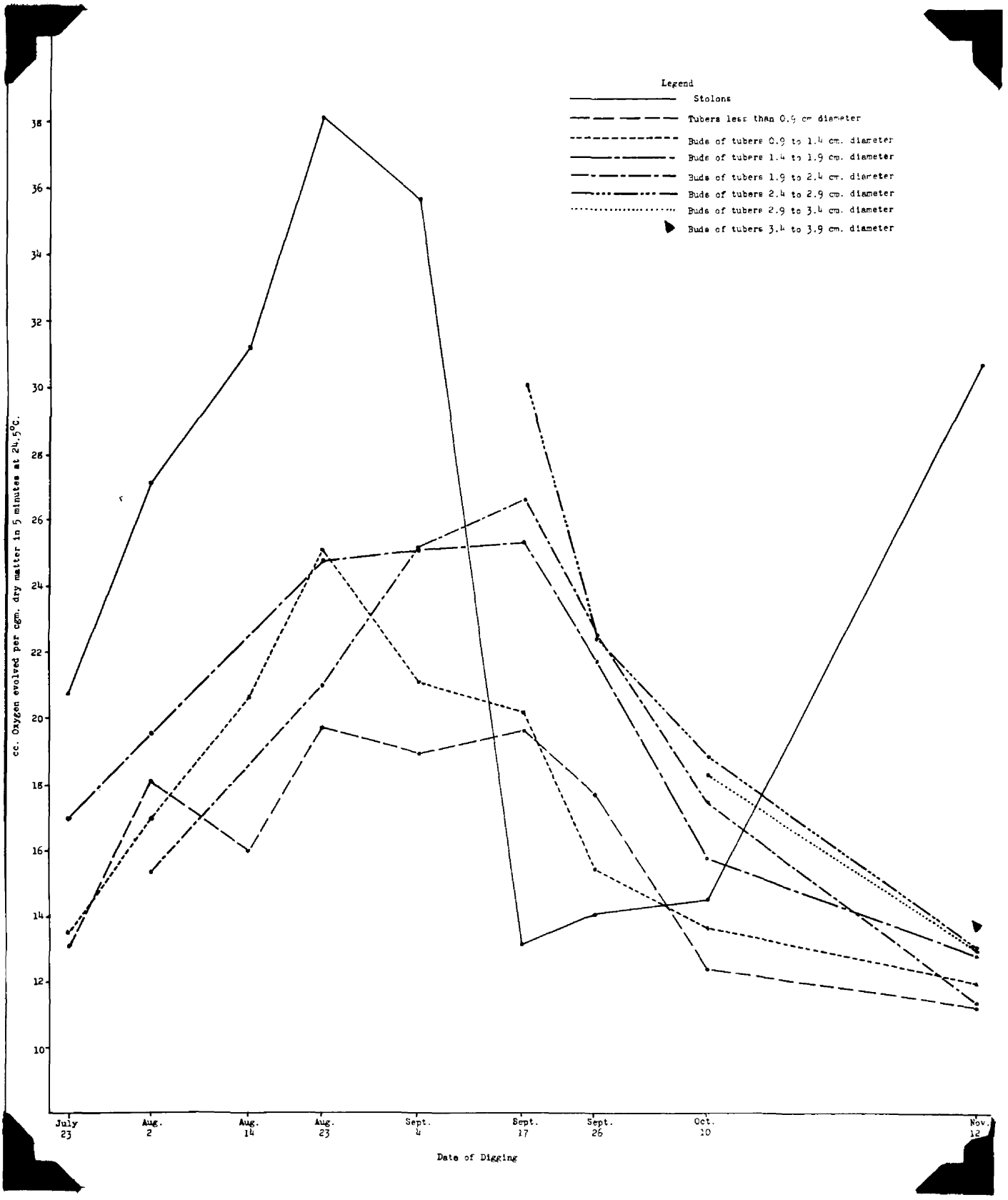

Fig. 1. Catalase activity of stolons, tubers, or terminal buds of Jerusalem artichoke tubers of the variety Blanc Ameliore during the period of tuber development and entrance into the rest period in 1934.

Table 6. -- Catalase activity during initiation of rest in the developing tubers of Jerusalem artichoke. Variety Chicago. Season of 1934.

Digging date	Tuber diameter in cm.							
	Untuberized stolons	less than 0.9	0.9-1.4	1.4-1.9	1.9-2.4	2.4-2.9	2.9-3.4	3.4-3.9
Expressed as cc. O_2 evolved per 0.04 g. fresh tissue in 5 minutes at 24.5°C.*								
July 23	15.58	9.95	9.43	8.05	-----**	-----	-----	-----
Aug. 2	13.98	9.75	10.78	11.30	-----	-----	-----	-----
Aug. 14	12.75	10.28	12.02	11.70	-----	-----	-----	-----
Aug. 23	11.65	10.25	10.55	-----	-----	-----	-----	-----
Sept. 4	15.75	13.30	14.40	13.53	-----	-----	-----	-----
Sept. 17	-----	12.28	12.20	13.80	14.10	14.63	-----	-----
Sept. 28	-----	13.90	14.38	13.88	14.18	14.78	14.75	-----
Oct. 12	-----	13.60	14.20	12.65	14.13	14.20	14.98	15.15
Nov. 12	-----	11.03	12.75	12.83	13.78	14.25	15.00	-----
Expressed as cc. O_2 evolved per centigram dry matter in 5 minutes at 24.5°C.								
July 23	32.43	12.94	13.13	10.97	-----	-----	-----	-----
Aug. 2	32.60	15.26	15.26	15.19	-----	-----	-----	-----
Aug. 14	45.20	28.08	33.76	29.62	-----	-----	-----	-----
Aug. 23	35.73	29.20	25.00	-----	-----	-----	-----	-----
Sept. 4	28.97	25.38	28.74	25.63	-----	-----	-----	-----
Sept. 17	-----	16.69	19.40	23.71	20.09	31.60	-----	-----
Sept. 28	-----	17.10	20.18	20.50	26.16	22.02	24.34	-----
Oct. 12	-----	15.94	18.28	23.00	18.69	17.11	18.31	18.86
Nov. 12	-----	11.37	13.12	14.56	14.08	16.32	17.36	17.36

* Determinations made on terminal buds only, except with stolons and tubers less than 0.9 cm. where the whole stolons or tubers were used. Figures are averages of duplicate determinations.

** -----No material available for determination.

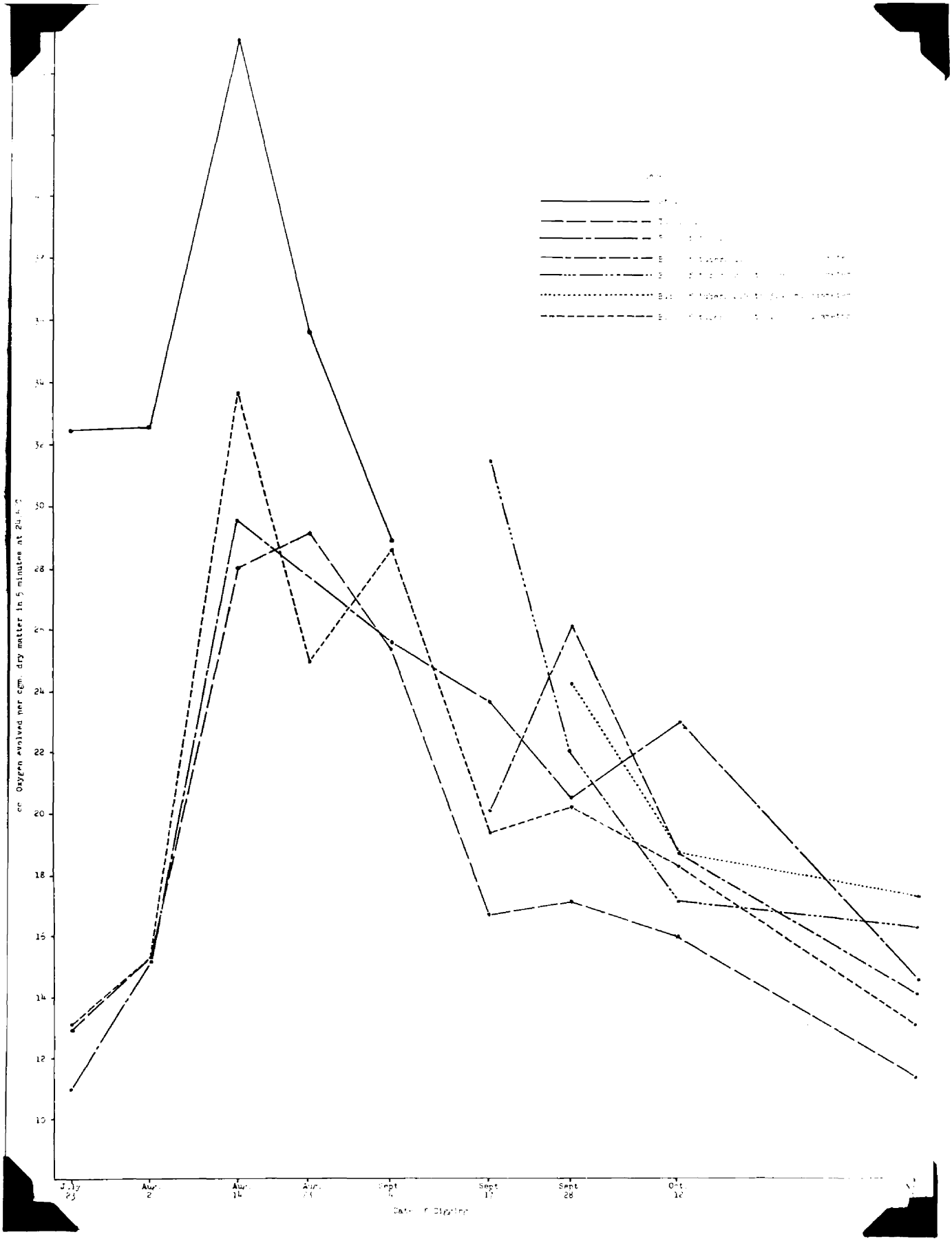

Fig. 2. Catalase activity of stolons, tubers, or terminal buds of Jerusalem artichoke tubers of the variety Chicago during the period of tuber development and entrance into the rest period in 1934.

these data shows that in most cases this greater activity of the larger tubers continues to the end of the period studied.

These results of catalase determinations 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 size tubers (data of Tables 1 and 2), and with the delayed entrance into rest by larger sizes of tubers as compared with smaller tubers, as shown in Tables 3 and 4. The data taken together suggest a higher metabolic rate in the first formed tubers (the larger ones later on), a"first-call" on carbohydrates and other substances used for growth and storage, and a delayed rest period because of this higher metabolic rate.

A falling metabolic rate, as indicated by catalase activity, appears to characterize the early stages of the resting state.

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 felt that since the rest period has been shown by other workers to be confined to buds in other plants and is not systemic in nature, that analyses of bud series might give some information on significant carbohydrate changes occurring during the entrance into rest. In order to find what changes occur in whole tubers during the same period, the largest-tuber-size class for which a fairly complete series was available was analyzed. In Tables 7 to 9 results are given of chemical analyses of terminal buds from tubers over 1.4 cm. in diameter of the variety Blanc Ameliore and Chicago , and of tubers 1.9 to 2.4 cm.

Table 7. -- Chemical composition of terminal buds, and tubers of Jerusalem artichoke during the period of tuber development in 1934. Variety Blanc Ameliore. Per cent. of fresh weight.

Date of harvest	Dry matter	Free levulose	Free Reducing substances (as glucose)	Total levulose	Total hot-water-soluble reducing substances (as levulose)	Total alcohol-soluble reducing substances (as invert sugar)	Acid hydrolyzable hot-water-insoluble polysaccharides (as glucose)
			Buds from tubers over 1.4 cm. diameter				
Aug. 14	11.46	.08	.95	1.25	4.74	4.05	.55
Aug. 23	12.20	.01	.77	2.00	5.04	4.00	.54
Sept. 4	13.27	.00	.17	4.44	6.66	3.98	.43
Sept.17	12.17	.00	.34	2.77	6.28	4.85	.35
Sept.26	15.25	.00	.05	7.45	9.95	5.58	.49
Oct. 10	18.16	.00	.01	9.65	13.17	7.46	.41
Nov. 12	23.12	.00	.00	11.75	16.70	10.31	.62
			Tubers 1.9 to 2.4 cm. in diameter (approximately 15 g.)				
Aug. 2	15.46	.00	.25	8.06	10.09	4.19	.60
Aug. 14	16.69	trace	.35	10,30	13.79	4.72	.65
Aug. 23	15.45	trace	.22	8.24	10.76	4.77	.66
Sept. 4	13.00	trace	.18	6.69	8.87	3.99	.63
Sept.17	13.41	.00	.20	6.77	9.38	4.79	.48
Sept.26	15.65	trace	.04	8.51	11.66	5.20	.49
Oct. 10	18.33	trace	.01	10.61	13.93	6.11	.39
Nov. 12	21.76	.00	.02	11.16	15.43	9.65	.61

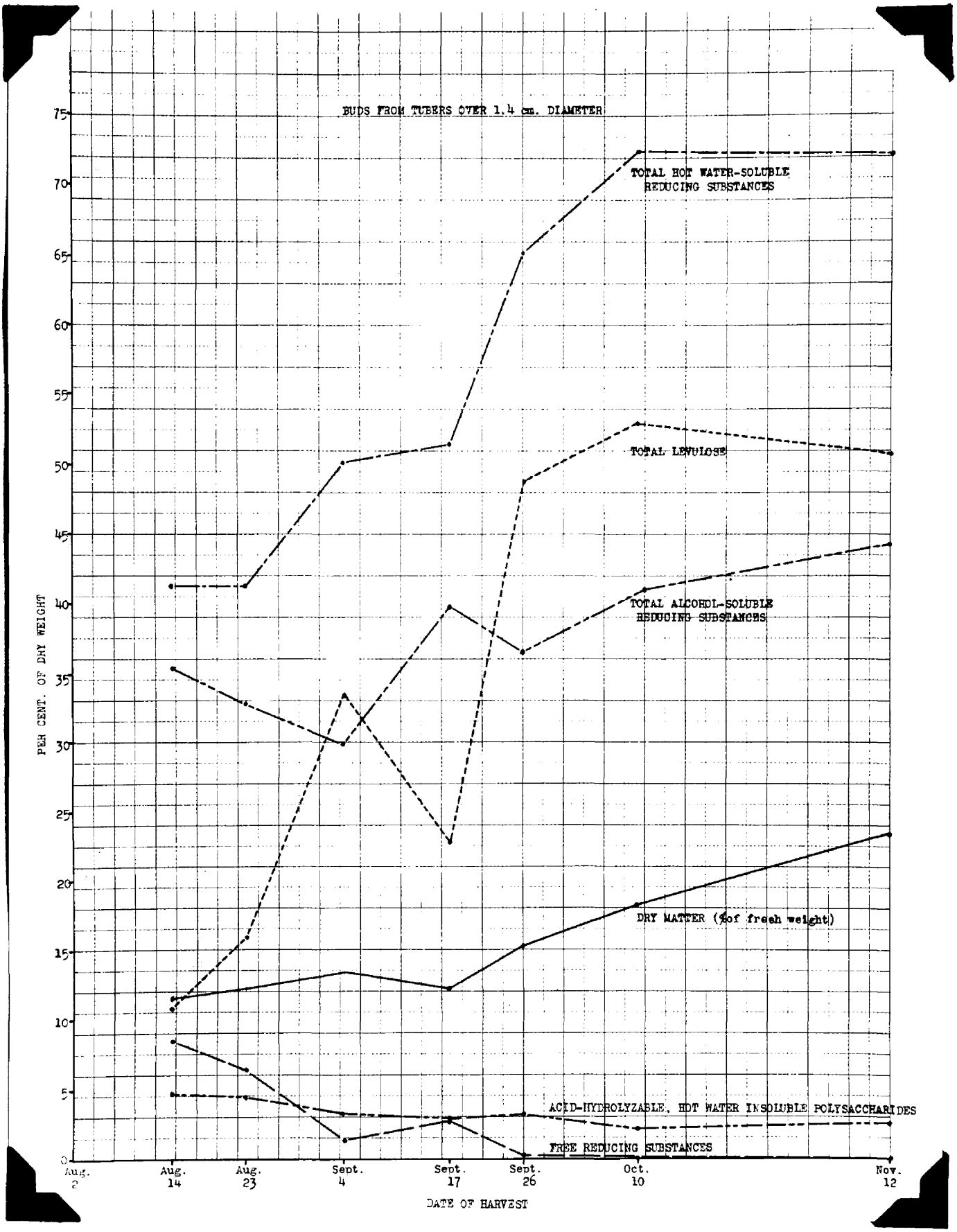

Fig. 3. Percentages of dry matter and various carbohydrate constituents in terminal buds of Jerusalem artichoke tubers over 1.4 cm. in diameter, harvested on different dates during the period of tuber development in 1934. Variety Blanc Ameliore.

Table 8.--Chemical composition of terminal buds, and tubers of Jerusalem artichokes during the period of tuber development in 1934. Variety Blanc Ameliore. Per cent. of dry weight.

Date of harvest	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 subst. / Hot-water sol. reducing subst.	Ratios: Free reducing substances / Alcohol-soluble reducing subst.	Ratios: total levulose / hot-water sol. reducing subst.
				Buds from tubers over 1.4 cm. diameter					
Aug. 14	.71	8.33	10.85	41.36	35.35	4.76	.855	.236	.262
Aug. 23	.10	6.35	15.97	41.35	32.78	4.46	.793	.194	.386
Sept. 4	.00	1.26	33.45	50.15	29.94	3.24	.597	.042	.667
Sept.17	.00	2.76	22.76	51.57	39.81	2.89	.772	.069	.441
Sept.26	.00	0.32	48.85	65.21	36.54	3.18	.560	.009	.749
Oct. 10	.00	0.05	53.10	72.49	41.06	2.20	.566	.001	.733
Nov. 12	.00	0.00	50.79	72.22	44.60	2.70	.618	.000	.703
				Tubers 1.9 to 2.4 cm. in diameter (approximately 15.g.)					
Aug. 2	.00	1.60	52.13	65.29	27.10	3.90	.415	.059	.798
Aug. 14	trace	1.61	51.19	68.22	28.30	3.81	.415	.057	.750
Aug. 23	trace	1.44	53.31	69.62	30.85	4.24	.443	.047	.766
Sept. 4	trace	1.40	51.37	68.17	30.45	4.88	.447	.046	.754
Sept.17	.00	1.45	50.48	69.94	35.70	3.61	.510	.040	.722
Sept.26	trace	0.25	54.39	74.56	33.24	3.12	.446	.007	.730
Oct. 10	trace	0.04	57.90	75.99	33.34	2.12	.439	.001	.762
Nov. 12	.00	0.12	51.30	70.88	44.35	2.81	.626	.003	.724

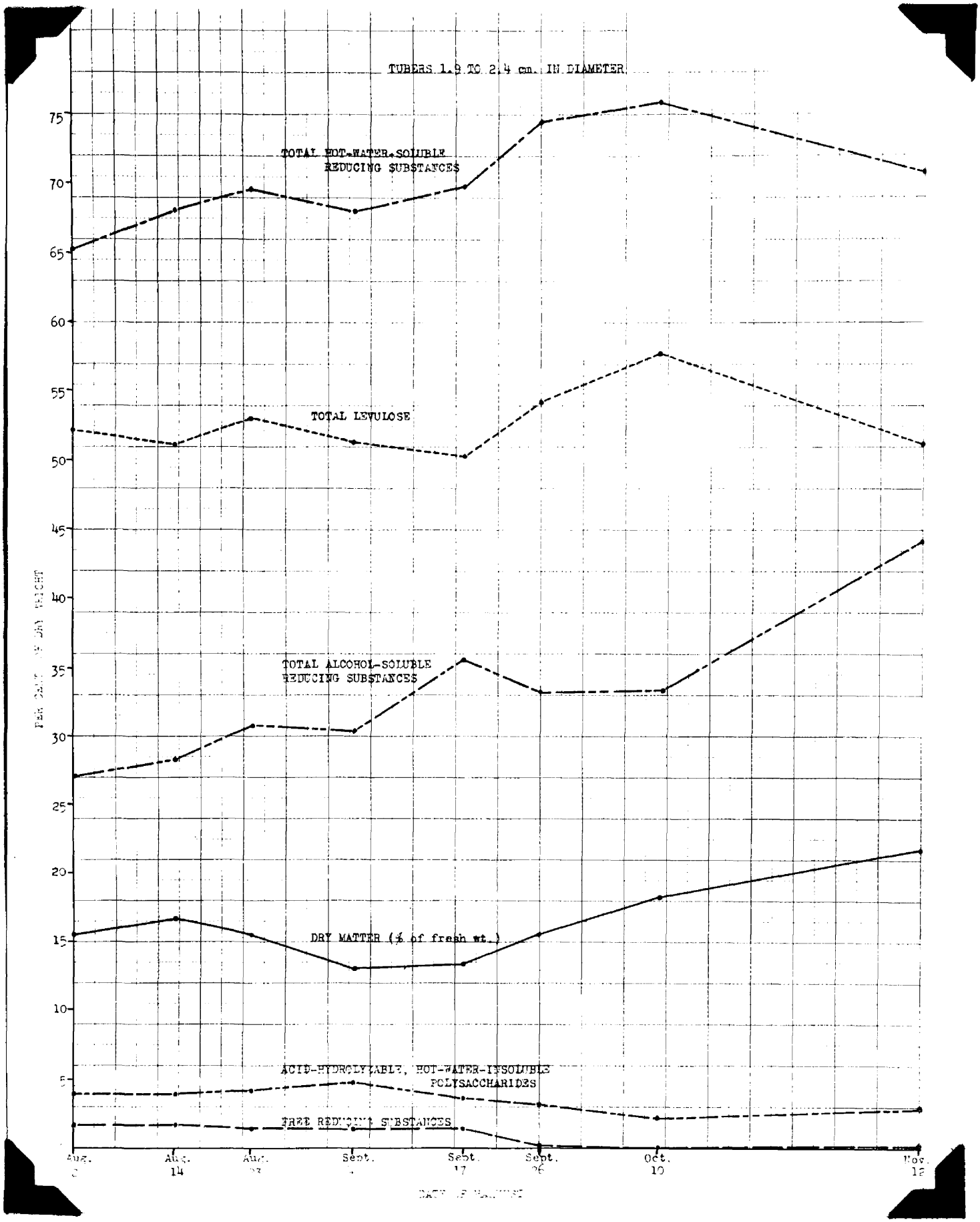

Fig. 4. Percentages of dry matter and various carbohydrate constituents in Jerusalem artichoke tubers 1.9 to 2.4 cm. in diameter harvested on different dates during the period of tuber development in 1934. Variety Blanc Ameliore.

Table 9. -- Chemical composition of terminal buds of tubers over 1.4 cm. in diameter in the variety Chicago, during the period of tuber development in 1934.

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 subst. / Hot-water-sol. reducing subst.	Ratios: Free reducing substances / Alcohol-soluble reducing subst.	Ratios: Total levulose / Hot-water-sol. reducing subst
					Per cent. Fresh Weight					
Sept.17	13.99	.00	.18	6.65	8.65	5.38	.48	.622	.034	.769
Sept.28	16.07	.00	.05	7.64	10.32	5.49	.45	.532	.008	.740
Oct. 12	20.39	.00	.00	9.90	12.95	7.61	.57	.587	.000	.765
Nov. 12	24.98	trace	.00	11.14	16.43	8.66	.73	.527	.000	.678
					Per cent. dry weight					
Sept. 17		.00	1.32	47.56	61.83	38.47	3.46			
Sept. 28		.00	0.29	47.52	64.24	34.18	2.78			
Oct. 12		.00	0.00	48.55	63.51	37.31	2.80			
Nov. 12		trace	0.00	44.59	65.76	34.68	2.92			

in diameter of the variety Blanc Ameliore for the 1934 season. The data for Blanc Ameliore are also presented graphically in Figures 3 and 4.

The most striking feature of the data is the much greater changes in composition exhibited by terminal buds than occurred in the whole tubers during the period studied. It will be noted that the content of hot water-soluble reducing substances, levulose, and dry matter are lower, and the amount of free reducing substances, and alcohol-soluble reducing substances 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. The tubers exhibit relatively much smaller fluctuations in composition throughout this period.

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

Some interesting relationships are shown by the calculated ratios of the various fractions to each other given in Tables 8 and 9. The ratio of alcohol-soluble substances, (which include dextrose, free levulose, sucrose, and the more labile, higher dextrose-containing inulides) to hot-water-soluble substances (which include 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 fact probably indicates 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, because of the more or less regular changes occurring in the various fractions throughout the season, to point to any abrupt or large change or changes, among the fractions studied, which might account for entrance of buds into the resting condition, nevertheless a noticeable change occurred in most fractions around September 20, and 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.

DISCUSSION (Part I)

The experimental data indicate very clearly that "rest" and "maturity" are quite distinct considerations in the life of the artichoke tuber. "Maturity" is a rather vague term, difficult of definition, and conveying different meanings to different people. With the artichoke, maturity is commonly known as that condition existing in tubers when the tops of the plant are fully developed (usually dead due to senescence), when the tubers have attained their maximum size, and when they have attained a composition characterized by a maximum content of the less labile carbohydrate reserves. With the Jerusalem artichokes grown under conditions of this experiment, full maturity in the field, according to this definition, was not attained because the tops of the plants were killed by frost while still in an actively functioning condition.

"Rest" on the other hand is that condition existing in the plant or plant organ, when growth does not occur even though all external conditions are favorable to growth. Although full maturity was not reached in the tubers studied, rest was initiated in stolons and tubers widely differing in their apparent degrees of development, long before the maturation process was stopped by frost. The data show that the degree of development, at least as judged by size alone, bears a fairly definite relation to the time of initiating of rest. This relationship is, however, the reverse of what might be expected in that the data show rest to be established first in the least developed organs, stolons and smaller tubers, rather than in the larger size, more developed tubers. Apparently attainment of so-called "maturity" did not determine "rest".

Catalase activity is reported in the investigations of Appleman (2, 6), Heinicke (36), Harding (34), Pope (59), and numerous others, as showing good correlations with various metabolic processes in plants. A good correlation exists in the studies at hand, between catalase activity, time of tuber differentiation, and time of entrance into rest. When the resting condition is first evident among tubers on a plant, the larger (first formed) tubers exhibit higher catalase activity and are later is entering complete rest than the smaller tubers. In studies involving sprouting tests during tuber development, tuber size of artichokes must, therefore, be taken into account. Haber (33) appears to have minimized the importance of this factor. In discussing his experiments he states that "Tubers harvested Sept. 27 germinated as promptly as tubers harvested Nov. 1 if stored for the same length of time at the same temperature. The tubers dug at the earlier date were smaller than those dug later and no doubt less mature, but maturity apparently does not affect germination." He does not define what he means by "maturity", but if he compares tubers of different sizes, his statement is valid only for tubers stored under the same conditions until rest is broken, but not for tubers if planted immediately after digging.

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

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 in the terminal buds of tubers. The relatively small changes in tubers appear to corroborate the findings of Colin (14) that the composition of

tubers is almost the same throughout the period of development. It is unfortunate that time did not permit analyzing tubers of the other sizes to observe whether or not composition varies between tubers of different sizes. Such analyses, particularly if made on buds of the various tuber sizes, should aid in proving whether chemical composition is associated with the difference in time of entering rest of the various sized tubers. The data do not support the statement of Meyer (54) that young tubers are rich in glucose, nor the findings of Collins and Gill (15) 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 (Tables 7, 8, 9).

The capacity for active growth in buds appears, from the data, to be closely associated with a low ratio of levulose to total hot-water-soluble carbohydrates and a correspondingly high ratio of alcohol-soluble reducing substances to hot-water-soluble reducing substances. No causal relationship is implied, but the high proportion of levulose in the reserve substances when rest is attained might be assumed to indicate inactivation of inulase 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. These are pure speculations, however, and the observed relation of carbohydrate changes to rest may be merely a coincidence bearing no fundamental relation to the real regulator of growth, whatever it may be.

The much greater changes occurring in buds than occur 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.

PART II.

EMERGENCE FROM THE REST PERIOD

MATERIALS AND METHODS

This phase of the problem was conducted in the Arlington Farm, Va., Beltsville, Md., and Washington, D. C., laboratories and greenhouses of the Bureau of Plant Industry, U. S. Department of Agriculture.

All tubers used in the experiments were from plants of uniform age, grown on the experimental plots at Arlington Farm, Va. (1931 and 1932), and at the U. S. Horticultural Field Station near Beltsville, Md. (1933 and 1934). Tubers were dug in the fall of each season during November or the first week in December, 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 of the desired size (in most cases one-ounce) were selected by weight within 8 grams of the desired size, then kept in a cool (about 15°-20°C.) greenhouse headhouse during the short period while the various experiments were being started.

Procedure for Chemical Treatments

In 1931 1-ounce 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 halves weighing approximately 1-ounce each. In 1932 only 1-ounce whole tubers of the varieties Blanc Ameliore and Chicago were treated, since the 1931 work had indicated a very similar response to treatments by both cut and whole tubers, except that when any treatment was toxic it was more toxic to the cut tubers.

Three types of treatment were used: (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 of time 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 of time after which the tubers were removed and planted; (c) the "Soak" method, in which tubers were submerged for given periods of time 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°-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°-75°F.) 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 the desired temperature ranges.

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 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 four 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 77-97 per cent.), and the other 7 at 50°F. (relative humidity 69-88 per cent.) in constant temperature chambers of the Cold Storage Laboratory of the Division of Fruit and Vegetable Crops and Diseases at Arlington Farm. The tubers of each of the other 21 samples were carefully packed in damp clay in manila paper bags, 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°F. (very low humidity), 32°F. (relative humidity 76-99 per cent.), and 32°F. (relative humidity 50-75 per cent.), respectively. An additional sample of about 250 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 beginning of the treatments, samples of each variety were removed from storage 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 5 to 8 tubers from each of the various lots planted was taken for chemical analysis.

In the 1932 studies 1-ounce tubers of 2 varieties, Blanc Ameliore and Chicago, were used. All tubers stored at 32°F., 36°F., and 50°F.,

were kept in manila paper bags. Tubers stored at 15°F. were packed in damp clay similar to the 18°F. 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 conducted in moist peat in the cool greenhouse 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°F. high humidity and at 50°F. Sprouting tests were conducted at 15-day intervals by planting 15 tubers in moist sand in the bench of a greenhouse kept at 65°-75°F. during the first thirty days of the experiment and at 55°F. thereafter. At each removal from storage, samples of tubers were taken for catalase and hydrogen-ion 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. No pH determinations were made in 1934.

Methods of Biochemical Analysis

Sampling. The whole tubers in 1931-32 were carefully washed in cool water, dried at once with a towel, ground through the fine knife of a meat grinder, the sample thoroughly mixed, a 100 gram sample quickly weighed out, and dropped immediately into sufficient boiling 95 per cent. alcohol (in a grass-top pint fruit jar containing 0.2 g. calcium carbonate) to give a resulting alcohol concentration of approximately 80 per cent. After boiling 20 to 30 minutes the jars were sealed.

The bud samples in 1932-33 were taken, after washing and drying the tubers, by removing the prominent buds from each tuber with a 9 mm. cork borer and saving each bud and the portion of the "plug" lying within one-eighth inch of the base of the bud at the tuber surface. Fifteen- or 25-gram samples were preserved at once by dropping the buds into boiling alcohol (95 per cent.) in an amount sufficient to give a final concentration of approximately 80 per cent. (Sealed in fruit jars the same as the whole tuber samples above.)

Extracting. The same procedure was used as outlined in Part I.

Dry Matter and Carbohydrate Fractions. The same procedures as given in Part I were used.

Nitrogen. Total alcohol-soluble- and alcohol-insoluble-organic nitrogen were determined on aliquots of the alcoholic extracts and alcohol-insoluble residues by the Kjeldahl-Gunning-Arnold method (8).

Hydrogen-ion Concentration. Hydrogen ion determinations were made on terminal buds, pith, and "cortex" separately. In taking bud samples, the outer bud scales and the epidermis at the base of the buds were first quickly removed with a scalpel to avoid introducing any foreign matter, the bud and a short plug of tuber tissue removed with a 9 mm. cork borer, and the portion of the plug deeper than one-eighth inch below the base of the bud discarded. 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.

In making a determination, the tissue was crushed on a small piece of doubled cheese cloth (previously dampened with water and the excess water wrung out) in a small agate mortar. The juice was then squeezed from the tissue into a small crucible, and the pH quickly determined on a drop or two of the juice by means of the Hydrogen-microelectrode devised by Bodine and Fink and modified by Brunstetter and Magoon (12), a saturated calomel electrode, and a Leeds and Northrup Type K potentiometer, using the technique of Brunstetter and Magoon (12). Composite samples of 5 tubers were used in all cases.

Catalase. Tissues were prepared in the same manner as those used in the pH determinations. The apparatus and technique outlined in Part I 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°F. and at 50°F., at the time they were removed from storage, and again immediately before the respiration determinations were begun.

With the facilities available, it was not possible to make the respiration determinations at the storage temperatures used, therefore determinations were made at a common temperature of 77°F. (25°C.) on comparable samples from the two storage chambers.

Upon removal of the samples from the storage chambers, they were transferred to a constant temperature room kept at 70°F. to allow the samples to approach the temperature at which the respiration determinations were to be made. (A 77°F. 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 kept there at room temperature (about 70°-77°F.) until the following morning when the respiration determinations were begun.

An apparatus patterned after that described by Harding, Maney, and Plagge (35) was found well suited to the needs of this study. This apparatus consists briefly of a washing train consisting of two bottles containing 50 per cent. KOH and one containing a $Ba(OH)_2$ solution, through which air is drawn before passing to the intake at the top of the respiration chamber, a 1-gallon wide mouth jar with a screw cap. A copper tube extending to the bottom of the respiration chamber serves to conduct the carbon dioxide laden air to Truog towers where the carbon dioxide is absorbed in a measured quantity of standard (0.2N) barium hydroxide. The air is then drawn through a small bottle of barium hydroxide solution (as a check on the completeness of carbon dioxide absorption), through a flow meter, and finally is withdrawn from the system by an electrically driven vacuum pump. 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 25°C.± .5° (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 one to one and one-half 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 thirty 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 tubers, but over 80 per cent. of the samples contained 45 or more tubers.

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

PRESENTATION OF RESULTS

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 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 (64) in 1933. Haber (33) has since (1934) also reported chemical treatments of Jerusalem artichoke tubers. Ethylene chlorhydrin, thiourea, and sodium thiocyanate were somewhat effective but sodium nitrate gave no response.

In this paper it will not be possible to present all the detailed observations made as to the effectiveness and toxicity of the various chemicals. Results of the various treatments for 1931-32 and 1932-33 are presented briefly in Tables 10, 11, and 12. The data in these tables give some idea of the effectiveness in shortening rest, as indicated by the time to the first evident sprout growth and the time when 50 per cent. of the tubers showed evidence of sprouting. The toxicity of certain treatments is indicated in the figures for percentage rotting. Sprouting was considered to have occurred when the buds showed the bud scales 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 per cent. or more of the buds, that normal plant development followed. As early as

Table 10. — Effect of various chemical treatments on the length of rest period in tubers of the varieties Blanc Ameliore and Tait in 1931-32.

Treatment	Blanc Ameliore						Tait					
	Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting) prior to June 1.		Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting prior to June 1.	
	Whole	Halves*	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves
Control	135	150	150	165	0.0	0.0	135	150	150	165	0.0	0.0
Soaked 1 hour in 1 per cent. NaSCN	135	150	165	195	0.0	0.0	---	---	---	---	-----	-----
Tubers split twice at right angles across basal end, parallel to main axis. Soaked 1 hour in 1 per cent. NaSCN	135	---	165	---	3.4	-----	---	---	---	---	-----	-----
Soaked 1 hour in 3 per cent. NaSCN	135	150	180	180	3.4	0.0	---	---	---	---	-----	-----
Soaked 1 hour in 1 per cent. NH_4SCN	135	150	180	180	3.3	3.1	150	150	165	165	0.0	9.7
Soaked 1 hour in 2 per cent. NH_4SCN	165	135	180	180	3.1	3.3	150	150	165	165	11.5	20.7
Soaked 1 hour in 3 per cent. NH_4SCN	30	150	180	180	13.3	28.1	150	150	165	---	42.3	78.6
Dipped in 0.5 molar $NaNO_3$	135	135	135	150	0.0	0.0	135	135	150	150	0.0	0.0
Dipped in 1 molar $NaNO_3$	135	135	150	135	0.0	0.0	135	135	150	150	0.0	0.0
Soaked 1 hour in 5 per cent. ethyl alcohol. Subjected to vapors 24 hours	30	15	150	150	6.7	0.0	120	15	135	150	0.0	0.0
Soaked 1 hour in 20 per cent. ethyl alcohol. Subjected to vapors 24 hours	15	15	30	30	0.0	33.3	15	15	15	---	36.7	40.0
Soaked 1 hour in 50 per cent. ethyl alcohol. Subjected to vapors 24 hours	30	---	---	---	90.0	100.0	75	---	---	---	96.7	100.0
Soaked 1 hour in 70 per cent. ethyl alcohol. Subjected to vapors 24 hours	30	---	---	---	93.3	100.0	---	---	---	---	-----	-----
Soaked 1 hour in 95 per cent. ethyl alcohol. Subjected to vapors 24 hours	---	---	---	---	100.0	100.0	---	---	---	---	-----	-----
Soaked 1 hour in 5 per cent. acetone. Subjected to vapors 24 hours	135	150	150	165	0.0	0.0	135	150	150	150	0.0	0.0
Soaked 1 hour in 20 per cent. 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 1000 for 24 hours	---	---	---	---	100.0	100.0	---	---	---	---	100.0	100.0
Subjected to ether vapors 1 part in 2000 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	0.0	135	135	150	150	0.0	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 per cent.) per liter space 24hrs	15	30	135	180	11.5	20.8	120	135	135	135	4.2	25.0
Soaked 2 hours in 0.2 per cent. ethylene chlorhydrin	15	15	150	135	0.0	4.3	105	15	150	135	0.0	8.3
Dipped in 6 per cent. ethylene chlorhydrin; subjected to vapors 24 hours	30	---	---	---	80.0	100.0	15	---	---	---	81.8	100.0
Dipped in 2 per cent. ethylene chlorhydrin; subjected to vapors 24 hours	15	15	30	---	42.1	81.5	15	135	30	---	31.6	83.3
Soaked in 3 per cent. thiourea for 1 hour	120	135	150	150	0.0	3.8	65	120	165	150	4.3	3.6
Soaked in 1 per cent. thiourea for 1 hour	120	120	150	150	0.0	0.0	120	120	135	135	4.0	7.7
Wrapped in cotton batting saturated with 10 per cent hydrogen peroxide; unwrapped after 7 days	135	---	165	---	40.0	-----	150	---	---	---	70.0	-----

* Whole: 1-ounce whole tubers; Halves: 1-ounce halves from 2-ounce whole tubers.

Table 11. -- Effect of various chemical treatments on the length of rest period in tubers of the varieties Chicago and Waterer in 1931-32.

Treatment	Chicago						Waterer					
	Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting prior to June 1		Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting prior to June 1	
	Whole	Halves*	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves	Whole	Halves
Control	150	150	150	150	0.0	0.0	180	180	195	195	0.0	0.0
Soaked 1 hour in 1 per cent. NH_4SCN	150	165	180	---	4.2	59.4	---	---	---	---	4.0	27.6
Soaked 1 hour in 2 per cent. NH_4SCN	165	150	180	180	16.0	37.5	---	---	---	---	15.6	4.0
Soaked 1 hour in 3 per cent. NH_4SCN	---	---	---	---	100.0	100.0	---	---	---	---	36.0	100.0
Dipped in 0.5 molar $NaNO_3$	150	135	150	165	0.0	0.0	165	165	---	---	32.0	80.0
Dipped in 1 molar $NaNO_3$	150	150	150	150	0.0	0.0	150	120	---	---	0.0	0.0
Soaked 1 hour in 5 per cent. 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 per cent. ethyl alcohol. Subjected to vapors 24 hours	15	15	15	15	4.3	0.0	30	45	135	90	26.9	13.8
Soaked 1 hour in 5 per cent. acetone. Subjected to vapors 24 hours	120	135	135	165	4.3	0.0	150	135	---	---	68.0	6.3
Soaked 1 hour in 20 per cent. 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	---	0.0	-----	---	---	---	---	----	-----
Subjected to ether vapors 1 part in 10,000 for 24 hours (tubers dug in Nov.)	120	---	135	---	4.5	-----	---	---	---	---	----	-----
Subjected to ether vapors 1 part in 20,000 for 24 hours (tubers dug in Nov.)	120	---	135	---	4.2	-----	---	---	---	---	-----	-----
Subjected to ether vapors 1 part in 20,000 for 24 hours (tubers dug Dec. 21)	45	---	75	---	0.0	-----	---	---	---	---	----	-----
Subjected to chloroform vapors 1 part in 400, 1,000, 2000, or 10,000 24 hrs.	---	---	---	---	100.0	100.0	---	---	---	---	100.0	100.0
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	0.0	120	120	180	180	10.0	10.0
Subjected to carbon disulphide 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	0.0	135	135	180	180	12.5	0.0
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	0.0	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	54.3
Subjected to ethylene chlorhydrin vapors at 0.75 cc. (40 per cent.) 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 per cent. ethylene chlorhydrin	30	15	165	150	13.0	6.7	120	120	180	165	16.0	40.6
Dipped in 6 per cent. ethylene chlorhydrin; Subjected to vapors for 24 hours	15	30	---	---	56.5	93.3	30	---	---	---	95.8	100.0
Dipped in 2 per cent. 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 per cent. thiourea for 1 hour	30	15	---	---	65.4	83.9	165	165	---	---	24.0	22.2
Soaked in 1 per cent. 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 per cent. hydrogen peroxide; unwrapped after 7 days	30	---	180	---	30.0	----	---	---	---	---	90.0	-----

* Whole: 1-ounce whole tubers; Halves: 1-ounce halves from 2-ounce whole tubers.

Table 12. -- Effect of various chemical treatments on length of rest period in tubers of the varieties Blanc Ameliore and Chicago in 1932-33.

Treatment	Blanc Ameliore						Chicago					
	Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting prior to June 10		Days to first sprouting		Days until 50 per cent. of tubers sprouted		Per cent. rotted (before sprouting prior to June 10	
	Cool*	Warm	Cool	Warm	Cool	Warm	Cool	Warm	Cool	Warm	Cool	Warm
Control	120	45	135**	75	66.7	37.5	60	45	135	120	20.0	21.3
Soaked 2 hours in 3 per cent. NaSCN	60	30	---	---	83.3	68.0	90	30	150	90	48.0	42.3
Soaked 1 hour in 5 per cent. NaSCN	30	30	---	---	88.0	92.3	60	30	---	---	72.0	92.6
Soaked 1 hour in 5 per cent. ethyl alcohol; subjected to vapors 24 hours	60	15	105	75	24.0	40.0	30	30	90	75	0.0	8.0
Soaked 1 hour in 20 per cent. ethyl alcohol; subjected to vapors 24 hours	15	15	90	15	15.4	40.0	15	15	75	---	0.0	60.0
Soaked 1 hour in 20 per cent. 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	0.0
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 per cent. ethylene chlorhydrin; subjected to vapors 24 hours	15	15	15	15	10.0	0.0	15	15	30	30	0.0	15.4
Dipped in 6 per cent. 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 per cent.) per liter space for 24 hours	30	15	120	60	19.2	4.0	60	30	135	90	4.0	12.0
Soaked 2 hours in 5 per cent. thiourea	30	30	30	30	28.0	8.0	30	30	30	30	12.0	0.0

* Cool: planted in 45°-55°F. greenhouse; Warm: planted in 65°-75°F. greenhouse.

** Days until 50 per cent. of sound tubers at the previous examination sprouted.

1909, McCallum (53) noted that some substances used on potatoes stimulated buds quite vigorously but at the same time killed tissues of the tuber. He said: "This stimulation is confined entirely to the dormant buds, starting them into activity, and does not imply any further influence upon the later growth of the plant, either as regards foliage or tubers." 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 Plates IV, V, VI. Note that although tubers were planted early in December 1931 and that growth was soon stimulated, that very little actual sprout growth had occurred by March 3, 1932.)

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

Tables 10, 11 and 12 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- 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 12 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 sprouting, under field

conditions, usually occurs while the soil temperature is still quite low. It appears, however, that for tests of efficacy of a chemical in breaking rest that the higher temperatures may be better. (Compare illustrations of similarly treated tubers sprouted under the two temperature conditions, shown in Plates VII to XII.)

The following classification according to the effects of the treatments summarizes, in a general manner, the results secured over the two-year period on the four varieties with cut and uncut tubers, and two sprouting temperatures. The classification is based on the data of Tables 10 to 12, and on other data and observations not here presented.

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

Soaking in 20 per cent. ethyl alcohol for 1 hour, followed by vapors 24 hrs.

Soaking in 5 per cent. thiourea for 2 hours and planting at once.

Dipping in 2 per cent. ethylene chlorhydrin solution, followed by vapors 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 per cent. acetone 1 hour, followed by vapors 24 hours.

Dipping in 6 per cent. ethylene chlorhydrin solution, followed by vapors 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 per cent., 70 per cent., or 95 per cent. ethyl alcohol 1 hour, followed by vapors for 24 hours.

Soaking in 3 per cent. sodium thiocyanate for 2 hours and planting at once.

Soaking in 5 per cent. 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 hrs.

Exposing to ethyl bromide vapors 1 part in 5,400 of air for 24 hours.

Exposing to carbon disulphide vapors, 1 part in 17,500 of air for 24 hours.

Wrapping tubers in cotton batting saturated with 10 per cent. 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 per cent, or 3 per cent. sodium thiocyanate 1 hour, and planting at once.

Soaking in 1 per cent., or 2 per cent. ammonium thiocyanate 1 hour, and planting at once.

Soaking in 5 per cent. ethyl alcohol 1 hour, followed by vapors 24 hours.

Soaking in 5 per cent. acetone 1 hour, followed by vapors 24 hours.

Soaking in 1 per cent., or 3 per cent. thiourea 1 hour, and planting at once.

Dipping in 0.5 molar, or 1 molar sodium nitrate, and planting at once.

Exposing to carbon tetrachloride vapors 1 part in 14,000 of air for 24 hrs.

Exposing to ether vapors 1 part in 10,000 or 20,000 of air for 24 hours.

Exposing to 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 per cent. solution in 1300 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 some of the chemically treated lots are shown in Plates IV to XII.

Although considerable shortening of the rest period was found with some of these chemical treatments, subsequent growth and development was in all cases much slower than that induced when the rest period was terminated by the low temperature treatments described below. 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 which 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 studied are presented in Tables 13 and 14. 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°F. to 32°F., not only when the time to 50 per cent. sprouting is considered, but also when the time for production of first sprouts is the measure. 36°F can be seen to be only slightly less effective than 32°F. in reducing the sprouting time, but 50°F. is markedly poorer than the lower temperatures. Since the data on the degree 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°F., continued to shorten the sprouting time until by the time the sprouting trials were terminated, 50 per cent. sprouting was occurring in less than 7 days from planting. There were only minor differences in sprouting times between

Table 13. — Effect of temperature conditions to which dormant Jerusalem artichoke tubers were exposed, on length of rest period in 1931.

Period of exposure in days	Blanc Ameliore						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
Days from planting until 50 per cent of tubers sprouted*																								
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	---	--	--	--	--	--	--	--	--	--	--	--
Days from planting to first evident sprouting																								
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	---	--	--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--
Per cent. 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	0	19	15	0	12	19	29	0	54	0	0	0	8	4
30	84	0	0	0	4	0	10	0	0	0	0	63	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	0	15	33	0	0	0	36	0	50	0	0	0	4	0
75	77	0	0	0	4	0	35	0	0	0	0	5	67	9	0	0	19	0	76	0	0	0	0	0
90	91	5	0	0	72	0	20	0	0	0	0	7	100	0	0	0	0	0	77	27	0	0	5	0
105	92	0	0	0	72	0	--	-	-	-	-	-	---	-	-	-	-	-	--	--	-	-	-	-

* Percentage based on number of sound tubers at preceding examination.

(1) All tubers rotted without sprouting.

Table 14. — Effect of temperature conditions to which dormant Jerusalem artichokes were exposed, on length of rest period in 1932, 1933, and 1934.

Period of exposure in 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 until 50 per cent. of tubers sprouted*																		
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
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
Per cent. 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

* Percentage based on number of sound tubers at preceding examination.

(1) All tubers rotted without sprouting.

tubers stored under the two conditions of humidity at 32°F. Rosa (61) noted similar results with potatoes stored under different humidity conditions at 4°C. and 30°C.

Sprouting tests on tubers stored in field pits, where the temperature was subject to fluctuations between about 30° to 40°F., show such tubers to be intermediate in their sprouting response between the 36°F. and 50°F. constant temperature treatments. The two temperatures below 32°F. which were used (18°F. in 1931-32, and 15°F. 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 breakdown of tissues of the tubers, the pith in particular, quickly decomposing. Although several attempts were made to thaw tubers frozen at these low temperatures, by bringing them from the low temperatures to successively higher temperatures for successive periods of about 1 day each, none of the attempts were successful. These failures seem strange, too, because under natural conditions in the field the tubers are usually frozen over winter, yet are perfectly sound when dug in the spring. It is probable that thawing under the latter conditions is a much more gradual process and that the soil temperature at the depth of the tubers in the field does not get as low as those used in this study. The latter idea is supported by the excellent results secured with tubers kept in field pits during the winter.

Plates XIII, XIV, XV show differences in sprouting exhibited by tubers of the variety Tait in 1931-32 after exposure to the various temperature conditions for 15, 30, and 45 days respectively. Plates XVI to XX illustrate the differences shown by the variety Blanc Ameliore in 1933-34 when stored at 32°F. and 50°F. for 15, 30, 45, 60, and 75 days. The data in Table 14 show that in the 1933-34 season the sprouting response of the samples

stored at 50°F. was not markedly inferior to that of samples stored at 32°F. when the time to 50 per cent. sprouting is used as the criterion, yet it is plainly evident from the photographs that the growth response is much poorer with the 50° lots. Neither the 32° nor the 50° samples gave normal growth at the end of 15 days exposure; at 30 days the 32° sample gave normal sprouts, but it was not until at least 60 days exposure that the 50° treatment showed normal sprouting. This inferiority of the 50° samples is even more noticeable in the photographs of the 1934-35 experiments given in Plates XXI, XXII, and XXIII. 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 deciding what are effective storage treatments for breaking rest, it therefore seems necessary to distinguish between those treatments which "break" rest, and those which not only "break" it, but also induce normal plant development. Gericke (30) noted a much slower growth in potatoes planted immediately after maturation of the crop as compared with those that underwent a normal length of rest period before being planted.

From experiments conducted since publication of a preliminary report (63) of the 1931 experiments, Haber (33) arrived at essentially the same conclusions as those discussed in this and the preliminary report relative to the shortening of rest by low temperatures.

Another factor which would necessarily be taken into account in any practical method of breaking the rest period is that of susceptibility of tubers to diseases during and following treatment. The data given in Tables 13 and 14 show that, in general, a much greater percentageof the tubers treated at 50°F. rotted after planting than at any of the lower

temperatures (above freezing) employed. Johnson (45) 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 standpoints of more rapid breaking of rest, inducing normal plant development, and in keeping down the amount of rotting, it is evident that the 32°F. and 36°F. temperature treatments are far superior to the 50°F. treatment.

Catalase Activity. Results of catalase determinations made on terminal buds, pith, and cortex of Blanc Ameliore and Chicago tubers exposed at 32°F. and 50°F. for the various periods in 1933-34 and in 1934-35 are given in Tables 15, 16, and 17, and in Figures 5, 6, and 7. There were noticeable fluctuations in the moisture content of tubers stored for the different periods and under different temperature conditions, therefore it was thought desireable to present data on the dry weight basis as well as the fresh basis.

Critical examination of these data 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 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 50°F. treated tubers showed greater activity per unit fresh weight than the corresponding 32°F. tubers on any date, although the values are much more nearly alike for the two treatments in 1934-35 than in 1933-34.

Table 15. -- Catalase activity in relation to the rest period of Jerusalem artichoke tubers stored at 32°F. and 50°F. Variety Blanc Ameliore. Season 1933-34.

Days in storage	Buds		Cortex		Pith	
	32°F.	50°F.	32°F.	50°F.	32°F.	50°F.
cc. oxygen evolved per .04 g. bud tissue or .08 g. pith or cortex tissue in 5 minutes at 24.5°C.*						
0	7.66	7.66	5.54(1)	5.54(1)	5.54(1)	5.54(1)
16	6.65	8.85	4.45	5.40	3.10	4.53
31	5.75	8.40	4.07	5.93	2.83	4.13
45	4.68	8.55	3.85	7.00	2.73	4.83
60	5.50	11.25	4.55	8.35	2.83	7.00
74	5.78	9.53	3.83	9.18	2.80	8.50
cc. oxygen evolved per centigram dry matter in 5 minutes at 24.5°C.						
0	7.65	7.65	3.17(1)	3.17(1)	3.17(1)	3.17(1)
16	6.04	6.08	2.26	2.59	2.53	3.43
31	5.16	6.92	2.01	2.76	2.10	2.95
45	4.46	8.15	1.89	3.59	2.12	3.49
60	5.02	9.72	2.33	3.67	2.21	5.01
74	7.00	7.98	2.45	6.40	2.80	6.43

* Average of duplicate determinations.

(1) Determinations were made on single "plugs through the tubers instead of on cortex and pith separately.

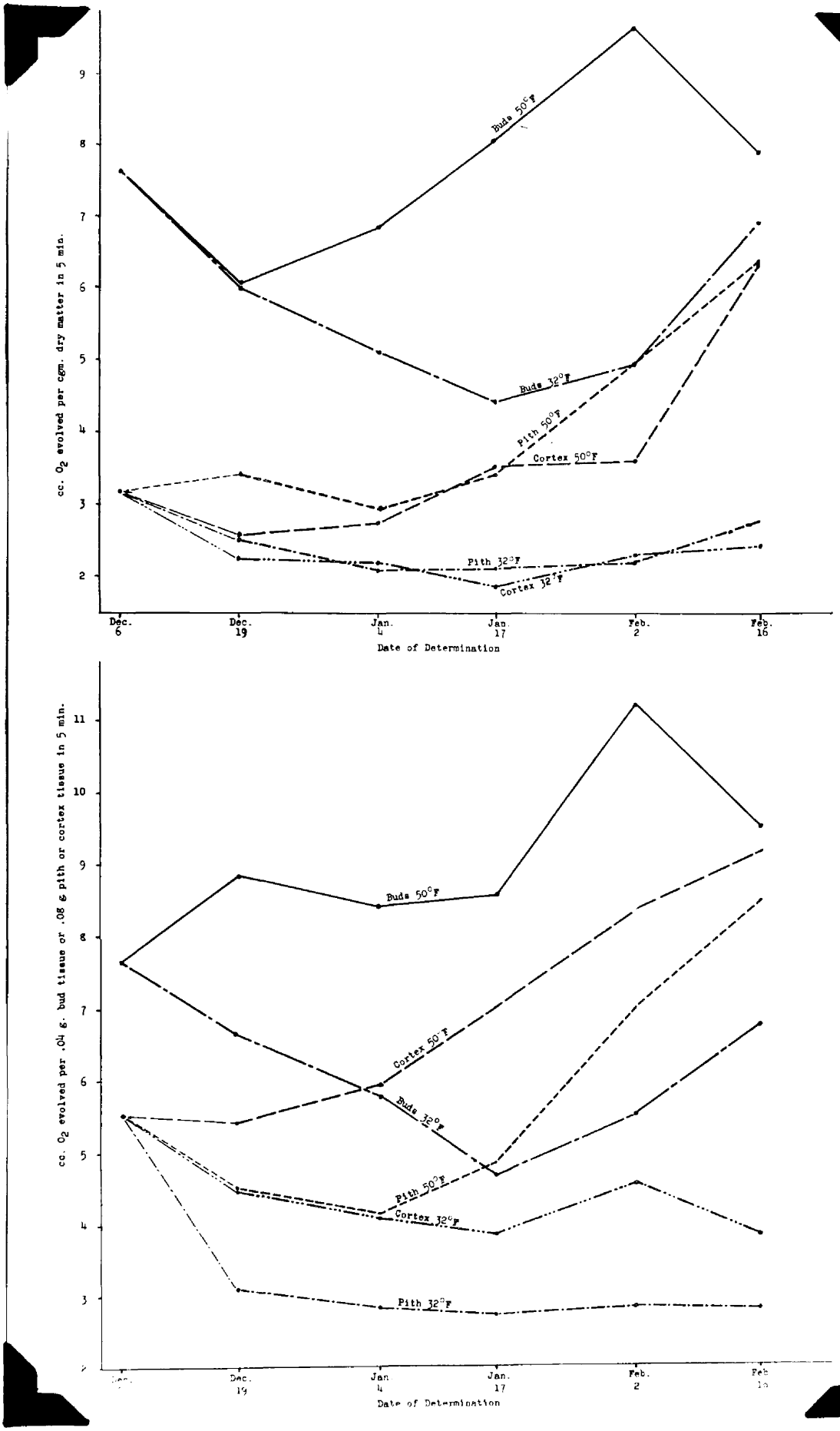

Fig. 5. Catalase activity of bud, pith, and cortex tissues of Jerusalem artichoke tubers stored at 32°F. and 50°F. for different periods of time in 1933-34. Variety Blanc Ameliore.

Table 16. -- Catalase activity in relation to the rest period of Jerusalem artichoke tubers stored at 32°F. and 50°F. Variety Blanc Ameliore. Season 1934-35.

Days in storage	Buds		Cortex		Pith	
	32°F.	50°F.	32°F.	50°F.	32°F.	50°F.
cc. oxygen evolved per .04g. bud tissue or .08g. pith or cortex tissue in 5 minutes at 24.5°C.*						
0	6.95	6.95	6.15	6.15	3.90	3.90
14	8.00	9.20	6.95	7.35	5.05	5.35
31	8.33	8.43	7.15	6.68	5.58	5.35
44	8.53	8.60	7.48	6.13	5.03	4.55
58	7.00	8.08	8.15	7.00	5.53	5.35
73	7.98	10.05	7.36	6.90	4.93	5.55
94	7.60	12.43	6.33	9.98	7.75	5.05
cc. oxygen evolved per centigram dry matter in 5 minutes at 24.5°C.						
0	6.94	6.94	3.32	3.32	3.62	3.62
14	7.68	8.39	3.58	3.64	4.60	4.89
31	7.07	6.98	3.16	2.64	4.20	3.81
44	7.75	7.52	3.65	2.80	4.17	3.76
58	6.24	6.32	3.74	2.74	4.50	3.92
73	7.05	8.59	3.38	2.62	4.10	4.14
94	(1)	(1)	(1)	(1)	(1)	(1)

* Average of duplicate determinations.

(1) An accident to the dry matter samples prevented calculation of the 94-day results to the dry basis.

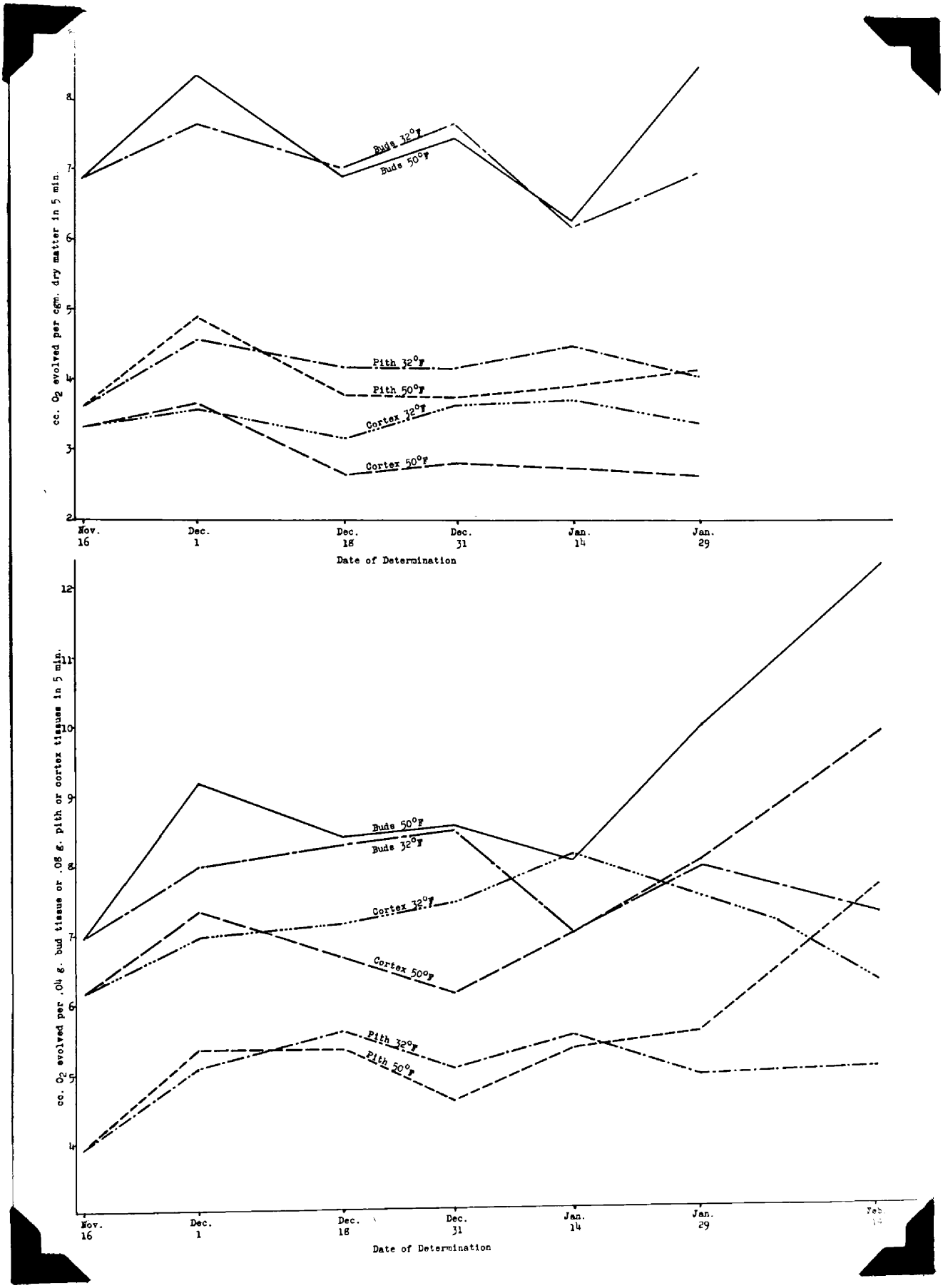

Fig. 6. Catalase activity of bud, pith, and cortex tissues of Jerusalem artichoke tubers stored at 32°F. and 50°F. for different periods of time in 1934-35. Variety Blanc Ameliore.

Table 17. — Catalase activity in relation to the rest period of Jerusalem artichoke tubers stored at 32°F. and 50°F. Variety Chicago. Season 1934-35.

Days in storage	Buds		Cortex		Pith	
	32°F.	50°F.	32°F.	50°F.	32°F.	50°F.
cc. oxygen evolved per .04g. bud tissue or .08g. pith or cortex tissue in 5 minutes at 24.5°C.*						
0	8.30	8.30	7.55	7.55	4.80	4.80
17	10.90	10.38	9.55	10.00	7.25	6.30
34	10.85	9.45	12.40	10.20	7.60	5.68
46	11.75	9.60	13.35	10.38	6.95	6.40
60	11.10	10.08	11.53	11.03	5.90	6.60
74	10.60	9.03	11.85	9.10	8.00	5.63
95	10.78	12.70	10.95	13.55	7.28	8.68
cc. oxygen evolved per centigram dry matter in 5 minutes at 24.5°C.						
0	7.53	7.53	3.40	3.40	3.82	3.82
17	9.39	8.76	4.32	4.11	5.29	4.60
34	8.37	6.08	4.52	3.73	5.02	3.35
46	9.10	6.67	4.83	3.56	4.92	3.79
60	8.36	6.18	4.22	3.30	4.06	3.46
74	7.77	6.32	4.07	3.02	4.67	3.25
95	(1)	(1)	(1)	(1)	(1)	(1)

* Average of duplicate determinations.

(1) An accident to the dry matter samples prevented calculation of the 95-day results to the dry basis.

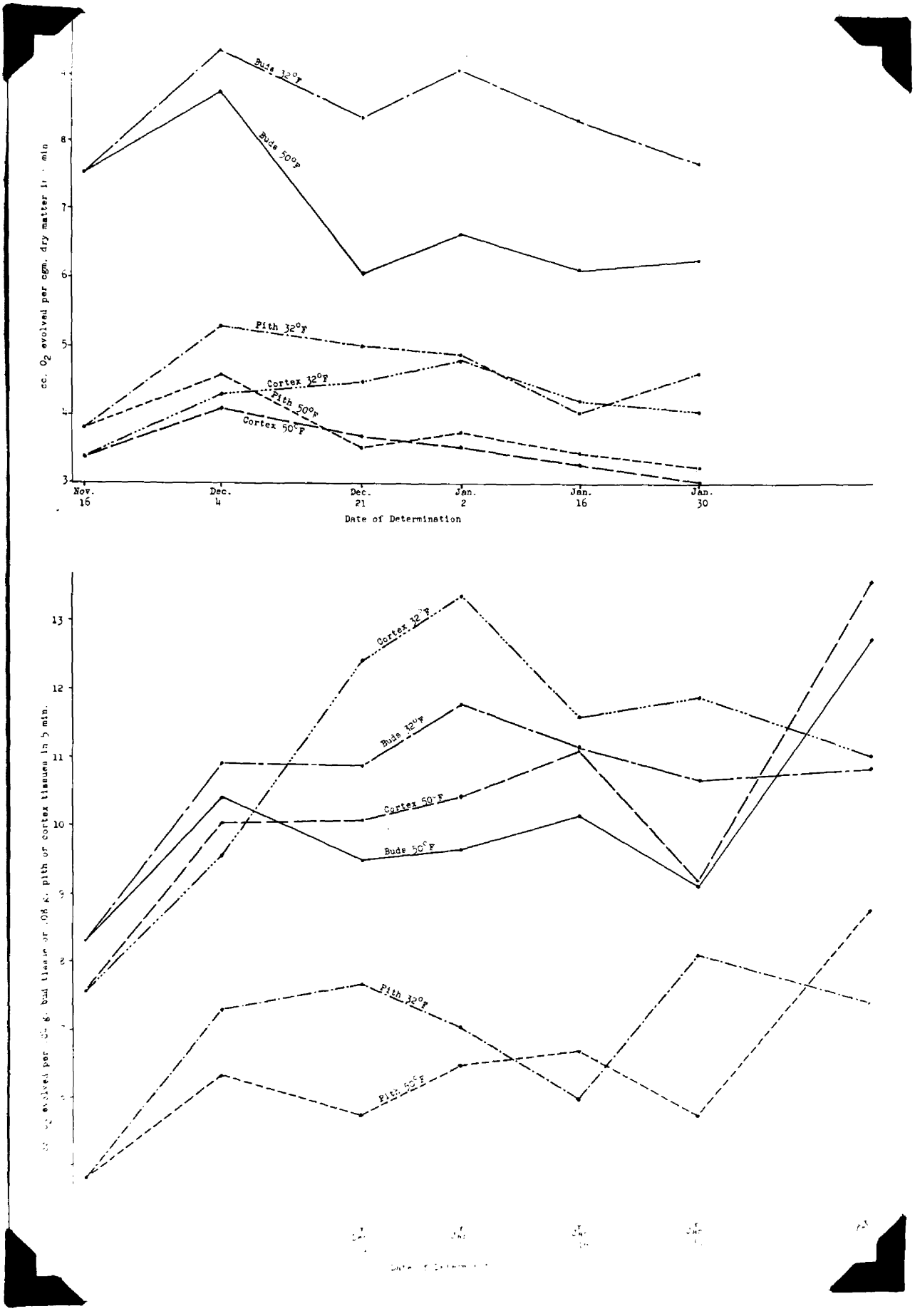

Fig. 7. Catalase activity of bud, pith, and cortex tissues of Jerusalem artichoke tubers stored at 32°F. and 50°F. for different periods of time in 1934-35. Variety Chicago.

The trends in catalase activity over the whole period studied are quite dissimilar in the two seasons especially for the buds of the 32°F. 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 season when growth was more nearly alike in these samples, (as judged by the time to 50 per cent. sprouting), than in 1934 when the sprouting response was not so similar.

In Blanc Ameliore the relationships between the cortex catalase values of the 32°F. treatments and the 50°F. treatments are different in the two seasons. The same is 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 fresh weight in the two treatments was just reversed. In Chicago the tissues of 32° tubers exhibited considerably greater activity than the corresponding tissues of the 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 non-resting condition (immediately following breaking of rest) irrespective of the previous treatment, was unfruitful. It was thought possible that the catalase value for a 32° 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.

Hydrogen-ion Concentration. Table 18 gives data on the effect of the 50°F. and 32°F. exposures on the pH of tubers of the variety Blanc Ameliore studied in 1933-34.

A rather large difference in pH of buds was found at the end of the first 15 days exposure. At that time the 32° sample showed an increase of over .7 pH as compared with the unstored initial sample, while the 50° sample showed a decrease of almost .3 pH unit. The 50° sample thus had a hydrogen-ion concentration almost 10 times that of the 32° sample. This difference, however, did not persist. At the end of 30 days storage there was a difference of only about .2 pH between the two storage lots (the 50° sample exhibiting the less acid condition) and the differences thereafter remained relatively small.

There was also a rather large difference in the pH of the pith tissues (.5 pH unit) at the end of the first 15 day storage period but the values were not widely different for the remainder of the period studied.

The pH of the cortex of the tubers was only slightly affected by the temperatures employed. The values for the 50° samples were slightly higher until the 60-day exposure period was reached.

A trend toward decreased acidity during emergence from rest was evident in all three tissues studied. The minimum acidity was found, for all three tissues and both storage conditions, to occur at the 60-day storage period. Reference to Table 14 reveals that this was also

Table 18. — Changes in pH of tubers of the variety Blanc Ameliore stored for various periods of time in 1933-34.

Period of exposure (in days)	pH					
	Terminal Buds		Cortex		Pith	
	32°F.	50°F.	32°F.	50°F.	32°F.	50°F.
0	5.48	5.48	5.84	5.84	5.90	5.90
15	6.21	5.24	6.00	6.02	6.19	5.63
30	5.90	6.14	5.77	5.79	5.84	5.85
45	6.06	6.08	5.98	6.10	6.11	5.99
60	6.30	6.21	6.22	6.20	6.19	6.17
75	6.11	6.05	5.99	5.66	6.03	5.88

the period when both treatments reached the 50 per cent. sprouting point within 15 days after planting.

Respiration. In Table 19 results of the respiration experiments conducted in the 1934-35 season on the two varieties Blanc Ameliore and Chicago, are presented. The data are expressed on three different bases. The expression as milligrams carbon dioxide per unit fresh weight is open to some objection since the moisture content of the samples is somewhat variable. If the rate of evolution of carbon dioxide per unit dry weight be used then it may be argued that respiration is a measure of the living organism which includes the water, and the expression on the dry weight basis is thus incorrect. Probably the best measure of respiratory activity is that given on the per-tuber basis, since tubers were of uniform size in all lots. Data on the latter basis are presented graphically in Figure 8. A study of the data shows that, in this experiment, the relative respiratory values between treatments are practically the same regardless of the manner of expression used. Only with the 45- and 60-day lots of Chicago are the relationships between the 32°F. and 50°F. treatments reversed when expressed on the fresh weight basis, as compared with the dry weight, or per-tuber methods of expression.

No very good 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 per cent. 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°F. in Blanc Ameliore) yet the fact that the differences between the two treatments are even

Table 19. — Rates of respiration of Jerusalem artichoke tubers stored at 32°F. and 50°F. for various periods of time. Tubers placed in storage November 16, 1934.

Date of determination	Blanc Ameliore 32°F.	Blanc Ameliore 50°F.	Date of determination	Chicago 32°F.	Chicago 50°F.
Expressed as mg. CO_2 evolved per average tuber per hour*					
Nov. 23**	.889	.889	Nov. 23**	.617	.617
Dec. 4	.998	.786	Dec. 7	1.158	.897
Dec. 21	.977	1.044	Dec. 24	1.175	1.166
Jan. 3	1.032	1.045	Jan. 5	1.325	1.299
Jan. 17	.934	1.003	Jan. 19	1.422	1.384
Feb. 1	1.378	1.329	Feb. 2	1.607	1.262
Expressed as mg. CO_2 evolved per kilo fresh weight per hour*					
Nov. 23**	35.48	35.48	Nov. 23**	24.79	24.79
Dec. 4	40.59	34.26	Dec. 7	51.81	42.52
Dec. 21	42.22	48.10	Dec. 24	55.22	53.25
Jan. 3	51.65	53.76	Jan. 5	64.19	78.08
Jan. 17	40.59	49.87	Jan. 19	68.26	75.49
Feb. 1	63.89	74.02	Feb. 2	79.91	75.00
Expressed as mg. CO_2 evolved per kilo dry matter per hour*					
Nov. 23**	138.88	138.88	Nov. 23**	81.47	81.47
Dec. 4	177.76	131.11	Dec. 7	152.64	124.70
Dec. 21	154.56	167.27	Dec. 24	178.24	130.69
Jan. 3	176.42	178.24	Jan. 5	175.87	170.58
Jan. 17	149.20	165.60	Jan. 19	188.23	166.64
Feb. 1	229.93	238.86	Feb. 2	227.94	157.79

* Based on 4- to 6-hour "runs" after the first 3-hour period on all except the Nov. 23 samples. Only data for the first 3 hours was taken on the latter samples. Length of "run" was always the same for corresponding 32° and 50° samples.

** Samples not stored. Kept at room temperature (about 60°F.) from Nov. 16 to Nov. 23.

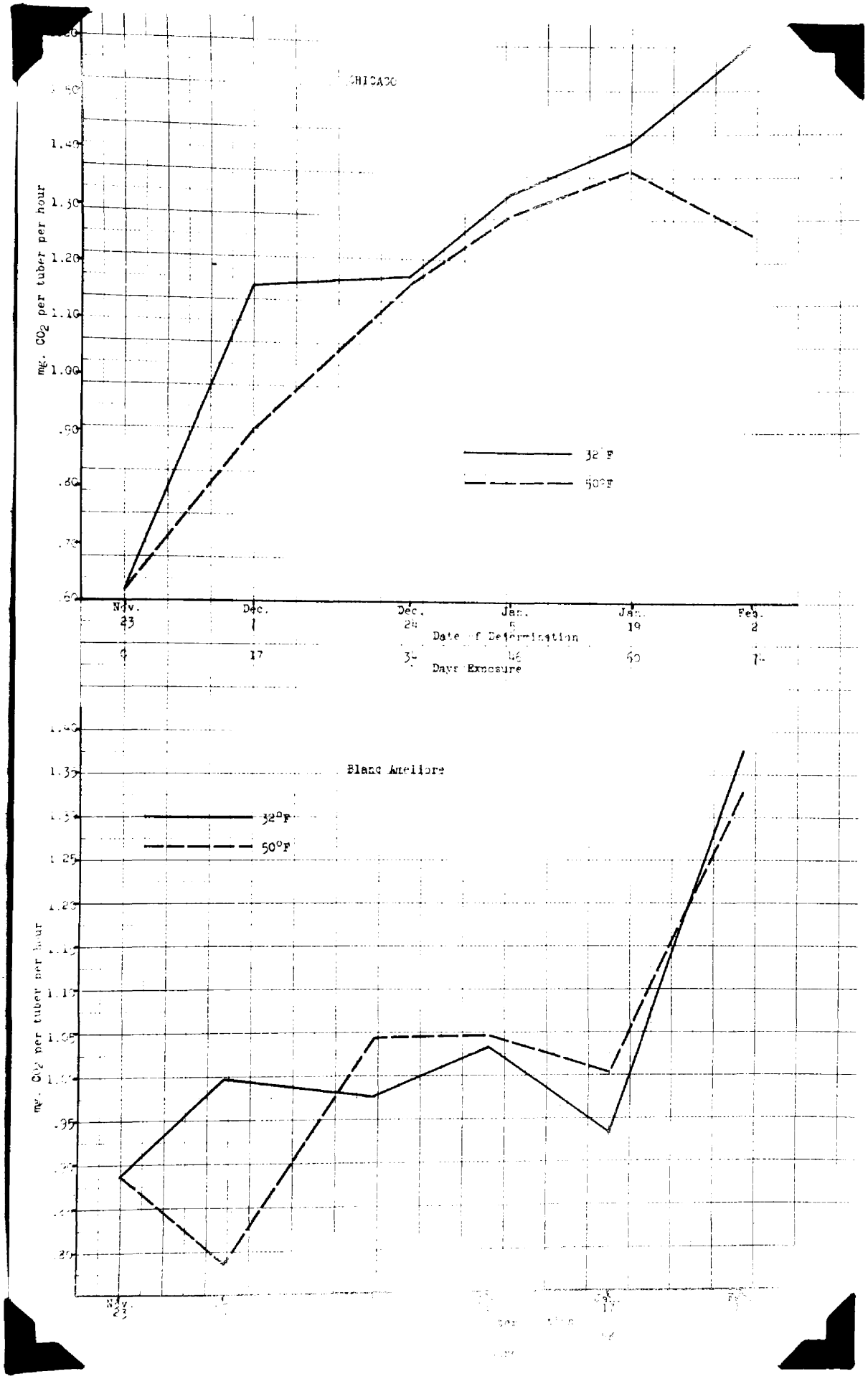

Fig. 8. Respiratory activity of Jerusalem artichoke tubers stored at 32°F. and 50°F. for different periods of time in 1934-35.

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 Chicago the respiratory rate of the 50° samples remained lower than that of the 32° lots over the entire period studied; 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° 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°F. 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. Samples of two varieties of the 1931-32 whole-tuber-samples were analyzed. In Blanc Ameliore the nitrogen fractions were determined but no analyses were made for carbohydrates in the alcoholic extract, free reducing substances, or the acid-hydrolyzable polysaccharide fraction. Although attempts were made to determine free levulose on a few samples, none of those analyzed showed more than traces, so no attempt was made to analyze for this carbohydrate in the remaining samples. In the Tait series the nitrogen fractions were omitted but all

other fractions included. Analysis of the 18°F. samples was omitted because of the tuber injury noted above.

Table 20 gives data for the Blanc Ameliore samples. The results of the Tait analyses are presented in Table 21 and in Figure 9.

The Blanc Ameliore 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 with the 32° high humidity exposure than with 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°F. treatment exhibited a considerably larger content of these hot-water-soluble reducing substances than either of the 32°F. treatments during the first 60 days of the experiment. The variety Tait 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 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 in Blanc Ameliore and the first 15 days with Tait, the levulose content (on the dry weight basis) was much higher with the 50°F. exposure than with the lower temperature treatments. The high levulose content suggests that a larger proportion of the reserves at 50°F. are in the form of inulin or closely related

Table 20. -- Chemical composition of Jerusalem artichoke tubers subjected to different temperature conditions for various periods of time in 1931-32. Variety Blanc Ameliore. Per cent. of dry weight.

Treatment	Period of exposure in days						
	15	30	45	60	75	90	105
Dry matter (per cent. of fresh weight)							
Control**	24.20	24.20	24.20	24.20	24.20	24.20	24.20
32°F. LH*	24.43	23.86	36.36	34.99	29.67	32.61	-----
32°F. HH*	22.97	24.87	27.41	24.78	24.17	25.58	-----
36°F.	25.56	25.44	24.62	23.18	24.37	25.61	27.46
50°F.	26.31	26.92	27.22	27.29	30.91	36.72	32.15
Field Pit	22.35	22.44	22.20	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°F. LH	.84	.79	.72	.94	1.07	.92	----
32°F. HH	.85	.95	103	1.01	1.10	.96	----
36°F.	.94	.87	.92	1.08	1.00	.93	.99
50°F.	.86	.88	.95	1.00	1.06	1.09	1.29
Field Pit	1.03	----	.90	1.14	1.06	1.03	1.27
Alcohol-insoluble nitrogen							
Control	.85	.85	.85	.85	.85	.85	.85
32°F. LH	.87	.82	.87	.88	.80	.98	----
32°F. HH	.84	.87	.88	.81	.82	.84	----
36°F.	.83	.79	.87	.76	.82	.78	.79
50°F.	.85	.77	.81	.80	.74	.93	.80
Field pit	.75	.80	.74	.83	.76	.83	.84
Total nitrogen							
Control	1.92	1.92	1.92	1.92	1.92	1.92	1.92
32°F. LH	1.71	1.61	1.59	1.82	1.87	1.90	----
32°F. HH	1.69	1.82	1.91	1.82	1.92	1.80	----
36°F.	1.77	1.66	1.79	1.84	1.82	1.71	1.78
50°F.	1.71	1.65	1.76	1.80	1.80	2.02	2.09
Field pit	1.78	----	1.64	1.97	1.82	1.86	2.11
Total hot-water-soluble reducing substances (as levulose)							
Control	60.61	60.61	60.61	60.61	60.61	60.61	60.61
32°F. LH	60.92	61.92	53.58	59.67	65.91	58.55	-----
32°F. HH	61.67	60.22	60.96	60.45	61.84	58.56	-----
36°F.	65.10	62.72	65.75	62.53	60.69	63.55	62.02
50°F.	63.25	67.38	63.11	62.72	59.78	58.99	60.73
Field pit	62.61	63.90	60.53	59.94	60.83	60.27	60.32
Total levulose							
Control	52.20	52.20	52.20	52.20	52.20	52.20	52.20
32°F. LH	48.71	49.77	44.53	46.48	52.31	45.45	-----
32°F. HH	48.37	45.60	48.08	47.69	47.96	47.29	-----
36°F.	55.20	50.31	49.95	50.78	45.17	50.57	53.84
50°F.	57.37	57.25	55.81	49.48	48.80	48.29	46.30
Field pit	52.87	53.89	49.82	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°F. LH	12.21	12.15	9.05	13.19	13.60	13.10	-----
32°F. HH	13.30	14.62	12.88	12.76	13.88	11.27	-----
36°F.	9.90	12.41	15.80	11.75	15.52	12.98	8.18
50°F.	5.88	10.13	7.30	13.24	10.98	10.70	14.43
Field pit	9.74	10.01	10.71	14.23	13.33	12.15	12.50

*LH-low humidity; HH-high humidity.
**Original tubers at harvest time.

Table 21. — **Chemical composition of Jerusalem artichoke tubers subjected to different temperature conditions for various periods of time in 1931-32. Variety Tait. Per cent. of dry weight.**

Treatment	Period of exposure in days					
	15	30	45	60	75	90
Dry matter (per cent. of fresh weight)						
Control**	24.34	24.34	24.34	24.34	24.34	24.34
32°F. LH*	21.43	24.33	28.55	28.13	30.62	40.65
32°F. HH*	22.04	22.33	21.78	22.70	24.26	23.01
36°F.	23.97	29.11	25.13	24.51	27.81	26.15
50°F.	30.51	25.69	28.67	29.11	28.34	30.12
Field pit	17.27	22.19	20.82	18.02	21.18	21.17
Free levulose						
Control	.05	.05	.05	.05	.05	.05
32°F. LH*	2.46	1.20	.84	.46	.78	.86
32°F. HH	1.35	.52	.59	.70	.53	.35
36°F.	1.00	----	.38	.39	.29	.49
50°F.	.04	.28	.12	.50	.99	.29
Field pit	.42	.05	.05	.09	.03	.08
Free reducing substances (as dextrose)						
Control	.13	.13	.13	.13	.13	.13
32°F. LH	3.37	2.15	1.84	1.34	1.84	1.68
32°F. HH	2.30	1.43	1.41	1.88	1.48	----
36°F.	1.46	.87	1.09	1.36	1.43	1.31
50°F.	.71	1.08	.89	1.23	2.00	1.09
Field pit	1.82	.81	.72	1.03	.40	.86
Total levulose						
Control	47.18	47.18	47.18	47.18	47.18	47.18
32°F. LH	39.38	36.13	34.15	34.24	35.19	34.39
32°F. HH	37.27	38.79	33.53	34.89	38.16	34.66
36°F.	39.36	40.03	32.00	37.13	36.14	37.29
50°F.	41.05	38.61	33.17	35.97	37.72	35.95
Field pit	35.98	35.65	31.91	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°F. LH	41.87	39.16	41.09	41.57	40.88	38.10
32°F. HH	-----	40.40	40.62	42.99	43.35	41.73
36°F.	40.89	39.66	37.86	43.08	41.38	40.45
50°F.	35.26	40.10	37.21	40.11	40.08	39.12
Field pit	-----	39.73	38.71	41.63	36.43	-----
Total hot-water-soluble reducing substances (as levulose)						
Control	67.02	67.02	67.02	67.02	67.02	67.02
32°F. LH	69.02	62.13	66.73	62.53	65.76	56.66
32°F. HH	62.95	63.08	61.36	63.06	61.63	60.80
36°F.	68.04	62.75	58.62	65.36	55.50	61.14
50°F.	63.68	65.32	59.28	63.03	63.57	61.92
Field pit	63.93	64.40	59.76	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°F. LH	3.50	3.88	3.58	3.88	3.80	1.88
32°F. HH	3.56	4.35	3.94	3.99	4.22	4.32
36°F.	3.46	2.60	3.76	3.74	3.88	4.26
50°F.	3.61	3.40	3.36	3.64	3.73	3.69
Field pit	3.86	3.72	3.77	3.98	4.41	3.89

* LH-low humidity; HH-high humidity.
**Original tubers at harvest time.

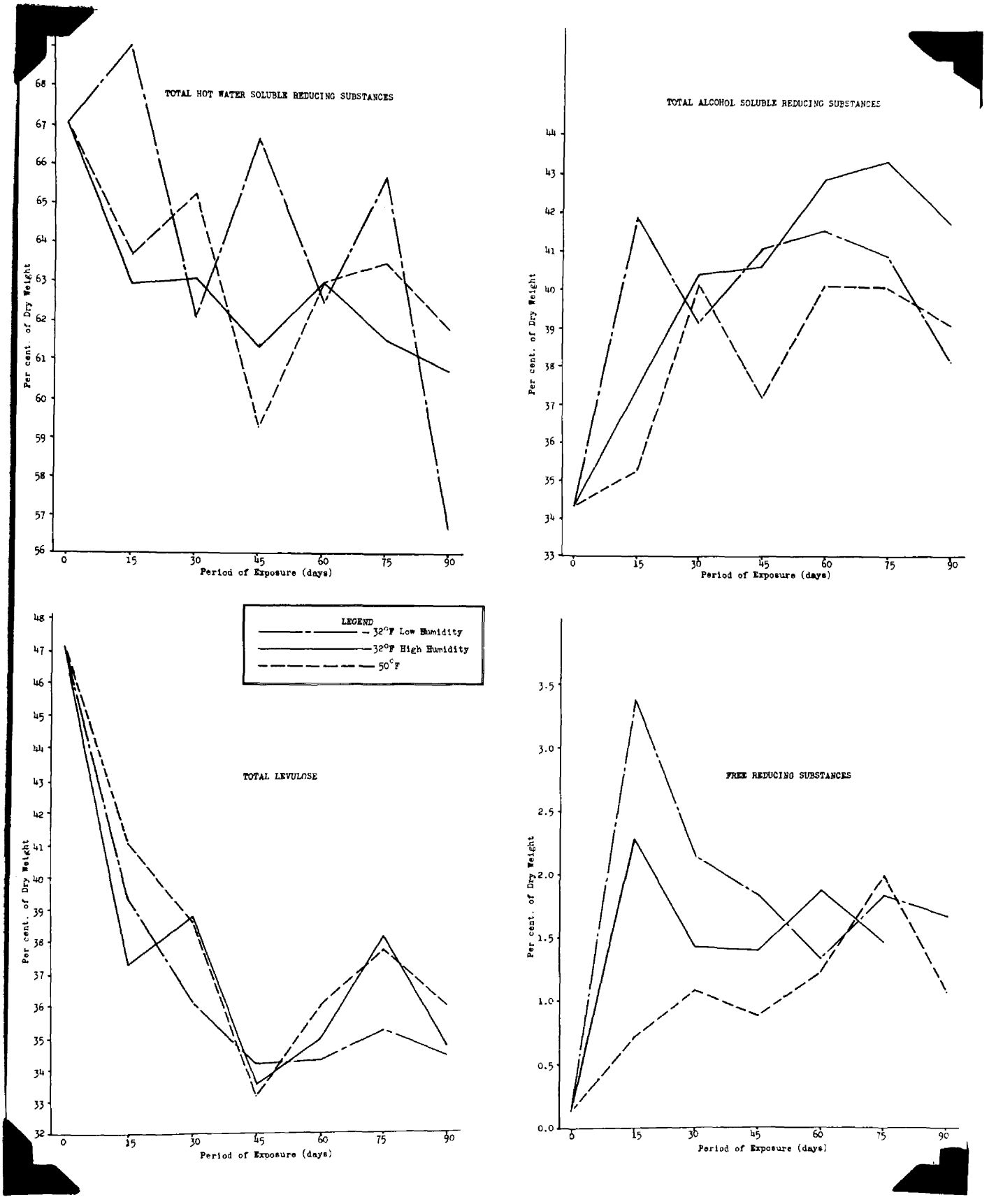

Fig. 9. Percentages of carbohydrate constituents in whole tubers during storage under three conditions for different periods of time in 1931-32. Variety Tait.

higher-levulose inulides than at the lower temperatures. This contention is supported by the figures 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 non-alcohol-soluble substances, largely inulin or higher inulides. Further, the data show that not only is the percentage of alcohol-soluble (more labile) reducing compounds smaller at 50°, but that of this 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°F., but not until 75 days exposure at 50°F.

The reducing substances other than levulose in the total hot-water-soluble fraction (largely glucose) in Blanc Ameliore also indicate that at 50° 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, we are not justified in assuming that the reducing substance content of the 50° samples was different from that of those 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 paper, showed no free reducing substances where no free levulose could be detected.

A higher free levulose content during the first 45 days of exposure at 32° than at 50° is observed in Table 21. It appears, however, that this is not of universal occurrence under these conditions since the free

levulose content was either non-existent, or so small as to be unmeasureable in the variety Blanc Ameliore.

The acid-hydrolyzable hot-water-insoluble polysaccharide fraction formed a slightly higher percentage of the dry matter from the 15 to 75 day lengths of exposure at the 32° exposures than at 50°. The differences are not large, however, and are probably of little significance.

1932 Bud Analyses. Tables 22 and 23 and Figures 10 and 11 give data on the composition of buds of the Blanc Ameliore and Chicago tubers.

A striking similarity can be noted in the relative composition of the buds and of the similarly treated whole tubers, even though the actual percentage compositions are different and that the same variety was used in only one case in both series.

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 the two conditions of humidity at 32° than exist between either of these and the 50°F. exposure.

The total levulose content of the 50° samples is consistently higher in both varieties, and total alcohol-soluble reducing substances lower (in Blanc Ameliore only up to 45 days exposure) 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 per cent. of the dry matter to be in the form of free reducing substances and almost 3.3 per cent of the dry matter

Table 22. — Chemical composition of buds from Jerusalem artichoke tubers previously subjected to different temperature conditions for various periods of time in 1932-33. Variety Blanc Ameliore. Per cent. of dry weight.

Treatment	Period of exposure in days				
	15	30	45	60	75
Dry matter (per cent. of fresh weight)					
Control **	28.45	28.45	28.45	28.45	28.45
32°F. LH*	31.29	34.48	34.21	36.29	41.29
32°F. HH*	33.10	27.66	28.62	30.61	33.36
36°F.	31.77	30.42	29.81	30.53	30.31
50°F.	32.42	32.84	31.85	32.75	37.11
Field pit	27.58	25.10	-----	23.19	22.91
Free levulose					
Control	.00	.00	.00	.00	.00
32°F. LH	3.27	2.38	2.52	.78	1.43
32°F. HH	2.09	2.28	1.43	---	1.19
36°F.	1.80	1.78	1.54	.67	.43
50°F.	.28	.71	.33	---	.60
Field pit	.52	.08	----	.05	.00
Free reducing substances (as dextrose)					
Control	1.06	1.06	1.06	1.06	1.06
32°F. LH	3.83	3.99	4.47	1.83	2.61
32°F. HH	2.40	3.85	2.50	2.20	2.19
36°F.	2.46	2.88	2.64	1.75	1.61
50°F.	.84	1.72	1.10	----	1.47
Field pit	1.61	1.38	----	1.05	1.07
Total levulose					
Control	51.42	51.42	51.42	51.42	51.42
32°F. LH	51.86	49.18	47.75	47.13	44.35
32°F. HH	50.60	46.17	44.87	47.34	46.69
36°F.	50.45	48.11	48.62	47.44	46.55
50°F.	51.66	53.28	50.67	54.54	49.29
Field pit	47.09	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°F. LH	59.53	62.03	60.39	56.05	58.04
32°F. HH	60.31	61.79	58.88	62.06	60.13
36°F.	61.93	64.26	62.70	58.44	61.53
50°F.	49.36	57.45	57.43	61.25	55.84
Field pit	57.94	-----	-----	55.72	57.36
Total hot-water-soluble reducing substances (as levulose)					
Control	74.60	74.60	74.60	74.60	74.60
32°F. LH	75.16	83.24	76.26	71.60	70.71
32°F. HH	78.40	72.92	61.83	73.50	73.97
36°F.	79.30	75.62	74.59	73.96	73.35
50°F.	74.30	76.11	74.16	81.78	75.69
Field pit	74.49	68.53	-----	67.70	63.89
Acid-hydrolyzable hot-water-insoluble polysaccharides (as dextrose)					
Control	3.07	3.07	3.07	3.07	3.07
32°F. LH	2.97	3.93	3.40	3.95	4.35
32°F. HH	3.01	3.65	3.70	4.33	3.82
36°F.	2.70	3.60	3.23	3.84	4.18
50°F.	3.56	3.35	3.64	3.54	3.36
Field pit	3.65	3.59	----	4.19	4.00

* LH-low humidity; HH-high humidity.
**Original tubers at harvest time.

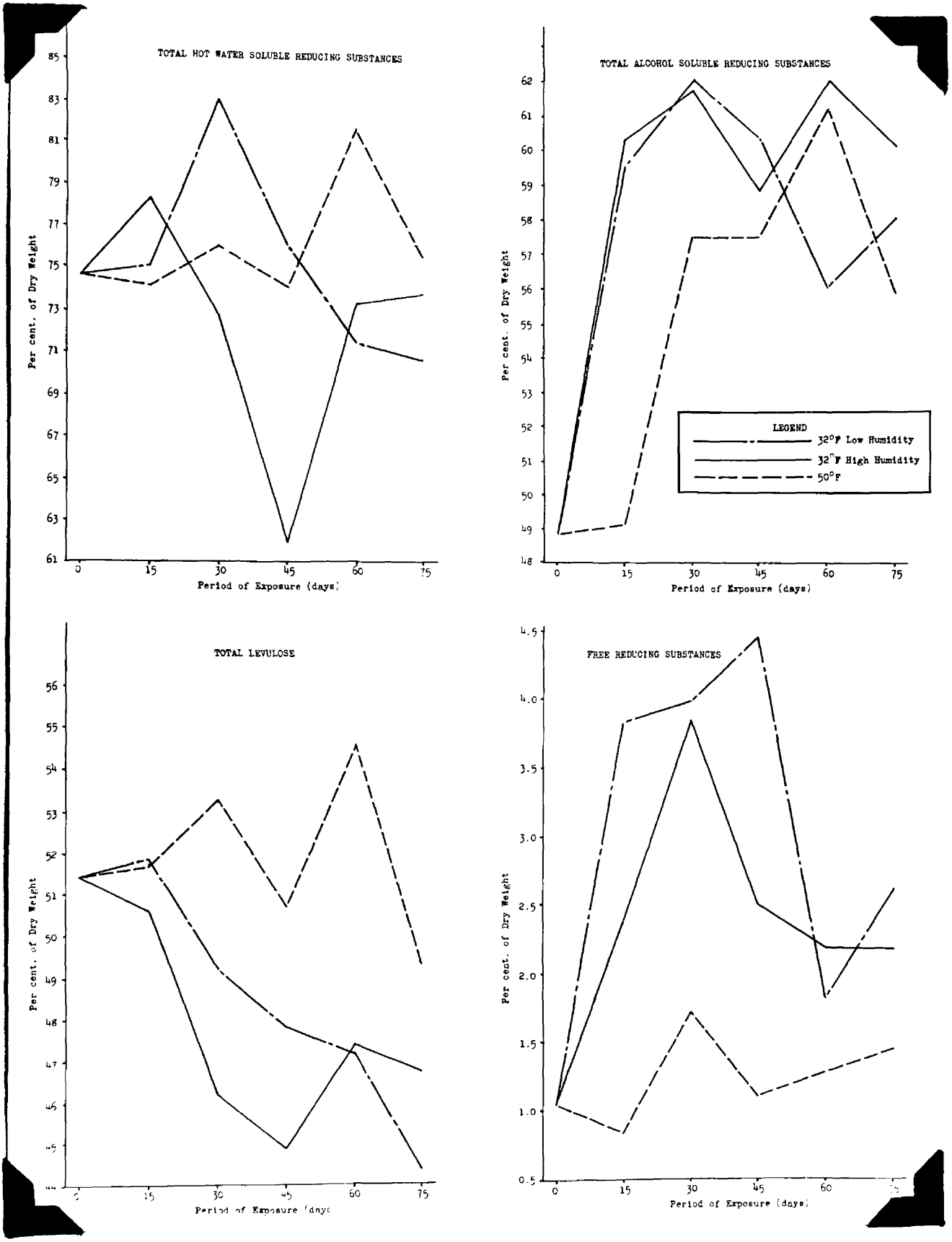

Fig. 10. Percentages of carbohydrate constituents in buds of tubers during storage under three conditions for different periods of time in 1932-33. Variety Blanc Ameliore.

Table 23. — Chemical composition of buds from Jerusalem artichoke tubers previously subjected to different temperature conditions for various periods of time in 1932-33. Variety Chicago. Per cent. of dry weight.

Treatment	Period of exposure in days				
	15	30	45	60	75
Dry matter (per cent. of fresh weight)					
Control**	34.65	34.65	34.65	34.65	34.65
32°F. LH*	34.33	34.04	35.65	34.74	38.11
32°F. HH*	34.57	32.88	-----	31.25	34.86
36°F.	33.70	33.11	-----	33.30	30.02
50°F.	37.89	31.28	28.66	29.13	34.98
Field pit	30.70	24.20	23.99	23.13	23.90
Free levulose					
None found with any temperature treatment or period of storage.					
Free reducing substances					
None found with any temperature treatment or period of storage.					
Total levulose					
Control	48.53	48.53	48.53	48.53	48.53
32°F. LH	45.28	46.19	40.67	39.24	41.35
32°F. HH	43.88	43.21	-----	37.25	42.22
36°F.	43.77	43.14	-----	46.13	37.08
50°F.	46.27	45.20	44.54	42.45	44.02
Field pit	45.34	41.43	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°F. LH	47.87	46.93	46.01	46.00	45.07
32°F. HH	43.98	47.04	-----	44.80	47.43
36°F.	47.50	44.46	-----	44.98	42.74
50°F.	37.18	41.40	42.44	40.86	38.90
Field pit	49.90	46.06	48.36	46.66	46.64
Total hot-water-soluble reducing substances (as levulose)					
Control	70.58	70.58	70.58	70.58	70.58
32°F. LH	66.78	69.50	63.34	61.50	62.76
32°F. HH	64.00	62.57	-----	60.58	62.40
36°F.	65.53	60.26	-----	63.54	55.78
50°F.	64.64	65.07	64.68	61.32	62.71
Field pit	67.74	63.39	63.59	60.19	61.85
Acid-hydrolyzable hot-water-insoluble polysaccharides (as dextrose)					
Control	4.05	4.05	4.05	4.05	4.05
32°F. LH	3.57	4.48	4.85	4.58	4.82
32°F. HH	3.84	4.36	----	4.78	4.83
36°F.	4.07	4.83	----	4.40	5.23
50°F.	4.00	4.46	4.43	4.48	4.06
Field pit	4.10	5.17	4.58	4.58	4.65

* LH-low humidity; HH= high humidity.

** Original tubers at harvest time.

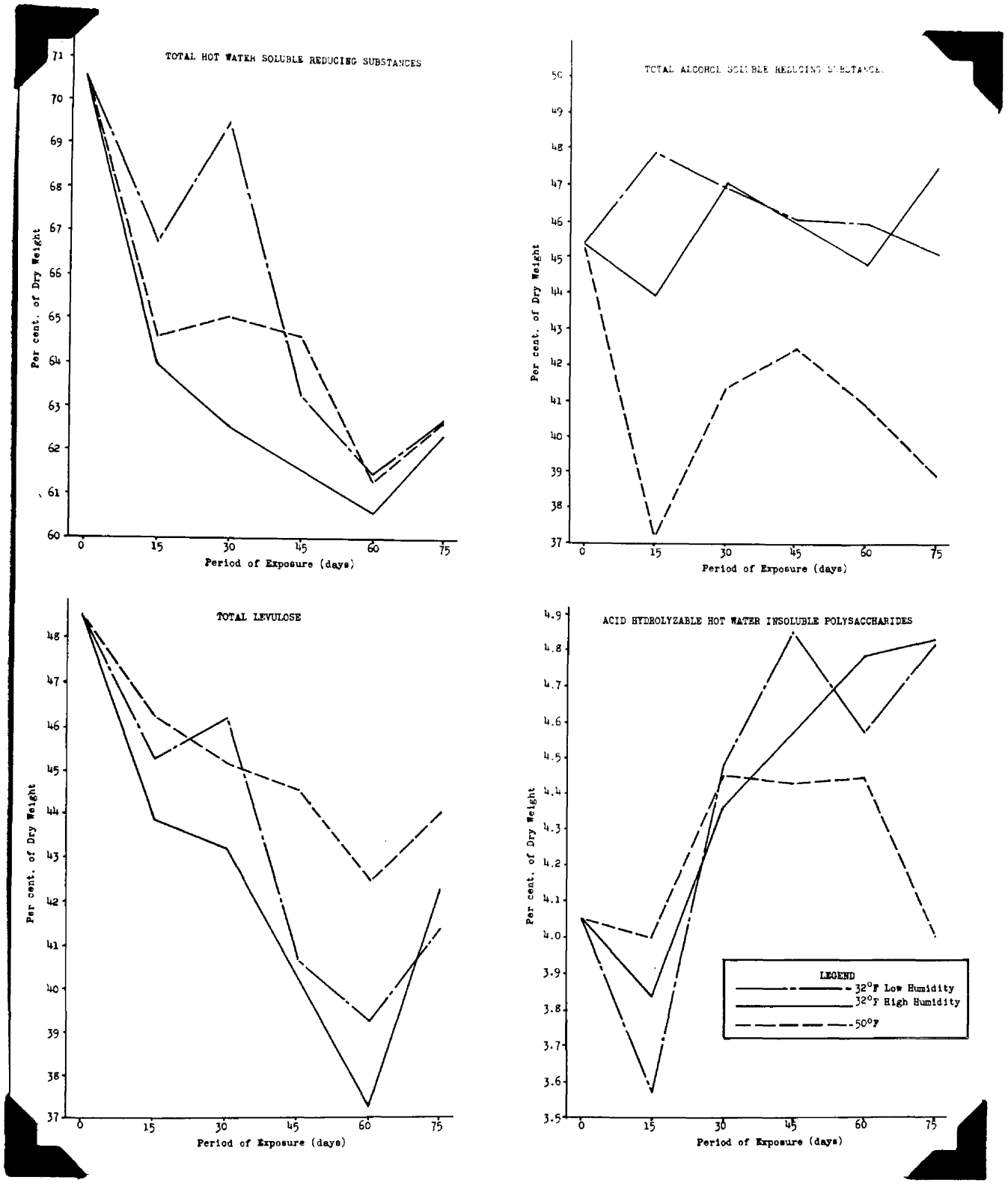

Fig. 11. Percentages of carbohydrate constituents in buds of tubers during storage under three conditions for different periods of time in 1932-33. Variety Chicago.

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 gives a strong suggestion of some importance of free levulose and free reducing substances to the general regularily of the rest breaking response to temperature. However, since these changes do not occur, or at least are not apparent, in all varieties, we must necessarily conclude 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° 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 composition of the whole tubers, or of buds of such tubers in any of the three varieties, at least in those fractions studied. There is no evidence in the data 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 13 and 14, with these chemical analyses do show, however, that growth of buds occurs at a time when the total levulosan content is at or near a minimum, and the more soluble carbohydrate constituents at a correspondingly high value.

DISCUSSION (Part II)

It appears that the real growth releasing or controlling factor is entirely separate from those changes in composition which allow growth to attain normal expression. In practice, what we really want, in searching for treatments that break rest, are treatments that not only break rest but give normal growth as well. The low temperature treatments influence both responses favorably while higher temperatures may affect neither response very much, or possibly only the second.

Although a few chemical treatments in these experiments were found effective in breaking rest, it is significant that very few of them gave subsequent normal, vigorous 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.

Denny (22) 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 (5, 4, 7), and others. Denny suggests that the sucrose changes may be better evidence in judging the effectiveness of a chemical in breaking rest, than the changes in reducing sugars. In the present 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 these fractions were not evident in large enough amounts in tubers of other varieties to be measureable. 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 50°F. treated samples. 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 which might otherwise be suspected of being important to growth releasal, 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 non-resting 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 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) which was activated or set in motion by the exposure, thus making growth possible.

No consistent relation was found in these studies between catalase activity, respiration, and pH 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. This does not preclude the possibility of catalase being a valid measure of the resting or non-resting state of the buds if we assume that by its changed metabolic state the bud can influence the metabolism of the rest of the tuber. The data obtained, however, do not give sufficient evidence to make certain any relation of catalase to the resting or non-resting condition of the terminal buds.

Another puzzling result is 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. We might expect just the opposite since the 32° samples were the ones which showed the growth response first and in a more vigorous manner. If catalase measures the relative metabolic rate, then we would expect the 32° samples to show the greater magnitude of catalase values. When we examine the data for the variety Chicago in 1934-35, we find 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 the

constant temperature storage, to allow the 32° samples to attain their maximum catalase activity, while the 50° samples may have already reached the maximum. Kimbrough (47) has shown such a situation to obtain in the case of respiration with potatoes stored at various temperatures. There is another possibility, -- that catalase activity of Jerusalem artichoke tubers is gradually reduced with storage at 32°F., in a manner similar to that found in potatoes by Appleman (3), 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 1934-35 with 32° storage than with the 50° treatment? The limited pH data presented in this paper would partly substantiate such a hypothesis provided it be assumed that the wide difference in active acidity noted at the end of the first storage period determines the subsequent catalase response, and that this pH change is of general occurrence. Only a single season's data are available, and on only a single variety. It seems unwise to assume a universal occurrence of such a change until further data substantiate the data at hand. This seems particularly true since other measures of metabolic activity studied showed considerable fluctuations and contradictions between varieties and with the same variety in different seasons.

The trend toward decreased acidity during emergence from rest noted in this study has been reported by other workers on rest period. Abbot (1) found decreased acidity in twigs of apple and peach trees during the change from dormancy to active growth. Mitra (56) also noted an approach toward neutrality in apple twigs during the dormant period. Rosa (60) working with potatoes noted that the reaction of tissues about the eyes changes toward neutrality during the dormant period, although he found no definite relation of pH to growth releasal.

It would be interesting to know whether, and to what extent, a decreasing pH accompanies the entrance into rest by the Jerusalem artichoke tuber, corresponding to the increasing pH accompanying emergence from rest.

It is surprising that the differences between the respiratory rates of the 32° and 50° lots are not larger than the data show them to be. Table 24 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°F. temperature. Kimbrough's (47) work with potatoes showed a much higher respiratory rate to occur for a period after removal from low temperature storage, of potatoes, than occurred in potatoes stored continuously at higher temperatures.

A consistently increasing respiratory rate has been found in artichoke tubers removed to a higher temperature after storage at either 32°F. or 50°F. for increasingly longer periods of time. Kimbrough (47) has already reported a similar situation with potatoes. He found an increasing respiratory rate, upon removal to higher temperatures, in tubers stored at 36°F. for an increasingly longer time up to 3 weeks, but little increase in respiratory rate thereafter. In the artichokes studied the respiratory rate has continued to show this increase for over ten weeks of storage.

While discussing the matter of inferior growth following certain treatments, it seems a justifiable criticism of certain investigations of

Table 24. — Losses in weight of Jerusalem artichoke tubers during storage at 32°F. and 50°F. and during a 72-hour period at 70°F. immediately following removal from the 32°F. and 50°F. storage conditions.

Period in storage (days)	Per cent. loss in weight during storage		Per cent. of original weight lost during the 72-hour period at 70°F.		Per cent. moisture at end of 70°F. period	
	32°F.	50°F.	32°F.	50°F.	32°F.	50°F.
			Variety Blanc Ameliore			
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
			Variety 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	0.95	64.9	52.5

the rest period, at least one of which included the Jerusalem artichoke (33), that the time of breaking of rest was judged solely by the time when sprouts were visible above ground. It is obvious that while rest was broken in some of the tubers illustrated in the plates referred to above, for example lots c, 1, 2, 6, and 10 in the first photograph of Plate XXI, no sprout growth would be visible above ground for a considerable period of time if the tubers were planted at any ordinary planting depth. (The tubers illustrated in Plates XXI toXXIII were purposely kept just at the soil surface, while those in Plates XIII to XV were actually covered.) 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 indicatesthat the two conditions are regulated by entirely different agencies (at least directly), and that care must be taken to differentiate between them.

In concluding this discussion, it seems desirable to point out that this study has been largely an exploratory one. Very little was known about the rest period of the Jerusalem artichoke at the time this study was started, in fact, a single short paper by Boswell (11) comprised the entire literature on the subject at that time. The first attack on the problem was a practical one -- finding means of terminating the resting condition. While the results of chemical treatments were on the whole disappointing, the results with temperature treatments have been very

gratifying. Subsequent studies on initiation of rest, catalase activity, pH, 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. It might have been desirable, in conducting these investigations, to have used but a single variety as a source of material for all studies. Future investigations must follow such a course to a large extent. It is felt, however, that in these preliminary studies it has been helpful rather than detrimental to have used several varieties, not always the same in all seasons. This course has, for instance, proven the universality of the sprouting response to low temperature exposures, and it has at the same time 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. Universally applicable evidence can hardly be derived in a single clone of a variable population of clones exposed to variable environments.

SUMMARY AND CONCLUSIONS

Part I. Entrance into Rest

1. 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.

2. 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 in the total number of tubers and stolons produced. This is interpreted as indicating a higher rate of metabolism in the large (first formed) tubers, which apparently given them a first call on elaborated growth and storage materials.

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

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

5. Catalase activity of stolons and terminal buds of tubers reached a maximum value at, or some 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 general the larger size tubers continued to have the higher catalase activity.

6. 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 percentages of total hot-water-soluble reducing substances, total levulose and dry matter were lower, and the percentages of free reducing substances 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 Oct.10).

7. The data point toward an accumulation of the less labile reserve carbohydrates such as inulin or the higher inulides bearing a high degree of association (but not a causal relation) with the resting condition.

Part II. Emergence from Rest.

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

2. The effects of holding in cold storage rooms at 15°F., 18°F., 32°F.,

36°F., 50°F., and in field pits for various periods, on the sprouting response, catalase activity, pH, respiratory rate, and chemical composition of tubers of four varieties of Jerusalem artichokes were studied.

3. The sprouting response was poor from the 15°F., 18°F., and 50°F. lots. Freezing injury occurred at the two lowest temperatures. The sprouting response was very prompt and vigorous from 32°F., 36°F. and field pit stored tubers, and was the best at the 32°F. exposures. The period of exposure required for good responses at the 32°, 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.

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

5. 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.

6. 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.

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

8. The chemical constituents of the variously exposed tubers or buds of tubers do not appear, from these studies, 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 breaking of rest.

9. No consistent relation was found, in these studies, between catalase activity, respiration, and pH of buds and tubers of the two varieties studied in two seasons, or between any of these factors and the sprouting response after subjecting the tubers to 32°F., and 50°F. exposures.

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

11. Any hope of success in solving the rest period problem appears to lie in intensive study of buds, rather than whole tubers.

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ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to all those whose assistance has made these studies possible. He is particularly indebted to the following members of the United States Department of Agriculture: to Dr. V. R. Boswell for his many kindly suggestions and criticisms both of the experimental procedures and of the manuscript; to Dr. M. N. Pope and Dr. B. C. Brunstetter for loans of, and suggestions as to the use of the catalase apparatus and hydrogen-ion equipment, respectively; to the Staff of the Handling, Transportation and Storage Section of the Division of Fruit and Vegetable Crops and Diseases, and especially to Mr. R. C. Wright for providing the controlled-temperature storage facilities; and to Mr. L. E. Barrett for competent assistance in making some of the chemical analyses. He also wishes to thank Dr. A. L. Schrader and Dr. H. B. Cordner of the Division of Horticulture, University of Maryland for their corrections of the manuscript.

Explanation of Plates I, II, III.

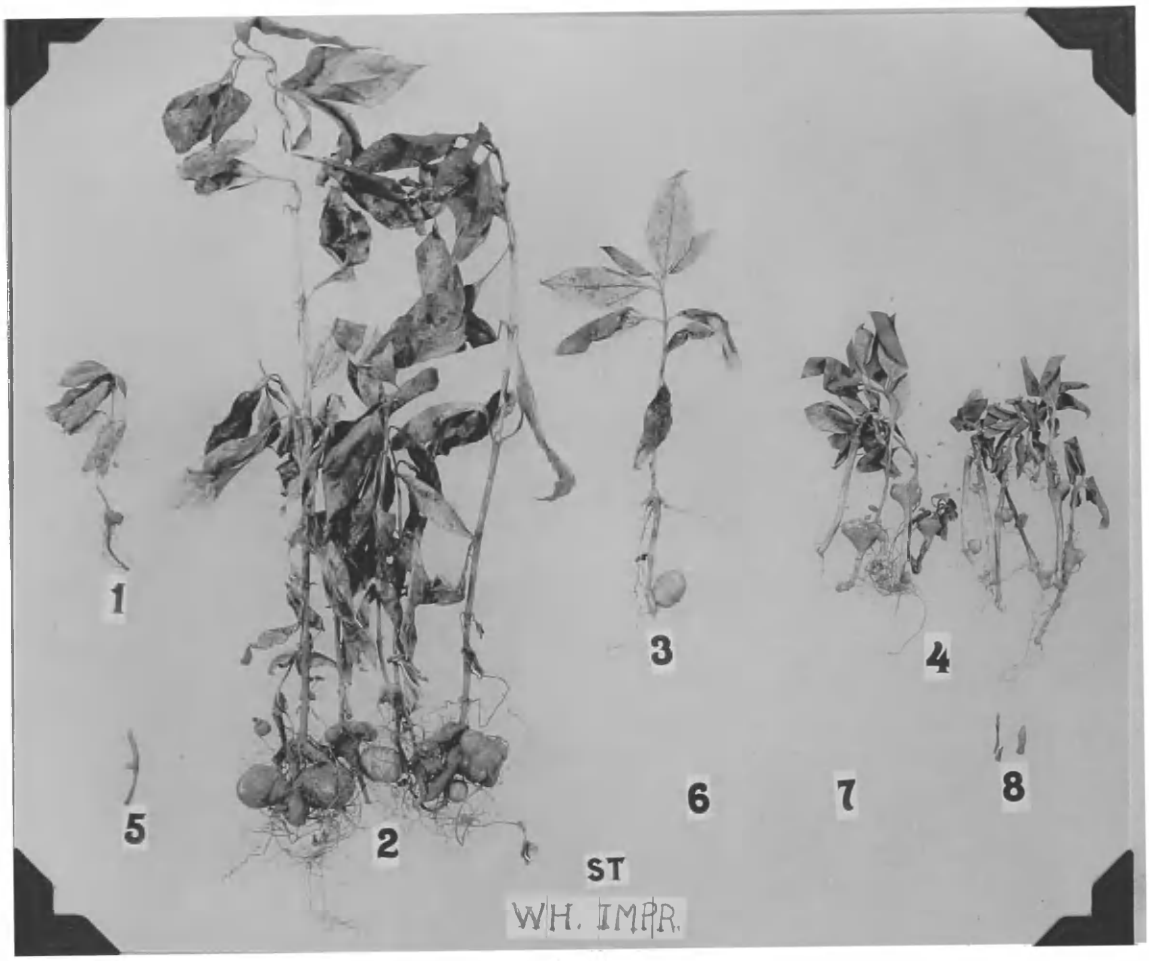
Effect of stolon and tuber size and time of harvest on ability of stolons and tubers to sprout when planted in a greenhouse immediately after being dug in the field. Each photograph shows the relative sprout growth (and in some cases the extent of new tuber development) on November 19, 1934, of specimens from one stolon or tuber size-class. The numbers 1, 2, 3, etc. in each photograph refer to the date of harvest as follows: 1-July 23; 2-Aug. 2; 3-Aug. 14; 4-Aug. 23; 5-Sept. 4; 6-Sept. 17; 7-Sept. 26; 8-Oct. 10. (The plants or tubers shown were the only ones surviving).

Plate I Upper Photo - Untuberized stolons.
Lower Photo - Tubers less than 0.9 cm. in diameter.

Plate II Upper Photo - Tubers 0.9 to 1.4 cm. in diameter.
Lower Photo - Tubers 1.4 to 1.9 cm. in diameter.

Plate III Upper Photo - Tubers 1.9 to 2.4 cm. in diameter.
Lower Photo, top row - Tubers 2.4 to 2.9 cm. in diameter.
Lower Photo, bottom row - Tubers 2.9 to 3.4 cm. in diameter.

Plate I.



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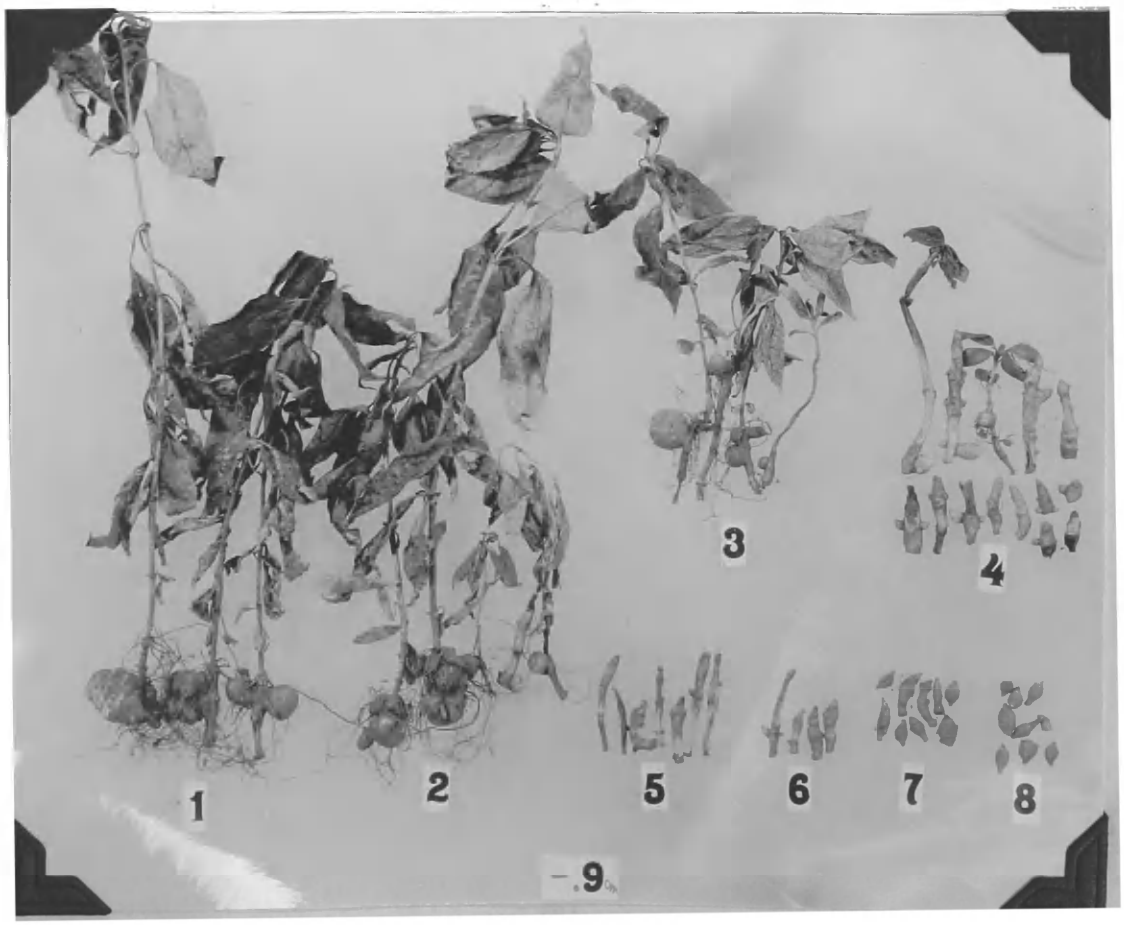

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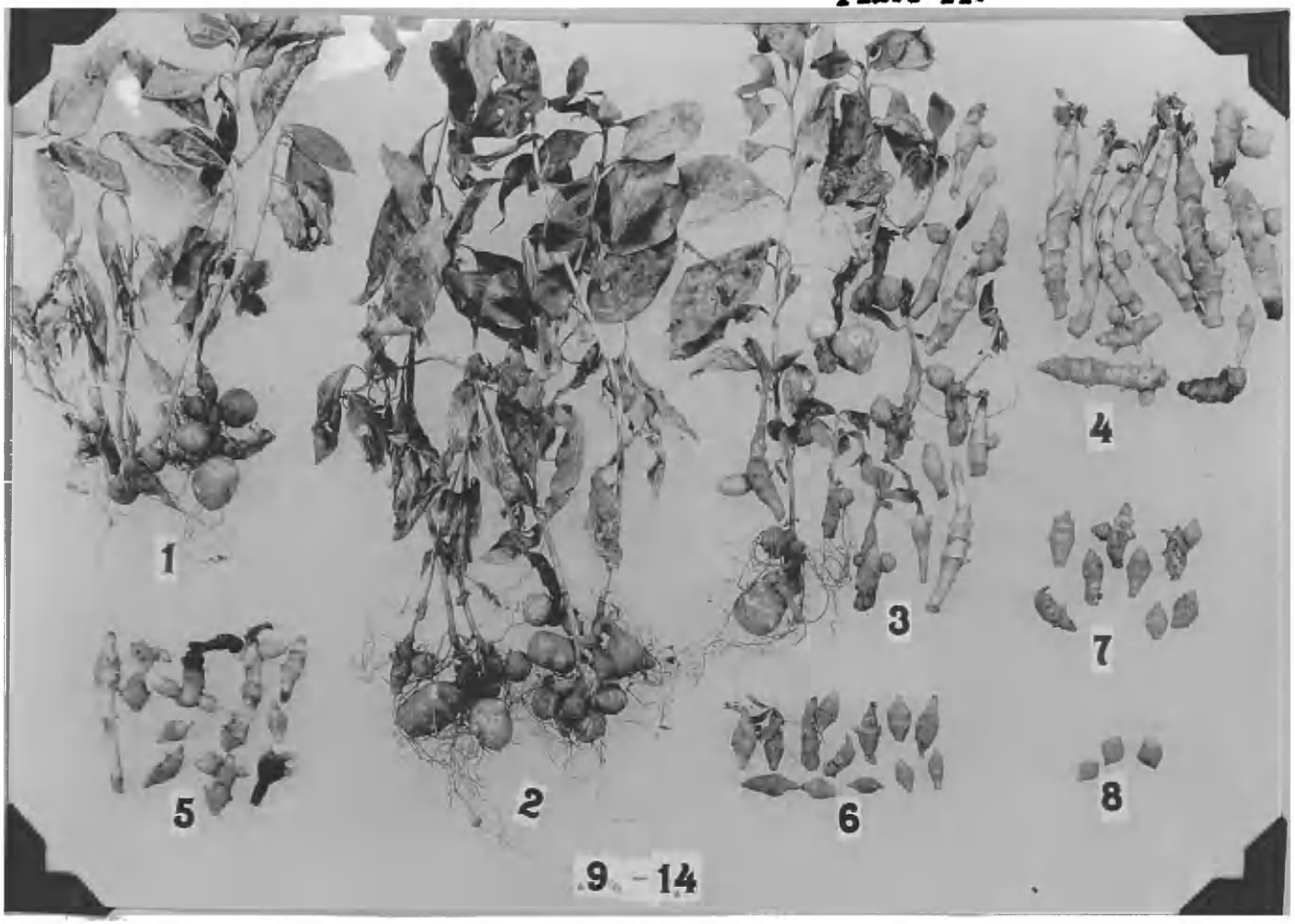

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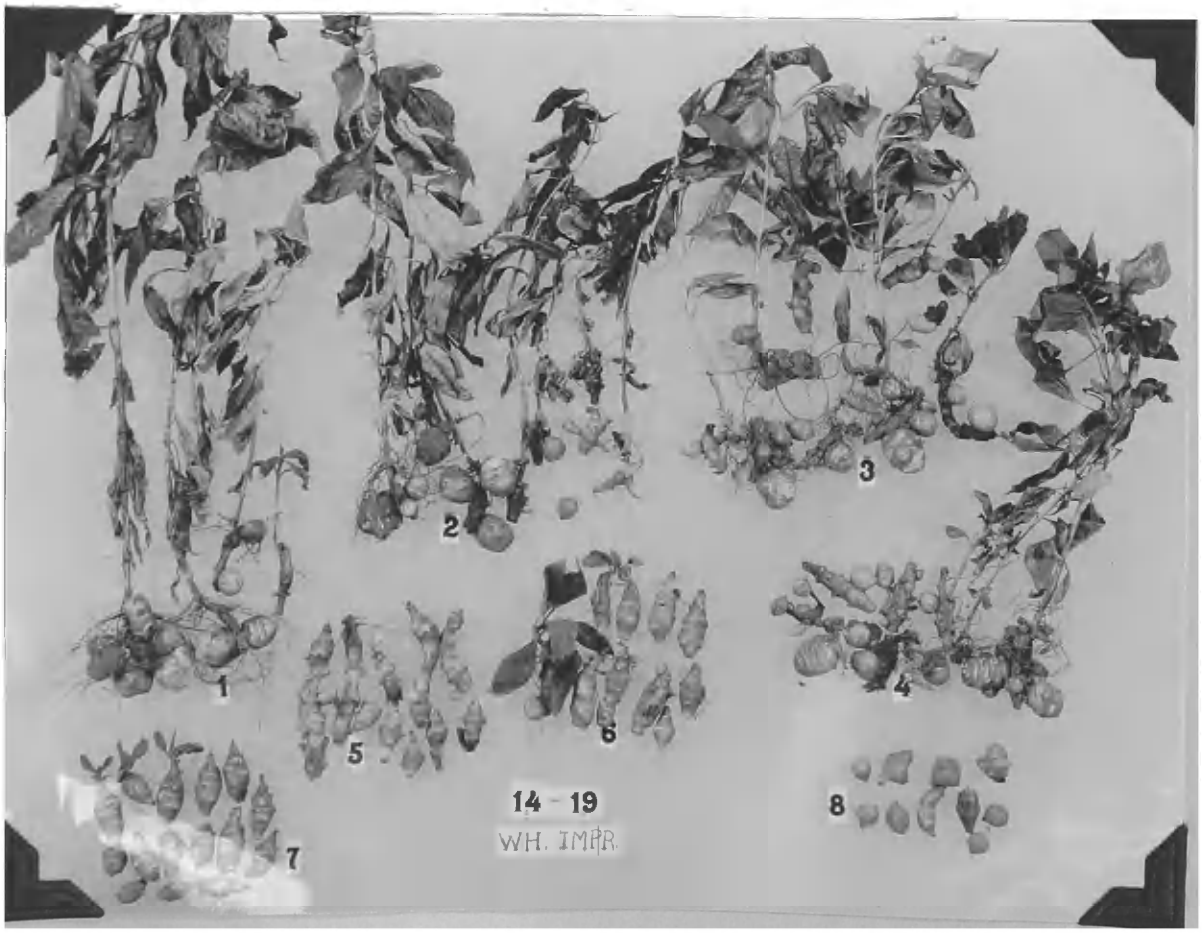

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Plate III

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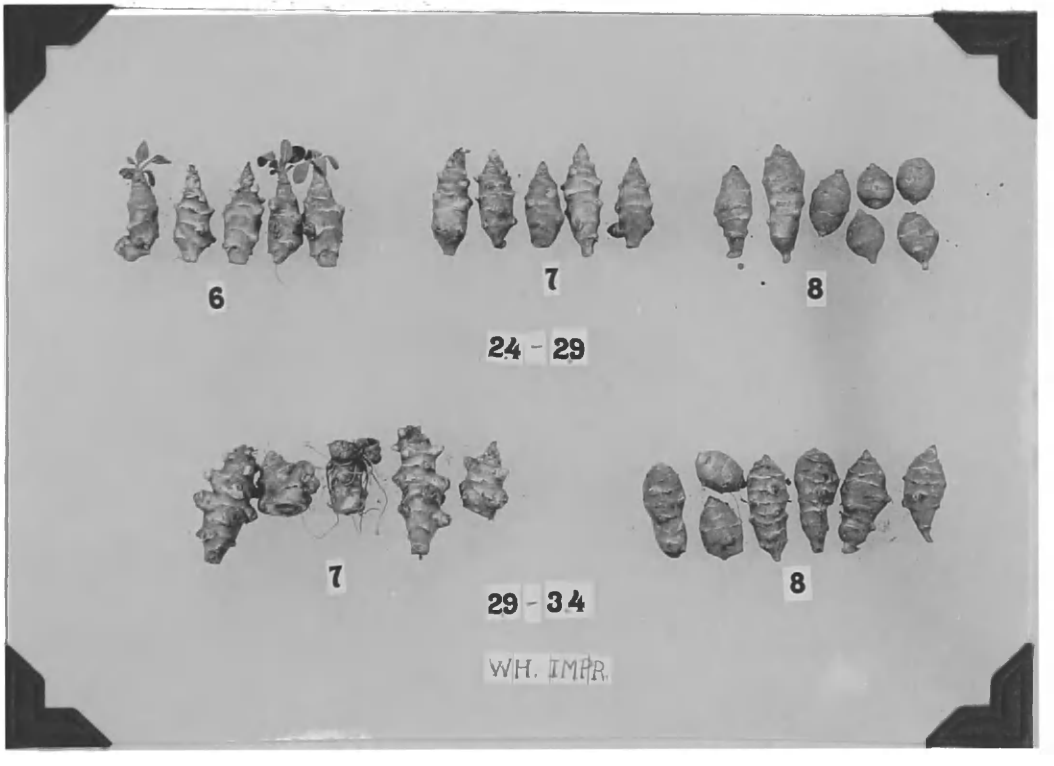

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Explanation of Plates IV, V, VI.

Effect of various chemical treatments in breaking rest in 1931-32.

Plate IV

Lot 38 -- Tait tubers soaked in 20% alcohol 1 hour, removed and stored in closed container 24 hours. Planted Dec. 5, 1931. Photographed Mar. 3, 1932.

Lot 18 -- Tait tubers soaked in 20% acetone 1 hour, removed and stored in closed container 24 hours. Planted Dec. 3, 1931. Photographed Mar. 3, 1932.

Lot 28 -- Tait tubers exposed to CS_2 vapors at 1 cc. per 35 liter space for 24 hours. Planted Dec. 4, 1931. Photographed Mar. 3, 1932.

Unlabeled bottom row -- Control. Tait tubers untreated and planted in peat Nov. 30, 1931. Photo Mar. 3, 1932.

Plate V

Lot 52 -- Tait tubers exposed to ethyl bromide vapors at 4 cc. per 32 liter space for 24 hours. Planted Dec. 10, 1931. Photographed Mar. 3, 1932.

Lot 53 -- Ditto of Lot 52 but with 6 cc. ethyl bromide.

Lot 29 -- Tait tubers exposed to CS_2 vapors at 2 cc. per 35 liter space for 24 hours. Planted Dec. 4, 1931. Photographed Mar. 3, 1932.

Bottom row: Same control as in Plate IV.

Plate VI

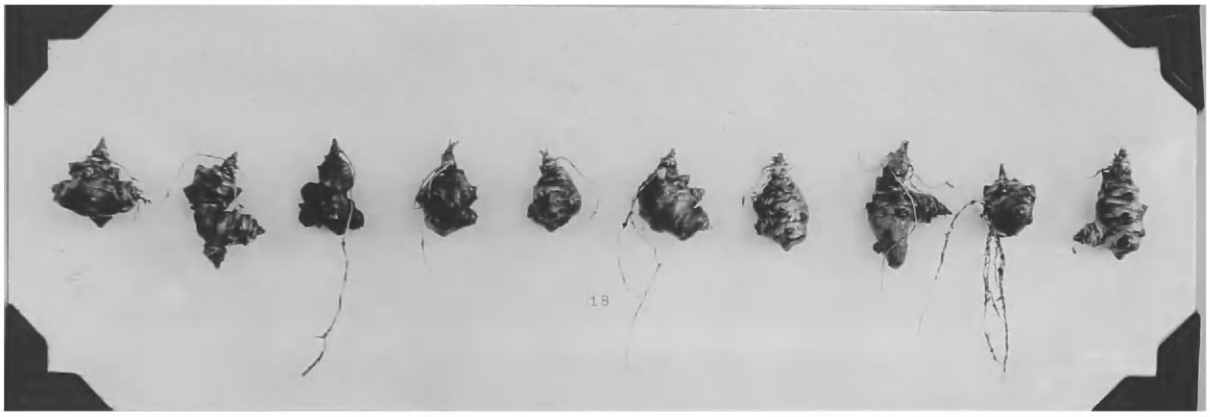
Lot 19 -- Blanc Ameliore tubers soaked in 20% alcohol 1 hour, removed and stored in closed container for 24 hours. Planted Dec. 3, 1931. Photo Mar. 15, 1932.

Lot 23 -- Same as Lot 19 but with 20% acetone.

Lot 27 -- Blanc Ameliore tubers exposed to CS_2 vapors for 24 hours. Planted Dec. 3, 1931. Photographed Mar. 15, 1932.

Bottom row: Blanc Ameliore control planted Nov. 25, 1931.

Plate IV



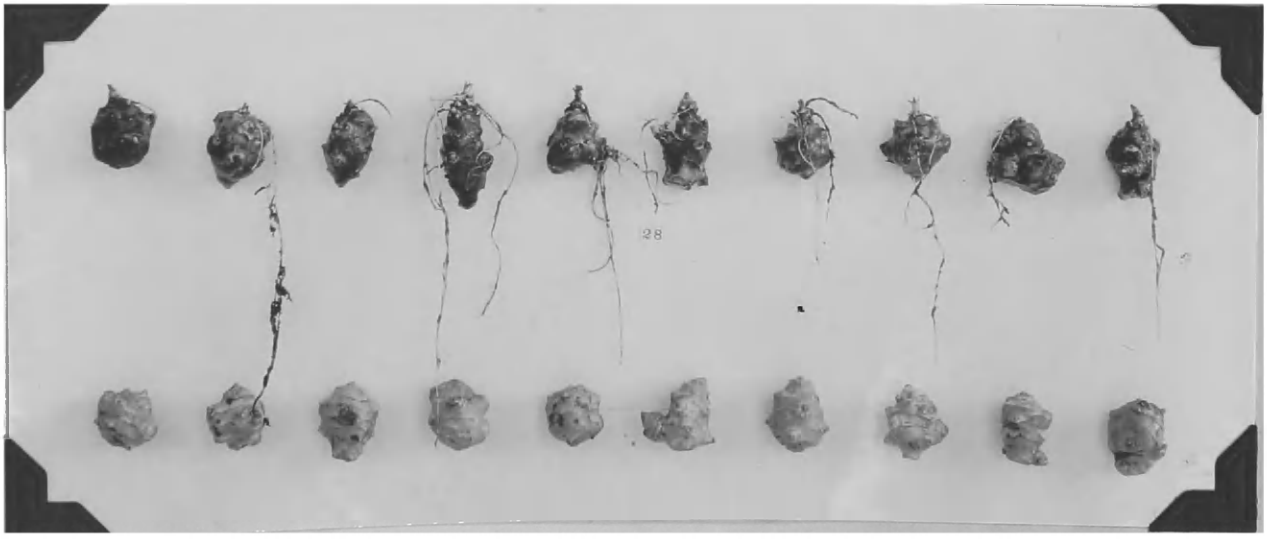
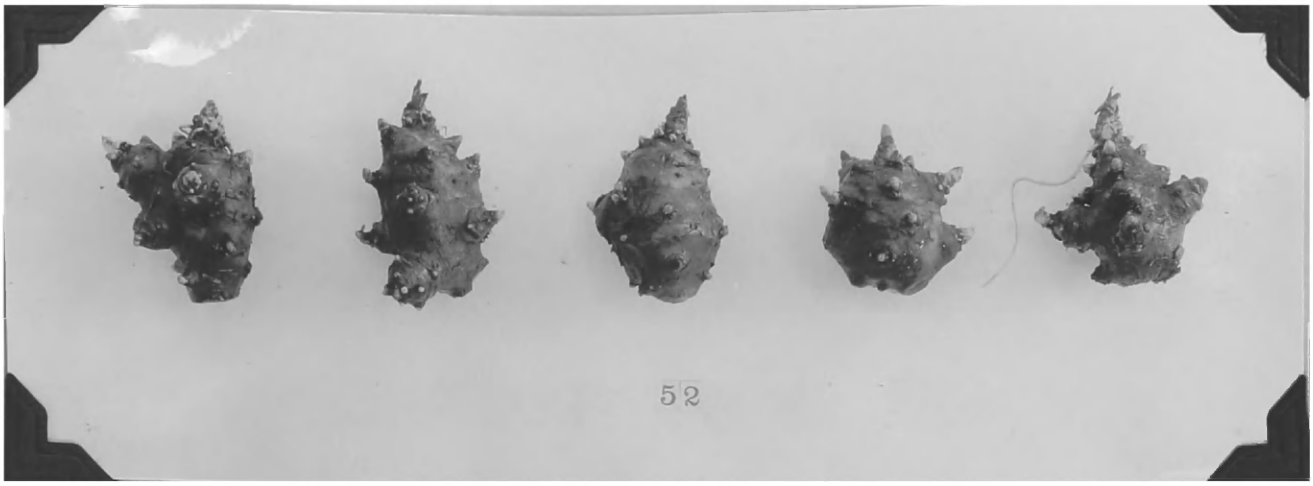
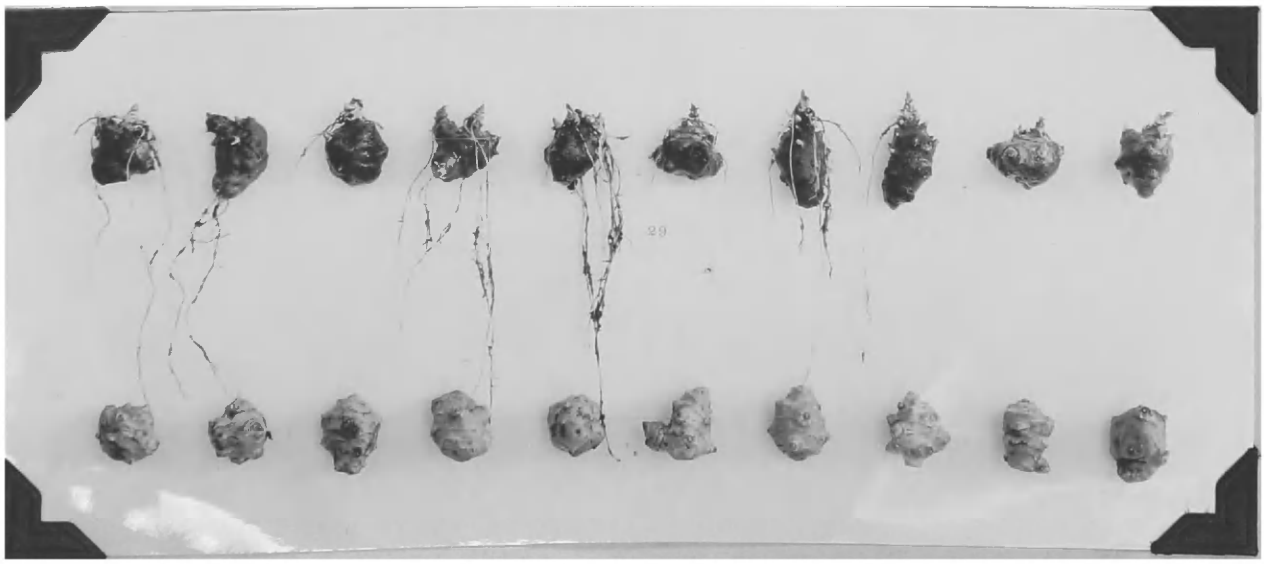


Plate V





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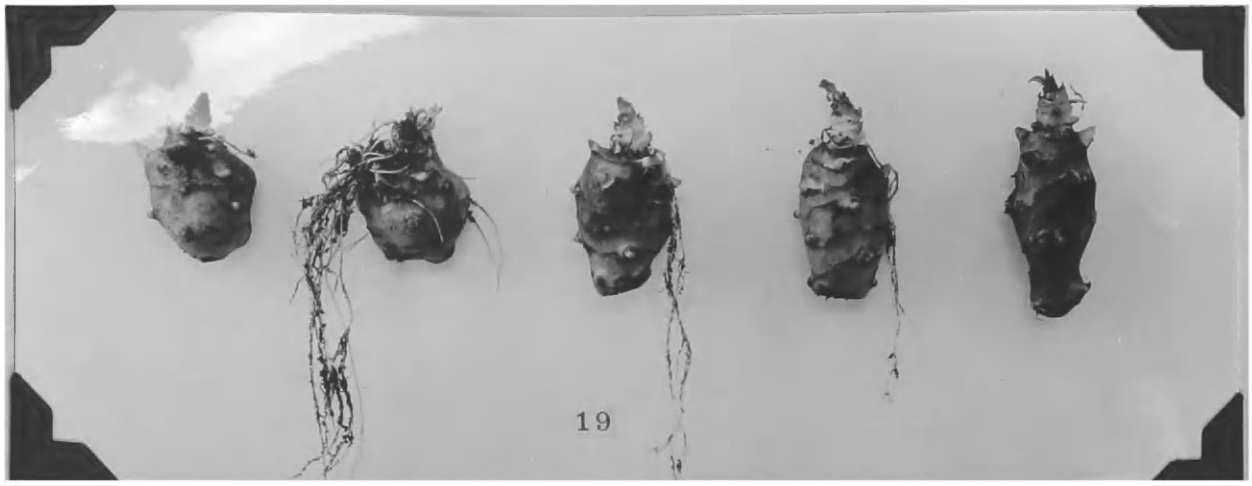
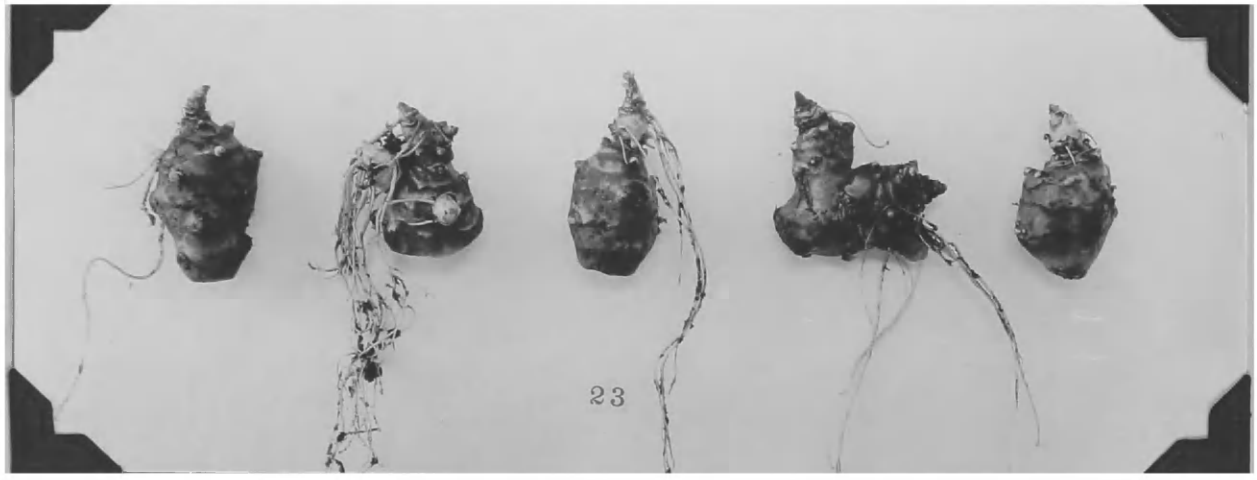
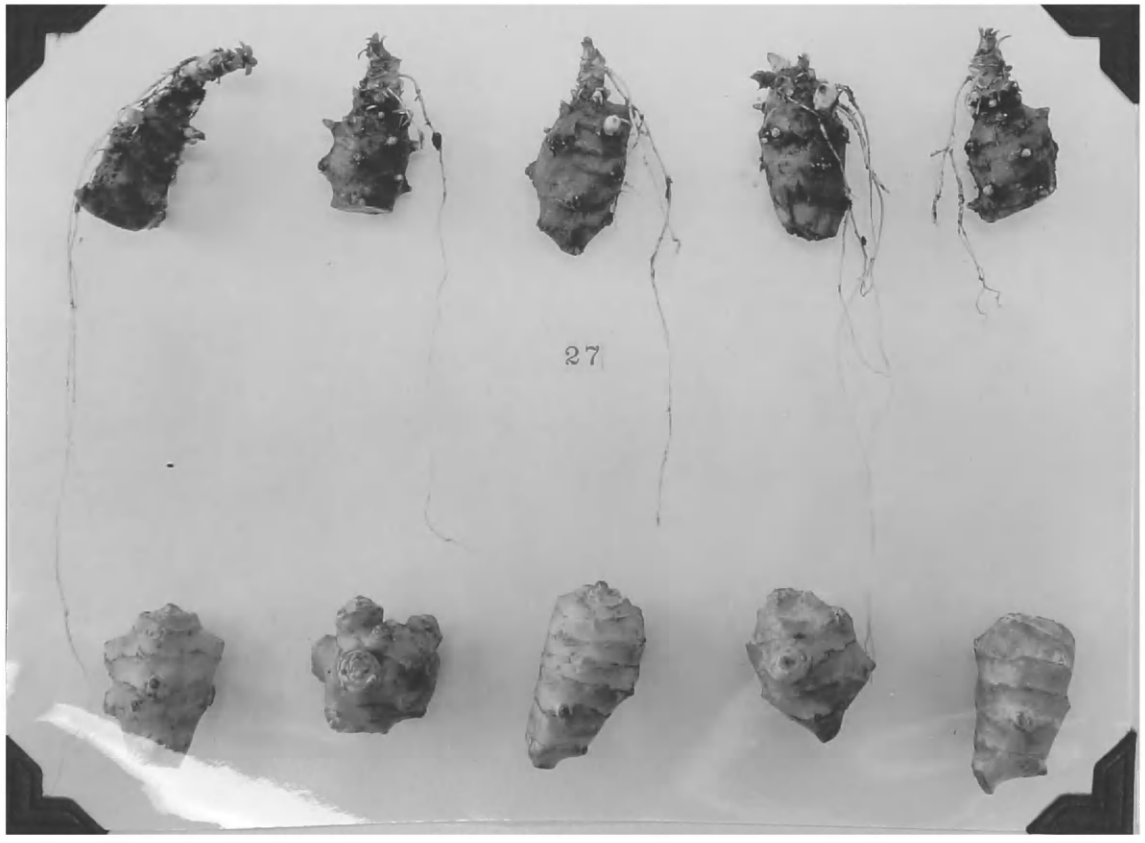






Explanation of Plates VII to XII

Effect of various chemical treatments in breaking the rest period of Blanc Ameliore tubers in 1932-33, when tubers were planted in a cool greenhouse or in a warm greenhouse after treatment.

Plate VII Lot 2 - Control planted in cool greenhouse Dec. 3, 1932. Photographed Jan. 11, 1933.
Lot 6 - Control planted in warm greenhouse Dec. 6, 1932. Photographed Jan. 9, 1933.

Plate VIII Lot 9B - Tubers treated with chloroform vapors at .05 cc. per liter space 24 hours. Planted Dec. 8, 1932 in cool greenhouse. Photographed Jan. 11, 1933.
Lot 10B - Ditto of 9B but planted in warm greenhouse.

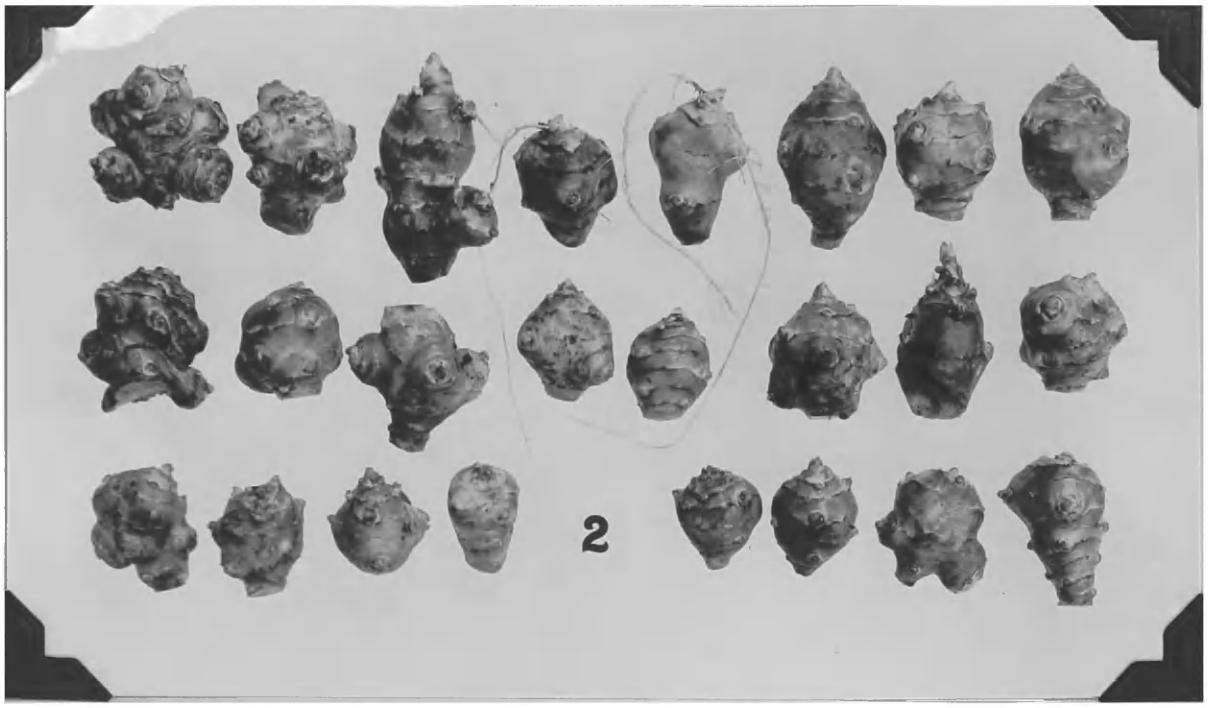
Plate IX Lot 23B - Tubers soaked in 20% alcohol 1 hour, removed and stored in closed container 24 hours. Planted in cool greenhouse Dec. 13, 1932. Photographed Jan. 12, 1933.
Lot 24B - Ditto of 23B but planted in warm greenhouse.

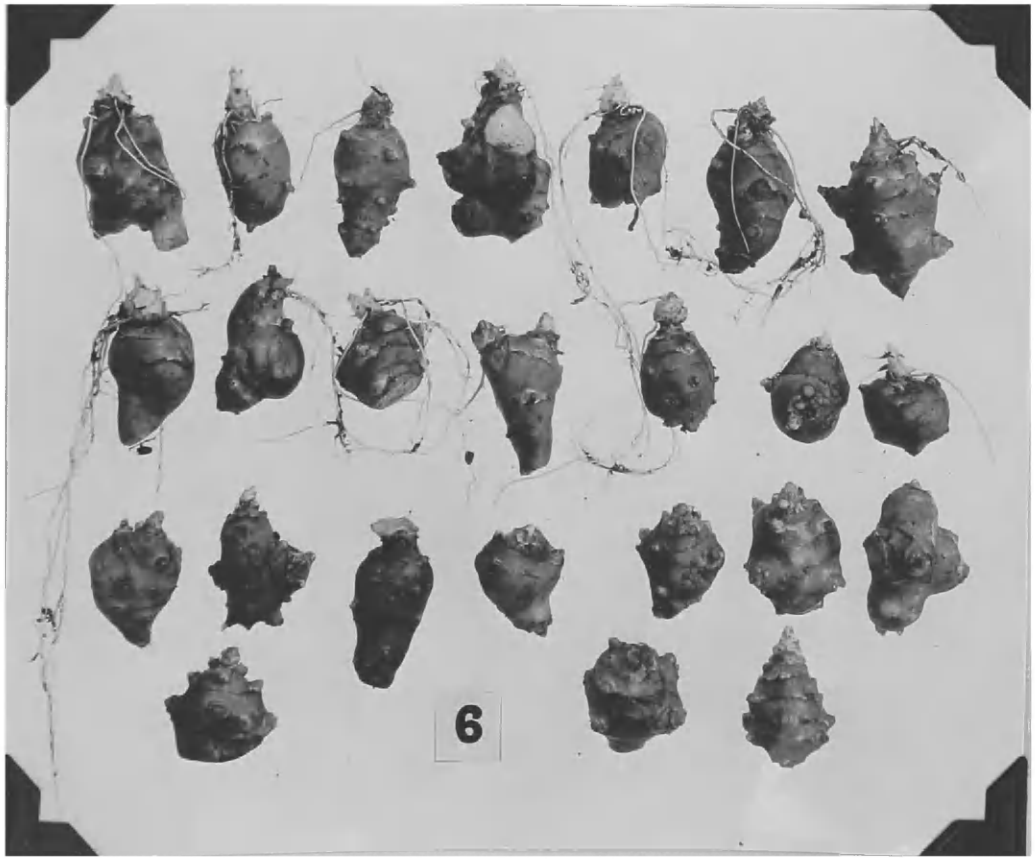
Plate X Lot 27B - Tubers soaked in 20% acetone 1 hour, removed and stored in closed container 24 hours. Planted in cool greenhouse Dec. 15, 1932. Photographed Jan. 12, 1933.
Lot 28B - Ditto of 27B but planted in warm greenhouse.

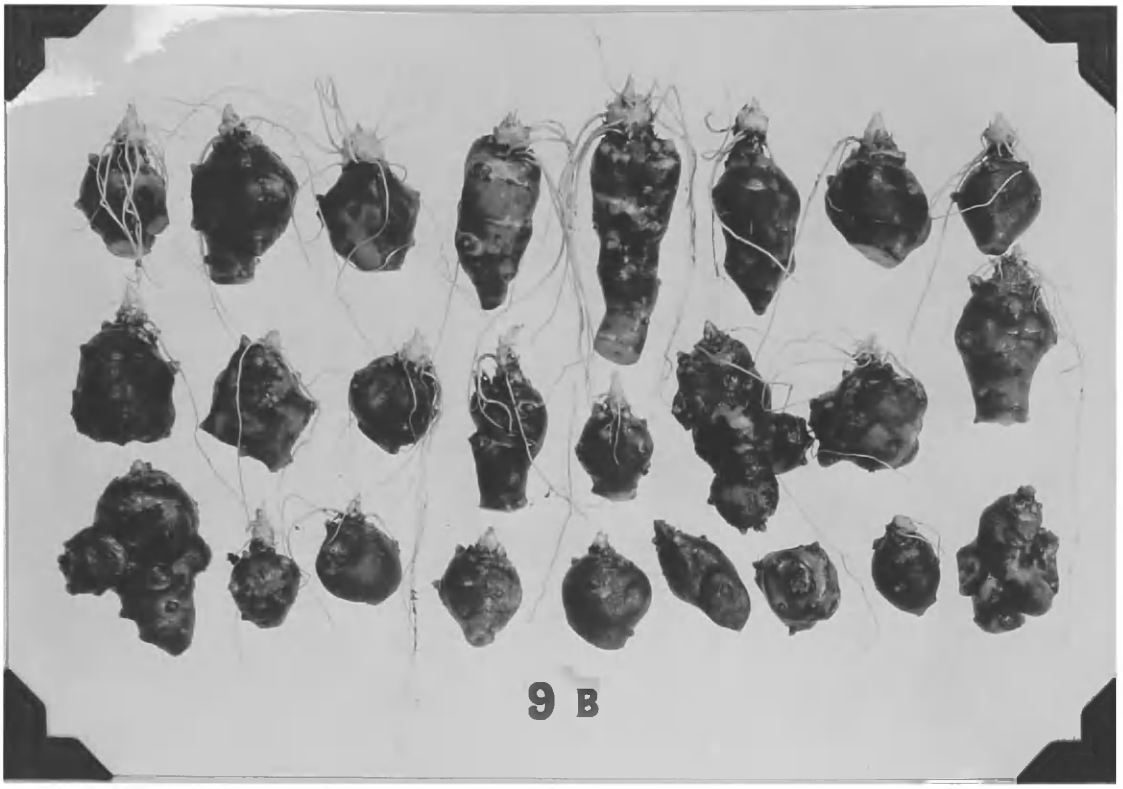
Plate XI Lot 29B - Tubers dipped in 2% ethylene chlorhydrin, removed and stored in closed container 24 hours. Planted in cool greenhouse Dec. 16, 1932. Photographed Jan. 12, 1933.
Lot 30B - Ditto of 29B but planted in warm greenhouse.

Plate XII Lot 31B - Tubers dipped in 6% ethylene chlorhydrin, removed and stored in closed container 24 hours. Planted in cool greenhouse Dec. 16, 1932. Photographed Jan. 13, 1933.
Lot 32B - Ditto of 31B but planted in warm greenhouse.

Plate VII



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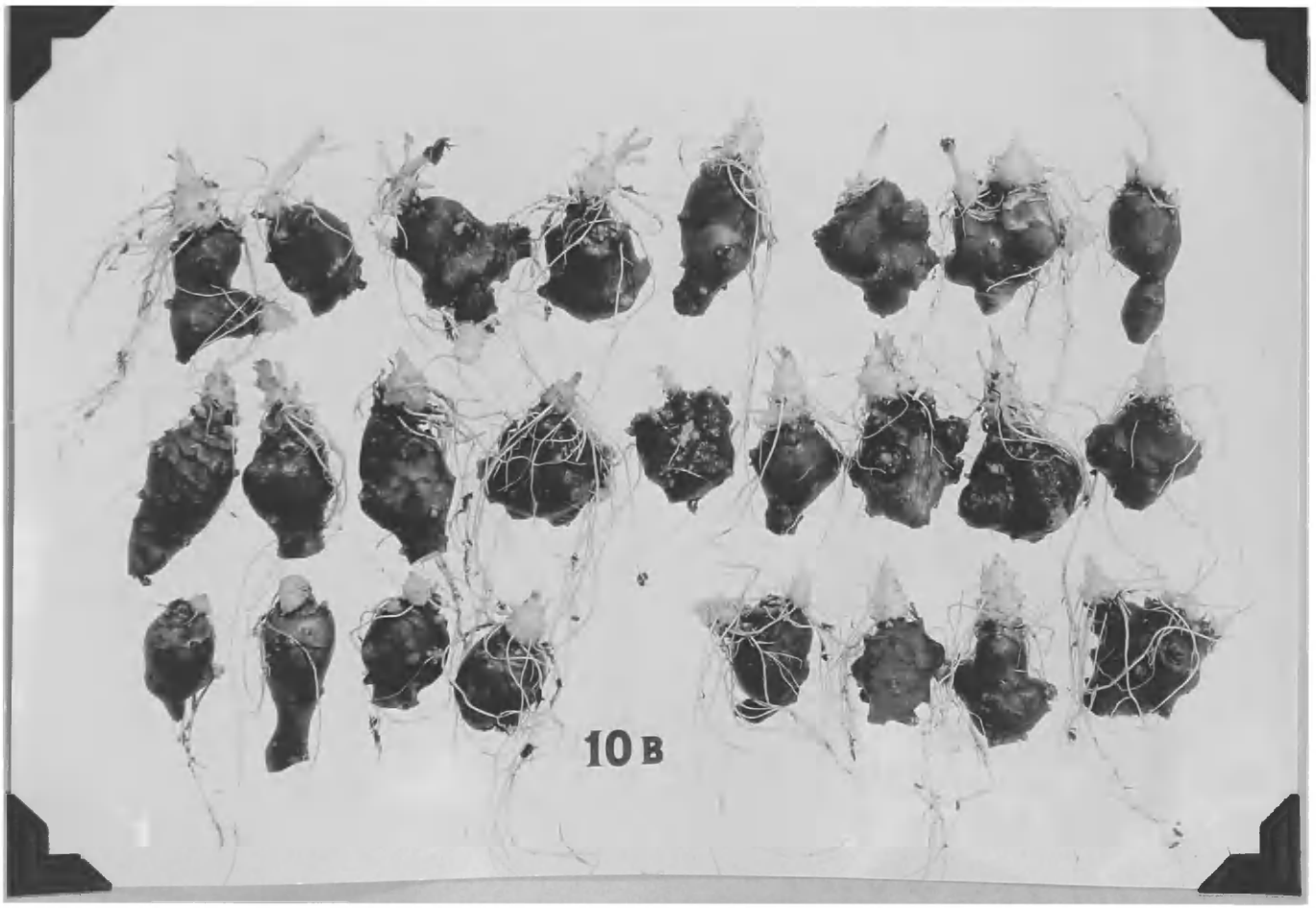
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Plate IX

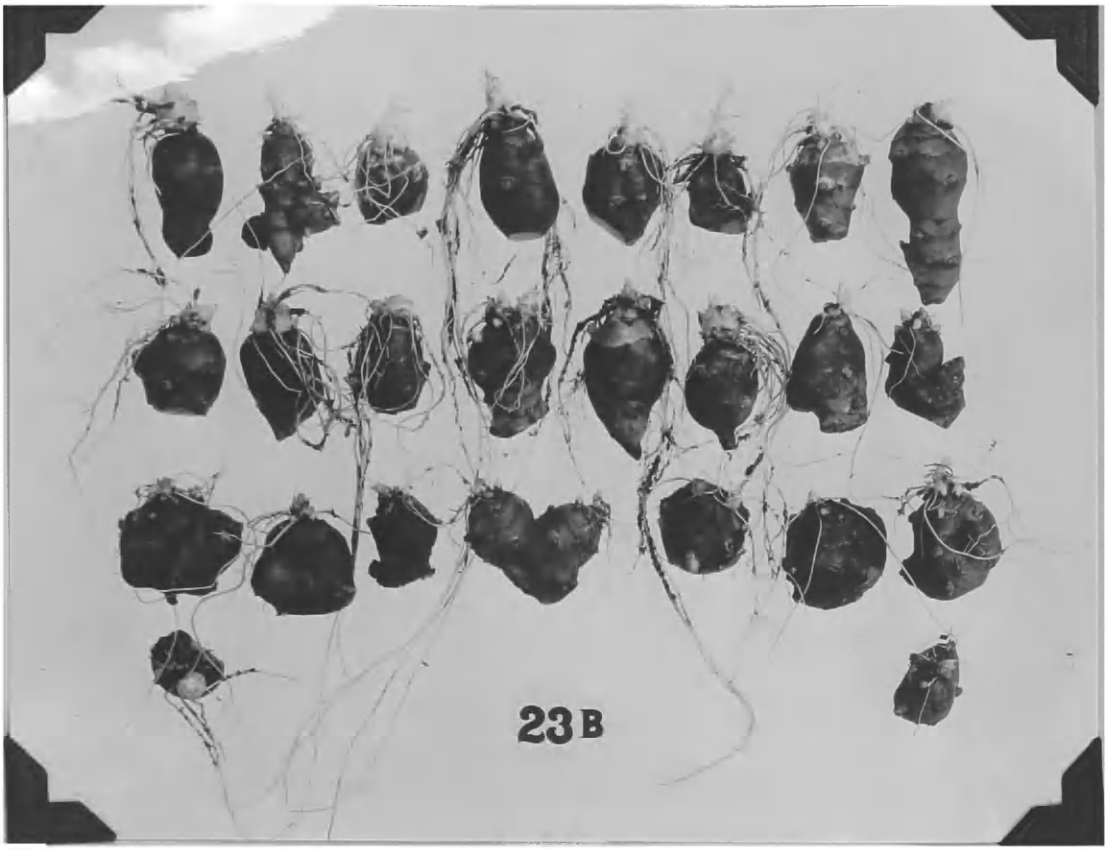
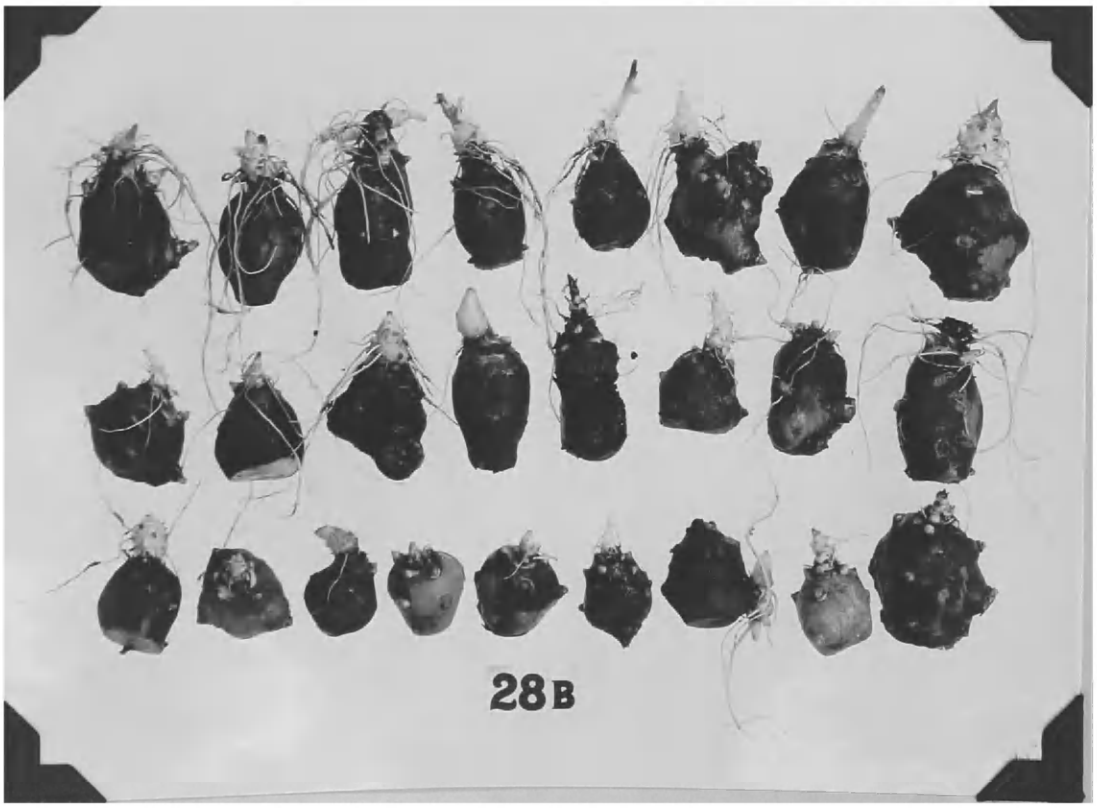


Plate X



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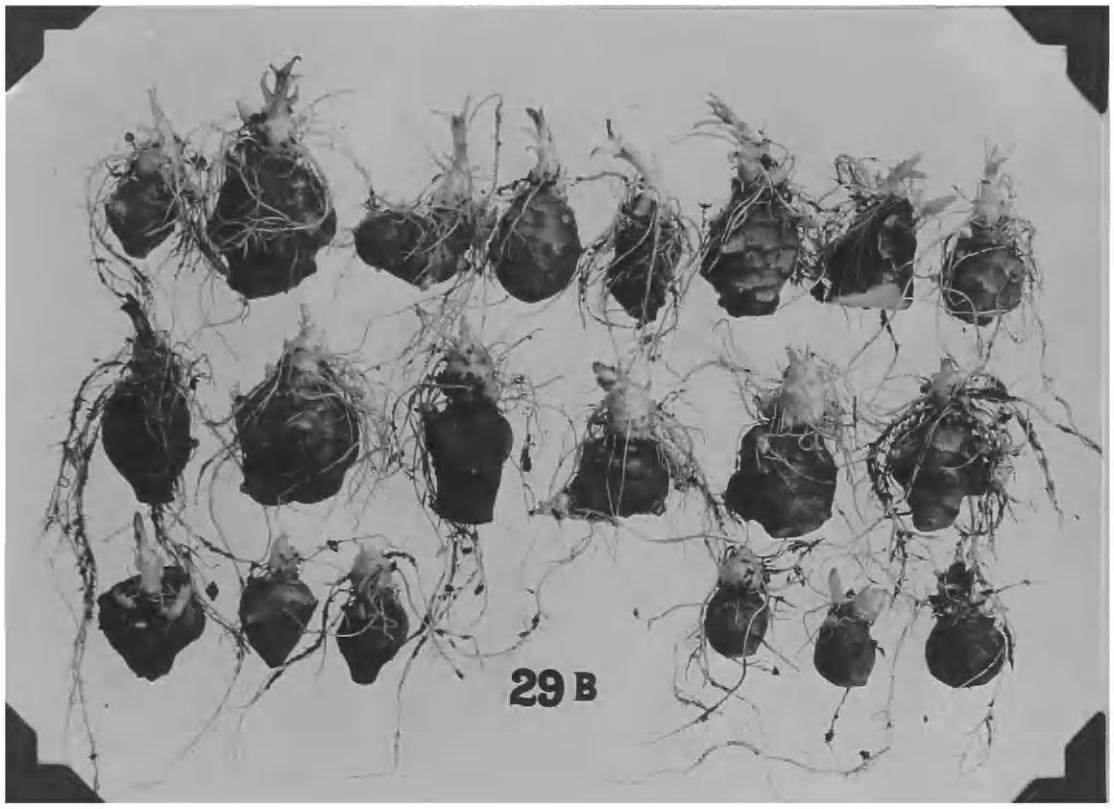

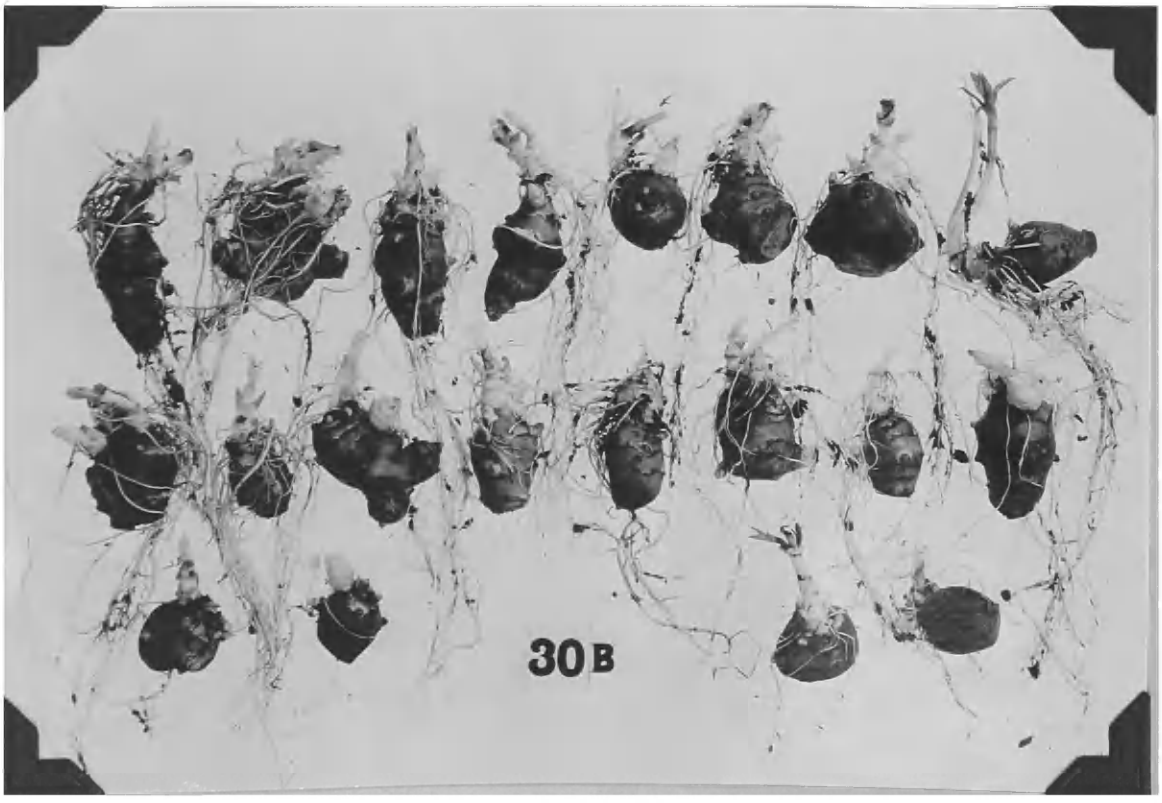

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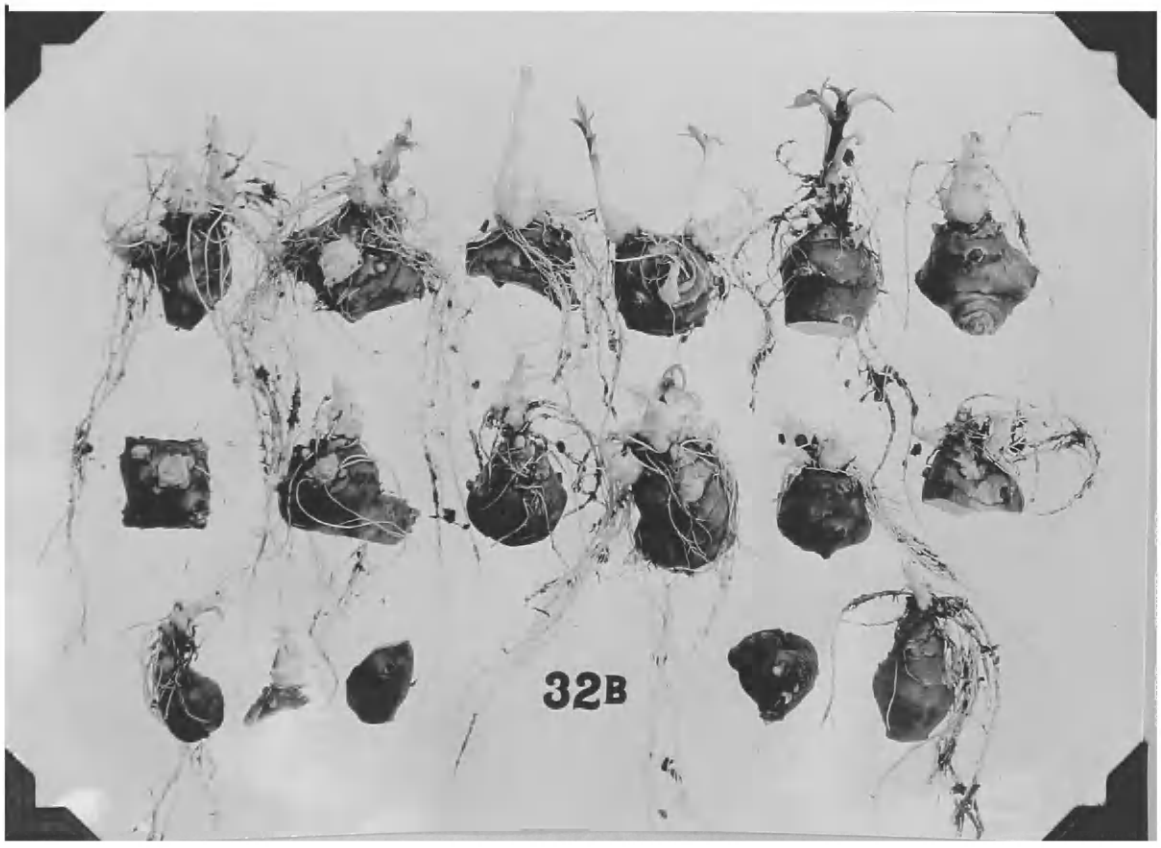


Explanation of Plates XIII to XV

Relative development of Tait tubers when planted in peat after storage under different conditions for various periods. Placed in storage Dec. 5, 1931. Photographed March 9, 1932.

Plate XIII Flat 127 - A: 36°F. storage. Removed and planted Dec. 22.
B: 50°F. " " " " " "

Flat 128 - A: 32°F. low humidity storage. Planted Dec. 22.
B: 32°F. high humidity " " " "

Flat 129 - A: 18°F. Removed to 50°F. chamber Dec. 19, planted Dec. 22.
B: Stored in field pit. Planted Dec. 22.

Plate XIV Flat 143 - A: 18°F. storage. Removed to 50°F. chamber Jan. 6; planted Jan. 7.
B: 32°F. Low humidity storage. Planted Jan. 7.

Flat 144 - A; 32°F. High humidity storage. Planted Jan. 7.
B: 36°F. storage. Planted Jan. 7.

Flat 145 - A: 50°F. storage. Planted Jan. 7.
B: Stored in field pit. Planted Jan. 7.

Plate XV Flat 155 - A: 18°F. storage. Removed to 50°F. chamber Jan. 21. Planted Jan. 22.
B: 32°F. Low humidity storage. Planted Jan. 22.

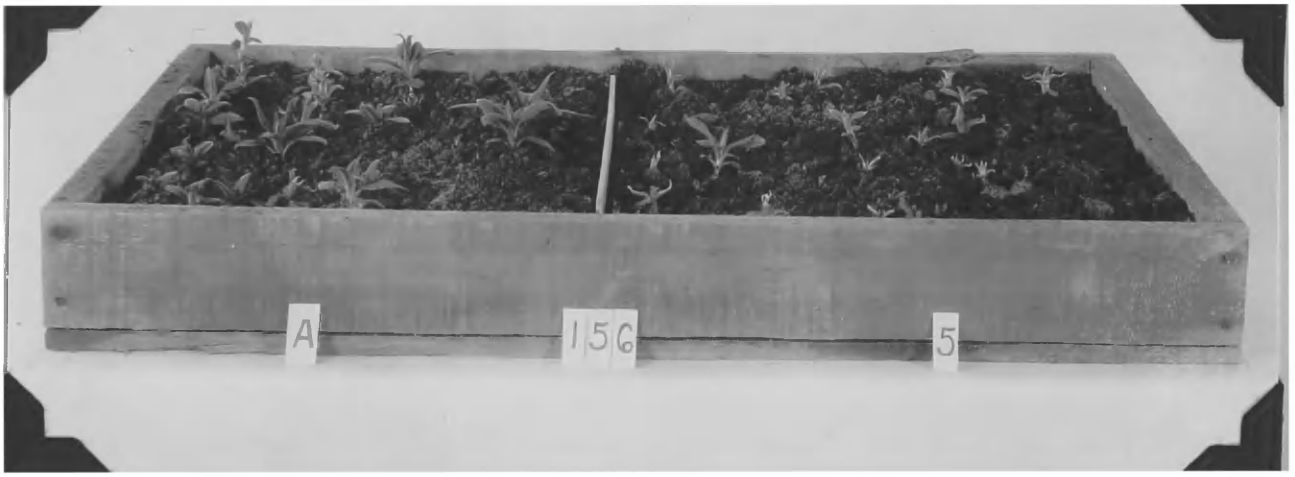
Flat 156 - A: 32°F. High humidity storage. Planted Jan. 22.
B: 36°F. storage. Planted Jan. 22.

Flat 157 - A: 50°F. storage. Planted Jan. 22.
B: Stored in field pit. Planted Jan. 22.

Plate XIII

Plate XIV

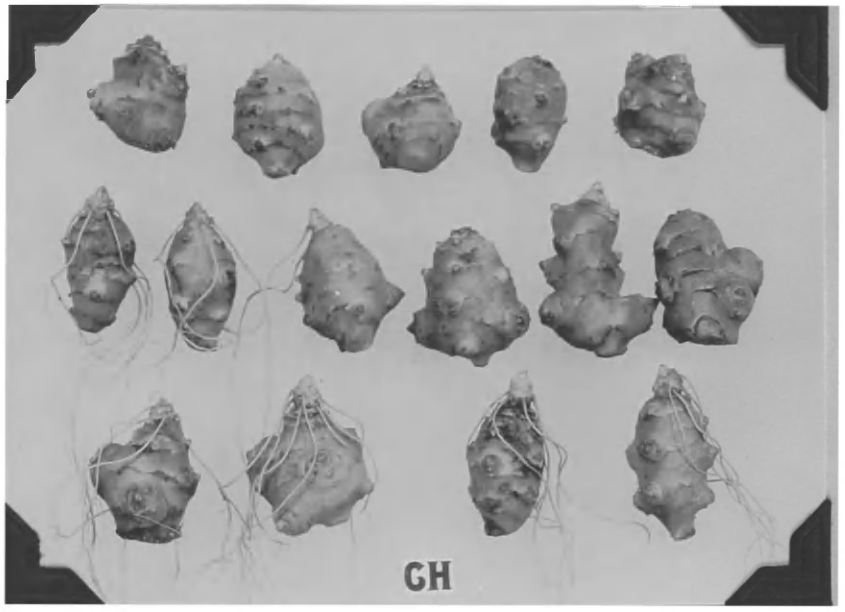
Plate XV



Explanation of Plates XVI to XX

Relative development of Blanc Ameliore tubers when planted in sand after storage under different conditions for various periods. Placed in storage Dec. 2, 1933. Photographed Feb. 15, 1934, except lots 9 and 10 which were photographed on March 1.

Plate XVI	Lot CH:	Control lot planted Dec. 2, 1933.
	Lot 1:	50°F. storage. Planted Dec. 18
	Lot 2:	32°F. High humidity storage. Planted Dec. 18.
Plate XVII	Lot 3:	50°F. storage. Planted Jan. 2.
	Lot 4:	32°F. High humidity storage. Planted Jan. 2.
Plate XVIII	Lot 5:	50°F. storage. Planted Jan. 16.
	Lot 6:	32°F. High humidity storage. Planted Jan. 16.
Plate XIX	Lot 7:	50°F. storage. Planted Jan. 31.
	Lot 8:	32°F. High humidity storage. Planted Jan. 31.
Plate XX	Lot 9:	50°F. storage. Planted Feb. 14.
	Lot 10:	32°F. High humidity storage. Planted Feb. 14.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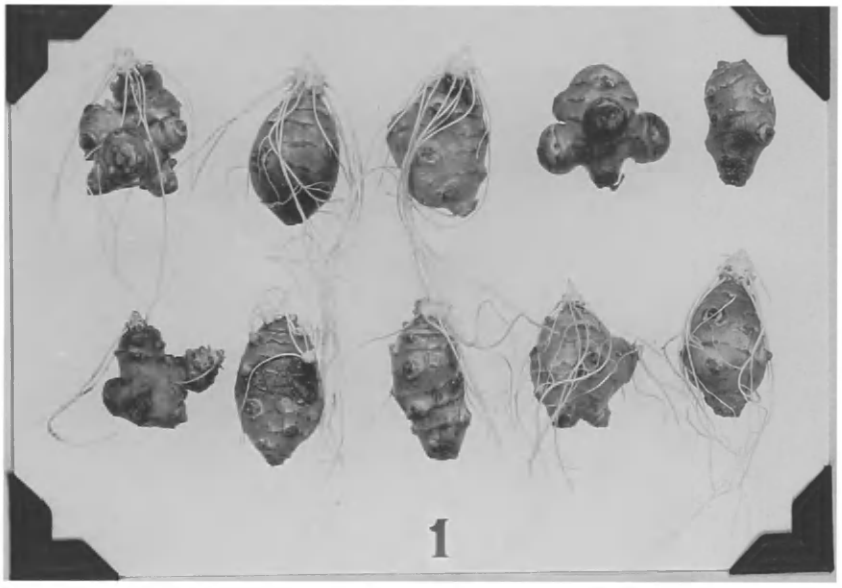
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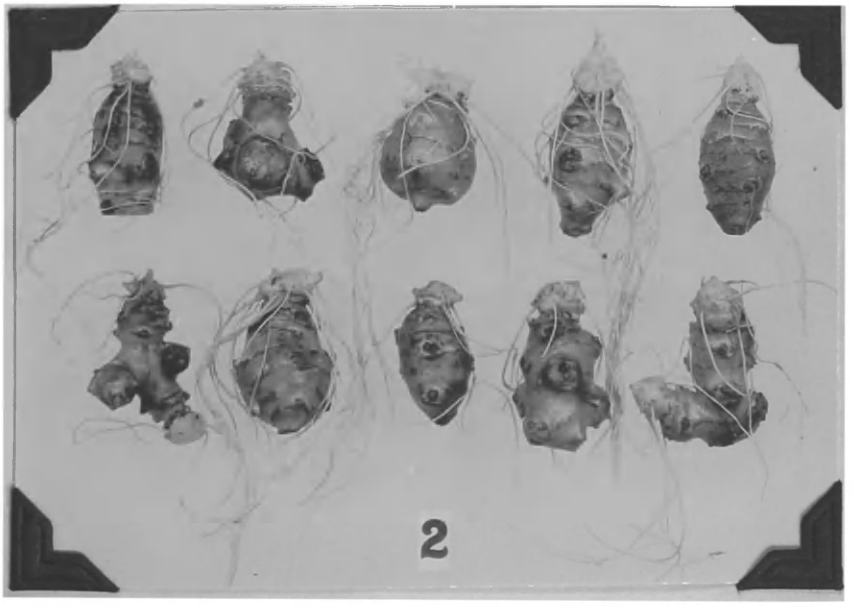
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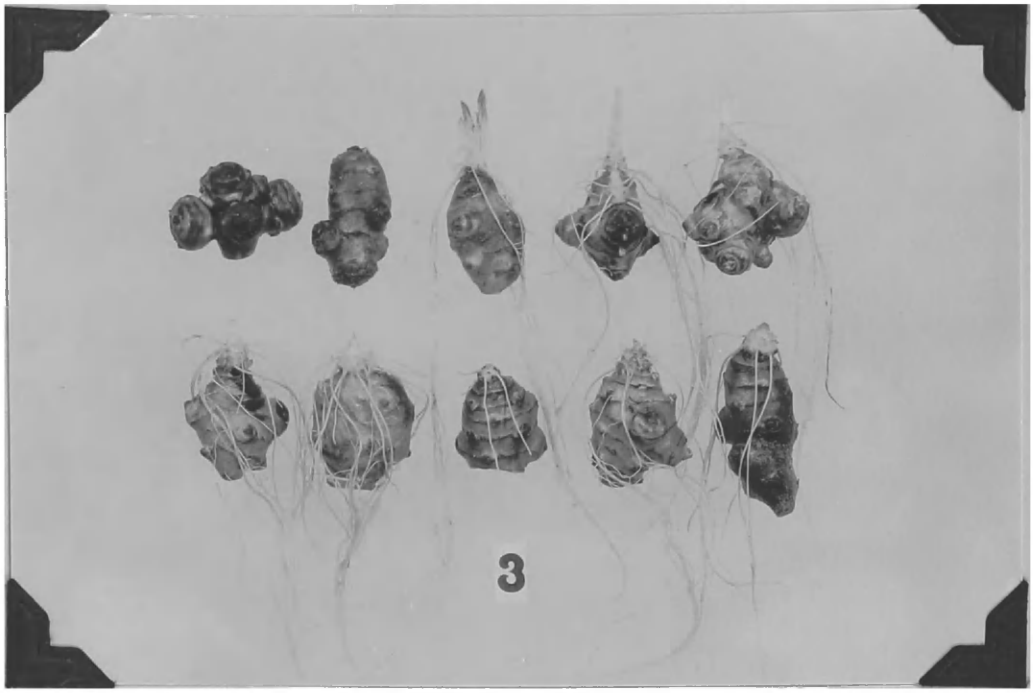
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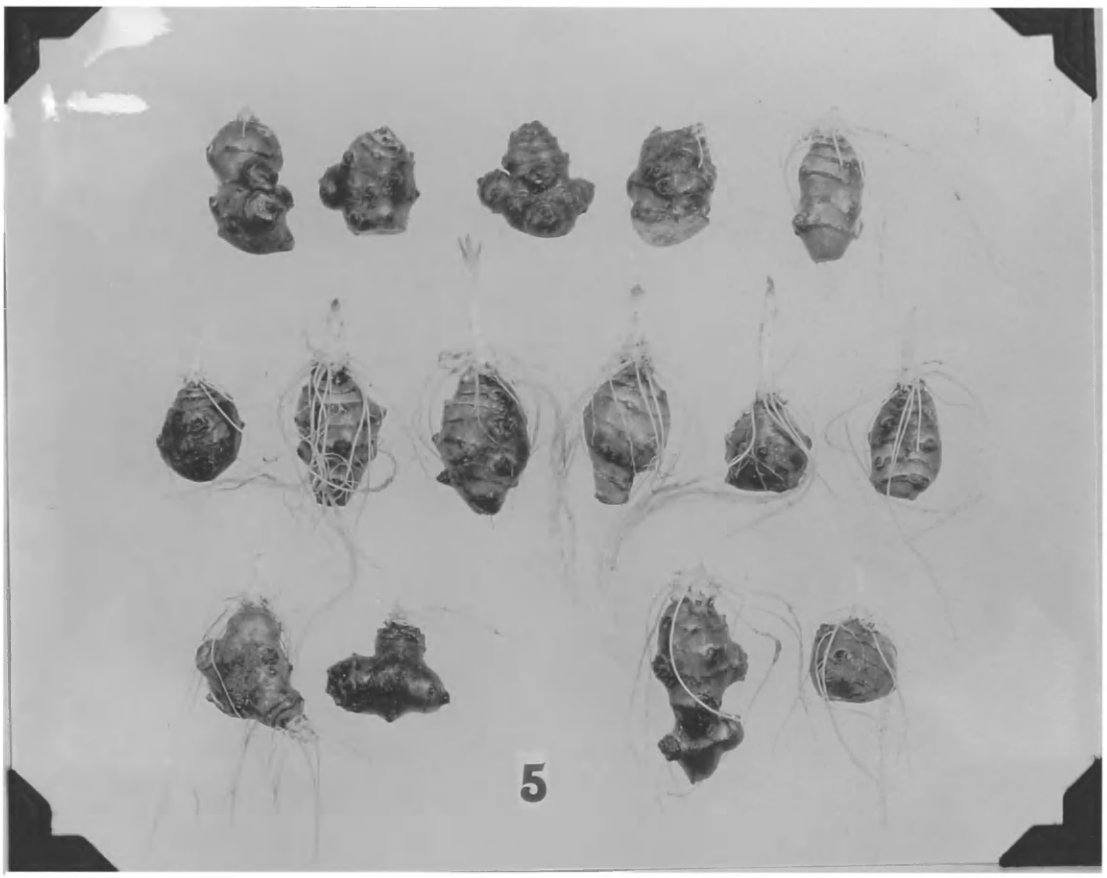
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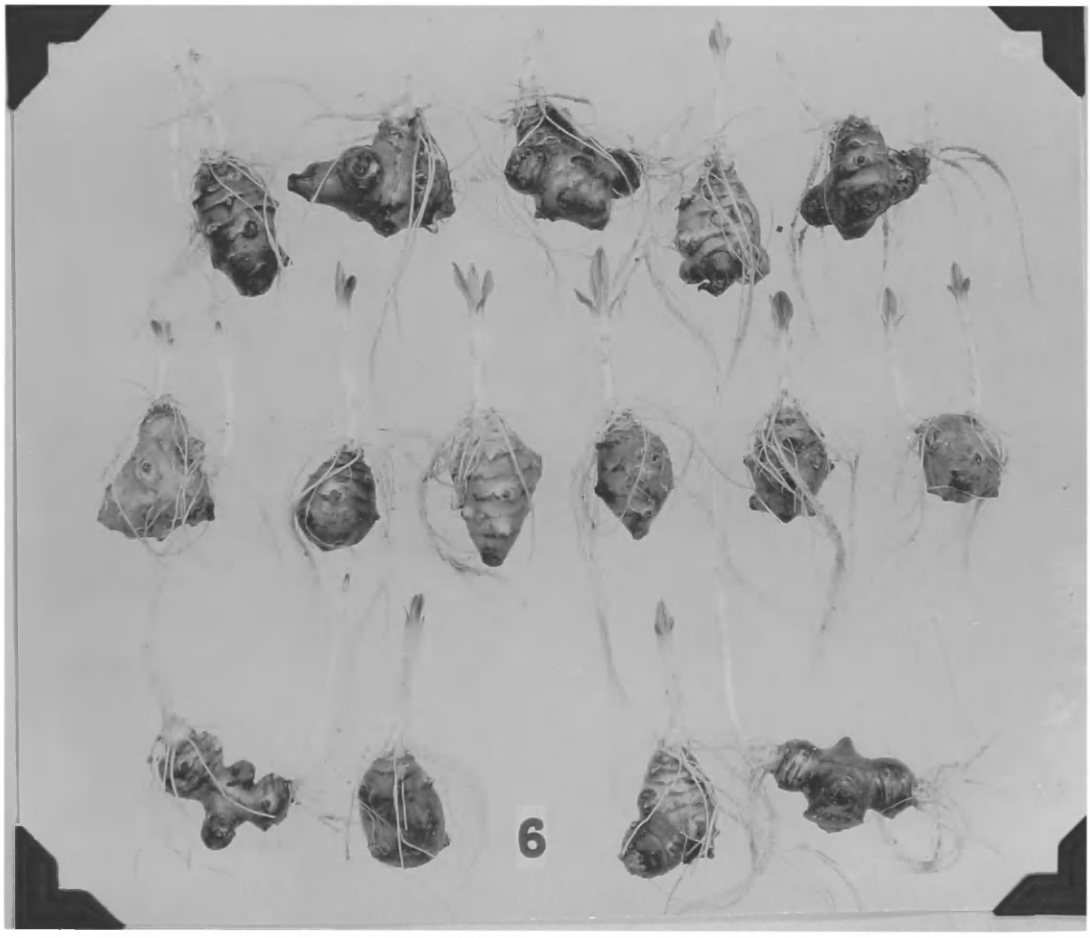
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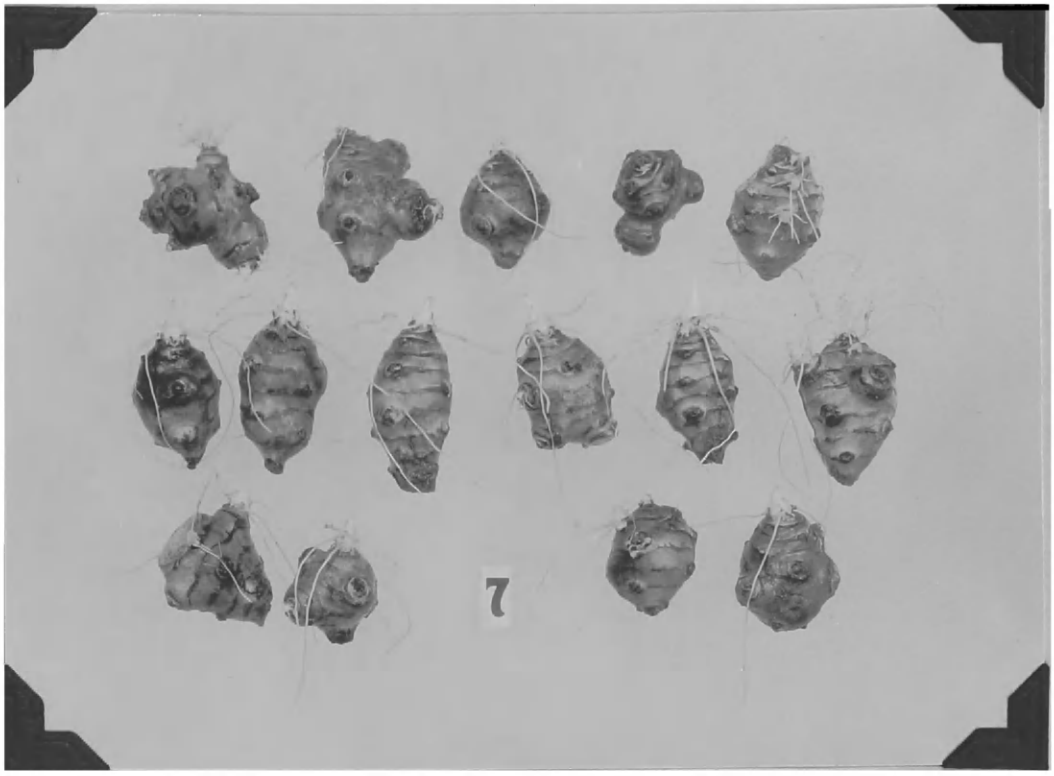
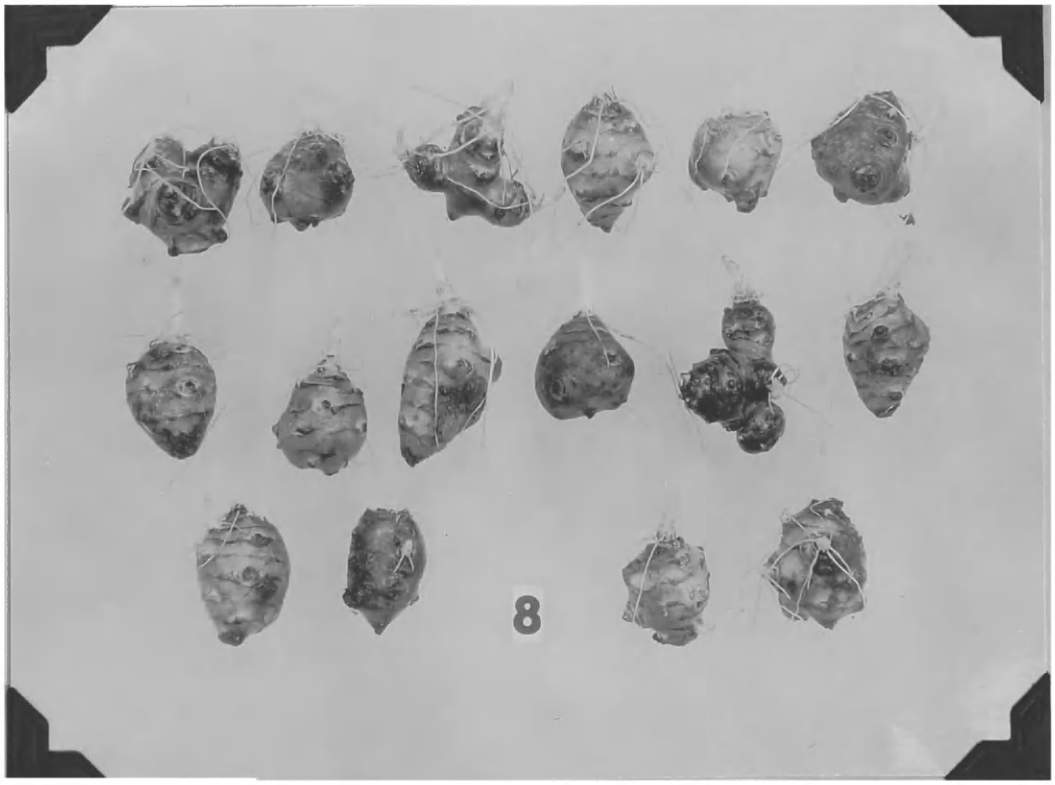
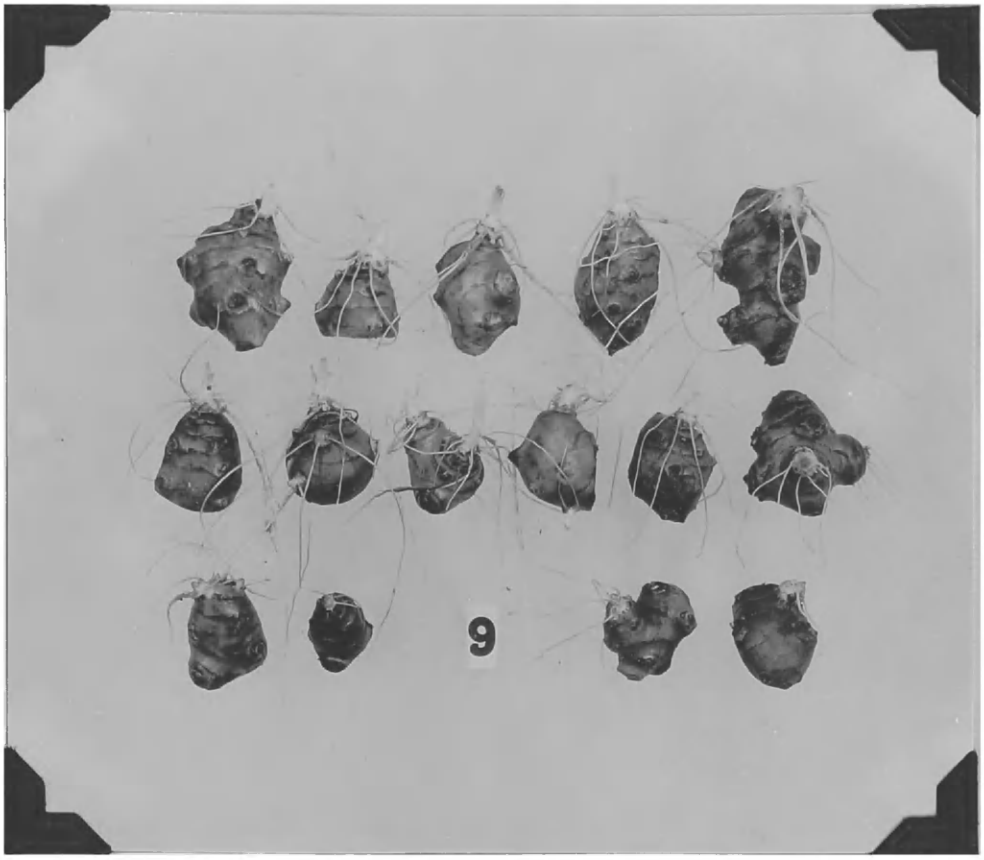
Plate XIX



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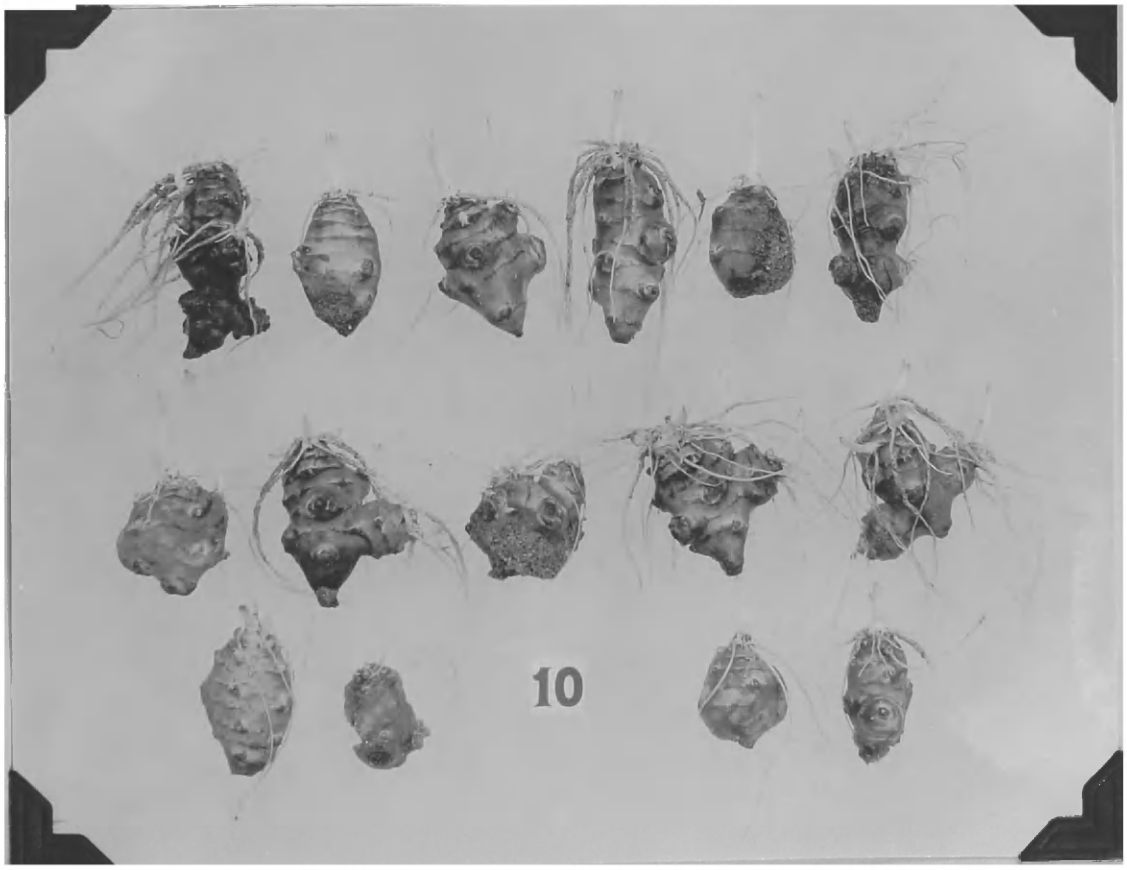
10

Explanation of Plates XXI to XXIII

Relative development of Blanc Ameliore and Chicago tubers when planted in sand after storage at 50°F. or 32°F. High humidity for various periods. Placed in storage Nov. 16, 1934.

Plate XXI Upper Photo: Relative development of the various lots of the variety Blanc Ameliore when photographed on March 5, 1935. Treatments as follows:

c - Control planted Nov. 17, 1934
1 - 32°F. High humidity. Planted Nov. 30.
2 - 50°F. storage. Planted Nov. 30.
5 - 32°F. High humidity. Planted Dec. 17.
6 - 50°F. storage. Planted Dec. 17.
9 - 32°F. High humidity. Planted Dec. 30.
10 - 50°F. storage. Planted Dec. 30.
13 - 32°F. High humidity. Planted Jan. 13.
14 - 50°F. storage. Planted Jan. 13.
17 - 32°F. High humidity. Planted Jan. 28.
18 - 50°F. storage. Planted Jan. 28.
RC1 - (second from left) 32°F. High humidity. Planted Feb. 18.
RD1 - (extreme left) 50°F. storage. Planted Feb. 18.

Middle and Bottom photos: Same samples as in upper photo, photographed Apr. 9, 1935.

Plate XXII Photographs taken Apr. 9, 1935, of same samples as shown in the upper photo of Plate XXI.

Plate XXIII Relative development of the various lots of the variety Chicago when photographed on March 4, 1935.

c - Control planted Nov. 17, 1934.
1 - 32°F. High humidity. Planted Dec. 3.
2 - 50°F. storage. Planted Dec. 3.
3 - 32°F. High humidity. Planted Dec. 20.
4 - 50°F. storage. Planted Dec. 20.
5 - 32°F. High humidity. Planted Jan. 1.
6 - 50°F. storage. Planted Jan. 1.
7 - 32°F. High humidity. Planted Jan. 15.
8 - 50°F. storage. Planted Jan. 15.
9 - 32°F. High humidity. Planted Jan. 29.
10 - 50°F. storage. Planted Jan. 29.
RC11 - 32°F. High humidity. Planted Feb. 19.
RD11 - 50°F. storage. Planted Feb. 19.

Plate XXI

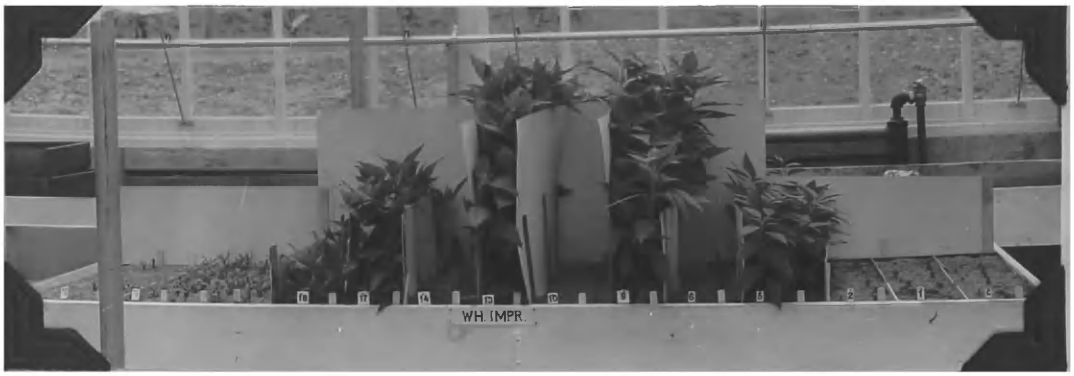

Plate XXII

Plate XXIII

Explanation of Plate XXIV

Apparatus used for the determination of catalase activity. (without thermostatic equipment).

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Plate XXIV