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STUDIES OF THE CULTURE AND CERTAIN VARIETIES OF THE JERUSALEM ARTICHOKE
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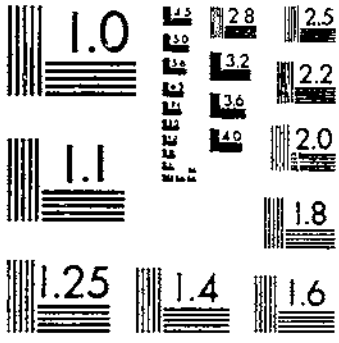

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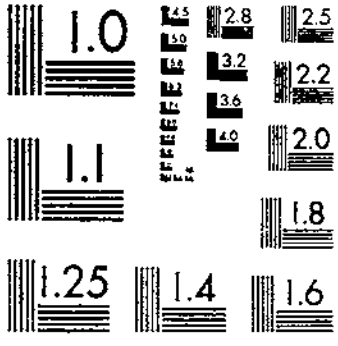

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Technical Bulletin No. 514 May 1936

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C.

STUDIES OF THE CULTURE AND CERTAIN VARIETIES OF THE JERUSALEM ARTICHOKE

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(The Bureau of Plant Industry in Cooperation with the Agricultural Experiment Stations of Illinois, Minnesota, and Oregon)

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INTRODUCTION

Although the Jerusalem artichoke (*Helianthus tuberosus* L.) is native to North America and its culture has been developed on a rather large scale in some parts of Europe, the crop in the United States has remained unimportant except in a few localities. A widespread interest in the plant has developed in this country only within the last decade or so, and largely as a result of its possible value as a source of raw stock for the manufacture of levulose and of alcohol.

The interest in the crop and the seemingly immediate future possibilities have resulted in some unfounded and overenthusiastic optimism and in a number of rather ill-fated commercial ventures. The misfortunes accompanying certain unsuccessful crop-production projects were doubtless due (1) to limited demand and inadequate market facilities for the crop, and (2) to an almost complete lack of information concerning the yields reasonably to be expected, the

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adaptability of the crop, soil and climatic requirements, cultural methods, and particularly the labor requirements. The culture of the Jerusalem artichoke appears to offer no more possibilities for easy profit than numerous farm crops that are extensively grown at present. With the commercial outlet as limited as it is at this writing (1936), growers should carefully determine in advance of planting how their crop can be marketed.

The present interest in the crop and the necessity of obtaining sound basic information in preparation for possible future developments have demanded that certain studies be made. These studies were designed to furnish a basis for developing an economical and efficient system of culture and to prevent as far as possible costly and even disastrous experiences of farmers and others. It is doubtless more important to understand the limitations of a "new" crop than to know merely what a few unusually successful persons have accomplished with it.

In addition to providing immediately valuable practical information on the growing of the Jerusalem artichoke, this cooperative program of study has offered an opportunity to add to the knowledge of the response of plants to different environments. The results are of fundamental as well as practical interest.

Since the history, description, and present uses of the Jerusalem artichoke are extensively treated in a previous publication (*6*),[1] the present bulletin will deal chiefly with the cooperative experiments and their relation to crop production.

PLAN OF INVESTIGATION

The Bureau of Plant Industry and a number of State agricultural experiment stations had conducted independent investigations on the Jerusalem artichoke for a number of years prior to 1930. In late 1930 plans were developed jointly by representatives of the Bureau and of the experiment stations of Illinois, Louisiana,[2] Minnesota, and Oregon for conducting comprehensive studies according to a procedure as nearly uniform as possible for all locations. The Bureau furnished the planting stock of numerous varieties so that all workers would be using identical plant material.

The Middle Atlantic, Middle West, South, North, Great Plains (Wyoming), and the Pacific Northwest were the regions selected for these studies, in an effort to cover the country as thoroughly as practicable with the limited resources available. These several regions are characterized by widely differing conditions of soil and climate, and to such an extent that in the instance of certain studies a uniform method of procedure was not adapted to all locations. Plot sizes and certain other details necessarily departed from the prearranged plan at some of the locations, on account of previously established systems of field management or culture. The northern locations obviously afforded less opportunity to vary times of planting and of harvest than did the more southerly places. All cooperating agencies experienced reductions in funds available for the work, after it was started, so that the original plan could not be carried out completely.

[1] Italic numbers in parentheses refer to Literature Cited, p. 60.

[2] Although cooperative arrangements were completed and plots planted by J. C. Miller, of the Louisiana Agricultural Experiment Station, a succession of disasters to the experimental material prevented obtaining data of value. However, the cooperation of the station is acknowledged.

These uncontrollable conditions resulted in incomplete series of data, which greatly increased the task of analyzing the results and which also tend to limit the dependability of broadly applicable conclusions. Despite these difficulties, there was a very distinct agreement in the trend of results in most of the studies regardless of location or slight differences in procedure imposed by local conditions. On account of this almost complete agreement in trend of results of the several studies, the generalizations that are reached are believed to be safe.

The original plan outlined for each location a 3-year study of the following problems:

(1) Varietal adaptability (20 varieties grown).
(2) Effect of size of seed piece upon plant development and yield and size of tubers.
(3) Effect of depth of planting upon yield and distribution of tubers.
(4) Effect of time of planting upon yield and size of tubers.
(5) Effect of spacing in the row and between rows upon yield per plant and per acre, and upon size and number of tubers.
(6) Relation of time of cutting tops for silage to crude-fiber content of tops, and to yield, size, and number of tubers.
(7) Method of eradicating "volunteer" plants.

The individual plot data obtained by the several writers, together with notes and comments, were sent to the senior writer, who prepared the tables, made the statistical analyses, and prepared a rough draft of a report, which was then jointly worked into form for publication. This plan insured uniformity of treatment of the material and at the same time enabled each investigator effectively to bring out important local observations and interpretations of results.

ENVIRONMENTAL CONDITIONS

Briefly, the principal features of the environment to which the several crops were subjected at the several locations were as follows.

ILLINOIS

The plots were located at Urbana, which lies at approximately 40° north latitude and 730 feet above sea level. The artichokes were planted on grassland soils common to central Illinois. The soils varied in texture from silt loam to clay loam; in color, from light brown to black; in underdrainage, from moderate to slow. The average growing season is about 176 days, as determined by the average date of the last killing frost (Apr. 25) in the spring and of the first killing frost (Oct. 18) in the fall. The normal rainfall is about 20.7 inches for the period from April to September, inclusive, the heaviest precipitation occurring in May. There is frequently a deficiency of rain in summer, resulting in some retardation of crop development. The mean monthly temperatures range from 50.7° F. for April to 74.9° for July and down to 66.6° for September.

The weather for the seasons of 1931 and 1932 was not far from normal, but 1933 was very hot and dry, with very low yields resulting.

MINNESOTA

The plots were located at Excelsior, about 25 miles northwest of St. Paul, at approximately 45° north latitude and 1,000 feet above sea level. The soil is classified as Hayden loam and is a fertile,

moderately heavy soil with a slight tendency to bake. The average growing season is about 142 days, with May 10 the average date of the last killing frost in the spring and September 30 the first in the fall. The normal rainfall is 17.87 inches for the period from May to September, inclusive, the heaviest precipitation occurring in June. There is frequently a deficiency of rain in summer, resulting in some retardation of crop development. The mean monthly temperatures range from 57.7° F. for May to 72.3° for July and down to 61.4° for September.

The weather for the season of 1931 was ideal for the growth of the Jerusalem artichoke, but both 1932 and 1933 were hotter and drier than normal, with medium low yields resulting.

OREGON

The plots were located at Corvallis, some 50 miles from the Pacific Ocean, at approximately 44° 30′ north latitude and 255 feet above sea level. The soil is classified as Newberg sandy loam and is a fertile, friable soil admirably adapted to the culture of the Jerusalem artichoke. The average growing season is about 213 days, with April 10 the average date of the last killing frost in the spring and November 10 the first in the fall. The normal rainfall is about 11 inches for the period from April to October, inclusive, the heaviest precipitation occurring in April, May, and October. The seasonal distribution of rainfall is fairly uniform. The mean monthly temperatures range from 50.4° F. for April to 66.0° for August and down to 53.1° for October. The climatic and soil conditions in this part of Oregon are as nearly ideal for the culture of the Jerusalem artichoke as in any place known in the United States, and are much superior to most regions.

WASHINGTON, D. C.

Washington, D. C., near which plots were located, lies at approximately 39° north latitude, on tidewater. The plots were situated at elevations varying from about 10 to 100 feet above sea level. In 1931 the plots were located at the Arlington Experiment Farm, Rosslyn, Va., on sandy loam soil, and in 1932 on a silt loam soil of artificial origin that had been formed by dredging from the Potomac River. In 1933 the plots were near Beltsville, Md., on soil classified as Sassafras sandy loam. The average growing season in the vicinity of Washington, D. C., is about 189 days, with April 17 the average date of the last killing frost in spring and October 24 the first in the fall. The normal rainfall is about 26 inches for the period from April to October, inclusive, with heaviest precipitation occurring in July. The seasonal distribution is usually fairly uniform. The mean monthly temperatures range from 53.3° F. for April to 76.7° for July and down to 57.4° for October.

The weather for 1931 and 1932 was nearly normal for the area, but hotter and much below average in rainfall in 1933. The 1933 yields were quite low.

WYOMING

The plots were located about 6 miles west of Cheyenne, at approximately 41° north latitude and 6,200 feet above sea level. The soil is classified as Cheyenne loam, heavy phase, which is a moderately fertile soil of medium texture. The average growing season is about

115 days, the last killing spring frost occurring about May 22 and the first killing fall frost about September 15. Since the normal rainfall for the year is but 14.54 inches, these investigations were conducted on irrigated land. Ample irrigation water was available, and about 18 to 20 acre-inches was applied for the season, at such intervals as were required. The mean monthly temperatures range from 48.3° F. for May to 67° for July, down to 57° for September.

Despite fertile soil and adequate irrigation water, this region is not very suitable for the culture of the Jerusalem artichoke on account of the short season.

STATISTICAL ANALYSIS OF DATA

The original plan would have provided a wealth of data on each problem studied if it could have been carried through completely, since it called for quadruplicate plots of each treatment (in many cases involving three varieties) for 3 years in five locations. Such data, collected from a uniformly conducted series of treatments and plots, are well adapted to statistical treatment by Fisher's (*2*) method of analysis of variance. In order to use this method of analysis satisfactorily in a study involving several criteria of classification, data must be available for a complete tabulation relating to the various factors being studied. In other words, in determining the variance due to each of several causes of variance, each class must consist of data relating to exactly the same components as does every other class. Also, part of the analysis will fail unless each component of each class (and the entire class) involves equal or proportionate frequencies or numbers of individual items that enter into the class or its components. Methods have been developed for dealing with disproportionate frequencies in classes, but they are very laborious and the results are only approximate. Therefore, in analyzing the results of the present studies, only those comparisons were made which permitted the use of equal frequencies in all components of all classes.

The unavoidable deviations from the original plan obviously made it impossible to set up complete tabulations for all locations in analyzing the results of many of the studies. Consequently it was necessary in many instances to make several individual tabulations according to differing bases of classification for but one, two, or more locations at a time, in order to observe the trend of results for all locations where data were obtained. Since this so greatly increased the number of tables required for summarizing results for more than a single location, it is impracticable and perhaps undesirable to present them all in detail. Although only 42 such tables are presented, the results of 94 separate analyses of variance are shown. About 200 such analyses were carried through incidentally to the preparation of this bulletin, but about half were omitted, as they only confirmed the results and trends presented and would have altered none of the following discussions materially.

It is recognized that in the analysis of many of the tables (as 10, 13, 20, 22, and others) data have been included which make impossible an identification of the several sources of variation that contribute to the variance for "tests." It is true that the combining of results involving odd varieties and the varying numbers of years and

places preclude the determination of variance due to variety, to year, and to place. However, in many instances in this preliminary work it appears to be more important to know the response to treatment and the extent of the variance among a large number of widely distributed tests (and the interactions between treatments and tests) than to know in detail the variances of the several factors contributing to the variance for a much smaller number of tests.

It should be stated that before tabulating together certain groups of tests, as in the tables mentioned, analyses had been made, for the several groups separately and in different combinations, that permitted determination of variance due to variety, to place, and to other factors. These results, when considered with variances due to treatments, were so consistent that it was evident that responses due to treatments were generally of the same order regardless of place, variety, or year. This evidence thoroughly justifies the use of data and methods of analyzing the data as herein presented. The combining of rather heterogeneous data has buried variances due to certain sources of variation in the large variance for "tests", in some instances, but at the same time it has the very important advantage of including valuable results from many additional places, years, or varieties that otherwise would have been excluded from consideration.

The primary purpose of this bulletin is to determine how the Jerusalem artichoke responded to specific cultural practices over the wide range of conditions observed. Although it is highly desirable to develop interpretations of variations in response that are as complete as possible, it is here considered undesirable to attempt to develop such interpretations on a limited amount of data and largely at the expense of valuable additional data. Even though more detailed interpretations might be possible, they might be more limited in scope and applicability (because of limited data) than the broader conclusions drawn from a greater number of places and tests.

A very useful discussion of these methods of analysis, together with convenient F tables for determining significance of differences in variance, have been published recently by Snedecor (*7*).

In the interest of brevity and simplicity of tabular form the sums of squares and values of F for significance of differences have been omitted from the tables of analysis of variance. Many F values of importance are mentioned in the discussions of the numerous tables. If the F values lie between the 5-percent and 1-percent points or if they exceed the 1-percent point it is so indicated in the tables. In all these instances the F values involve the "errors" indicated in the respective tables. If the sums of squares are of interest to the reader, they are easily obtained by multiplying the mean square (abbreviated as V in many tables) by the corresponding number of degrees of freedom (abbreviated as *df*).

Numerous tables of analysis of variance will be noted which contain figures in parentheses. These figures represent values which, in the course of the analysis, were found to be quite insignificant when compared with the corresponding residual variance (error) or remainder and which are included in the remainder (error) that appears in the table. The parenthetic values had no statistical significance when referred to their residual errors, and so may be considered on the one hand as only "error", and therefore as components of a new residual error with a larger number of degrees of freedom. This new remainder

error is the one shown without parentheses. On the other hand, the variances in parentheses are frequently important for comparison with the values for other factors that contribute to total variance, and so should not be buried in a complex remainder.

In the interest of brevity, the tables of analysis of variance of the more complex tables of results list only those factors and interactions that are considered really essential to the discussions as presented. An effort has been made to avoid burdening the tables with pointless or confusing details. The variances due to replication, in practically all tables, are not shown but are included in the error because they were so nearly zero values. After all, there is no good reason why, in cases involving several treatments, years, and places, there should be any correlated variation among the various replications that were distributed and numbered for tabulation purely at random. There is good argument for leaving these infinitesimal values in remainder error.

The magnitude of differences between means required for significance is calculated as twice the standard error of a difference.

STUDIES OF VARIETIES

About 1920 D. N. Shoemaker, formerly horticulturist of the Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry, began a rather extensive collection of Jerusalem artichoke tubers and seeds from both domestic and European sources in an effort to obtain superior varieties and stocks. He made tuber selections from mixed stocks, and also grew some 15,000 seedlings in continued efforts to obtain high-yielding materials that would be adapted to commercial culture. Large size, comparative smoothness, and limited spread of tubers in the soil were sought, as well as high yield and high levulose content. Of several hundred lots grown in row tests over a period of years near Washington, D. C., about 75 numbers appear to be worth further trial and study. To determine the probable range of adaptability, a number of small lots of tubers were sent to W. L. Burlison in Illinois in 1931 and to H. S. Schoth in Oregon in 1932. Unfortunately, identical lists were not sent to both workers, so data are available for only 20 varieties grown in Illinois, Oregon, and near Washington, D. C. These varieties represented a wide range in growth habit, tuber shape, tuber color, and yield. Three of these varieties—Blanc Ameliore, Chicago, and Waterer—had been chosen as the experimental material for the cultural studies reported herein. They were selected not for their high-yielding capacity (they are only medium) but because of their marked differences in growth habit and tuber character, to determine whether growth habit would affect the response to different conditions of culture.

MATERIALS

The Blanc Ameliore variety is the only one of the list of 20 discussed here that was received under a varietal name. Chicago and Waterer were so named by D. N. Shoemaker because of the source of the stocks as obtained by him. It is very doubtful if these "varieties" can be obtained anywhere in commercial quantity, with the exception of Blanc Ameliore. It is probable that on account of lack of widespread commercial importance the seedsmen and grow-

ers who furnished most of the original samples from which these 20 stocks were increased have not retained control of the particular parent stocks from which they were supplied. The Bureau of Plant Industry is maintaining very small plantings of all these numbers and some 50 others to prevent their identity from being lost.

Some of the principal characteristics of the 20 numbers referred to, together with the sources of the stocks, are listed in table 1. These meager data are far short of a thorough varietal description, but at present such a description is hardly necessary.

METHODS

The varieties were planted in single-row plots varying in length in the different tests, but plots of all varieties were the same length in a single test. Plots in Oregon were 40 feet long; in Illinois, 160 feet; and near Washington, D. C., 132 feet.

TABLE 1.—*Principal characteristics of 20 varieties and stocks of Jerusalem artichoke*

Variety or accession no.	Source of stock	Growth habit	Tuber character	Tuber color	Time of blooming
Blanc Ameliore	Vilmorin-Andrieux & Cie., Paris, France	Tall, spreading	Medium smooth	White	Medium.
Chicago	Vaughan's Seed Store, Chicago, Ill	Medium to tall, spreading	Tapering conic, medium smooth.	Brownish white	Very early.
26944	J. L. Coker, Hartsville, S. C	Very tall, not spreading	Small, medium smooth	do	Medium.
26983	J. A. Boyce Seed Co., Seattle, Wash	do	Smooth	Tinged red	Do.
26984	Hallewell Seed Co., San Francisco, Calif	Tall, spreading	Medium smooth	Red	Late.
26992	Jacob Kaufman, Seattle, Wash	Tall, not spreading	Fairly smooth	Reddish	Medium.
27002	Vilmorin-Andrieux & Cie., Paris, France	Very tall, not spreading	Medium smooth	Red	Do.
27007	George Tait & Sons, Norfolk, Va	Tall, not spreading	do	White	Do.
27079	Vilmorin-Andrieux & Cie., Paris, France	do	do	Clear white	Late.
27081	do	Medium to tall, not spreading.	Small, medium smooth	Brownish white	Medium late.
27082	do	Tall, not spreading	Long conic, medium smooth	White, red tinge	Late.
27090	do	Medium height and spread	Medium smooth	Brownish white	Do.
27095	do	do	Rough	do	Do.
27096	do	Low, not spreading	Medium smooth	do	Do.
27098	do	Medium, not spreading	do	do	Medium late.
Waterer	Hosea Waterer, Philadelphia, Pa	Very tall, not spreading	Short spindle, smooth	do	Medium early.
27574	L. B. Scott, Norfolk, Va	Tall, spreading	Rather rough	White, red tinge	Early.
27585	Haage & Schmidt, Erfurt, Germany	Low, not spreading	Fairly smooth	do	Medium.
27632	William Rennie & Co., Ltd., Toronto, Canada.	Tall, not spreading	Medium smooth	Brownish white	Early.
28098	Vilmorin-Andrieux & Cie., Paris, France	do	do	do	Medium.

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YIELDS

Table 2 presents the mean yields for each location and for all locations where grown. It is clear that although the varieties do not show exactly the same order in yielding power at the three locations, the tendency to do so is pronounced. The varieties finally ranked as "good" are good in all tests, and those ranked "poor" are rather consistently low.

TABLE 2.—*Mean yields per acre of 20 varieties and stocks of Jerusalem artichoke grown for 3 years at Urbana, Ill., Corvallis, Oreg., and near Washington, D. C.*

Variety or accession no.	Yield per acre				Rank
	Urbana, Ill.	Corvallis, Oreg.	Washington, D. C.	Mean	
	Tons	*Tons*	*Tons*	*Tons*	
Blanc Amelioré	6.43	18.42	7.90	10.92	Medium.
Chicago	4.98	10.96	8.48	11.14	Do.
26944	9.28	21.51	8.88	13.22	Good.
26983	5.14	16.73	9.63	10.50	Medium.
26984	6.36	20.60	6.32	10.90	Do.
26992	6.53	16.92	8.60	10.35	Do.
27002	5.11	18.29	8.54	10.65	Do.
27007	8.11	18.62	9.55	12.10	Good.
27070	8.81	15.52	8.90	11.08	Medium.
27081	6.89	15.14	6.00	9.54	Do.
27082	6.23	15.19	9.47	10.30	Do.
27090	5.55	14.97	8.40	9.64	Do.
27095	7.07	18.08	11.13	12.20	Good.
27096	1.05	8.71	7.60	6.09	Poor.
27098	7.57	14.81	8.52	10.30	Medium.
Waterer	6.01	17.11	7.01	9.91	Do.
27571	10.95	20.78	11.40	14.38	Good.
27585	4.80	9.66	9.76	8.17	Poor.
27632	6.55	14.00	10.01	10.40	Medium.
28008	7.74	19.98	7.53	11.75	Do.
Mean	6.58	16.73	8.74	10.69	

The analysis of variance (table 3) shows that for all locations combined the interaction between variety and place is significant with reference to residual error, indicating that the varieties rank somewhat differently in the different locations. This can be observed also in table 2, but the differences in rank are not great.

TABLE 3.—*Analysis of variance of data for table 2*

Place and source of variation	Degrees of freedom	Mean square	Place and source of variation	Degrees of freedom	Mean square
Illinois, Oregon, and Washington, D. C.:			Washington, D. C.:		
Total	179	39.145	Total	59	16.843
Between varieties	19	[1] 27.906	Between varieties	19	5.202
Between places	2	[1] 1,714.513	Between years	2	[1] 382.626
Between years	2	[1] 165.819	Error (varieties × years)	38	3.443
Varieties × places	38	[1] 11.203	Illinois:		
Varieties × years	38	8.126	Total	59	17.731
Places × years	4	[1] 396.014	Between varieties	19	11.445
Error (varieties × places × years)	76	5.388	Between years	2	[1] 270.702
Oregon:			Error (varieties × years)	38	7.244
Total	59	26.031			
Between varieties	19	[1] 33.035			
Between years	2	[1] 299.119			
Error (varieties × years)	38	8.155			

[1] Exceeds 1-percent point.

Considering the varietal means for all locations, there are practically infinite odds that there are differences in yield among the varieties. The variance due to variety is significantly greater than that for interaction between variety and place (observed $F = 2.4$; 5-percent point is less than 2.04), thus indicating that certain varieties are consistently superior in all three locations where observed.

It appeared advantageous to present separate analyses for each of the three locations, since the significant interaction between varieties and places indicated some differences in relative value of varieties in the various places. Unfortunately, but little was gained by this procedure on account of the extreme variations in yield from year to year, induced by unfavorable conditions, and the very small number of tests. As measured by the individual errors of the respective locations or of all locations combined (table 3), only the Oregon tests revealed significant varietal differences for a single location. Despite the lack of statistical significance of differences among varieties grown near Washington, D. C., and in Illinois, the tendencies are consistent with those evident in the Oregon tests. The accumulative results of all tests have a definite value for the individual location because of the proved consistent superiority of certain numbers, regardless of place.

The means for all locations show that nos. 27574, 26944, 27095, and 27007 are rather outstanding. A difference of 2.19 tons is calculated to represent significance. The highest yield (14.38 tons) was from no. 27574, the other three varieties lying within or approximating the limits set by this variety and the maximum yield that can be considered significantly lower than the highest yielding lot. Contrariwise, no. 27585 is a definitely inferior variety since it lies within a similar range established by the lowest yielding variety, no. 27096. No. 27002 yielded almost exactly the mean yield of the 20 varieties. Only the two highest, 27574 and 26944, significantly exceed this, while only 27096 and 27585 are significantly inferior.

No. 27574 is of particular interest also on account of its high levulose content, which will be pointed out in the next section of this discussion of varieties.

Even this short list of varieties shows definitely that the question of the producing capacity of varieties is one of major importance and must receive careful and thorough attention before large-scale production is undertaken. Although it appears that high-yielding varieties may be expected to retain high rank over a wide range of conditions, the matter of adaptability is of some importance.

LEVULOSE AND TOTAL SUGAR CONTENT

Although no studies of the chemical composition of the tubers were included in the cooperative work reported in this bulletin, it may be well to present at this point certain hitherto unpublished data on varieties grown near Washington, D. C. Investigators in the Bureau of Standards of the United States Department of Commerce (*3, 4*) have studied the Jerusalem artichoke tuber for some years in connection with their work upon the preparation of levulose. Over a period of years they have made many hundreds of analyses of single samples of individual varieties and stocks obtained from the collection grown by D. N. Shoemaker, formerly of the Bureau of Plant Industry. The analyses reported in table 4 were taken from data furnished by the Bureau of Standards and represent amounts of sugars determined

after conversion or hydrolysis. These represent but a fraction of the data available, but are presented as an indication of the probable performance of the 20 varieties listed in table 2.

TABLE 4.—*Content of total sugars and levulose equivalent in percentage of fresh weight of Jerusalem artichoke tubers grown near Washington, D. C.*

Variety or accession no.	November 1925		December 1926		November 1927		November 1928		November 1930		January 1932		Mean	
	Total	Levulose	Total	Levulose	Total	Levulose	Total	Levulose	Total	Levulose	Total	Levulose	Total	Levulose
Blanc Amelioré	15.20	12.01	12.10	8.51	14.88	12.50	15.80	11.90	23.00	19.20	13.00	9.10	15.69	12.21
Chicago	17.14	13.73	10.67	13.80	18.20	14.87	18.00	15.20	21.50	18.80	15.30	11.00	17.82	14.67
26914	13.70	10.50	13.30	11.15	15.04	11.30	16.60	13.10	22.40	21.00	13.50	9.20	15.77	12.72
26983	13.50	11.20	12.16	9.60	14.90	12.34	11.40	9.40	21.00	18.30	14.20	10.30	14.53	11.85
26984	15.61	13.20	14.75	12.45	16.60	13.00	17.90	15.00	22.40	20.10	14.30	10.60	16.84	14.07
26992	14.32	12.01	11.36	8.34	15.25	13.28	17.50	12.30	20.00	19.00	13.40	9.00	15.07	12.43
27002	12.69	10.30	13.09	10.44	12.30	9.82	15.00	12.80	23.10	21.50	13.00	9.30	14.88	12.34
27007	13.20	10.26	13.64	11.84	17.26	13.75	15.80	12.00	22.10	19.00	13.50	9.00	15.92	12.74
27079	18.09	14.70	16.26	12.69	19.34	15.00	16.10	12.90	24.00	20.40	16.60	11.50	18.40	14.08
27081	15.10	12.55	15.12	11.60	15.85	12.06	15.60	12.50	22.80	19.70	12.50	9.00	16.16	12.90
27082	16.65	14.20	13.50	10.70	19.50	16.56	16.40	13.20	21.70	19.00	15.40	10.70	17.29	14.07
27090	14.61	11.95	13.41	10.12	16.75	13.68	15.10	12.00	21.30	18.30	12.50	9.10	15.62	12.51
27095	16.77	13.40	15.30	12.12	20.30	16.72	19.10	15.10	21.30	17.00	14.70	10.50	17.93	14.20
27096	16.63	14.75	17.06	14.81	17.80	14.81	17.10	13.70	20.20	17.70	12.90	8.70	16.58	13.58
27098	16.46	14.15	15.04	11.58	18.45	15.27	17.40	13.80	21.00	18.70	13.90	9.70	17.04	13.88
Waterer	17.46	16.23	16.24	13.48	18.45	15.85	20.70	17.40	22.60	19.40	12.10	8.30	17.48	14.04
27574	18.78	16.27	16.59	13.32	18.10	15.17	21.00	17.80	23.00	21.20	15.60	11.50	19.01	15.88
27585	13.82	11.00	16.08	13.00	17.42	14.05	14.10	9.20	21.00	18.00	13.00	9.50	15.41	12.77
27632	12.81	10.70	13.09	10.50	12.45	9.08	15.70	10.40	22.70	20.50	11.00	8.30	14.03	11.73
28098	13.40	11.00	13.96	10.98	14.37	11.16	14.90	11.40	21.50	18.90	14.20	10.10	15.38	12.24
Mean	15.23	12.72	14.37	11.39	16.65	13.64	16.31	13.05	21.98	19.32	13.73	9.81	16.38	13.33

The figures in table 4 represent practically the entire range in percentage of levulose and total sugar that has been found among varieties that produce moderate or good yields of tubers of medium or larger size. Certain sorts that produce very small and commercially worthless tubers may show a much higher percentage of levulose and total sugar.

It will be noted in table 4 that the analysis of the tubers of individual varieties varied quite widely between seasons. Unfortunately, information is not available by which these differences can be definitely explained. The year 1930 was very dry, possibly accounting in part for the high levulose content that year. The 1932 analyses were made in January, later in the season than in any of the previous years. Traub and others (*8*) have shown that the levulose and dextrose content of the tubers are highest in November, decreasing through the winter. It thus appears that lateness of analysis will partly explain the low results of 1932.

The last two columns of table 4 present the 6-year mean levulose and total sugar content for each variety. The 6-year mean for all varieties is 13.33 percent of levulose and 16.38 percent total sugars. Using the figure for error shown in table 5, it is calculated that a 6-year mean difference in levulose between 2 varieties must be as great as 1.56 percent if it is significant. Upon this basis it will be noted that there are 3 varieties, Chicago, no. 27079, and Waterer, that show levulose analyses insignificantly lower than the best variety, no. 27574, which showed 15.88 percent. Sixteen varieties are significantly inferior to the best. From another standpoint, there are

9 varieties that appear significantly superior to the poorest of the lot which is no. 27632 with only 11.73 percent levulose. In addition to the 4 good varieties mentioned above, these latter 9 include nos. 26984, 27082, 27095, 27096, and 27098. All of these show analyses that are above the mean for the whole table, but only Waterer and no. 27574 are significantly superior to the mean value of 13.33 percent.

TABLE 5.—*Analysis of variance of data for table 4*

Source of variation	Degrees of freedom	Mean squares	
		Levulose	Total sugars
Total	119	11.668	11.830
Between varieties	19	[1] 8.169	[1] 10.510
Between tests (years)	5	[1] 240.180	[1] 174.648
Error (tests × varieties)	95	1.833	1.908

[1] Exceeds 1-percent point.

A difference in total obtainable sugars between two means must be as great as 1.60 percent to be significant. There is such a close relationship between quantities of total sugars and of levulose that the comments in the preceding paragraph, with reference to differences in levulose among varieties, hold also for total sugars, in general. Fifteen varieties are significantly inferior to the best. Chicago, no. 27079, and Waterer are again insignificantly inferior, as also is no. 27095. No. 27081 and the same 9 superior varieties listed in the preceding paragraph are significantly superior to no. 26983, the lowest in total sugars.

Only variety no. 27574 is consistently high in both levulose and total sugar content and in yield. Considering the marked tendency for poor yield and tuber character to be associated with high levulose content, this is an unexpected and most encouraging indication of what might be hoped for in the development of superior commercial stocks.

These data indicate a mean levulose equivalent of approximately 4,350 pounds per acre for no. 27574 in contrast with 2,650 pounds for the entire group of varieties and only 1,400 pounds for no. 27096. It should be borne in mind, however, that these figures are only relative and do not indicate probable absolute yields of levulose. At this writing, a large-scale commercial manufacture of levulose from Jerusalem artichokes has not become a reality. If it does become a reality one cannot expect a factory yield of 100 percent of the levulose found upon analysis of raw stock. These relative amounts also are calculated from yields of small experimental plots that indicate good rather than average results to be expected under general farming conditions.

The figures for total sugars are of importance in view of a recently revived interest in the possible value of this crop as a raw material for ethyl alcohol manufacture. Assuming that 1 pound of sugars will yield one-half pound of alcohol, the following varietal differences may be calculated: No. 27574 produced the equivalent of about 395 gallons per acre, the mean for all 20 varieties about 250 gallons, and

no. 27096 only about 145 gallons. In terms of yield per ton of raw stock the differences are not so great. For example, no. 27574 would yield about 27 gallons, an average variety about 24 gallons, and such varieties as nos. 26983 and 27632 only about 21 gallons. Again, it is emphasized that these are only estimates, based on chemical analyses and upon relatively high yielding experimental plots. Actual yields of tubers harvested under average conditions probably would be but 50 to 65 percent of these experimental results, and alcohol yields will of course be below the theoretically possible yield per ton of raw material.

SIZE OF SEED PIECE

METHODS

In preparing stock for the studies upon size of seed piece the following procedure was used when cut and whole tubers were to be compared: Tubers were sorted from a large quantity of field-run material and weighed rapidly, one at a time, on a torsion balance. Those deviating in weight not more than 10 percent, plus or minus, from the desired size were retained for planting. For the cut tubers, specimens of twice the required weight of seed piece were selected and cut in half as accurately as the eye could judge. Tests in which cut and whole pieces were not compared were planted with a mixture of cut and whole pieces of the indicated sizes. Pieces weighing ¼, ½, 1, and 2 ounces were used.

Individual plots consisted of single rows 40 feet long with rows 4 feet apart and hills 2 feet apart in Minnesota. Near Washington, D. C., and in Oregon and Wyoming similar rows were 5 feet apart; the hills were 2 feet apart in the row except in Oregon, where they were 4 feet. Plots were in duplicate in Oregon and in quadruplicate at the other locations. The results of the Oregon tests are not combined with the others on account of the larger sizes of seed piece used. They were 2, 3, and 4 ounces in size, of the same range of sizes as is commonly planted locally. In all tests one seed piece was planted in each hill.

Before harvest, the number of stalks per hill was recorded, then the plots were harvested by hand. The weight and number of tubers per plot were recorded.

RESULTS

CUT VERSUS WHOLE SEED

Before considering the effect of size of seed piece upon yield and quality of the crop, it is of interest to inquire whether there is any marked difference in behavior of cut and whole seed. This is of special importance in the following discussions, since many of the plots were planted with mixtures of variable proportions of both kinds. Furthermore, the question is of great practical interest.

Table 6 presents comparisons of whole and cut tubers of four sizes of seed piece, carried on for 3 years near Washington, D. C., and 1 year at Cheyenne, Wyo. It is evident in the mean yields for Washington that there was no great difference between cut and whole seed, and this is further substantiated by the insignificance of the variance between them (table 7). A single season's results at Cheyenne, however, showed the whole seed to be superior. This possibly may be

explained by the tendency for the cut pieces to be dried out more seriously under arid conditions of high elevation than in the more humid regions, which are at low elevation, resulting in a greater difference in behavior between the cut and whole seed.

TABLE 6.—*Effect of cut v. whole seed pieces of different sizes on yield per hill of Jerusalem artichokes grown near Washington, D. C., and at Cheyenne, Wyo.*

[Quadruplicate plots]

Place and year	Yield per hill from seed pieces of indicated size and condition							
	¼ ounce		½ ounce		1 ounce		2 ounces	
	Cut	Whole	Cut	Whole	Cut	Whole	Cut	Whole
Washington, D. C.:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1931	1.49	1.60	1.75	1.88	2.20	2.38	2.20	2.01
1932	7.08	6.05	6.55	6.58	7.18	6.49	8.11	7.20
1933	1.64	1.76	1.65	1.97	1.96	2.19	2.15	2.41
Mean	3.37	3.14	3.32	3.47	3.75	3.68	4.16	3.87
Mean (cut and whole)	3.26		3.39		3.72		4.01	
Cheyenne, Wyo.:								
1933	1.54	....	1.07	3.00	2.95	3.76	3.72	3.69
Mean (cut and whole) [1]	....		3.05		3.63		3.94	

[1] Based on totals for 2 locations.

TABLE 7.—*Analysis of variance of data for table 6*

Place and source of variation	Degrees of freedom	Mean square
Washington, D. C.:		
Total	95	5.075
Between treatments	1	.293
Between years	2	[1] 202.192
Between sizes	3	[1] 2.773
Treatments × years (tests)	2	[1] 1.853
Error (remainder)	87	.356
Cheyenne:		
Total	31	1.286
Between treatments	1	[1] 8.778
Between sizes	3	[1] 5.287
Error (remainder)	27	.584

Place and source of variation	Degrees of freedom	Mean square
Washington, D.C., and Cheyenne:		
Total	95	4.858
Between treatments	1	.745
Between tests	3	[1] 133.703
Between sizes [2]	2	[1] C. 433
Treatments × tests	3	[1] 2.378
Treatments × sizes	2	[3] 1.321
Sizes × tests	6	[3] 1.097
Error (remainder)	78	.387

[1] Exceeds 1-percent point.
[2] ½-, 1-, and 2-ounce pieces only.
[3] Between 5-percent and 1-percent points.

Although the mean yields for Washington, D. C., and Cheyenne together suggest a superiority of whole over cut seed, the analysis of variance (table 7) shows the difference to be significant. One year's data at Cheyenne are inadequate for reaching a decision on this point.

EFFECT OF SIZE OF SEED PIECE ON YIELD

Since the Oregon tests were made with seed pieces of 2, 3, and 4 ounces, a range of sizes different from the others, the results are presented separately. Table 8 shows very little difference in yield

per hill from different sizes of seed piece. The analysis of variance (table 9) shows the variance due to size of seed piece to be barely significant with reference to residual error. The required magnitude of a significant difference between the 2-year means is 0.63 pound and for the 1-year means, 0.89 pound. From this it appears that the small superiority in yield (about 10 percent) of the 3-ounce piece over the 2-ounce piece is significant in the individual years and for the 2 years together. In no case is the 4-ounce piece superior to the 2-ounce. The means for the 2 years show that the 4-ounce piece produced yields significantly lower than the 3-ounce and essentially the same as the 2-ounce. It is suggested that the profusion of stems, stolons, and tubers produced by the largest piece resulted in such a crowded condition within the individual hill that optimum top and tuber development was slightly retarded. However, the mean number of stems for the three successive sizes of seed piece was but 1.9, 3.1, and 3.8, respectively. The plants of the 4-ounce plots tended to be a few inches taller, and the tubers per hill were greater in number but smaller in size.

TABLE 8.—*Effect of size of seed piece on yield per hill of different varieties of Jerusalem artichoke grown in Oregon*

[Duplicate plots]

Year and variety	Yield per hill from seed pieces of indicated size		
	2 ounces	3 ounces	4 ounces
1932	*Pounds*	*Pounds*	*Pounds*
Blanc Amelioré	13.55	13.55	11.28
Chicago	9.34	10.18	11.00
Waterer	9.59	11.89	11.66
Mean	10.82	11.87	11.31
1933			
Blanc Amelioré	13.41	13.61	13.45
Chicago	8.37	9.34	8.30
Waterer	7.75	8.32	7.73
Mean	9.84	10.42	9.85
Mean for 2 years	10.33	11.15	10.58

TABLE 9.—*Analysis of variance of data for table 8*

Source of variation	Degrees of freedom	Mean square
Total	35	4.885
Between sizes of seed piece	2	[1] 2.103
Between varieties	2	[2] 51.204
Between years	1	[1] 15.184
Varieties × sizes of seed piece	4	1.469
Varieties × years	2	[1] 10.944
Years × sizes of seed piece	[3] (2)	(.236)
Remainder	(22)	(.632)
Error	24	.598

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.
[3] Values in parentheses have been combined to give those identified as "error."

Under Oregon conditions the 3-ounce piece gave an increased yield over the 2-ounce at the rate of 1,786 pounds per acre in return for an additional calculated 136 pounds of seed. The desirability of seed pieces larger than 3 ounces is not indicated. It is not to be concluded that these results are applicable under other conditions of culture, but rather the opposite. The very high yields obtained in Oregon indicate a set of conditions particularly favorable for this crop, which are found in but few regions.

The data on yields resulting from the use of different sizes of seed piece in Minnesota, Wyoming, and near Washington, D. C., are presented in table 10 and the analysis of variance in table 11. The means of all tests show a progressive increase in yield as the size of piece is increased from one-fourth ounce to 2 ounces. Variance due to size of piece is very highly significant when referred to residual error. Despite this fact, the residual error is of such magnitude that the difference between mean yields for the ¼- and ½-ounce pieces is not significant. (Observed=0.19 pound; calculated required=0.46 pound.) All other differences are significant.

TABLE 10.—*Effect of size of seed piece on yield per hill of different varieties of Jerusalem artichoke grown in Minnesota and Wyoming and near Washington, D. C.*

[Quadruplicate plots]

Place and variety	Year	Yield per hill from seed pieces of indicated size			
		¼ ounce	½ ounce	1 ounce	2 ounces
		Pounds	*Pounds*	*Pounds*	*Pounds*
Minnesota:					
Blanc Ameliore	1931	5.90	6.10	6.28	6.60
Mammoth French White	1931	5.85	6.25	6.08	6.83
Do	1932	2.44	4.16	4.08	5.00
Chicago	1932	1.79	1.64	1.69	3.91
Waterer	1932	.96	.89	1.47	1.75
No. 20723-14	1933	1.20	1.43	2.40	2.25
Chicago	1933	2.48	2.63	3.33	3.18
Washington, D. C.:					
Blanc Ameliore	[1] 1931	1.40	1.75	2.20	2.20
Do	[2] 1931	1.60	1.88	2.38	2.01
Do	[1] 1932	7.08	6.55	7.18	8.11
Do	[2] 1932	6.05	6.58	6.40	7.20
Do	[1] 1933	1.64	1.66	1.96	2.15
Do	[2] 1933	1.76	1.97	2.10	2.41
Wyoming:					
Waterer	[1] 1933	1.54	1.07	2.95	3.72
Do	[2] 1933	3.01	3.00	3.76	3.09
Mean		2.98	3.17	3.63	4.07

[1] Cut seed pieces.
[2] Whole seed pieces.

TABLE 11.—*Analysis of variance of data for table 10*

Source of variation	Degrees of freedom	Mean square
Total	239	4.583
Between sizes of seed piece	3	[1] 14.191
Between tests	14	[1] 67.600
Sizes of seed piece × tests	42	1.738
Error (remainder)	180	.404

[1] Exceeds 1-percent point.

Since the variance due to size of piece is significantly greater than that due to interaction between size of piece and test ($F=19.2$; 1-percent point less than 4.3) it is concluded that size of seed piece significantly affects yield under all conditions of these studies. Since a wide range of conditions is represented, it is safe to say that, in general, the seed piece should be at least 1 ounce in weight, and preferably 2 ounces. Under conditions similar to those in the coastal counties in Oregon, pieces as large as 3 ounces can profitably be planted.

In the interests of economy in publication additional tables of analysis of yields as affected by size of seed piece are omitted. It should be stated, however, that the data for Minnesota and for Washington, D. C., were tabulated and analyzed separately and also the data for the Blanc Ameliore variety alone for all locations. In all cases, variance due to size of piece was significant. The differences in the Minnesota tests were greater and of higher statistical significance than those in the Washington tests. The mean yields in pounds per hill of the Blanc Ameliore variety, for the four successive sizes of piece were: For Minnesota, 3.18, 3.90, 4.25, and 4.62; for Washington, 3.16, 3.68, 3.97, and 4.24. The mean yields of the several varieties grown in Minnesota were, for the four successive sizes of piece, 2.95, 3.30, 3.62, and 4.21. The greatest source of variation in all instances (except in Oregon) was seasonal differences. The remarkably similar conditions for the 2 years of the Oregon tests gave such a low variance due to year that it was exceeded by the variance due to variety (table 9).

EFFECT OF SIZE OF SEED PIECE ON NUMBER OF STEMS PER HILL

Since the variances due to factors other than size of seed piece were small and relatively unimportant, only the mean values for the six Oregon tests need be given. The numbers of stems per hill from 2-, 3-, and 4-ounce seed pieces were 1.87, 3.05, and 3.82, respectively. The analysis of variance (table 12) shows these differences to be very highly significant.

TABLE 12.—*Analysis of variance of data relating to effect of size of seed piece on number of stems per hill of Jerusalem artichokes grown in Oregon* [1]

Source of variation	Degrees of freedom	Mean square
Total	17	0.8220
Between sizes of seed piece	2	[2] 5.7006
Between years	1	.0200
Between varieties	2	[2] .5830
Error (remainder)	12	.1004

[1] 3 varieties grown in 2 seasons.
[2] Exceeds 1-percent point.
[3] Between 5-percent and 1-percent points.

Similar data for the plots in Minnesota, Wyoming, and near Washington, D. C., are shown in tables 13 and 14. A glance at the latter shows that with reference to residual error the variances due to size of piece, to test, and to interaction between size and test, all are highly significant. Furthermore, variance due to size of piece is highly significant when referred to the interaction between size of piece and test. (Observed $F=16.0$; 1-percent point $=5.95$.)

Thus, from tables 12, 13, and 14 it may be safely concluded that the increase in number of stems accompanying increase in size of seed piece, up to the limit observed, is a practically universal occurrence with this plant.

TABLE 13.—*Effect of size of seed piece on number of stems per hill of Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*

[Quadruplicate plots]

Year and place	Stems per hill from seed pieces of indicated size			
	¼ ounce	½ ounce	1 ounce	2 ounces
	Number	*Number*	*Number*	*Number*
1931				
Minnesota	2.03	3.13	3.63	4.28
Washington, D. C.	1.52	2.86	4.80	7.23
1932				
Washington, D. C.	1.49	2.05	2.91	4.10
Do	1.41	1.73	3.20	4.50
1933				
Wyoming	2.10	2.20	2.65	3.45
Mean	1.70	2.39	3.40	4.75

TABLE 14.—*Analysis of variance of data for table 13*

Source of variation	Degrees of freedom	Mean square
Total	79	2.189
Between sizes of seed piece	3	[1] 35.360
Between tests	4	[1] 6.653
Sizes of seed piece × tests	12	[1] 2.216
Error (remainder)	60	.226

[1] Exceeds 1-percent point.

EFFECT OF SIZE OF SEED PIECE ON WEIGHT OF HARVESTED TUBERS

From the number and weight of tubers harvested per plot, the mean weight per tuber was calculated for all tests shown in table 10. Since the differences in tuber size accompanying the use of different sizes of seed piece were so slight throughout the detailed tabulation, only the mean values for the 15 tests need be given. Seed pieces weighing ¼, ½, 1, and 2 ounces yielded tubers weighing respectively 1.56, 1.55, 1.67, and 1.51 ounces. A glance at these figures raises doubt as to the significance of a difference between any two means. From table 15 one may determine that the variance due to size of piece is insignificant with reference to residual error. None of the interactions are significant.

TABLE 15.—*Analysis of variance of data relating to effect of size of seed piece on mean weight of harvested tubers of Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*[1]

Source of variation	Degrees of freedom	Mean square
Total	239	0.6136
Between sizes of seed piece	3	.2732
Between tests	14	[2] 8.4802
Between replicates	[3] (3)	(.0886)
Sizes × tests	(42)	(.1283)
Sizes × replicates	(9)	(.1034)
(Remainder)	(168)	(.1221)
Error	222	.1221

[1] 7 tests were made in Minnesota, 2 in Wyoming, and 6 near Washington, D. C. Quadruplicate plots.
[2] Exceeds 1-percent point. [3] Values in parentheses have been combined to give the value identified as error.

It thus appears from 15 tests involving several varieties in 3 locations and seasons, that size of seed piece of 2 ounces or smaller is without consistent effect on size of tubers harvested. The Oregon data indicate, however, that seed pieces above 2 ounces in weight result in a decreased size of tuber. Unfortunately, data are not available for Oregon for seed pieces below 2 ounces in weight, nor above 2 ounces for the other locations.

The mean tuber size harvested from 2-, 3-, and 4-ounce seed pieces was 3.54, 3.22, and 2.7 ounces, respectively. The analysis of variance (table 16) shows that the differences are significant (required difference=0.24 ounce), but this decrease in size is probably no disadvantage since such very large tubers (or multiple tubers) are involved.

TABLE 16.—*Analysis of variance of data relating to effect of size of seed piece on size of harvested tubers of Jerusalem artichokes grown in Oregon* [1]

Source of variation	Degrees of freedom	Mean square
Total	17	0.3570
Between sizes of seed piece	2	[2] 1.0331
Between years	1	[3] .5034
Between varieties	2	[3] 1.2227
Error (remainder)	12	.0879

[1] 3 varieties grown in 2 seasons.
[2] Exceeds 1-percent point.
[3] Between 5-percent and 1-percent points.

TIME OF PLANTING

METHODS

The plots in the tests relating to date of planting in Illinois were single rows 136 feet long, while at the other locations they were 40 feet long. The plots were in duplicate in Illinois and Oregon, and in quadruplicate in Minnesota, Wyoming, and near Washington, D. C. All plots at a single location were planted at a uniform depth and spacing, given uniform cultural conditions, and were harvested by hand. The tubers of each plot were counted and weighed.

In determining beforehand the dates for making experimental plantings, the earliest date on which soil and weather normally permitted field work was considered as *A*, i. e., as the first planting, regardless of calendar date. An effort was made to plant on or very near this earliest date. Subsequent plantings were to be spaced at intervals for as long as seed stock could be held in good condition or until it was apparent that the shortness of the remainder of the growing season would not permit satisfactory tuber development before frost.

It may appear that such variations in time of planting would preclude fair comparisons and combinations of results for reaching a generalized conclusion. On the contrary, earliness or lateness of planting cannot properly be evaluated on a calendar basis alone, but must be considered in relation to length of growing season available and to the characteristics of the prevailing weather of each region.

Thus, the earliest possible planting time is always indicated as *A* and the latest as *E*, regardless of length of time from *A* to *E*. In a region of fairly long and mild spring, followed by a long growing season, there supposedly would be a greater range of time over which planting might be expected to be satisfactory. In northerly regions or those where unfavorable weather conditions occur fairly early, one would expect a rather short successful planting period. The medium planting date is marked *C*, regardless of number of plantings or length of possible planting range. The indicated planting dates are thus relative and should not be considered apart from the local conditions of the several tests. The actual dates of the several plantings are shown in table 17.

TABLE 17.—*Dates of planting of the various plots in the studies of effect of time of planting on Jerusalem artichokes in Illinois, Minnesota, Oregon, and Wyoming and near Washington, D. C.*

Place and year	Date of planting—				
	A	*B*	*C*	*D*	*E*
Illinois:					
1931	.....	Apr. 15	Apr. 30	May 20	June 8
1932	.....	Apr. 14	Apr. 29	May 14	
Minnesota:					
1931	.....	Apr. 29	May 6	...do.....	May 27
1932	.....	.....	May 2	...do.....	May 31
1933	.....	.....	...do.....	May 29	
Oregon:					
1932	.....	Apr. 15	May 6	.....	
1933	.....	Apr. 17	...do.....	.....	
Washington, D. C.:					
1931	.....	Apr. 15	May 8	.....	
1932	Apr. 5	...do.....	Apr. 30	May 16	June 1
1933	Mar. 30	Apr. 13	Apr. 28	May 13	May 26
Wyoming:					
1933	.....	.....	May 16	.....	May 31

RESULTS

EFFECT OF TIME OF PLANTING ON YIELD

On account of unavoidable irregularities in number and dates of plantings at the several locations and in the different years, it is possible to combine results of but few tests involving more than two planting dates. A large number of tabulations have been made so as to include as many tests as possible in observing the yield differences accompanying differences in planting time. In many tests unequal frequencies were involved, thus limiting the number of sources of variance that can be evaluated when the tabulated data are analyzed.

The most extensive data were obtained in the Washington, D. C., tests and these are presented in tables 18 and 19. It will be noted that although there is high significance for variance due to time of planting in the experiment as a whole, there is no significant difference in yield between any two of the first three plantings. (Maximum observed mean difference for all tests=0.22 pound; calculated required=0.41 pound.) The third and fourth plantings resulted in very marked successively lower yields, each being quite significantly different from all the others.

TABLE 18.—*Effect of date of planting on yield per plant of Jerusalem artichokes grown near Washington, D. C.*

[Triplicate plots]

Year and variety	Yield per plant from planting [1]—				
	A	*B*	*C*	*D*	*E*
1932	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Blanc Ameliore	7.00	6.09	5.51	4.49	2.98
Chicago	6.22	7.47	7.74	5.73	3.83
Waterer	5.01	5.07	4.16	3.41	1.70
Mean	6.08	6.41	5.80	4.55	2.86
1933					
Blanc Ameliore	2.65	2.77	2.60	1.98	1.31
Chicago	2.03	1.53	1.89	1.98	1.37
Waterer	1.70	1.43	1.68	1.40	1.05
Mean	2.13	1.91	2.09	1.70	1.24
2-year mean	4.10	4.16	3.94	3.17	2.05

[1] Planting *A* was made approximately on Apr. 1; successive plantings were made at approximately 2-week intervals.

TABLE 19.—*Analysis of variance of data for table 18*

Source of variation	Degrees of freedom	Mean square
Total	80	4.581
Between dates of planting	4	[1] 14.469
Between years	1	[1] 246.115
Between varieties	2	[1] 15.348
Dates of planting × years	4	[1] 5.820
Dates of planting × varieties	8	.663
Varieties × years	2	[1] 7.911
Error (remainder)	68	.424

[1] Exceeds 1-percent point.

Comparisons of the values in table 19 will show highly significant variances due to season (years), varieties, and interactions involving season, when these are referred to residual error. The variance due to time of planting is not significantly different from that due to interaction between planting date and year. (Observed $F=2.47$; 5-percent point=6.39.) Thus, although, in general, delay in planting reduces yields as indicated, this response varies from year to year, depending upon conditions. A 2-week delay in planting in some instances may result in no loss but even in an increase if the earlier planting should happen to have been made when soil conditions were temporarily bad or the temperature unusually adverse.

In the Oregon tests including three varieties, two plantings were made each season. The results, together with data for comparable plantings in Illinois and Minnesota and near Washington, D. C., are shown in tables 20 and 21. The two plantings at Oregon were approximately 3 weeks apart each season, which represents a longer interval than between the *B* and *C* plantings in any other instance. However, the interval is too short to be rated as *B* to *D*. The classification is admittedly rough, and this must be borne in mind when noting the very severe reduction in yield that resulted from the later planting. The results are doubtless exaggerated as compared with other *B* and *C* plantings.

TABLE 20.—*Effect of time of planting on yield per hill of Jerusalem artichokes grown in Illinois, Minnesota, and Oregon and near Washington, D. C.*

[Duplicate plots]

Place	Variety	Year	Yield per hill from planting [1]—	
			B	*C*
			Pounds	*Pounds*
Oregon	Blanc Ameliore	1932	14.03	7.50
	Chicago	1932	11.29	4.90
	Waterer	1932	11.89	5.34
	Blanc Ameliore	1933	13.64	11.00
	Chicago	1933	9.35	5.65
	Waterer	1933	8.32	6.21
	Mean		11.42	6.77
Washington, D. C.	Blanc Ameliore	1932	7.05	5.50
	Chicago	1932	7.60	8.13
	Waterer	1932	5.09	4.17
	Blanc Ameliore	1933	2.35	2.44
	Chicago	1933	1.17	1.69
	Waterer	1933	1.13	1.44
	Mean		4.07	3.89
	Mean (12 tests)		7.75	5.33
Illinois	Blanc Ameliore	1931	3.65	2.83
	Mann	1931	3.90	4.25
	Doelle	1931	3.83	3.15
	Blanc Ameliore	1932	2.70	1.03
Minnesota	do	1932	8.72	6.94
Washington, D. C.	do	1931	2.47	1.46
Mean (18 tests)			6.57	4.71

[1] See table 17 for actual dates.

TABLE 21.—*Analysis of variance of data for table 20*

Source of variation	Illinois		Oregon and 2 years near Washington, D. C.		Entire table	
	df [1]	*V* [1]	*df*	*V*	*df*	*V*
Total	15	6.622	47	14.203	71	13.046
Between dates of planting	1	[3] 1.010	1	[4] 72.006	1	[4] 62.720
Between tests	3	[4] 2.036	11	[4] 38.820	17	[4] 43.866
Dates of planting × tests	3	.330	11	[4] 7.906	17	[4] 9.204
Error (remainder)	8	.154	24	.457	30	1.116

Source of variation	Oregon		Oregon and 2 years near Washington, D. C.	
	df	*V*	*df*	*V*
Total	23	10.381	47	14.203
Between dates of planting	1	[4] 129.875	1	[4] 72.000
Between years	1	.103	1	[4] 66.454
Between places			1	[4] 287.492
Between varieties	2	[4] 30.109	2	[4] 28.060
Dates of planting × places			1	[4] 58.348
Dates of planting × years	1	[4] 20.258	1	[4] 3.200
Dates of planting × varieties	(2)	(.136)	(2)	(.304)
Places × years			1	[4] 35.990
Varieties × years	2	[4] 4.437	(2)	(.886)
Error (remainder)	16	.467	39	2.262

[1] Degrees of freedom.
[2] Mean square (variance).
[3] Between 5-percent and 1-percent points.
[4] Exceeds 1-percent point.

For Oregon, alone and also together with Washington, table 21 shows a high interaction between planting date and year, as observed for Washington alone in tables 18 and 19. Although the significance of decrease in yield accompanying later planting is very high over a period of years, these studies show that perfectly consistent results are not to be expected every year, since variance due to planting date is not significantly greater than that of planting dates × years. (For Oregon, observed F=6.4; 5-percent point=161.4. For Oregon and Washington, D. C., observed F=21.8; 5-percent point=161.4.) Despite the marked differences in yields of the three varieties that can be compared in the 1932 and 1933 crops in Oregon and near Washington, the varietal response to time of planting is very consistent. In both cases the interactions of these two factors were quite insignificant when referred to residual error. (Observed F=1.0 or less than 1.0; 5-percent point=3.0 or more.)

Considering the entire 18 tests shown in tables 20 and 21, the differences in yield due to planting date are very highly significant (required difference=0.50 pound). The interaction between dates of planting and tests is also highly significant. Despite the very great odds that delay in planting gives different results in different tests, the variance due to time of planting in all locations combined is greater than that for the interaction just mentioned. (Observed F=6.74; 5-percent point=4.45.) It thus appears safe to predict an appreciable reduction in yield from such a 2-week delay in most places over a period of a few or several years.

It is also of interest to note the response to further delayed planting in several locations. Tables 22 and 23 present yield data for plantings made at times *C*, *D*, and *E* for 2 years in Minnesota and 2 years near Washington. The means for the 10 tests show, as in the previous tables, a consistent decrease in yield as planting is delayed. As in the other tables, analyzed variances due to date of planting, to test, and to interaction between these two, are all highly significant when referred to residual error. Likewise, variance due to date of planting is higher than interaction between date of planting and test (observed F=15.5; 1-percent point=6.01), permitting generalization on the basis of these results.

TABLE 22.—*Effect of time of planting on yield per hill of Jerusalem artichokes grown in Minnesota and near Washington, D. C.*

[Triplicate plots]

Place and variety	Year	Yield per hill from planting—		
		C	*D*	*E*
		Pounds	*Pounds*	*Pounds*
Minnesota:				
Blanc Amelioré	1931	7.50	6.58	5.42
Do	1932	3.64	3.28	1.20
Chicago	1932	1.62	1.79	1.61
Waterer	1932	1.46	.80	1.12
Washington, D. C.:				
Blanc Amelioré	1932	5.51	4.50	2.98
Chicago	1932	7.74	5.73	3.83
Waterer	1932	4.12	3.41	1.70
Blanc Amelioré	1933	2.69	1.99	1.31
Chicago	1933	1.89	1.99	1.37
Waterer	1933	1.68	1.40	1.05
Mean		3.79	3.15	2.17

TABLE 23.—*Analysis of variance of data for table 22*

Source of variation	Degrees of freedom	Mean square
Total	80	4,110
Between dates of planting	2	[1] 20,071
Between tests	9	[1] 32,255
Between replications	2	[1] 2,373
Dates of planting × tests	18	[1] 1,203
Error (remainder)	58	.140

[1] Exceeds 1-percent point.

Although details are omitted here, it should be stated that additional tables have been constructed and summarized in table 24, bringing together all data that can be properly combined for a total of 9 tests of *B*, *C*, and *D* plantings in Illinois, Minnesota, and near Washington, D. C.; 13 tests involving only *C* and *D* planting dates in those same locations, and 13 tests of *C* and *E* planting dates for Minnesota, near Washington, and Wyoming. Twelve of these last-mentioned 13 tests involved 4 groups, each consisting of the same 3 varieties, and occurring once in Minnesota, once in Wyoming and twice near Washington. This part of the *C* and *E* tests, indicated as *Y* in table 24, permitted a determination of the variance due to variety. In every set of comparisons (table 24) successive delays in planting resulted in successively lower yields. In every case the variance due to planting was significant when referred to either the residual error or to the interaction between planting dates and tests (table 25).

TABLE 24.—*Summary of four unpublished tables showing effect of time of planting on yield per hill of Jerusalem artichokes grown in four locations*

[Plots in duplicate or triplicate]

Table	Location of combined tests	Total tests	Yield per hill from planting—			
			B	*C*	*D*	*E*
		Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*
W	Illinois, Minnesota, and Washington, D. C.	9	4.43	4.07	3.11	----------
X	Minnesota and Washington, D. C.	13	----------	3.42	2.85	----------
Y	Minnesota, Wyoming, and Washington, D. C.	12	----------	2.90	----------	1.50
Z	....do	13	----------	3.31	----------	1.81

TABLE 25.—*Analysis of variance of data for tables summarized in table 24*

Source of variation	Table *W*		Table *X*	
	df	*V*	*df*	*V*
Total	53	6.173	51	4.144
Between dates of planting	2	[1] 8.430	1	[1] 4.212
Between tests	8	[1] 31.912	12	[1] 16.078
Dates of planting × tests	16	[2] 1.071	12	.280
Replicates			1	[2] 2.844
Error (remainder)	27	.523	25	.317

TABLE 25.—*Analysis of variance of data for tables summarized in table 24*—Con.

Source of variation	Table Y		Table Z	
	df	*V*	*df*	*V*
Total	71	2.850	77	4.084
Between dates of planting	1	[1] 37.976	1	[1] 43.950
Between tests			12	[1] 20.020
Between groups of tests [3]	3	[1] 36.254		
Between varieties	2	[1] 8.146		
Dates of planting × varieties	2	.873		
Dates of planting × tests			12	[1] 1.833
Dates of planting × groups of tests	3	[2] 4.501		
Between replications			2	[1] 1.164
Error (remainder)	60	.491	50	.118

[1] Exceeds 1 percent point.
[2] Between 5-percent and 1-percent points.
[3] A group of tests consists of 3 varieties at a single location in a single season that is comparable with other similar groups of the same 3 varieties in other locations and seasons or the same location in other seasons.

Thus, although it has not been possible to set up all data relating to time of planting in a single table for analysis, consistent results are observed for the several partial summaries. With the exception of the tests near Washington, it is shown that all plantings following the earliest one actually planted yielded successively less. In general, these results hold also for Washington, D. C., but a few exceptions occurred. It is, therefore, safe to recommend the earliest practicable planting. The data also show that delays early in the planting season cause relatively less decrease in yield (and sometimes absolutely less) than a similar delay later on.

EFFECT OF TIME OF PLANTING ON SIZE OF TUBER HARVESTED

Tables 26 and 27 show that delayed planting brings about a decrease in the size of the tubers harvested. The tuber size appears to be distinctly though not highly correlated with relative yields. Mean tuber size in the Washington, D. C., plots decreased 28 percent between the *A* and *E* plantings while the yields for the same plots decreased 50 percent. In Minnesota, size decreased 49 percent between *D* and *E* plantings, and yield decreased 40 percent.

Considering the Minnesota and Washington, D. C., data either separately or in combination, the variances due to date of planting are all highly significant with reference to residual error and also to interaction between date of planting and test. The differences are obviously so great that it is unnecessary to present the *F* values. In the Oregon plots very striking differences were observed between the two plantings. The mean tuber sizes for planting dates *B* and *C* for all tests combined were 3.29 and 2.44 ounces, respectively, representing a relative decrease of 26 percent. The decrease in yield was 41 percent.

VARIETAL RESPONSE TO TIME OF PLANTING

Reference to tables 19, 21, 23, 25, and 27 will reveal no instance in which there was a significant interaction between date of planting and variety. It will be recalled that the three varieties compared throughout these studies were chosen for their marked differences in growth habit and time of maturity, or apparent cessation of activity

in the fall. Despite marked consistent differences in yield, as shown by high variance due to variety, they behaved alike in response to planting time.

TABLE 26.—*Effect of date of planting on mean weight of harvested tubers of Jerusalem artichoke in Minnesota and near Washington, D. C.*

[Triplicate plots]

Place and variety	Year	Weight of tubers from planting [1]—				
		A	*B*	*C*	*D*	*E*
		Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*
Washington, D. C.:						
Blanc Amelioré	1932	1.33	1.13	1.01	0.95	0.86
Chicago	1932	1.52	1.50	1.73	1.45	1.10
Waterer	1932	1.32	1.27	1.15	.92	.76
Mean		1.39	1.30	1.30	1.11	.91
Blanc Amelioré	1933	1.80	1.64	1.76	1.42	1.49
Chicago	1933	.91	.92	1.01	.97	.79
Waterer	1933	.69	.89	.87	.58	.47
Mean		1.13	1.08	1.15	.99	.92
2-year mean		1.26	1.19	1.22	1.05	.91
Minnesota:						
Blanc Amelioré	1932			2.22	1.40	.81
Chicago	1932			1.30	.84	.91
Waterer	1932			1.10	.83	.65
Mean				1.54	1.02	.70
Mean (9 tests)				1.33	1.04	.87

[1] Planting A was made approximately on Apr. 1; successive plantings were made at approximately 2-week intervals.

TABLE 27.—*Analysis of variance of data for table 26*

Place and source of variation	Analysis 1		Analysis 2	
	df	*V*	*df*	*V*
Washington, D. C.:				
Total	89	0.1633	89	0.1633
Between dates of planting	4	[1].3756	4	[1].3756
Between varieties	2	[1] 1.8806		
Between years	1	[1].4805		
Between tests			5	[1] 1.0914
Dates of planting × varieties	8	.0422		
Dates of planting × years	4	.0471		
Varieties × years	2	[1] 2.8580		
Dates of planting × tests			20	[1].0934
Error (remainder)	68	.0374	60	.0172
Minnesota:				
Total	26	[1].2306		
Between dates of planting	2	[1] 1.3338		
Between tests	2	[1].9224		
Dates of planting × tests	4	[1].2532		
Error (remainder)	18	.0392		
Minnesota and Washington, D. C.:				
Total	80	.1761	80	.1761
Between dates of planting	2	[1] 1.4344	2	[1] 1.4344
Between varieties	2	[1] 1.9504		
Between groups of tests	2	.0794		
Between individual tests			8	[1].9871
Dates of planting × varieties	4	.0468		
Dates of planting × tests	4	[1].1794	16	[1].1252
Varieties × tests	4	[1].9540		
Error (remainder)	62	.0389	54	.0243

[1] Exceeds 1-percent point.

The data for both Minnesota and Washington, D. C., in table 26 were analyzed by another break-down (not shown) in addition to that presented in table 27, in order to determine whether there were significant interactions of planting date and variety with reference to size of tubers harvested. A barely significant interaction (F=5-percent point) appeared in the single season's results from Minnesota, but in neither the Washington results not those of the combined locations. In all of the varieties observed thus far an appreciable decrease in size of tubers resulted from delayed planting and in all to about the same relative extent.

DEPTH OF PLANTING

METHODS

All plots to be compared with reference to depth of planting the seed piece were planted on the same date at any one location in a single year. Furrows were opened to such a depth that the seed piece would be covered to the desired depth when the furrow was closed. Special care was taken to drop the pieces at the same level in the furrow, then they were carefully covered by hand and the row leveled off. Efforts were made to change the contours of soil surface as little as possible in cultivating the plots, to avoid the addition or removal of soil from the immediate vicinity of the plants. Some difficulty in this connection was encountered where irrigation was necessary, and those results will be found rather at variance with the others.

At harvest time the tubers of five typical hills of each plot at Washington, D. C., and in Wyoming were carefully removed, one at a time, to successive depths, the number and weight being recorded for successive 2-inch depths for each plot. The number and position of stolons were also noted on these plants. The object was to determine whether planting depth influences the depth of the tubers to be harvested or the depth of origin of the stolons on which they are borne. After the removal of the tubers from the selected hills, the remainder of the plot was harvested by hand in the usual manner.

The plot sizes in the several locations were the same as those described for time of planting (p. 20). The number of plots was as follows: In Oregon and Illinois, duplicate; near Washington, triplicate; in Wyoming, quadruplicate. Certain of the plots in Wyoming were damaged, reducing the number for which complete data are available. All yields were recorded on an individual plot basis, but certain of the data on responses other than yield have been compiled from means of plots in a single test. The final mean values are not affected, but the estimated errors, of course, are higher than if calculated on an individual plot basis.

RESULTS

EFFECT OF DEPTH OF PLANTING ON YIELD

The most extensive set of data upon depth of planting was obtained in the Oregon tests. Although but a single location is involved, these data are of sufficient interest to be presented and analyzed separately from those of other tests. Tables 28 and 29 show the response of three varieties to planting at depths of 3, 4, 5, and 6 inches in 1932 and 1933. The results are not very consistent either among

the varieties or for the 2 years. Despite these fluctuations, the 2-year means for all varieties show a generally best yield from the 4-inch depth, and the difference is significant. (Observed minimum difference between means=1.27 pounds; calculated required difference=1.03 pounds.) The mean for the 6-inch depth is significantly lower than for the 5-inch and approximates a significant difference from the 3-inch depth.

TABLE 28.—*Effect of depth of planting on yield per hill of 3 varieties of Jerusalem artichoke at Corvallis, Oreg.*

[Duplicate plots]

Year and variety	Yield from planting of indicated depth			
	3 inches	4 inches	5 inches	6 inches
	Pounds	*Pounds*	*Pounds*	*Pounds*
1932				
Blanc Amelfore	12.70	18.23	13.41	13.06
Chicago	9.57	12.83	15.21	13.05
Waterer	12.94	13.40	7.73	8.04
Mean	11.73	14.82	12.12	11.88
1933				
Blanc Amelfore	12.36	13.91	12.80	12.84
Chicago	11.46	10.09	11.71	8.91
Waterer	8.77	7.78	7.62	6.05
Mean	10.86	10.59	10.73	9.27
2-year mean	11.30	12.70	11.43	10.59

TABLE 29.—*Analysis of variance of data for table 28*

Source of variation	Degrees of freedom	Mean square
Total	47	8.647
Between planting depths	3	[1] 9.421
Between years	1	[1] 62.267
Between varieties	2	[1] 80.354
Planting depths × varieties	6	[1] 11.064
Planting depths × years	3	[2] 6.057
Varieties × years	[3] (2)	(2.142)
Remainder	(30)	(1.559)
Error	32	1.596

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.
[3] Values in parentheses are combined to give the value identified as error.

Table 29 shows significant variances due to variety, year, and the interactions planting depth × variety and planting depth × year. Significant differences in yield between these three varieties will be noted throughout these studies. The variance due to planting depth is not significantly greater than either of the two interactions involving depth. Therefore, with these limited data no definite conclusions as to varietal response can be reached. In the light of observations reported later, it would seem that many of the varietal differences in response are due merely to chance. It can only be said that, in the long run, 4 inches is the best planting depth and that 6 inches is definitely too deep.

In tables not presented here were combined the results of all tests in Oregon, Wyoming, and near Washington, D. C. Since the same varieties were not planted in all places, determination of varietal response, unfortunately, is precluded. Again, as for Oregon alone, the 4-inch depth was found to be the best (8.95 pounds per hill), 3 and 5 inches nearly equal (7.91 and 8.16 pounds) and next in order, with the 6-inch depth definitely inferior to those of 3 and 5 inches (7.48 pounds). The variance due to depth was highly significant with reference to residual error (observed F=22.4; 1-percent point =4.31) but not with reference to the interaction of planting depth and test (observed F=1.68; 5-percent point=2.96). The interaction was significant with reference to residual error (observed F=13.5; 1-percent point<2.29). In this instance the factor of test involved both variety and place, so that causes of the variations in results could not be determined. The conclusions reached are the same as for Oregon alone.

When the data from triplicate plots near Washington are analyzed alone, the yields for the successive 3-, 4-, 5-, and 6-inch depths, respectively, are found to be 3.23, 3.58, 3.46, and 3.10 pounds per hill. Although the trend of the results agrees with those of the Oregon plots, the variance due to depth of planting is not significant (observed F=2.5; 5-percent point=2.92).

Since the combination of all the Oregon data with the less extensive Wyoming and Washington, D. C., data (see second paragraph above, discussing tables not presented) might produce a table top-heavy with results from Oregon, tables 30 and 31 are presented.

TABLE 30.—*Effect of depth of planting on yield per hill of Jerusalem artichokes grown in Oregon and Wyoming and near Washington, D. C.*

[Duplicate plots]

Place	Variety	Year	Yield from planting of indicated depth			
			3 inches	4 inches	5 inches	6 inches
			Pounds	*Pounds*	*Pounds*	*Pounds*
Oregon	Blanc Ameliore	1932	12.70	18.23	13.44	13.66
		1933	12.36	13.91	12.86	12.84
		1931	1.90	2.12	2.02	1.80
Washington, D. C.	do	1932	5.58	6.94	6.44	5.40
		1933	2.18	2.26	2.07	1.88
Wyoming	Waterer	1933	1.75	1.96	2.51	2.32
Mean			6.08	7.57	6.56	6.32

TABLE 31.—*Analysis of variance of data for table 30*

Source of variation	Degrees of freedom	Mean square
Total	47	29.279
Between planting depths	3	[1] 5.179
Between tests	5	[1] 264.696
Planting depths × tests	15	[1] 1.938
Error (remainder)	24	.334

[1] Exceed 1-percent point.

The data for 2 years in Oregon and for 3 years near Washington, D. C., all relate to the Blanc Ameliore variety. The Wyoming figures were obtained upon Waterer. Removal of part of the dominating effect of the high Oregon yields results in more striking relative differences in yield at the different planting depths.

As in other tables referred to, table 30 shows that the 4-inch depth gave distinctly the highest yield. The significance of variance due to depth (table 31) is very high, as is also that due to interaction of planting depth × test. Again, variance due to planting depth is not significantly greater than that of planting depth × test. (Observed F=2.67; 5-percent point=3.29.) For comparing the mean yields of the six tests, a difference of 0.47 pound is calculated to be significant.

In a further effort to analyze the data in a way that would permit drawing definite conclusions as to the specific applicability of the results obtained in general, the values for a single variety, Blanc Ameliore, were analyzed for 2 years each in Oregon and near Washington, D. C. No additional information was gained.

In the Illinois studies of depth of planting, tubers were planted at 3, 5, and 7 inches in 1931 and 3½, 5½, and 7 inches in 1932. In analyzing the data, the 3- and 3½-inch depths were tabulated in the same column, and the 5- and 5½-inch together. In 1932 the yields from the three depths were almost identical, being 2.71, 2.70, and 2.73 pounds per hill, respectively. In 1931 they were less close together, yielding 3.05, 3.15, and 2.75 pounds per hill, respectively. Since only a single variety was used, involving a total of but 12 plots, significance could not be expected for such small differences in yield. Variance due to depth was 0.036, and when referred to a residual error of 0.031 was obviously insignificant. Nevertheless, planting at a depth of less than 4 inches or more than 6 inches tended to be inferior to that at the moderate depth of 5 to 5½ inches.

One year's results in Wyoming indicated the desirability of rather deep planting (5 inches), but this was exceptional and based on a single set of quadruplicate plots. It is possible that planting at a depth less than 5 inches under semiarid, high-altitude conditions resulted in insufficient moisture in proximity to the seed pieces, which are easily desiccated.

EFFECT OF DEPTH OF PLANTING ON DEPTH OF STOLON ORIGIN

Regardless of the depth of planting of the seed piece, practically no stolons were found to emerge from the stems of the plants more than 6 inches below the soil surface. This finding is only what would be expected, since no seed pieces were purposely planted deeper than 6 inches.

Under Wyoming conditions depth of planting seemed to be without effect upon the position of origin of stolons. The figures for Wyoming in table 32 represent means of 10 records taken for each planting depth listed. Table 33 shows that for Wyoming the variance due to planting depth is practically identical with that due to residual error. There was much more variation among replications than among treatments. These results are discussed later.

TABLE 32.—*Effect of depth of planting on depth of stolons at point of origin upon the main stem of Jerusalem artichokes grown in Wyoming and near Washington, D. C.*

Place	Year	Stolons [1] arising at depth of 0 to 4 inches from seed pieces planted at indicated depth			
		3 inches	4 inches	5 inches	6 inches
		Percent	*Percent*	*Percent*	*Percent*
Washington, D. C.[2]	1931	80.0	58.0	50.2	43.7
	1933	100.0	74.0	62.6	57.9
	Mean	90.4	66.0	56.4	50.8
		Inches [3]	*Inches* [3]	*Inches* [3]	*Inches* [3]
Wyoming	1933	3.71	3.90	3.59	3.76

[1] Expressed as percentage of total number of stolons on plant.
[2] 5 plants per plot; triplicate plots.
[3] Mean depth of stolons below soil surface (10 records per treatment).

TABLE 33.—*Analysis of variance of data for table 32*

Place and source of variation	Degrees of freedom	Mean square
Washington, D. C.:		
Total	23	397,363
Between tests	1	[1] 1,427,584
Between planting depths	3	[1] 1,840,315
Tests × depths of planting	3	12,554
Error (remainder)	16	115,307
Wyoming:		
Total	39	.281
Between planting depths	3	.238
Between replications	3	[2] .805
Error (remainder)	33	.237

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.

In 1932 a windstorm so damaged the plots near Washington, D. C., that attempts to study stolon and tuber distribution were useless. After heavy rain, the full-grown plants were literally "tipped over" soon before harvest, lifting large clumps of tubers from the soil on the windward side of the plants. Tubers and stolons were so greatly disturbed that their normal positions could not be determined. The crop had to be promptly harvested or soil shoveled over the exposed tubers to prevent damage by rodents and by desiccation.

Some very interesting data were obtained, however, in 1931 and 1933. Since over 98 percent of the stolons arose within the upper 6 inches of soil, the differences between 100 and the values in the first part of table 32 represent fairly accurately the percentage of the stolons arising in the 4-inch to 6-inch soil zone.

The stolons arising at depths greater than 6 inches were on stems apparently arising from pieces accidentally placed deeper than 6 inches or on stems that came from the lower side of the seed piece and that grew downward slightly before curving to a straight upward position. Excessive covering of the row may have occurred in a few

cases. It will be noted first that the stolons were deeper in 1931 than in 1933. The reason for this is not clear since the plots were on light, sandy loam soils both years; if any difference existed, the soil was lighter in 1933 than in 1931. The loss of the 1932 material was very unfortunate, since those plots were on much heavier, silt loam soil and would have afforded a valuable comparison.

Table 32 shows that as the planting depth increased the depth of stolon origin tended to increase in the Washington, D. C., plots. The 2-year means indicate 90 percent of the stolons in the first 4 inches for the 3-inch planting depth, decreasing consistently to 51 percent in the 6-inch planting depth. The variance due to depth of planting (table 33) is highly significant, as is also that due to test. However, the interaction of depth × test is practically negligible, indicating a very high degree of dependability of the results under the conditions of this study.

EFFECT OF DEPTH OF PLANTING ON SIZE OF TUBERS HARVESTED

Table 34 shows the mean sizes of tubers harvested for each test. Although it appears that the tubers from the 4-inch planting depth are considerably larger than those from the other treatments (see mean for 10 tests), the analysis of variance (table 35) shows that differences between planting depths are not significant when referred to residual error. Despite the lack of significance of differences, the tendency for tuber size to vary with tuber yield is of interest.

TABLE 34.—*Effect of depth of planting on mean weight of harvested tubers of Jerusalem artichokes grown in Oregon and Wyoming and near Washington, D. C.*

Place and test	Weight of tubers from indicated depth of planting			
	3 inches	4 inches	5 inches	6 inches
	Ounces	*Ounces*	*Ounces*	*Ounces*
Total of 10 tests in 3 places [1]	1.73	2.36	2.09	2.17
3 tests at Washington, D. C. [2]	1.01	1.10	1.07	1.04

[1] 3 varieties, 2 years in Oregon; 1 variety, 3 years near Washington, D. C.; 1 variety, 1 year in Wyoming. No replications.
[2] 1 variety, 3 years, triplicate plots.

TABLE 35. *Analysis of variance of data for table 34*

Place and source of variation	Degrees of freedom	Mean square	Place and source of variation	Degrees of freedom	Mean square
Oregon, Wyoming, and Washington, D. C. [1]			Washington, D. C.: [3]		
Total	39	1.1264	Total	35	0.0329
Between depths	3	.6827	Between depths	3	.0136
Between tests	9	[2] 3.8815	Between tests (years)	2	[2] .3569
Error (remainder)	27	.2573	Between replications	2	.0018
			Replications × depths	6	.0115
			Error (remainder)	22	.0077

[1] 3 varieties, 2 years in Oregon; 1 variety, 3 years near Washington, D. C.; 1 variety, 1 year in Wyoming. No replications.
[2] Exceeds 1-percent point.
[3] 1 variety, 3 years, triplicate plots.

EFFECT OF DEPTH OF PLANTING ON DISTRIBUTION OF TUBERS

Only rather fragmentary data were obtained relative to the effect of depth of planting upon the distribution of tubers in the soil at harvest time. Two years' data were obtained near Washington, D. C., and 1 year's in Wyoming. Although not extensive, they are of considerable interest and appear in tables 36 and 37. Results are presented both on the basis of weight of tubers and number of tubers.

It may be noted first that the percentage of the total number found in a single soil zone is essentially the same as the percentage of the total weight found in the same zone, indicating no great difference in size of tubers from the various zones. The significance of this observation is hardly clear, since it is based on such limited data, but it would seem to indicate that stolon and tuber development are initiated at the various soil depths at about the same time and that tuber enlargement proceeds at an approximately similar rate regardless of tuber depth.

In the Washington, D. C., tests in both years there was a definite tendency for increasing depth of planting to increase the depth of the tubers harvested. The percentage of total found in the 4- to 6-inch layer of soil increased in 1933 from 1 percent in the 3-inch planting depth to over 38 percent in the 6-inch plots. In 1931, on somewhat heavier soil, about 13.5 percent of the tubers were found in the 4- to 6-inch level of the 3-inch plots and 34 percent in the corresponding level of the 6-inch plots. Table 37 shows that the variance due to planting depth is very highly significant.

TABLE 36.—*Effect of depth of planting of Jerusalem artichokes on distribution of tubers harvested, expressed as percentage of total weight or number of tubers harvested that were taken from various soil depths*

BASED ON WEIGHT OF TUBERS HARVESTED

Place	Year	Depth of tubers harvested (inches)	Tubers from seed pieces planted at indicated depth			
			3 inches	4 inches	5 inches	6 inches
			Percent	*Percent*	*Percent*	*Percent*
Washington, D. C.[1]	1933	0 to 4	98.1	91.5	70.4	60.3
		4 to 6	1.9	8.5	29.6	39.7
		Below 6	0	0	0	0
Wyoming [2]	1933	0 to 4	24.6	34.3	31.9	53.8
		4 to 6	57.7	36.1	38.8	38.7
		Below 6	17.7	29.6	39.3	7.5

BASED ON NUMBER OF TUBERS HARVESTED

Washington, D. C.[1]	1931	0 to 4	83.6	67.3	72.2	59.4
	1933	do	99.0	91.7	70.8	61.6
	Mean		91.3	79.5	71.5	60.5
Do.[1]	1931	4 to 6	13.4	26.9	27.8	33.9
	1933	do	1.0	8.3	29.2	38.4
	Mean		7.2	17.6	28.5	36.2
Wyoming [1]	1933	0 to 4	31.2	37.5	32.2	72.0
	1933	4 to 6	50.2	36.9	24.6	21.2
	1933	Below 6	18.6	25.6	43.2	6.7

[1] Quadruplicate plots.
[2] Duplicate plots.

TABLE 37.—*Analysis of variance of data for table 36*

BASED ON WEIGHT OF TUBERS HARVESTED

Source of variation	Washington, D. C., tubers from 0–4-inch depth		Wyoming, tubers from indicated depth					
			0–4 inches		4–6 inches		Below 6 inches	
	df	*V*	*df*	*V*	*df*	*V*	*df*	*V*
Total	15	300.673	7	311.220	7	221.189	7	447.050
Between planting depths	3	[1] 1,255.072	3	310.040	3	302.597	3	383.275
Between replications	[2] (3)	(75.072)	(1)	(125.000)	(1)	(13.005)	(1)	(58.681)
Error (remainder)	12	69.348	4	311.430	4	160.132	4	494.881

BASED ON NUMBER OF TUBERS HARVESTED

Source of variation	Washington, D. C., tubers from indicated depth				Source of variation	Wyoming, tubers from indicated depth					
	0–4 inches		4–6 inches			0–4 inches		4–6 inches		Below 6 inches	
	df	*V*	*df*	*V*		*df*	*V*	*df*	*V*	*df*	*V*
Total	31	255.045	31	197.517	Total	7	512.285	7	203.430	7	499.611
Between planting depths	3	[1] 1,349.493	3	[1] 1,283.074	Between replications	(1)	(47.045)	(1)	(68.445)	(1)	(1.805)
Between tests	1	[1] 823.765	1	[3] 315.005	Between planting depths	3	751.285	3	347.430	3	466.302
Depths × tests	3	[3] 284.345	3	241.621	Error (remainder)	4	332.805	4	95.440	4	524.592
Error (remainder)	24	85.389	24	62.007							

[1] Exceeds 1-percent point.
[2] Values in parentheses are included in the values identified as error.
[3] Between 5-percent and 1-percent points.

Unfavorable conditions interfered somewhat with these tests in Wyoming. The values in the table represent means of duplicate plots but are of doubtful significance on account of great discrepancies between duplicates. The reason for these discrepancies has not been determined. The behavior of the 6-inch depth of planting is not at all in conformity with the trend of the other Wyoming plots or with the Washington, D. C., results. Among the 3-, 4-, and 5-inch plots, however, there appears to be a tendency for deeper planting to result in deeper tuber development. The analysis of variance (table 37) shows none of these apparent trends to be significant.

With reference to the lack of influence of depth of planting on depth of stolon formation and of tubers in the Wyoming tests, the following possible explanation is suggested. Under irrigation, it may be that there is a comparatively narrow soil zone within which moisture conditions are conducive to stolon and tuber development. Application of water by the furrow method produces a temporary high water table in the rows, beneath the plants. Such repeated applications may prevent origination of stolons at depths as low as those found in certain nonirrigated places where the soil-moisture conditions are subject to less drastic change.

The data are too meager to permit drawing very definite conclusions, but they indicate that planting as deep as 5 or 6 inches will materially increase the labor of harvesting by inducing deep tuber development.

PLANTING DISTANCES

METHODS

Plots for the studies of the effect of planting distance on yield and development of the Jerusalem artichoke, for a single location and season, were planted all on the same day. Size of seed piece was as nearly the same as possible for all plots in a single test, but differed in different locations. In the Oregon tests 2- to 3-ounce seed pieces were planted at a depth of about 5 inches; in the other tests, 1- to 2-ounce seed pieces were planted at a depth of about 4 inches. Plots for studies of the effect of distance between hills in the row were planted in rows 4 feet apart in Illinois, Minnesota, and Wyoming. In Oregon and near Washington, D. C., the rows were 5 feet apart. In the studies of the effect of distance between rows, the hills were 2 feet apart in the row except in Oregon, where they were 4 feet apart on account of the enormous top growth normally made there. Each plot was harvested by hand the hills counted, and the tubers counted and weighed.

Calculations of all yields were made on a yield-per-acre basis.

RESULTS

EFFECT OF DISTANCE BETWEEN HILLS ON YIELD PER ACRE

As in the other studies reported, variations in planting plans at the various locations have necessitated the examination of the results by an overlapping series of tables instead of by a single table combining all data. Despite the disadvantages of such a procedure, some conclusions can be drawn from the data herein presented.

Table 38 shows the yields obtained by planting at 12, 24, 30, and 36 inches between hills, in Wyoming and near Washington, D. C. For both locations, alone and in combination, the variances due to distances between hills are all so much greater than those representing residual error that mere inspection indicates their significance (table 39). There are also significant interactions between tests and planting distances, indicating distinctly variable responses among the several tests. Although all these interactions are quite significant, the variances due to planting distance are all still significantly greater than the interactions. (For Washington, D. C.: Observed $F=16.2$; 1-percent point=4.87. For Wyoming: Observed $F=7.6$; 5-percent point=4.76. For combined data: Observed $F=3.8$; 5-percent point=2.92.) Thus, despite local and seasonal variations in response in these two locations, it can be concluded safely that yields per acre are materially influenced by the distance between hills in the row. Table 38 shows no real difference between 24- and 30-inch spacings near Washington, D. C., but the differences for Wyoming and for all other spacings in both places are relatively great. As a basis for determining the significance of differences in comparing individual means in the table, the calculated differences required for significance are: For Washington, D. C., 0.84 pound; for Wyoming, 1.23 pounds; and for the combined results, 0.53 pound.

TABLE 38.—*Effect of distance between hills on yield per acre of Jerusalem artichokes grown near Washington, D. C., and in Wyoming*

[Quadruplicate plots]

TESTS NEAR WASHINGTON, D. C.

Year and variety	Yield per acre from plantings at indicated distance between hills			
	12 inches	24 inches	30 inches	36 inches
1931	*Tons*	*Tons*	*Tons*	*Tons*
Blanc Amellore	6.21	3.20	4.00	3.14
1932				
Blanc Amellore	23.21	18.19	18.22	16.24
Chicago	21.91	17.96	16.98	15.49
Waterer	21.24	14.27	14.88	13.58
1933				
Blanc Amellore	8.03	6.64	6.19	5.83
Chicago	7.73	6.74	6.01	5.73
Waterer	6.65	5.13	4.89	4.71
Seedling 30	10.05	8.55	8.61	6.78
Mean	13.30	10.08	9.98	8.91

TESTS IN WYOMING

1933				
Blanc Amellore	12.22	9.62	5.73	4.52
Chicago	8.41	6.73	5.65	4.87
Waterer	6.60	7.75	4.65	4.31
Mean	9.09	8.04	5.35	4.67
Mean for 2 locations	12.30	9.52	8.72	7.77

TABLE 39.—*Analysis of variance of data for table 38*

Place and source of variation	Degrees of freedom	Mean square
Washington, D. C		
Total	127	42.149
Between distances between hills	3	[1] 126.167
Between replications	3	[1] 30.707
Between tests	7	[1] 622.179
Tests × distances between hills	21	[1] 7.775
Tests × replications	21	[1] 8.241
Error (remainder)	72	2.647
Wyoming:		
Total	47	7.003
Between distances between hills	3	[1] 53.687
Between tests (varieties)	2	[1] 22.142
Tests × distances between hills	6	[1] 7.055
Error (remainder)	36	2.263
Washington, D. C., and Wyoming:		
Total	175	35.409
Between distances between hills	3	[1] 107.142
Between replications	3	[1] 35.874
Between tests	10	[1] 356.939
Tests × distances between hills	30	[1] 43.033
Error (remainder)	129	3.101
Varietal differences:		
Total	143	38.518
Between distances between hills	3	[1] 150.368
Between varieties	2	[1] 60.850
Between tests	2	[1] 1,708.723
Between replications	3	[1] 14.641
Varieties × distances between hills	6	1.515
Varieties × tests	4	[1] 7.512
Tests × distances between hills	6	[1] 27.460
Tests × varieties × distances	12	[1] 73.384
Error (remainder)	105	1.824

[1] Exceeds 1-percent point.

The last part of table 39 shows the analysis of variance of the three varieties that occurred uniformly near Washington, D. C., in 1932 and 1933 and in Wyoming in 1933. It is of particular interest because it shows that despite enormous variances due to other factors and interactions there was no significant interaction between varieties and distances. Since no significant reaction appears between planting distance and such diverse varieties as Blanc Ameliore, Chicago, and Waterer, under the conditions indicated for these tests, it seems to be perfectly reasonable to group together for analysis individual tests involving disproportionate varietal frequencies. Obviously, such a procedure precludes identification of the effect of the varietal component of the factor for tests, but that is relatively unimportant in the present studies. Lack of uniformity of plot procedure, insofar as the variety planted is concerned, should not detract from the validity of the results.

Variance due to replication is presented in table 39, since this was one of the rare instances in these studies where it was significantly greater than residual error. Most of this effect was due to a steep and consistent gradient in the field where the Washington, D. C., plots were located 1 year.

Table 40 presents data for 12-, 18-, 24-, and 30-inch spacings in Illinois and Minnesota. The trends of the yields are similar to those presented in table 38, but the differences are less striking. In these particular tests the number of plots was rather small and the differences great between some of the tests. Under such conditions only low odds of significance and somewhat questionable conclusions can be expected. Nevertheless, variance due to planting distance (table 41) is significant with reference to residual error, although it is not significantly greater than interaction between planting distances and tests. (Observed $F=1.63$; 5-percent point=3.86.) The calculated required difference for significance between means is 1.35 tons. The 30-inch spacing thus yielded definitely less than the 12- or 18-inch; and the 24-inch less than the 12-inch. More comprehensive data on the 12-, 18-, and 24-inch spacings in Minnesota cast doubt on the validity of the particular Minnesota results shown in table 40.

TABLE 40.—*Effect of distance between hills on yield per acre of Jerusalem artichokes grown in Illinois and Minnesota*

[Quadruplicate plots]

Place and year	Yield per acre from plantings at indicated distance between hills			
	12 inches	18 inches	24 inches	30 inches
Illinois	*Tons*	*Tons*	*Tons*	*Tons*
1931	11.90	11.23	11.20	9.90
1932	12.97	16.38	14.16	12.61
Mean	12.44	13.81	12.72	11.26
Minnesota				
1932	21.70	18.88	16.40	18.67
1933	8.21	5.57	7.04	4.58
Mean	14.96	12.23	11.70	11.63
Mean of 2 locations	13.69	13.02	12.24	11.44

TABLE 41.—*Analysis of variance of data for table 40*

Source of variation	Degrees of freedom	Mean square
Total	31	24.596
Between distances between hills	3	[1] 7.553
Between tests	3	[2] 222.978
Tests × distances between hills	9	[1] 4.627
Error (remainder)	16	1.827

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.

Table 42 presents the results of six tests in Minnesota involving a number of varieties over a period of 3 years. It will be seen that no important difference in yield existed between the 12- and 24-inch distances, although the 18-inch plot appears much lower than either. The variance due to planting distance for the table as a whole is not significant when referred to residual error and is even smaller than the interaction of tests and planting distances (table 43). It thus appears that within a planting-distance range of 12 to 24 inches, under Minnesota and Illinois conditions, yields per acre are not greatly affected; certainly they have not shown any consistent behavior in these studies.

TABLE 42.—*Effect of distance between hills on yield per acre of Jerusalem artichokes grown in Minnesota*

[Quadruplicate plots]

Year and variety	Yield per acre from plantings at indicated distance between hills		
	12 inches	18 inches	24 inches
	Tons	*Tons*	*Tons*
1931			
Mammoth French White	19.10	17.43	16.80
Do.[1]	19.16	10.43	15.11
1932			
Mammoth French White	6.24	6.09	11.09
Writerer	2.98	2.21	4.19
1933			
Chicago	9.36	8.79	8.70
No. 29723-14	7.48	6.16	6.52
Mean	10.72	9.32	10.41

[1] Planted in rows 3 feet apart; other tests planted in rows 4 feet apart.

TABLE 43.—*Analysis of variance of data for table 42*

Source of variation	Degrees of freedom	Mean square
Total	71	33.550
Between distances between hills	2	9.347
Between tests	5	[1] 412.712
Tests × distances between hills	10	[1] 10.639
Error (remainder)	54	3.632

[1] Exceeds 1-percent point.

If the data presented for the 12-, 24-, and 30-inch spacings (tables 38, 40, and 42) are placed in a single table for analysis as a whole, the results shown in table 44 are obtained. In the interest of economy of space the tabulation of the yields is not repeated. In 18 tests involving 7 different varieties grown in 3 different years on duplicate plots, the mean yields were 10.97, 9.59, and 8.19 tons per acre from plots planted in rows 12, 24, and 30 inches apart, respectively. Despite the tendency toward an insignificant or variable effect of planting distance on yield in Minnesota and Illinois, the consistent response in other locations outweighs it, resulting in significant differences between the means shown. The variance due to distance between hills is obviously highly significant with reference to residual error and to interaction between tests and distances between hills. This interaction also is significant with reference to residual error. Thus, in general, within the range of conditions represented, 12-inch spacing gives slightly higher yields than 24-inch and both 12- and 24-inch spacings yield substantially more than 30-inch spacing.

TABLE 44.—*Analysis of variance of data relating to effect of distance between hills on yield of tubers per acre of Jerusalem artichokes grown in Illinois, Minnesota, and Wyoming and near Washington, D. C.*[1]

Source of variation	Degrees of freedom	Mean square
Total	107	32.071
Between distances between hills	2	[2] 60.848
Between tests	17	[2] 182.878
Tests × distances between hills	34	[2] 4.274
Error (remainder)	54	1.887

[1] 18 tests involving 7 different varieties grown in 3 different years. Duplicate plots.
[2] Exceeds 1-percent point.

On account of the enormous top growth normally made under western Oregon conditions, the Jerusalem artichoke is usually planted at much wider spacing in Oregon than in most other places. In these studies, therefore, spacings in the row were established at 24, 30, 36, and 48 inches. The 48-inch spacing is common practice where the Oregon tests were made. The results with three varieties for 2 years are shown in tables 45 and 46. It will be noted that planting closer than 4 feet produced no significant difference in yield. The variance due to distance between hills was very low and not significantly greater than the residual error by either of the two methods of breaking down the data. The chief source of variation was in varieties grown. Interactions between years and spacing, between varieties and spacing, and between varieties and years were all significant with reference to residual error, and of greater (though not significantly greater) magnitude than the variance due to spacing. Apparently, such a large plant development is attained at 4-foot spacing under these conditions, which are so favorable for the plant that closer spacing only crowds the plants, permitting no greater total development per unit of area.

TABLE 45.—*Effect of distance between hills on yield per acre of Jerusalem artichokes grown in Oregon*

(Duplicate plots)

Variety and year	Yield per acre from plantings at indicated distance between hills			
	24 inches	30 inches	36 inches	48 inches
	Tons	*Tons*	*Tons*	*Tons*
Blanc Ameliore:				
1932	12.07	10.25	10.57	14.77
1933	14.09	16.09	15.45	16.35
Mean	13.08	13.67	13.01	15.56
Chicago:				
1932	14.50	12.24	13.08	12.21
1933	12.05	12.02	9.43	11.20
Mean	13.27	12.13	11.56	11.71
Waterer:				
1932	12.05	10.14	13.22	11.67
1933	10.30	8.78	8.86	8.75
Mean	11.18	9.46	11.04	10.21
Mean for 6 tests	12.51	11.72	12.87	12.49

TABLE 46.—*Analysis of variance of data for table 45*

Analysis 1			Analysis 2		
Source of variation	Degrees of freedom	Mean square	Source of variation	Degrees of freedom	Mean square
Total	47	6.545	Total	47	6.545
Between distances between hills	3	[1] 2.815	Between distances between hills	3	2.815
Between years	1	[2] 7.046	Between tests	5	[2] 39.703
Between varieties	2	[2] 67.472	Tests × distances between hills	15	[2] 5.176
Varieties × distances between hills	6	[1] 5.258	Error (remainder)	24	.958
Varieties × years	2	[2] 28.201			
Years × distances between hills	3	12.171			
Error (remainder)	30	1.086			

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.

EFFECT OF DISTANCE BETWEEN HILLS ON NUMBER AND YIELD OF TUBERS PER HILL

From the data on number of hills and number and weight of tubers per plot were calculated the mean numbers and weights of tubers per hill. These figures are of interest as an indication of the mean sizes of tubers developed and also because they emphasize more clearly than yields per unit area the effects of competition among plants of this crop.

Table 47 shows that in four tests in Minnesota, involving spacings of 12, 18, and 24 inches, each successively greater spacing resulted in a greater number and greater weight of tubers per hill, without exception. In table 18 the magnitudes of variances due to spacing are so great in comparison with error that reference to F values to show significance is unnecessary here.

TABLE 47.—*Effect of distance between hills on number and yield of tubers per hill of different varieties of Jerusalem artichoke grown in Minnesota*

[Quadruplicate plots]

Year and variety	Yield of tubers per hill from plantings at indicated distance between hills					
	12 inches		18 inches		24 inches	
1931	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*
Mammoth French White	33.8	3.78	44.0	5.10	58.1	6.08
Do.[1]	31.9	2.98	38.2	3.80	39.6	4.10
1933						
Chicago	15.3	1.79	18.3	2.48	21.0	3.20
26723-14	8.9	1.38	9.1	1.68	9.2	2.40
Mean	22.4	2.46	27.4	3.26	32.0	3.94

[1] Planted in rows 3 feet apart; all others in rows 4 feet apart.

TABLE 48.—*Analysis of variance of data for table 47*

Source of variation	Number of tubers		Yield of tubers	
	df	*V*	*df*	*V*
Total	47	269.13	47	2.091
Between distances between hills	2	[1] 363.07	2	[1] 8.795
Between tests	3	[1] 3,301.16	3	[1] 23.241
Tests × distances between hills	6	[2] 112.15	[3] (6)	(.393)
Error (remainder)	36	37.41	42	.261

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.
[3] Values in parentheses are included in the values identified as error.

Tables 49 and 51 show the tuber number and tuber yield, respectively, per hill, in response to spacings of 12, 24, 30, and 36 inches for several varieties and locations. There are but few tests in which the number or yield of tubers per hill at any stated spacing fails to exceed that of closer spacings. The response is distinctly more consistent than for yield per unit area. Tables 50 and 52 present the analyses of variance for the data in tables 49 and 51, respectively. They show in all instances such large variances due to distance between hills and such small values for error that inspection alone is sufficient to reveal the high significance of the former. It may be of interest, however, to present the calculated required differences for significance to facilitate comparisons. They are as follows:

	Tubers
For means of Wyoming tests in table 49	3.9
For means of Washington, D. C., tests in table 49	3.6
For means of all tests in table 49	3.3
	Pounds
For means of Wyoming tests in table 51	0.51
For means of Washington, D. C., tests in table 51	.38
For means of all tests in table 51	.32

TABLE 49.—*Effect of distance between hills on number of tubers per hill from Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*

[Quadruplicate plots]

Year	Place	Variety	Tubers per hill from plantings at indicated distance between hills			
			12 inches	24 inches	30 inches	36 inches
			Number	*Number*	*Number*	*Number*
1931	Minnesota	Blanc Ameliore	53.6	72.9	84.6	105.4
1933	Wyoming	do	26.6	32.1	26.0	25.0
		Chicago	13.0	18.4	22.5	20.6
		Waterer	10.3	18.2	14.9	17.6
		Mean	16.6	22.9	21.1	21.1
1931	Washington, D. C.	Blanc Ameliore	24.8	27.6	39.5	36.6
1932	do	do	53.1	78.4	97.2	104.1
		Chicago	48.6	68.7	76.0	93.0
		Waterer	48.5	59.0	77.0	83.8
1933	do	Blanc Ameliore	15.3	20.3	24.5	28.2
		Chicago	25.2	37.0	38.5	45.3
		Waterer	37.1	48.5	58.0	69.3
		26723-30	20.7	32.6	38.5	39.4
		Mean	34.2	46.5	56.2	62.5
		Mean (12 tests)	31.3	42.8	49.8	55.7

TABLE 50.—*Analysis of variance of data for table 49*

Source of variation	Washington, D. C.		Wyoming		Minnesota, Wyoming, and Washington, D. C.	
	df	*V*	*df*	*V*	*df*	*V*
Total	127	639.77	47	53.24	191	742.44
Between distances between hills	3	[1] 4,867.45	3	[2] 86.59	3	[1] 5,253.74
Between tests	7	[1] 7,882.30	2	[1] 633.40	11	[1] 971.48
Between replications	3	[1] 957.70	[3] (3)	(15.21)	3	[1] 350.71
Tests × distances between hills	21	[1] 182.05	(6)	(36.96)	33	[1] 269.31
Error (remainder)	93	51.35	42	23.21	141	65.56

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.
[3] Values in parentheses are included in the values identified as error.

TABLE 51.—*Effect of distance between hills on yield of tubers per hill from Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*

[Quadruplicate plots]

Year	Place	Variety	Yield of tubers from plantings at indicated distance between hills			
			12 inches	24 inches	30 inches	36 inches
			Pounds	*Pounds*	*Pounds*	*Pounds*
1931	Minnesota	Blanc Amelíore	3.05	5.84	7.70	8.30
1933	Wyoming	do	2.25	3.54	2.63	2.66
		Chicago	1.55	2.10	2.61	2.60
		Waterer	1.21	2.85	2.13	2.38
		Mean	1.67	2.83	2.45	2.57
1931	Washington, D. C.	Blanc Amelíore	1.14	1.18	1.87	1.73
1932	do	do	4.26	6.08	8.37	8.95
		Chicago	4.57	6.60	7.80	8.53
		Waterer	3.90	5.24	6.33	7.48
1933	do	Blanc Amelíore	1.47	2.44	2.84	3.24
		Chicago	1.42	2.48	2.76	3.13
		Waterer	1.22	1.88	2.25	2.60
		26723-30	1.85	3.14	3.95	3.75
		Mean	2.48	3.70	4.58	4.92
		Mean (12 tests)	2.37	3.66	4.31	4.62

TABLE 52.—*Analysis of variance of data for table 51*

Source of variation	Washington, D. C.		Wyoming		Minnesota, Wyoming, and Washington, D. C.	
	df	*V*	*df*	*V*	*df*	*V*
Total	127	6.333	47	0.612	191	5.769
Between distances between hills	3	[1] 38.059	3	[1] 2.992	3	[1] 47.446
Between tests	7	[1] 84.243	2	[2] 1.815	11	[1] 72.483
Between replications	3	[1] 3.048	.....	.....	(3)	(1.166)
Tests × distances between hills	21	[1] 1.700	[3] (0)	(.595)	33	[1] 2.204
Error (remainder)	93	.578	42	.384	144	.622

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.
[3] Values in parentheses are included in the values identified as error.

Although but a single year's results are available for Wyoming, there is a strong indication that at the 24-inch spacing the plants make the maximum development possible under those conditions and that at wider spacings lack of competition among plants is of no benefit with reference to individual plant development.

The data relative to mean size of tubers per plot are summarized in table 53. There it will be seen that as spacing is increased from 12 to 24 inches there is an apparently substantial increase in mean tuber size, but that wider spacings produce no further increase. In table 54 the variances due to spacing, for the three different groups of tests, are all significantly higher than those of residual error. Despite these highly significant values, the mean tuber size of the 12-inch spacing is the only one significantly different from the others.

The calculated difference required for significance in the different tests and groups of tests are as follows:

	Ounce
For means of Wyoming tests	0. 18
For means of Washington, D. C., tests	. 09
For means of all tests	. 08

TABLE 53.—*Effect of distance between hills on mean weight of harvested tubers of Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*

[Quadruplicate plots]

Place	Tests	Mean weight of tubers from plantings at indicated distance between hills			
		12 inches	24 inches	30 inches	36 inches
	Number	*Ounces*	*Ounces*	*Ounces*	*Ounces*
Minnesota	1	1. 16	1. 29	1. 46	1. 27
Wyoming	3	1. 71	2. 02	1. 94	2. 00
Washington, D. C.	8	1. 15	1. 20	1. 31	1. 26
Mean		1. 29	1. 45	1. 48	1. 45

TABLE 54.—*Analysis of variance of data for table 53*

Place and source of variation	Degrees of freedom	Mean square
Wyoming:		
Total	47	0. 1201
Between distances	3	[1] 1. 2337
Between tests	2	[1] 1. 4310
Error (remainder)	42	. 0494
Washington, D. C.:		
Total	127	. 1923
Between distances	3	[1] 1. 1364
Between tests	7	[1] 2. 8613
Error (remainder)	117	. 0340
Minnesota, Wyoming, and Washington, D. C.:		
Total	191	. 2417
Between distances	3	[1] 1. 3284
Between tests	11	[1] 3. 5318
Error (remainder)	177	. 0392

[1] Exceeds 1-percent point.

It is recognized that these data on mean tuber size illustrate but a part of the status of tuber development. Detailed data on frequency distributions of various tuber sizes are needed in order to draw sound conclusions as to the effect of cultural practices on market quality or grade of product. One of the writers [3] is making studies of effects of certain cultural practices on size distribution of tubers.

Despite the incompleteness of the data on tuber size, number, and yield per plant, it appears that size of tuber is reduced only by extreme crowding. Apparently, at spacings of 2 feet and further, the development of larger tops is accompanied by a more or less proportional increase in number of tubers set, this number being kept in balance or proportion with top development, so that the mean size that can be developed by the available elaborated foods remains nearly constant.

[3] C. E. Steinbauer.

EFFECT OF DISTANCE BETWEEN ROWS ON YIELD PER ACRE

In general, the effects of distance between rows on yield were much the same as those of distance between hills. When planted with 2 feet between hills, rows which are 3, 4, 5, and 6 feet apart have the same number of hills per acre as rows uniformly 4 feet apart but with hills spaced at 18, 24, 30, and 36 inches. Under similar conditions the yields might be expected to be similar for equal rates of planting.

On account of limited facilities, fewer data were obtained relative to row distance than to hill spacing.

Table 55 presents the results of row spacing studies near Washington, D. C., and in Wyoming. Although a rather consistent decrease in mean yields per acre accompanied increased spacing from 3 feet to 4 and 5 feet, the 6-foot spacing yielded practically the same as the 5-foot planting. In a number of individual tests, the 6-foot yield slightly exceeded the 5-foot yield. These discrepancies doubtless were due to plot heterogeneity, since there is no evident reason why these row spacings should produce responses fundamentally different from those of other similar tests and of hill spacings.

TABLE 55.—*Effect of distance between rows on yield per acre of Jerusalem artichokes grown near Washington, D. C., and in Wyoming*

(Duplicate plots)

Place, year, and variety	Yield per acre from plantings at indicated distance between rows			
	3 feet	4 feet	5 feet	6 feet
Washington:	*Tons*	*Tons*	*Tons*	*Tons*
1931, Blanc Ameliore	7.13	6.10	5.85	6.51
1933, Blanc Ameliore [1]	5.47	5.28	4.90	4.18
1933, Chicago [1]	5.36	4.84	4.27	4.30
1933, Waterer [1]	5.40	4.98	4.38	4.69
Mean	6.01	5.42	4.93	5.11
Mean for 1933 [1]	5.41	5.03	4.55	4.36
Wyoming:				
1933, Blanc Ameliore	5.33	5.43	5.11	5.20
1933, Chicago	5.44	3.75	3.72	3.45
1933, Waterer	6.51	3.83	2.01	1.91
Mean	5.76	4.34	3.61	3.56
Mean for 2 places	5.91	4.96	4.37	4.45

[1] These figures are based on means of quadruplicate plots.

In table 56, analyses of variance of portions of the data entering into table 55 are presented separately and for different combinations. In all five analyses, the variance due to row spacing is significant with reference to residual error. Only in the Wyoming tests is the interaction between varieties and row distances significant with reference to residual error. In this case variance due to spacing is not significantly greater than the interaction in question. (Observed $F=2.74$; 5-percent point $=4.76$.) In all the other comparisons, the lack of significance of interaction shows that the decrease in yield accom-

panying increased row distance can be counted on regardless of variety or test. The calculated difference required for significance between means for the entire table is 0.49 ton. Other required differences can be calculated from the mean squares shown for residual errors.

TABLE 56.—*Analysis of variance of data for table 55*

Source of variation	1933 data for Washington, D. C.		Total data for Washington, D. C.	
	df	*V*	*df*	*V*
Total	47	0.538	31	0.928
Between distances between rows	3	[1] 2.728	3	1.805
Between varieties	2	.335		
Between replications	3	1.945	1	.026
Between tests			3	4.751
Varieties × distances between rows	6	[1] 1.685		
Tests × distances between rows			(0)	(.241)
Error (remainder)	33	.116	[2]24	.379

Source of variation	1933 data for Wyoming		1933 data for Wyoming and Washington, D. C.	
	df	*V*	*df*	*V*
Total	23	2.091	47	1.391
Between distances between rows	3	[1] 6.304	3	[1] 6.786
Between varieties	2	[1] 6.305	2	2.551
Between places			1	[3] 6.003
Places × distances between rows			3	.940
Varieties × distances between rows	6	[1] 2.302	(6)	(1.545)
Error (remainder)	12	.246	33	.824

Source of variation	All data combined	
	df	*V*
Total	55	1.851
Between distances between rows	3	[1] 10.288
Between tests	0	[1] 8.601
Tests × distances between rows	(18)	(.525)
Error (remainder)	40	.420

[1] Exceeds 1-percent point.
[2] Values in parentheses are included in the values identified as error.
[3] Between 5-percent and 1-percent points.

Tables 57 and 58 present data for Illinois and Minnesota which are similar to those just discussed for Washington, D. C., and Wyoming but which involve fewer tests and varieties. The Washington and Wyoming data were tabulated separately to permit a determination of the effects of variety. The means for the four tests in table 57 show differences of approximately the same order as those for Washington and Wyoming, except that the decrease in yield continues to the 6-foot spacing. The relative decrease in yield is approximately 20 percent, accompanying a 50-percent decrease in number of plants per acre.

TABLE 57.—*Effect of distance between rows on yield per acre of Jerusalem artichokes in Illinois and Minnesota*

[Duplicate plots]

Place and variety	Year	Yield per acre from plantings at indicated distance between rows			
		3 feet	4 feet	5 feet	6 feet
		Tons	*Tons*	*Tons*	*Tons*
Illinois:					
Doelle	1931	13.65	11.60	11.38	11.14
Blanc Amelioré	1932	10.41	8.78	5.51	4.67
Mean		12.03	10.19	8.44	7.90
Minnesota:					
Blanc Amelioré	1931	16.04	16.41	15.28	14.54
Mammoth French White	1931	17.86	17.73	18.69	15.33
Mean		16.95	17.07	16.98	14.94
Mean for 4 tests		14.49	13.63	12.71	11.42

TABLE 58.—*Analysis of variance of data for table 57*

Source of variation	Illinois		Minnesota		Illinois and Minnesota	
	df	*V*	*df*	*V*	*df*	*V*
Total	15	9.302	15	3.375	31	18.222
Between distances between rows	3	[1] 13.926	3	[1] 4.272	3	[1] 13.803
Between duplicates	1	.003	1	[1] 16.042	1	[1] 8.226
Between tests	1	[1] 84.499	1	[1] 13.412	3	[1] 157.582
Tests × distances between rows					9	[1] 3.410
Error (remainder)	10	1.316	10	.833	15	.789

[1] Exceeds 1-percent point.
[2] Between 5-percent and 1-percent points.

The variances due to row spacing are significant with reference to residual error for Illinois and Minnesota separately and combined. The interaction between row spacings and tests for the combined data is significant with reference to residual error. The variance due to row spacing is also significantly greater than the interaction just mentioned. (Observed F=4.05; 5-percent point=3.86.) Thus, although there is variation in degree of response to row spacing, the results in these two States indicate that lower yields will accompany wider spacing with reasonable certainty.

Table 59 gives the analysis of variance of combined data from tables 55 and 57 involving a total of 11 tests in 4 regions. The mean yields were 9.03, 8.11, 7.40, and 6.68 tons per acre for 3-, 4-, 5-, and 6-foot rows, respectively. The variance due to row spacing is highly significant with reference to both residual error and the interaction between tests and spacings. The interaction is also significant with reference to residual error. The differences between all the variances are so great that inspection indicates the relatively high F values in comparisons.

It will be recalled that, in the Oregon tests, at constant row spacings and varying intervals between hills the results were contrary to those in other locations. The yields were practically the same for 24-, 30-,

36-, and 48-inch intervals between hills. Table 60 shows a similar result for different distances between rows, again contrary to the results from other places. In 1932 the mean yields from rows spaced 4, 5, and 6 feet apart remained nearly constant, but in 1933 the wider spacings showed successively higher yields. The 2-year means show but a slight increase in yield of the 6-foot over the 4-foot plots, approximately 10 percent.

TABLE 59.—*Analysis of variance of data relating to effect of distance between rows on yield per acre of Jerusalem artichokes* [1]

Source of variation	Degrees of freedom	Mean square
Total	87	23.083
Between distances between rows	3	[2] 17.618
Between tests	10	[2] 186.601
Tests × distances between rows	30	[2] 2.016
Error (remainder)	44	.857

[1] Combined data for tables 55 and 57.
[2] Exceeds 1-percent point.

TABLE 60.—*Effect of distance between rows on yield of 3 varieties of Jerusalem artichokes grown at Corvallis, Oreg.*

[Duplicate plots]

Year and variety	Yield per acre from plantings at indicated distance between rows		
	4 feet	5 feet	6 feet
1932	*Tons*	*Tons*	*Tons*
Blanc Amelioré	14.18	15.02	15.65
Chicago	9.08	8.72	10.24
Waterer	17.11	15.24	14.43
Mean	13.45	12.99	13.41
1933			
Blanc Amelioré	11.77	12.07	13.58
Chicago	8.64	9.38	10.87
Waterer	8.16	9.52	10.82
Mean	9.52	10.52	11.75
2-year mean	11.49	11.76	12.58

Table 61 shows the variance due to spacing to be significant with reference to residual error but not with reference to any of the interactions listed. Despite the significance of the differences between the 2-year means for 4- and 6-foot spacings (observed = 1.09 tons; calculated required = 0.75 ton) and that of variance referred to residual error, the lack of agreement in the two separate years should be borne in mind. Two tests are hardly sufficient to justify conclusions which are diametrically opposed to all other locations and which are not in conformity with other Oregon results. It is not very probable that the 6-foot spacing consistently outyielded the 4-foot and 5-foot spacings. However, the conclusion can be very safely drawn that neither the 4- nor 5-foot spacing outyields the 6-foot, under these Oregon conditions. These Oregon results are the more remarkable when it is

recalled that in the hill-spacing studies the rows were 5 feet instead of 4 feet apart, as elsewhere; and the hills in the row-spacing work were 4 feet instead of 2 feet apart.

TABLE 61.—*Analysis of variance of data for table 60*

Source of variation	Degrees of freedom	Mean square
Total	35	8.083
Between distances between rows	2	[1] 3.902
Between years	1	[2] 64.937
Between varieties	2	[2] 59.440
Distances between rows × years	2	[1] 3.998
Distances between rows × varieties	[3] (4)	(1.120)
Years × varieties	2	[2] 30.813
Error (remainder)	26	.831

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.
[3] Values in parentheses are included in the values identified as error.

Thus, in Oregon, increasing the area per plant from 16 to 24 square feet in the row studies and from 10 to 20 square feet in the hill-spacing trials resulted in no significant decrease in yield from approximately 12 tons per acre. In contrast, at other locations quite significant yield decreases accompanied much smaller relative increases in space, and this was at closer planting distances wherein competition might be expected to play a greater part than here.

EFFECT OF DISTANCE BETWEEN ROWS ON YIELD AND NUMBER OF TUBERS PER HILL

As in the tests on effect of distances between hills, increasing the distance between rows greatly increased the number of tubers and yields of tubers per hill. The results are so similar to those already presented that there is little point in tabulating them in detail here. Eight tests involving three different locations (Minnesota, Wyoming, and Washington, D. C.) resulted in mean yields of 1.75, 2.17, 2.55, and 2.84 pounds per hill, in rows 3, 4, 5, and 6 feet apart, respectively. The differences are all highly significant.

In addition to yield data, information on number of tubers per hill is of interest, but only indirectly, insofar as it has a bearing on the size of tubers produced. Instead of giving detailed data upon tuber number, the matter of size will be considered.

EFFECT OF DISTANCE BETWEEN ROWS ON MEAN SIZE OF TUBERS HARVESTED

Tables 62 and 63 show a slight tendency for the mean size of tubers to increase as the distance between rows is increased. This tendency, however, is pronounced only in rows 4 feet apart as compared with those 3 feet apart. Although the means for all tests show the mean tuber size for 5-foot rows to be 1.54 ounces, compared with 1.48 and 1.30 ounces for 4-foot and 3-foot rows, respectively, the apparent superiority in size is quite insignificant (required for significance, 0.163 ounce) except over the 3-foot spacing. Table 63 shows that among the three locations the variance due to spacing is significant with reference to residual error only in the Wyoming tests. The differences in those tests have sufficient weight to reveal significance in the combined Wyoming and Washington, D. C., data.

TABLE 62.—*Effect of distance between rows on mean weight of tubers of Jerusalem artichokes grown in Minnesota and Wyoming and near Washington, D. C.*

[Duplicate plots]

Place and year	Variety	Weight of tubers from plantings at indicated distance between rows			
		3 feet	4 feet	5 feet	6 feet
		Ounces	*Ounces*	*Ounces*	*Ounces*
Minnesota, 1931	Blanc Amelioro	1.36	1.53	1.28	1.48
	Mammoth French White	2.05	2.21	2.65	2.15
Mean		1.70	1.87	1.96	1.81
Wyoming, 1933	Blanc Amelioro	1.41	1.95	2.03	1.99
	Chicago	1.73	1.88	2.23	2.03
	Waterer	1.69	2.10	2.14	2.06
Mean		1.61	1.97	2.13	1.99
Washington, D. C., 1933	Blanc Amelioro	.97	1.22	1.04	1.12
	Chicago	.89	.96	.88	1.00
	Waterer	.80	.80	.83	.92
Mean		.88	.99	.91	1.01
Mean for Wyoming and Washington, D. C.		1.24	1.48	1.52	1.50
Washington, D. C., 1931	Blanc Amelioro	.84	.85	.81	.82
Mean for 4 tests, Washington, D. C.		.87	.95	.89	.96
Mean for total of 6 tests		1.30	1.48	1.54	1.50

TABLE 63.—*Analysis of variance of data for table 62*

Source of variation	Minnesota		Wyoming		Washington, D. C., 1933		Washington, D. C., 4 tests		Wyoming and Washington, D. C., 1933		Total, all tests	
	df	*V*	*df*	*V*	*df*	*V*	*df*	*V*	*df*	*V*	*df*	*V*
Total	15	0.274	23	0.062	23	0.021	31	0.023	47	0.288	71	0.326
Between distances between rows	3	.048	3	1.302	3	.022	3	.017	3	[1] .203	3	[1] .207
Between tests	1	[2] .905	2	.071	2	1.130	3	1.114	5	[2] 2.362	8	[2] 2.525
Tests × distances between rows	3	.119	6	.017	6	.007	9	.007	15	.034	24	.007
Error (remainder)	8	.088	12	.029	12	.020	16	.020	24	.025	36	.000

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.

A reconsideration of the data in table 53 is particularly interesting at this point. The hill spacings listed there are equivalent to 4, 8, 10, and 12 square feet per plant. No increase in size of tuber is noted in spacings above 8 square feet. In table 62, the spacings represent 6, 8, 10, and 12 square feet per plant, and again no increase in tuber size is found for plots having more than 8 square feet. Furthermore, the four final means of table 53 are remarkably similar, respectively, to those of table 62.

HARVESTING TOPS AS FOR SILAGE

References in the literature (*5*, *6*) to the value of harvesting the above-ground portions of the Jerusalem artichoke plant for silage have raised the question as to the effect of this practice on the yield and

quality of the tubers. Obviously, the effect on the tuber crop will depend largely on the time that the tops are harvested. Schoth (*5*), working in Oregon, presented limited data showing that when the tops were removed, September 25, the yields of three varieties were but 0.8 to 0.9 ton per acre, while leaving the tops undisturbed until after frost resulted in yields of 5.5 to 6.5 tons. Likewise, the suitability of tops for silage depends on their stage of development, since they become quite woody and lose their leaves as maturity approaches.

METHODS

Studies were conducted for one season in Illinois, two seasons in Minnesota, and three seasons near Washington, D. C. From 1 to 3 varieties were included in the plots at each location, giving a total of 12 tests during the progress of this work.

Blocks of one or more varieties were planted early to provide a supply of as uniform material as could be obtained. Individual plots were 40 feet long and consisted of single rows 4 feet apart planted with hills 2 feet apart except near Washington, where the rows were 5 feet apart. In Illinois duplicate plots were provided, and triplicate plots of each variety in the other locations.

It has been suggested that the optimum time of harvesting the tops, in order to get maximum yield of silage and to avoid excessive woodiness of the material, would be about or just after the time of flowering. This stage, then, was arbitrarily considered as medium (*C*), and harvests were made both earlier and later as well as at that stage. In the Illinois studies, one early harvest (*A*) was made about 7 weeks before *C*, and one 4 weeks after, at maturity (*E*). The *A* harvest was much earlier than in the other tests and is not strictly comparable. In Minnesota also three harvests were made (*A*, *C*, and *E*), at intervals of about 3 weeks. Near Washington, five harvests were made at intervals of 12 days, except the last (*E*), which followed *D* by approximately 4 weeks. The *E* harvests in all locations involved practically mature plants that had lost a large proportion or most of their leaves. Table 64 shows the dates upon which the tops were harvested from the several plots.

TABLE 64.—*Dates on which tops of Jerusalem artichokes were harvested*

Place and year	Date of indicated harvest of tops				
	A	*B*	*C*	*D*	*E*
Illinois:					
1931	Aug. 12	----------	Oct. 5	----------	Nov. 2
Minnesota:					
1931	Sept. 14	----------	Oct. 6	----------	Oct. 20
1932	Sept. 19	----------	...do.....	----------	Oct. 28
Washington, D. C.:					
1931	Aug. 31	Sept. 9	Sept. 19	Oct. 3	Nov. 10
1932	Aug. 25	Sept. 7	...do.....	...do.....	Nov. 5
1933	...do.....	Sept. 6	Sept. 18	Oct. 2	Oct. 31

The tops were cut near the soil surface, the green weight was determined per plot, and the number of harvested hills recorded. In the Minnesota and Washington, D. C., tests the tops from several typical hills were chopped into a composite sample which was thoroughly

mixed and from which samples were drawn for the determination of moisture and crude fiber.

The tubers in the hills from which the tops were removed were left in place until the time of harvesting all plots, when the weight and number of tubers per plot were determined.

Moisture and crude fiber were determined by the recommended procedure of the Association of Official Agricultural Chemists (*1, pp. 280-281*).

RESULTS

EFFECT OF TIME OF TOP REMOVAL ON YIELD OF TUBERS

The most extensive data upon the effects of early top removal were obtained near Washington, D. C. In 1931 but one variety was grown, while in 1932 and 1933 three were studied. Table 65 presents the results for the Blanc Ameliore variety as grown near Washington for 3 years. Without exception, successively later top removal resulted in markedly increased numbers and yields of tubers per hill. Reference to table 66 shows that the variances due to time of top removal are so very much greater than residual error that they are of practically infinite odds of significance. Those variances are also significantly greater than interaction between dates of removal and years. (For number of tubers: Observed $F=7.16$; 1-percent point=7.01. For yield of tubers: Observed $F=5.46$; 5-percent point=3.84.) Thus, one may confidently expect such results, consistently, year after year, within the range of conditions of these observations. The differences between 3-year means are all highly significant (minimum observed=0.30 pound and 4.5 tubers; calculated required difference=0.30 pound and 4.4 tubers), with one exception—the difference in yield of tubers between the *A* and *B* harvests. This exception serves to emphasize what is apparent in the table. Up to and including the second harvest (Sept. 6–9) the tubers had hardly begun to enlarge, averaging only about 0.018 to 0.024 pound in size, or 40 to 50 per pound; and yielding only about a half pound per hill, or about one-ninth of their ultimate yield. Even at the supposed optimum time for top cutting, the yield of tubers was but 25 to 30 percent of the ultimate yield.

TABLE 65.—*Effect of time of top removal on number and yield per hill of Jerusalem artichoke tubers of the Blanc Ameliore variety grown near Washington, D. C.*

[Triplicate plots]

Year	Yield of tubers per hill after top removal [1]									
	A		*B*		*C*		*D*		*E*	
	Number	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*
1931	19.1	0.24	21.8	0.45	33.3	0.73	52.4	1.60	63.5	2.03
1932	35.0	.71	39.1	1.19	68.8	2.82	91.3	6.01	98.2	7.79
1933	10.6	.22	14.5	.26	10.8	.69	21.0	1.30	28.3	2.31
Mean	21.6	.39	26.1	.64	39.6	1.41	54.9	2.97	63.3	4.35

[1] *A* represents earliest removal; *B*, second earliest; *C*, medium; *D*, medium late; *E*, late. See p. 52 for explanation.

TABLE 66.—*Analysis of variance of data for table 65*

Source of variation	Number of tubers		Yield of tubers	
	df	*V*	*df*	*V*
Total	44	768.24	44	4.853
Between dates of removal	4	[1] 2,906.59	4	[1] 25.249
Between years	2	[1] 8,708.59	2	[1] 34.799
Years × dates of removal	8	[1] 495.82	8	[1] 4.920
Error (remainder)	30	44.09	30	.109

[1] Exceeds 1-percent point.

Table 67 presents data for three varieties for 1932 and 1933. The final means in table 67 are in very close agreement with those of table 65 for the Blanc Ameliore variety. An inspection of the detailed results for the Waterer variety indicates that its tubers develop somewhat later than do those of the other varieties. It is a late variety. The significant interaction of date of top removal × variety (table 66) emphasizes this varietal difference. Although Chicago "matures" distinctly earlier than Blanc Ameliore, it does not appear to develop its tubers any earlier. Earliness of flowering and dropping of leaves may or may not be associated with early development of large tubers.

TABLE 67.—*Effect of time of top removal on number and yield per hill of tubers of three varieties of Jerusalem artichokes grown near Washington, D. C.*

[Triplicate plots]

Variety and year	Yield of tubers per hill after top removal [1]									
	A		*B*		*C*		*D*		*E*	
Blanc Ameliore:	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*
1932	35.0	0.71	39.1	1.19	68.8	2.82	91.3	6.01	98.2	7.79
1933	10.6	.22	14.5	.26	16.8	.69	21.0	1.30	28.3	2.31
Mean	22.8	.47	26.8	.73	42.8	1.76	56.2	3.60	63.2	5.05
Chicago:										
1932	26.9	.50	32.9	.87	51.2	2.03	75.4	5.82	82.2	6.87
1933	8.9	.15	12.1	.22	21.0	.50	31.0	1.34	38.7	1.95
Mean	17.0	.32	22.5	.54	36.1	1.29	53.2	3.58	60.5	4.41
Waterer:										
1932	25.0	.49	26.3	.70	36.3	1.22	50.0	3.01	67.7	5.75
1933	12.1	.13	19.4	.22	29.9	.39	38.2	.98	60.1	2.08
Mean	18.6	.31	22.8	.50	33.1	.81	44.1	2.00	63.9	3.91
Mean for 3 varieties	19.8	.37	24.0	.50	37.4	1.28	51.2	3.08	62.5	4.46

[1] *A* represents earliest removal; *B*, second earliest; *C*, medium; *D*, medium late; *E*, late. See p. 52 for explanation.

Table 68 shows that variances due to time of top removal are practically infinitely significant with reference to residual error and very highly so with reference to the interaction of varieties × dates of removal. (For number, observed $F=114.1$; for yield, observed $F=64.1$; 1-percent point = 7.01.) The kind of response shown may well be expected regardless of variety or year.

TABLE 68.—*Analysis of variance of data for table 67*

Source of variation	Number of tubers		Yield of tubers	
	df	*V*	*df*	*V*
Total	89	649.61	89	4.893
Between dates of removal	4	[1] 5,841.04	4	[1] 55.633
Between varieties	2	276.87	2	[1] 5.229
Between years	1	[1] 10,205.59	1	[1] 110.647
Years × dates of removal	4	[1] 732.48	4	[1] 16.305
Varieties × dates of removal	[2] (8)	(51.20)	8	[1] .808
Varieties × years	2	[1] 2,462.61	2	[1] 3.136
Error (remainder)	76	89.98	68	.207

[1] Exceeds 1-percent point.
[2] Values in parentheses are included in the values identified as error.

Data relating to three dates of top removal in Illinois and Minnesota are presented in table 69. Again, as in the more extensive Washington, D. C., tests, there is observed a very marked reduction in yield of tubers as a result of early top removal. The earliest removal (*A*) resulted in but about one-third the yield obtained when tops were cut at the supposed optimum time (*C*), and this in turn represented but about 60 percent of the ultimate yield. Table 70 shows the variance due to time of top removal to be very highly significant with reference both to residual error and to interaction between tests and dates of top removal. (Observed $F=11.7$; 1-percent point=8.65.)

TABLE 69.—*Effect of time of top removal on yield of tubers per hill of Jerusalem artichokes grown in Illinois and Minnesota*

[Triplicate plots]

Place and variety	Year	Yield per hill of tubers after top removal		
		A	*C*	*E*
		Pounds	*Pounds*	*Pounds*
Illinois:				
Doolle	1931	0.74	2.50	3.71
Minnesota:				
Blanc Amelioree	1931	.81	3.22	5.01
Do	1932	.80	1.37	2.18
Chicago	1932	.34	.78	1.77
Waterer	1932	.22	.72	1.08
Mean		.58	1.73	2.75

TABLE 70.—*Analysis of variance of data for table 69*

Source of variation	Degrees of freedom	Mean square
Total	44	2.050
Between dates of removal	2	[1] 17.625
Between tests	4	[1] 8.518
Tests × dates of removal	8	[1] 1.510
Error (remainder)	30	.294

[1] Exceeds 1-percent point.

EFFECT OF TIME OF TOP REMOVAL ON YIELD OF TOPS

As stated under Methods of this section, efforts were made to so time the removal of tops that the *C* or medium date would represent a high top yield and still avoid the disadvantages of too advanced maturity. Table 71 presents the green and dry weights of tops per plant, harvested from the Washington, D. C., plots.

TABLE 71.—*Effect of time of top removal on yield per hill of green and dry tops of Jerusalem artichokes grown near Washington, D. C.*

[Triplicate plots]

GREEN WEIGHT

Year and variety	Yield of tops per hill after top removal[1]				
	A	*B*	*C*	*D*	*E*
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1931					
Blanc Amelioré	9.62	8.53	8.60	8.56	1.80
1932					
Blanc Amelioré	10.57	11.10	11.60	9.13	2.82
Chicago	10.07	10.62	10.20	8.00	2.91
Waterer	8.71	8.70	8.90	8.74	3.40
1933					
Blanc Amelioré	5.80	4.66	5.07	3.02	1.26
Chicago	4.13	4.33	3.51	2.99	1.22
Waterer	4.15	4.08	3.47	2.90	1.17
Mean	7.58	7.44	7.36	6.33	2.09

OVEN-DRY WEIGHT

1931					
Blanc Amelioré	1.50	1.70	1.84	2.18	1.20
1932					
Blanc Amelioré	2.12	2.55	3.31	2.93	2.24
Chicago	2.49	2.78	3.33	2.66	2.05
Waterer	2.10	2.34	3.05	3.11	2.38
1933					
Blanc Amelioré	1.11	1.02	1.21	1.06	.63
Chicago	1.11	1.43	1.16	1.04	.62
Waterer	1.01	1.12	1.07	1.00	.49
Mean	1.64	1.85	2.14	2.00	1.38

[1] *A* represents earliest removal; *B*, second earliest; *C*, medium; *D*, medium late; *E*, late. See p. 52 for explanation.

It is a bit surprising that in two of the three seasons the highest green weight was obtained from the earliest harvests, while in the other year the *C* harvest yielded slightly more than the first two. The cause of this rather unexpected finding was not determined, but it is probably due to loss of lower leaves before the time of the *B* and *C* harvests. The loss of leaves that had occurred after the *C* harvest was quite noticeable. At the *E* harvest of the Washington, D. C., plots, the branches were practically bare. The 3-year means show a slight and statistically insignificant decrease in green weight from the *A*, through the *B*, to the *C* harvest. (Observed differences from $A=0.14$ and

0.22 pound; calculated required =0.67 pound.) However, the *D* and *E* harvests show very marked and significant losses in green weight. The variance due to time of removal is very highly significant with reference to residual error and to interaction between tests and time of removal (table 72). The interaction is so small as to be insignificant, with reference to residual error. Therefore, top cutting later than *C* not only yields older, woodier plants but a markedly lower green weight of material.

TABLE 72.—*Analysis of variance of data for table 71*

Source of variation	Green weight		Dry weight	
	df	*V*	*df*	*V*
Total	104	11.109	104	0.721
Between dates of removal	4	[1] 113.508	4	[1] 1.862
Between tests	6	[1] 97.210	6	[1] 9.947
Tests × dates of removal	24	1.471	24	[1] .180
Error (remainder)	70	1.175	70	.050

[1] Exceeds 1-percent point.

The values for dry weight of tops, of course, differ from the foregoing, but they also show a significant increase in dry weight from the *A* to the *C* harvest, followed by a decrease in the later ones. This decrease is doubtless chiefly due to loss of leaves, but there may also be a heavy loss of elaborated foods by translocation to the tubers. Table 72 shows the variance due to time of top removal to be very highly significant with reference to both residual error and interaction between tests and time of removal. The calculated required difference for significance between means for the seven tests is 0.14 pound. Thus, there are significant differences between any and all means. The *C* harvest is seen to yield significantly the greatest amount of dry matter per plant. But it should be recalled that top cutting at this time results in a serious reduction in the yield obtainable from undisturbed plants.

Table 73 shows the green and dry weights of tops harvested at three stages of development in Illinois and Minnesota. The effect of time of harvest upon green weight will be seen to be very similar to that observed for the Washington, D. C., plots. The dry weights also decrease rather consistently from the earliest harvest, in three of the five tests, but the data are rather limited and may not be representative of responses to conditions in those regions. It is possible, however, that in Minnesota, where the lower dry weights occurred at the *C* harvest, harvest time should be rated as *D* rather than *C*, on account of the brevity of the autumn season. It appears evident that at that time the plants were more nearly mature than was supposed beforehand. Regardless of the explanation, there appears to be no chance of obtaining a good yield of tops without reducing the tuber yield to a mere fraction of the ultimate yield.

TABLE 73.—*Effect of time of top removal on yield of green and dry tops per hill of Jerusalem artichokes grown in Illinois and Minnesota*

[Duplicate plots]

Place and year	Variety	Yield of tops per hill after top removal [1]					
		A		*C*		*E*	
		Green	Dry	Green	Dry	Green	Dry
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Illinois:							
1931	Blanc Amelfore	2.76	0.38	2.92	0.71	0.53	0.35
Minnesota:							
1931	do	7.17	1.53	5.34	1.32	4.35	1.25
1932	do	4.73	1.55	4.81	1.90	2.01	1.12
1932	Chicago	5.18	3.41	3.83	1.59	3.20	1.34
1932	Waterer	3.34	2.47	3.25	1.52	2.49	1.07
Mean		4.63	1.87	4.03	1.41	2.70	1.02

[1] *A* represents earliest removal; *B*, second earliest; *C*, medium; *D*, medium late; *E*, late. See p. 52 for explanation.

Table 74 shows for green weight a variance due to date of top removal that is highly significant when referred to residual error or to interaction between dates of removal and tests. The interaction, however, is not significantly greater than residual error, but is even insignificantly smaller. (Observed $F=1.23$; 5-percent point=3.12.) Variance in dry weight due to date of removal is significantly greater than that of residual error but not greater than the interaction of tests × dates of removal. (Observed $F=3.33$; 5-percent point=4.46.)

TABLE 74.—*Analysis of variance of data for table 73*

Source of variation	Green weight		Dry weight	
	df	*V*	*df*	*V*
Total	20	2.741	29	0.638
Between dates of removal	2	[1] 9.820	2	[1] 1.829
Between tests	4	[1] 10.055	4	[1] 2.169
Tests × dates of removal	8	.652	8	[1] .547
Error (remainder)	15	.801	15	.121

[1] Exceeds 1-percent point.

Table 75 presents the analysis of variance for a summary of the combined data for the *A*, *C*, and *E* harvests shown in tables 71 and 73. For the 12 tests, the mean yields of green and dry tops per hill were 6.41 and 1.74, 5.91 and 1.82, and 2.41 and 1.28 pounds after top removals *A*, *C*, and *E*, respectively. Note first that variances in both green and dry weights are of very great significance with reference to residual errors; they are also significant when referred to the respective interactions between tests and dates of removal. (Observed F for green weight=25.8; for dry weight=5.29; 5-percent point=3.44.) Thus it can be safely concluded that the response shown in the first part of table 73 can be expected with a high degree of probability. The maximum green weight of tops is obtained just before blossoming time and declines rapidly thereafter. The maximum dry weight, however, appears to be reached just after blossoming and before the dropping of leaves becomes noticeable.

TABLE 75.—*Analysis of variance of data relating to effect of removal of tops of Jerusalem artichokes on yield of green and dry tops per hill grown in Illinois and Minnesota and near Washington, D. C.*[1]

Source of variation	Green weight		Dry weight	
	df	*V*	*df*	*V*
Total	71	8.787	71	0.604
Between dates of removal	2	[2] 113.940	2	[2] 2.036
Between tests	11	[2] 27.053	11	[2] 3.077
Tests × dates of removal	22	[2] 4.419	22	[2] 1.385
Error (remainder)	36	.032	36	.081

[1] Duplicate plots.
[2] Exceeds 1-percent point.

CRUDE FIBER CONTENT OF TOPS IN RELATION TO TIME OF HARVEST

Limited data (*5*) on composition of artichoke tops both dried and as silage show that they may compare favorably with corn stover and silage, respectively. Obviously, overmaturity and dropping of leaves must be guarded against if this favorable composition is to be obtained. In the present studies, estimations of crude-fiber content were made to obtain a rough index of change of feeding quality as the tops approached maturity.

Table 76 shows the crude-fiber content of tops from the successive harvests from the plots near Washington, D. C. The crude-fiber content showed but little change, on the dry-weight basis, from the *A* to the *D* harvest, but the *E* lots were very much higher. As suggested earlier, this doubtless was due to heavy loss of leaves, with little more than the woody stems and branches remaining at harvest. On the fresh-weight basis crude fiber increased steadily from *A* to *D* from about 5 up to 8 percent, then very abruptly to about 25 percent in the last harvest. The fresh-weight values are of the greater importance here, because they better illustrate the nature of the product at the different times of harvest.

TABLE 76.—*Effect of time of top removal on crude-fiber content of tops of Jerusalem artichokes grown near Washington, D. C.*

DRY-WEIGHT BASIS

Variety	Year	Crude-fiber content of tops after top removal[1]				
		A	*B*	*C*	*D*	*E*
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Blanc Amelioro	1932	24.71	25.78	22.67	22.34	42.94
Chicago	1932	20.28	27.80	24.63	28.13	45.28
Waterer	1932	23.87	27.56	22.19	20.92	43.71
Mean		24.95	27.05	23.16	23.80	43.98
Blanc Amelioro	1933	23.02	24.08	24.85	27.47	33.77
Chicago	1933	21.43	17.93	21.85	22.92	34.89
Waterer	1933	21.75	24.77	22.82	25.10	36.28
Mean		22.37	22.26	23.17	25.18	34.98
Mean for 6 tests		23.66	24.65	23.17	24.49	39.45
Blanc Amelioro	1931	26.82	27.86	27.76	27.45	46.55
Mean for 7 tests		24.11	25.11	23.82	24.91	40.49

[1] *A* represents earliest removal; *B*, second earliest; *C*, medium; *D*, medium late; *E*, late. See p. 52 for explanation.

TABLE 76.—*Effect of time of top removal on crude-fiber content of tops of Jerusalem artichokes grown near Washington, D. C.*—Continued.

FRESH-WEIGHT BASIS

Variety	Year	Crude-fiber content of tops after top removal				
		A	*B*	*C*	*D*	*E*
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Blanc Ameliore	1932	4.96	5.80	6.40	7.10	31.14
Chicago	1932	6.48	7.28	8.04	9.37	31.89
Waterer	1932	5.75	7.40	7.56	7.45	32.80
Mean		5.73	6.88	7.35	7.99	32.04
Blanc Ameliore	1933	4.56	5.28	5.91	7.44	17.11
Chicago	1933	5.76	6.03	7.20	7.60	17.71
Waterer	1933	5.30	6.80	7.05	8.49	15.18
Mean		5.21	6.00	6.72	7.97	16.67
Mean for 6 tests		5.47	6.43	7.04	7.98	24.81
Blanc Ameliore	1931	4.34	5.54	5.87	6.98	31.15
Mean for 7 tests		6.31	6.30	6.87	7.84	25.71

The first part of table 77 shows that for both the dry-weight and the fresh-weight basis the variance due to time of harvest is highly significant with reference to residual error and to interactions between varieties and times of harvest. Variance due to variety is very small, being no greater than remainder error. The interactions involving years and time of harvest gave variances of significance when referred to residual error. On the dry basis, variance due to time of harvest was significantly greater than this interaction (observed F=11.4; 5-percent point=6.39), but on the fresh basis it was not significantly greater (observed F=5.78; 5-percent point=6.39). Apparently, the high moisture content and the probably somewhat less mature stage of 1932 samples of the E harvest is responsible for this very high interaction between years and time of harvest. In other respects the data for the different years agree very well.

TABLE 77.—*Analysis of variance of data for table 76*

DATA FOR 1932 AND 1933

Source of variation	Dry-weight basis		Fresh-weight basis	
	df	*V*	*df*	*V*
Total	29	48.952	29	69.107
Between dates of harvest	4	[1] 239.968	4	[1] 307.085
Between years	1	[1] 67.261	1	[1] 109.510
Between varieties	2	.621	2	1.918
Years × dates of harvest	4	[1] 25.369	4	[1] 88.636
Varieties × dates of harvest	5	3.119	8	.908
Years × varieties	2	[1] 24.387	[2] (2)	(.003)
Error (remainder)	8	1.959	10	2.958

TOTAL DATA FOR 3 YEARS

Total	31	52.557	34	74.333
Between dates of harvest	4	[1] 300.351	4	[1] 518.311
Between tests	6	[1] 32.197	6	17.530
Error (tests × dates of harvest)	21	6.348	24	14.537

[1] Exceeds 1-percent point.
[2] Values in parentheses are included in the values identified as error.

Although there are no significant differences among the 2-year means of crude-fiber content (dry-weight basis) among the first four harvests, the lower content of the *C* lot approaches a significant difference when compared with that of *B*. A similar low content for the *C* lot will be noted in table 78, which shows the Minnesota results. Although the evidence is meager, there is an indication that blossoming (which occurred at or soon before the *C* harvest) is accompanied or followed shortly by such an increased efficiency of synthesis and storage of elaborated food reserves that the proportion of crude fiber is slightly lowered for a time. Cooler weather at this time may also be a factor by reducing the rate of respiration and translocation to a greater degree than synthesis of food materials.

The values for means of fresh weight for six tests show no decrease in crude fiber at any harvest, but it will be noted that the increase from *B* to *C* is distinctly less than for other consecutive harvests. The calculated required difference for significance between means is 2.0 percent, which would cast doubt upon the importance of the successive increases in crude fiber were they not so consistent in relation to time of harvest.

The Minnesota results differed from the Washington, D. C., results chiefly in lower crude-fiber content at the last harvest. Within the Minnesota tests, however, the same general observation can be made as discussed above. Table 78 contains the results of crude-fiber estimations made by E. L. Mallet, of the Minnesota Agricultural Experiment Station, and table 79 presents the analyses of variance of those data. It will be noted that although the data are rather limited the results are quite consistent, yielding low errors and showing highly significant differences between means of harvests.

TABLE 78.—*Crude-fiber content of tops of Jerusalem artichokes grown in Minnesota in relation to time of harvesting*

Variety	Year	Crude-fiber content of tops after indicated top removal					
		Dry-weight basis			Fresh-weight basis		
		A	*C*	*E*	*A*	*C*	*E*
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Blanc Ameliore	1931	29.44	27.34	30.90	6.72	7.66	9.91
Mammoth French White	1931	27.02	24.64	30.82	5.30	5.17	7.96
Mean		28.23	25.98	30.86	6.01	6.42	8.94
Blanc Ameliore	1932	21.62		21.42	6.59		9.64
Chicora	1932	26.49		31.89	8.98		13.46
Waterer	1932	21.63		27.56	7.01		11.25
Mean		23.25		28.96	7.54		11.45
Mean for 3 tests		25.21		29.72	6.95		10.51

TABLE 79.—*Analysis of variance of data for table 78*

Source of variation	Data for 1931				*A* and *E* data for 1931 and 1932			
	Dry-weight basis		Fresh-weight basis		Dry-weight basis		Fresh-weight basis	
	df	*V*	*df*	*V*	*df*	*V*	*df*	*V*
Total	5	6.114	5	3.211	9	17.858	9	6.085
Between dates of harvest	2	[1] 11.955	2	[1] 5.023	1	[2] 50.131	1	[2] 30.041
Between tests	1	4.559	1	[2] 5.723	4	[2] 23.914	4	[2] 5.661
Error (tests × dates of harvest)	2	1.051	2	.143	4	3.731	4	.295

[1] Between 5-percent and 1-percent points.
[2] Exceeds 1-percent point.

As mentioned previously, it is of considerable interest that crude-fiber content (on the dry-weight basis) for the *C* harvest was lower than that for the *A* harvest. (Observed difference=2.25 percent; calculated required for significance=1.68 percent.)

The determinations of crude fiber for both locations suggest that harvesting tops as late as *C* results in practically as good quality of raw product, for silage purposes, as does earlier harvesting. Apparently, even some little delay of harvest beyond *C*, before leaf fall becomes serious, would be accompanied by no great deterioration of the material. However, it should be borne in mind that harvests as late as *C* yield less green matter and in some cases less dry matter than earlier harvests. Still later harvests involve quite appreciable losses of both green and dry matter. And, of paramount importance to the grower who expects to harvest a crop of tubers, *C* harvests of tops result in tuber yields 40 to 60 percent lower than if the tops were undisturbed until frost, and *D* harvests 25 to 35 percent lower. It seems improbable that satisfactory yields of both forage and tubers can be obtained from the same plants. The most substantial increases in tonnage of tubers appear to occur after the optimum stage for harvest for forage is past.

ERADICATION OF VOLUNTEER GROWTH

Since it is practically impossible to remove all small tubers from the soil at harvest time, varying numbers and sometimes quite considerable quantities remain to sprout in the spring following the crop year. The large number of sprouts that usually appear emphasizes the difficulty of a really thorough harvesting of this crop. This volunteer growth is not easy to dispose of. Early plowing and sowing of some spring crops may break off or thoroughly cover the young tops that are showing at planting time, but the tubers have a remarkable resprouting capacity, so that a second set of sprouts will emerge to infest the spring crop sown on the land. Furthermore, even if most of the volunteer plants are killed and a few escape here and there over the field, they must be destroyed before August lest they form tubers which will sprout the following year.

No extensive or exhaustive studies were carried through in regard to this problem of eradication of volunteer growth, but some limited data were obtained and a number of trials and observations made that doubtless are worth reporting here.

METHODS

In 1931, near Washington, D. C., a field was used which had grown artichokes in 1930 and which showed a heavy volunteer growth. Five treatments were applied on single plots (each of eight rows 43 feet long) in this field of volunteer artichokes, beginning June 13 when the plants were 2 feet high. The treatments were as follows:

Plot 1.—Plants hoed off at soil surface and later sprouts removed at 7-day intervals.

Plot 2.—Plants hoed off at soil surface and later sprouts removed at 10-day intervals.

Plot 3.—Plants plowed under deeply and completely without previous cutting.

Plot 4.—Plants hoed off at soil surface and plot cultivated with ordinary row cultivator at 10- to 15-day intervals.

Plot 5.—Plants hoed off at soil surface and turned under as thoroughly as possible.

The efficacy of the eradication treatments was measured by counting the number of sprouts per row (or for the whole plot where it had been plowed) before the treatments were applied, and at intervals subsequent to the treatments. The number of sprouts appearing after treatment was then expressed as a percentage of the original number present per row or per plot.

In Illinois and Minnesota, various times of plowing under, disking, and planting of different crops were tried, and the results were evaluated by inspection. The methods used in those instances will be mentioned in the discussion of results.

RESULTS

WASHINGTON, D. C.

It was found that turning the plants completely under when they were 2 feet high gave fairly good control. Three weeks later, less than 1 percent of the original sprouts had been replaced by new ones. Four weeks after plowing there was a replacement of about 600 sprouts per acre, none of the new sprouts being over 4 inches tall. It appears that planting a quick-growing hay crop after plowing under in mid-June would give practical control, for the small sprouts would be shaded out. If not shaded out entirely, the few survivors could be hand pulled.

Hoeing off the tops before plowing resulted in less efficient eradication than careful plowing under without hoeing. Four weeks after plowing there was a replacement of about 2,500 sprouts per acre, which is considered rather far from satisfactory control. That number of survivors in competition with another crop would no doubt be very troublesome. It is probable that the loose tops on the soil surface so interfered with thorough plowing that a large number of tubers escaped deep covering.

Attempted control by hoeing off the tops and following this by cultivation at 10- to 15-day intervals approximates probable conditions in the culture of an early planted row crop immediately after artichokes. This method was still less efficient than either of the two just described. Two weeks after hoeing off the plants there was an approximately 50-percent replacement, equivalent to about 7,700 sprouts per acre. Four weeks after hoeing (after three cultivations) there was still a 20-percent replacement of sprouts, so this method cannot be considered effective.

Plots 1 and 2 were hoed repeatedly to determine how many crops of sprouts need to be removed before the tubers finally become exhausted and further sprouting prevented. The results of repeated removals at 7- and 10-day intervals are shown in table 80. It will be seen that the second and first hoeings in the respective plots were followed by increases in sprout number. This was doubtless the result of multiple sprouting of tubers rather than appearance of original sprouts from tubers not previously sprouted. Removals at 7-day intervals were in general less effective than at 10-day intervals, as shown by the values after the second removal. It required six removals at 7-day intervals to accomplish the same results as five removals at 10-day intervals, although the elapsed time was a little less. These data show clearly that merely chopping off sprouts is a poor method of control or even of ridding a field of the occasional plants that survive the more efficient methods. Hand pulling is far better. Hoeing or sprout cutting alone, as a method of eradication, is entirely too expensive of time and labor.

TABLE 80.—*Effect of repeated removal of sprouts by hoeing on replacement of sprouts of Jerusalem artichokes grown under field conditions*

Removal by hoeing no.	At 7-day intervals		At 10-day intervals		Removal by hoeing no.	At 7-day intervals		At 10-day intervals	
	Total days after first hoeing	Sprouts produced between hoeings[1]	Total days after first hoeing	Sprouts produced between hoeings[1]		Total days after first hoeing	Sprouts produced between hoeings[1]	Total days after first hoeing	Sprouts produced between hoeings[1]
		Percent		*Percent*			*Percent*		*Percent*
1	0	100.0	0	100.0	5	28	15.7	46	3.8
2	7	80.0	10	141.6	6	35	4.4	59	.2
3	14	107.8	20	85.1	7	42	.2	69	.0
4	21	31.6	30	32.9					

[1] Expressed as percentage of original number of sprouts in plot.

ILLINOIS

In an effort to determine what crops should follow artichokes in the rotation, the following crops were grown in 1931 on ground which had grown a heavy crop of artichokes in the 1930 season: Soybeans for hay, Sudan grass, oats, and corn. The check plot was summer-fallowed. None of these crops was successful in smothering out the artichokes, although there was a considerable difference in the degree to which the artichokes were suppressed. The plot that was fallowed during the 1931 season was practically free from artichokes during 1932. Of the crops, soybeans and corn appear to be the least successful in the rotation following artichokes.

Artichoke tubers start developing during August, and the corn and soybeans cannot be removed in time to start eradication. The corn and soybeans were so heavily infested with artichokes in 1932 that no crops could be secured. It was necessary to fallow during most of the summer to prevent the artichoke tubers from maturing. The oats were removed when mature and the ground was plowed August 5. It was possible to crop this plot in 1932, but some hand weeding was

required. One plot was seeded to Sudan grass on May 15. The first crop of hay was removed and the plot plowed on August 5. Another plot was seeded to Sudan grass on June 15, and the first crop of hay removed and ground plowed by August 20. These plots were cropped in 1932, but some hand weeding was required to prevent volunteer artichokes from maturing.

A rapidly growing hay crop such as Sudan grass is the most successful crop in a rotation following artichokes. A small-grain crop is next best. It is necessary to remove any crop and plow the ground early and to practice exceptionally clean cultivation throughout the remainder of the season.

MINNESOTA

The Minnesota trials, observations, and conclusions regarding eradication of volunteer growth from the 1930 artichoke crop may be summarized as follows:

The plot was allowed to stand untouched until about June 1, when the young plants were about 12 to 18 inches high. It was gone over then very thoroughly with a heavy double tractor-drawn disk harrow. About the middle of June the plots were again thoroughly disked and worked with a spring-tooth harrow. At that time new sprouts had come up and were standing about 8 inches in height. The disking or harrowing destroyed nearly all of these sprouts, and an examination of the tubers indicated that they were rapidly deteriorating—becoming soft and in some cases decaying. About July 1 the ground was plowed as deeply as possible, the plow running 8 to 9 inches deep. At that time there were still a good many sprouts showing, although the number had been greatly reduced. This was followed by disking and harrowing until the ground was in good condition, when it was planted to Sudan grass. This made a very rank heavy growth and practically smothered out all the weak sprouts that came up after the first of July. Any tubers which survive this treatment and send up a sprout the following year can easily be removed by hand digging, since there will be such a small number that a man can easily go over an acre in an hour or so. If a hoed crop such as corn were placed on the land the year following the Sudan grass, there would be no difficulty at all in taking care of any stray sprouts that might remain. If the land should be planted to small grains the year after Sudan grass there would still be no difficulty, as the spring oats or similar crop would greatly discourage the growth of the artichokes and the crop would be cut before the tubers would form.

SUMMARY AND CONCLUSIONS

This bulletin reports the results of the cooperative investigations of 20 varieties and certain cultural practices relating to the growing of the Jerusalem artichoke. The studies were carried out at the following locations by the agencies named: (1) Near Washington, D. C., by the Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry, United States Department of Agriculture; (2) at Urbana, Ill., by the Illinois Agricultural Experiment Station; (3) at Excelsior, Minn., by the Minnesota Agricultural Experimen; Station; (4) at Corvallis, Oreg., by the Division of Forage Crops and

Diseases cooperating with the Oregon Agricultural Experiment Station; and (5) at Cheyenne, Wyo., by the Division of Fruit and Vegetable Crops and Diseases.

The various problems receiving consideration at two or more of the locations named were as follows: (1) Varietal adaptability; (2) effect of size of seed piece on plant development, yield, and size of tubers; (3) effect of depth of planting on yield and distribution of tubers; (4) effect of time of planting on yield and size of tubers; (5) effect of spacing in the row and between rows on yield per plant and per acre and on size and number of tubers; (6) relation of time of cutting tops for silage to crude-fiber content of tops, and to yield, size, and number of tubers; and (7) eradication of volunteer plants.

All plots except those relating to certain varietal studies were replicated at each place each year.

All data except those relating to eradication of volunteer growth were subjected to statistical study by Fisher's method of analysis of variance as adapted by Snedecor (7).

Of 20 varieties grown in Illinois, Oregon, and near Washington, D. C., for 3 years, three varieties were outstandingly superior in yield in all locations, namely, nos. 27574, 27095, and 27007, followed closely by no. 26944. High-yielding varieties tended to be so in all locations, and the converse was also true, although the order of superiority was not identical for all locations. These facts indicate a very wide range of adaptability of certain superior sorts but also show that differences in regional adaptation among varieties should be given consideration in selecting a variety or stock for commercial culture.

Analyses of levulose content of hundreds of stocks and varieties (made by the Bureau of Standards, United States Department of Commerce, in cooperation with the Bureau of Plant Industry, United States Department of Agriculture) have shown a disconcerting negative correlation between tuber-yielding capacity and levulose content. Despite this high negative correlation, no. 27574, referred to as the highest yielding variety, showed the highest 6-year mean percentage of levulose and total sugars of the 20 varieties discussed in this bulletin. Thus, the search for high-yielding, high-analysis varieties is an entirely reasonable one which should yield further valuable results.

In comparing yields produced from seed pieces ¼, ½, 1, and 2 ounces in weight, in Minnesota and Wyoming and near Washington, D. C., each successively larger piece produced successively larger net yields. (Net yield equals total harvest minus amount required for planting.) In Oregon, seed pieces greater than 2 ounces in weight produced no greater yields than did 2-ounce pieces.

Increasing the size of seed piece was consistently accompanied by increase in number of stalks per hill, regardless of location or season. Each hill was planted with a single seed piece.

Increasing the size of the seed piece was not accompanied by increase in mean size of tubers harvested. In Oregon, very large seed pieces, 4 ounces in weight, produced a smaller mean size of tuber than did 2-ounce or 3-ounce pieces, but such tubers were still of good size.

In none of these studies could any plantings practicably be made early enough to result in yields being significantly lower than from any subsequent planting. Although in the Washington, D. C., tests there

was no significant difference in yield of plantings at any time during April, the results from all other locations (where weather conditions necessitated later planting) showed very marked decreases in yield for every planting after the first one made under those conditions. With apparently "everything to gain and nothing to lose", the earliest possible planting is to be recommended, regardless of variety or location.

Time of planting appears to exert on size of tubers harvested an effect more or less comparable with that on yield. If the yield is depressed by delayed planting, so is the mean tuber size. These results apply to all varieties observed.

Although the different planting depths studied have far less effect on yield than certain other factors considered in this work, there is a slight but consistent difference in favor of the 4-inch depth over the 3-, 5-, or 6-inch depth in the humid regions. In the Wyoming tests only (irrigated) was the 5-inch depth superior to the 4-inch depth. In all locations, 3 inches and 6 inches gave consistently inferior results.

In Wyoming, planting depth was apparently without effect on depth of stolon origin, possibly on account of the narrow zone within which favorable moisture conditions were maintained by irrigation. Near Washington, D. C., however, successively deeper plantings resulted in successively greater percentages of the stolons arising from the stem at a depth below 4 inches. As no seed pieces were purposely planted deeper than 6 inches, very few stolons arose at depths greater than that.

Depth of planting was without effect on size of tubers harvested, but it had a marked effect on depth of tubers harvested in the Washington, D. C., studies. Based on either number or weight of tubers, successively deeper plantings resulted in successively deeper tuber formation. Few tubers were found below a depth of 6 inches, but the percentage of the total harvest that came from the 4- to 6-inch soil zone increased very significantly with deeper planting. Deep planting thus increases the difficulty of harvesting.

In all locations except Oregon planting distances between hills greatly affected the yields. In general, the 12-inch spacing gave higher yields than the 18-, 24-, 30-, or 36-inch plantings, but there were exceptions. In Oregon 2-, 3-, and 4-foot spacings yielded equally well.

The 12-inch spacings produced tubers of significantly lower mean weight than did the wider spacings, but there were no differences among the others. Unfortunately, size distribution of the tubers of the crops at the several stations could not be determined, but only total weight and number of tubers. Thus there is some question as to the advisability of recommending a 12-inch spacing for eastern and midcontinental regions, even though the mean total yields per acre were in general the highest by about a ton. Pending further information on this point, spacings of 2 feet in the row are recommended except for conditions similar to those of the Oregon tests, where 4 feet is adequate.

Studies of row distances of 3, 4, 5, and 6 feet with the plants 2 feet apart in the rows showed consistently the highest yields per acre from the 3-foot distance in all locations except Oregon. There, 4-, 5-, and 6-foot spacings with the plants 4 feet apart in the row gave no significant differences in yield per acre.

In all locations the effects of rate of planting on number and yield of tubers per hill were quite consistent. As distances between hills or between rows were increased, the number and yield of tubers per hill increased. Only in Oregon, however, was the increase in yield per hill great enough to result in a practically constant yield per acre for all planting distances observed.

In Minnesota and Wyoming and near Washington, D. C., the 12-inch row interval and the 3-foot row spacing both resulted in mean sizes of harvested tubers significantly smaller than any of the other planting distances in the respective studies. There were no significant effects of spacing on tuber size among distances of planting that resulted in 8 square feet or more of ground area per plant.

Maximum yields of green tops were obtained by harvesting just prior to blossoming, but maximum yields of dry matter of tops resulted from harvesting just after blossoming. Top harvesting delayed beyond this latter time results in great losses of both green and dry matter on account of dropping of leaves, and also, possibly, very marked food translocation to the tubers.

Removal of tops at such time as to obtain maximum yields of dry matter very seriously interrupts tuber development, reducing the otherwise ultimate tuber yield by 40 to 60 percent. Harvesting tops early enough to obtain maximum green weight decreases tuber yields 65 to 75 percent. Even the very latest top harvest likely to produce forage of even medium quality and yield reduces tuber yields about 30 percent.

There is a gradual increase of crude fiber in the tops in percentage of fresh weight, from the earliest probable top harvest until appreciable leaf fall begins, after which there is a much more rapid increase. After many leaves are lost, the tops are apparently of only mediocre value as forage. On the dry-weight basis, crude fiber remains nearly constant from the earliest harvest of tops until leaf fall becomes appreciable, then increases greatly.

It seems very improbable that really satisfactory yields both of tops for forage and of tubers can be obtained from the same plants. A given acreage or plot should be grown for but one purpose.

Volunteer growth cannot be efficiently controlled by merely chopping or cutting off tops or sprouts, since it requires at least a half dozen treatments to be effective. Deep, very thorough, late spring or early summer plowing, after the volunteer growth has attained a height of about 1½ feet, is very effective, particularly if followed immediately by a quick-growing hay crop that forms a dense cover to shade out the few surviving sprouts. Any survivors should be hand pulled or destroyed, incidental to harvest of the hay crop, before tuber formation in August.

BRIEF CULTURAL RECOMMENDATIONS

Grow only strains known to be high-yielding and of acceptable composition, color, and shape.

Use only good, sound seed tubers that are free from injury and disease.

Plant as early as the soil can be properly worked in the spring.

Plant seed pieces approximately 2 ounces in weight, preferably whole, but cut if necessary.

Except in unusually favorable regions for the crop, as in the semihumid, western part of Oregon, plant in rows 3 feet apart with seed pieces 2 feet apart in the rows. In localities comparable to Corvallis, Oreg., plant in rows 5 to 6 feet apart with seed pieces 3 to 4 feet apart in the rows.

Cover the seed pieces to a depth of 4 inches except in certain arid regions at high altitude where the surface soil dries out quickly. Under such conditions plant 5 inches deep.

If the crop is grown for its tubers, leave the tops undisturbed until they are killed by frost.

Follow artichokes next season with a late-sown, quick-growing hay crop or cultivated crop. Plow deeply and thoroughly when volunteer artichokes are a foot or more high. Hand-pull the survivors, unless they will be destroyed by harvesting the crop in which they are growing before August.

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