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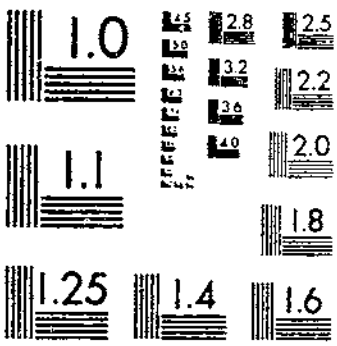

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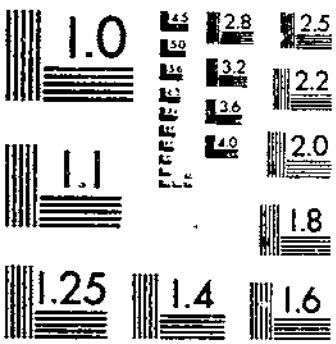

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THE JERUSALEM ARTICHOKE AS A CROP PLANT

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INTRODUCTION

The Jerusalem artichoke, *Helianthus tuberosus* L., is widely known but little used in the United States. It has been recommended in the past as feed for hogs, as a garden vegetable, and as a forage plant. Over a large part of the best corn-growing soils it will be long remembered as a persistent weed. It has recently taken on new interest from the announcement by the Bureau of Standards (*66*, *67*)[1] of a possible method of producing levulose from its tubers, and because of later interest in its possible value as a source of carbohydrates for alcohol manufacture.

The interest thus aroused calls for a thorough study of the plant, as there is now a widespread demand for various kinds of information about it. This bulletin is an attempt to collect and review what has been published up to 1927 on the Jerusalem artichoke, to serve as a basis for future work. Besides a summary of available literature, it includes a presentation of the results of preliminary work in the study of varieties and suggestions for improvement of varieties.

[1] Italic numbers in parentheses refer to the "Bibliography," p. 27.

163927—37——1

KINDS AND SOURCES OF SUGAR

Since this renewed interest in the Jerusalem artichoke is due to its furnishing a sugar, some information about sugars in general is given. Chemists recognize a long list of sugars, but the most common of these are sucrose, dextrose, and levulose.

Sucrose or cane sugar is widely distributed in nature and is the most readily obtained of all sugars. It is also the sugar most widely known and extensively produced. It is derived commercially in the United States from sugar cane, the sugar beet, and the maple tree.

Dextrose is found in a number of sweet fruits, in honey, and in the seeds, leaves, stems, roots, and blossoms of plants. Until recently it has been known commercially only in the unrefined form as brewing sugar, grape sugar, and under other trade names. It is an important ingredient of the sirup called glucose. It is now on the market in the pure crystalline form made from cornstarch.

Levulose or fruit sugar is found in many sweet fruits and in honey. Heretofore it has been very difficult to crystallize and has been made in the pure crystalline form only in small quantities and at very high cost.

In comparing these three sugars their relative sweetness is probably of greatest interest. Sweetness is not measured by chemical processes, but must be decided by tests in tasting by many persons. Individual capacities for delicate decisions as to taste vary greatly, so that figures expressing comparative sweetness will vary, depending on the method of conducting the test and on the number of persons who participate in the tasting.

Some recent tests of the comparative sweetness of cane sugar and levulose are here given. In all cases the sweetness of cane sugar is taken to be 100. The comparative sweetness of levulose has been reported by different investigators as follows:

1921. Th. Paul (*94*)	103
1922. Noel Deerr (*43*)	120
1922. Skinner and Sale (*103*)	150
1925. Biester, Wood, and Wahlin (*12*)	173.3
1927. Spengler and Traegel (*112*)	108

Dextrose is considerably less sweet than ordinary sugar, corresponding figures for it indicating that it is from 40 to 75 per cent as sweet as cane sugar.

Levulose takes up moisture much more readily than does cane sugar and will therefore lump more readily, and under extreme weather conditions of high humidity and high temperature it may liquefy if fully exposed to the air. It is also more soluble, and the coffee drinker who might use levulose for sweetening would find no undissolved sugar on draining his cup; also cakes and other foods made with levulose would better resist drying out than if ordinary sugar were used.[2]

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[2] Experiments in the production of levulose sirup from Jerusalem artichokes have been made by the U. S. Department of Agriculture, and this project is still under investigation in the Bureau of Chemistry and Soils.

Levulose bears the same relation to inulin that dextrose does to starch. Thus the occurrence of inulin in plants becomes of renewed interest.

Inulin was first discovered by Rose (*102*) in the rhizome of elecampane (*Inula helenium*) in 1804. It was first found in the Jerusalem artichoke by Braconnot (*17*) in 1824. It is a form of carbohydrate stored as reserve food by a number of plants. It is a white, tasteless powder, slightly soluble in cold water, very soluble in hot water, and insoluble in alcohol. It is found most abundantly in plants of the large order Compositae, in which the following species are recorded as containing it: *Artemisia vulgaris*, *Anacyclus pyrethrum*, *A. officinarum*, *Inula helenium*, *Arnica montana*, *Helianthus tuberosus*, *Tussilago farfara*, *Carlina acaulis*, *Arctium lappa*, *Cichorium intybus*, *Leontodon taraxacum*, *Scorzonera hispanica*, and garden varieties of dahlia. Doubtless other plants of this large family store their food reserves as inulin. This carbohydrate has also been found in the following families of plants: Violaceae, Malpighiaceae, Droseraceae, Candolleaceae, Goodeniaceae, Campanulaceae, Lobeliaceae, Myoporaceae, Liliaceae, Iridaceae, Amaryllidaceae, Poaceae, and in some Algae, e. g., the genera Neomeris, Acetabularia, Botryophora, and Polyphysa. This list is far from complete for known sources, and there must be many plant producers of inulin not known at present.

At the present stage of our knowledge the Jerusalem artichoke, dahlia, and chicory are the three plants which give most promise as producers of inulin. Of these, from the agronomic standpoint, the Jerusalem artichoke seems most suitable for the purpose.

BOTANICAL HISTORY, DISTRIBUTION, AND NAME OF THE PLANT

The first written notice of the Jerusalem artichoke is given by Champlain (*23*, *p. 107*, *117*), who speaks of seeing it in the gardens of the Indians at Mallebarre (now Nauset Harbor, Cape Cod, Mass.) on July 21, 1605. He says: "We saw also a great many Brazilian beans, and squashes of various sizes, good to eat; some tobacco and some roots that they cultivated, which had the taste of the artichoke." He is comparing the flavor of the new roots with that of the true artichoke (*Cynara scolymus*), a plant belonging to the same natural family. Although this is his first account of the plant, he must have known it from an earlier observation, since no tubers could have been obtained on Cape Cod at that season of the year. It is interesting to note that a day's careful search by the present writer around Nauset Harbor in November, 1925, failed to find any plant of Jerusalem artichoke. The soil does not promise well for the species, and in the 320 years since it was first seen it seems to have disappeared entirely.

Lacaita (*71*), who has carefully worked out the history of the plant, concludes that it was probably introduced into France by Lescarbot, a companion of Champlain. The first description is by Colonna in 1616 (*30*, *p. 13*), who figures and describes it from the garden of Cardinal Farnese at Rome as a plant very similar in

growth and flowering to many of the present-day sorts as grown at Washington, D. C. (Fig. 1.) The latitude and daily length of sunlight at Rome are those of the northern boundary of Pennsylvania. Colonna says the tubers were red. This may have been the same sort as that now known in France as Ordinaire.

Lauremberg (*72, p. 131*) in 1632 gives a more extended description with an illustration. (Fig. 2.) His work was done at Rostock, on the south shore of the Baltic Sea, which is in the latitude of southern Alaska. He shows a very different plant from Colonna's drawing, yet it is probably the same variety, since it does not bloom so far north, his account stating that it never blooms in Germany and only occasionally in Belgium following very hot summers. He says the tubers were red.

FIG. 1.—The original European variety of Jerusalem artichoke as it grew at Rome. (From Colonna's Ecphrasis, 1616)

The Jerusalem artichoke seems to have reached England in 1616 or 1617. The early accounts all credit the plant to Canada, which term then included much of what is now the United States. Linnaeus, who gave to the plant the botanical name which it still carries, in his first notice, Hortus Cliffortianus (*77*), says it is from Canada, but later in his Species Plantarum (*78*) he gives "habitat in Brazilia." This mistake was quoted for many years, and the plant was credited by the early American botanists as an introduced plant. Asa Gray's earlier editions of his Manual do not rank it as a native plant. It was as late as 1883 that Gray (*59*) concluded that it was native to the United States.

Its range is now usually given as from New York to Minnesota, southward to Georgia and Arkansas. Knowledge of its limits as a wild plant, however, is far from complete. If found north of the regions where it seeds it would seem reasonable to conclude that there

it had escaped from Indian or Caucasian cultivation. Surely the valley of the Potomac at Washington, D. C., is about as thickly dotted with colonies of seedlings as are those of the northern tributaries of the Ohio River.

The name "Jerusalem artichoke" has been a source of continual comment, since it is neither descriptive nor true. The first word has for many years been explained as an English corruption of the Italian word "girasole" meaning at present sunflower. The resemblance in flavor of the Jerusalem artichoke to the true artichoke has accounted for the latter half of the name. Lacaita (*71*) points out, however, that our English name Jerusalem artichoke was first used by Venner in 1622, which was earlier than there is any evidence that Italians used the word "girasole" for sunflower. Girasole was used in England at that time for the fire opal and for the castor-oil bean, and may have been applied to the new sunflower from these. The French name "topinambour" is as incongruous, though smoother. It is derived from a Brazilian tribe of Indians, some members of which in 1607 shared with the new tubers the enthusiastic interest of Parisians. It is also to be noted that the French now use the name "artichaut de Jérusalem" for our summer squashes of the flat-scallop varieties.

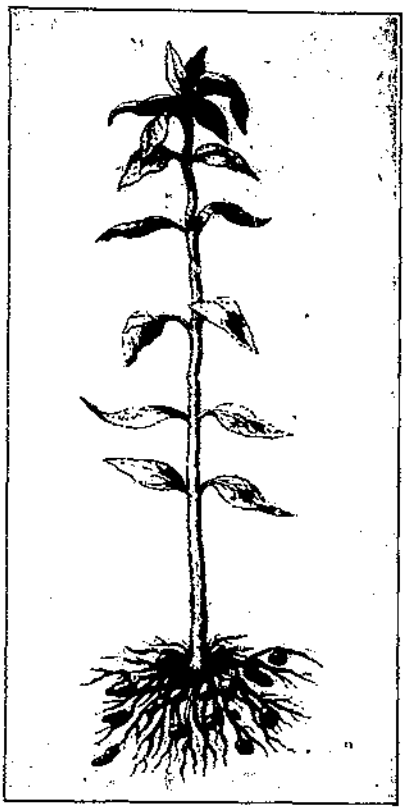

FIG. 2.—The same variety shown in Figure 1, but as it grew on the shores of the Baltic Sea. (From Peter Lauremberg, 1632)

The question of changing to a more appropriate name has been given consideration. Cockerell (*27*) suggests the present Italian name for sunflower, girasole. The Gardener's Chronicle, of London, England, in 1918 appointed a committee of three judges to award a prize for the best name. This award was given for the name "sunroot." Although both of these names have the merit of brevity, objections could be lodged against them, as against any other that might be proposed. It seems hardly worth while to try to change a name which has been in use for three centuries, unless it can be proved that it has led to confusion or that it has been a drag on the plant's popularity. Apparently neither can be well proved. Moreover, any attempt to establish such a change in name would probably be futile, as, if the plant does become important and popular, it may in all likelihood be called "choke" in spite of what may be written. Surely objections may be made to this name, but it, too, has the merit of brevity.

ECONOMIC HISTORY

The American aborigines of the eastern United States and of the upper Mississippi Valley used the Jerusalem artichoke as food, and outside of its natural range they doubtless cultivated it. Champlain found it in gardens on Cape Cod and at Cape Ann, Mass. It was noted on the St. Lawrence by early French explorers.

Indian agriculture was based on three exotic plants—corn, beans, and squashes. The seeds of these annuals had to be stored over winter and the plants had to be cared for to persist. Since this tuberous sunflower—the Jerusalem artichoke—required no care, the Indian usually gave it none, harvesting the natural crop. In this he is often followed by his Caucasian successor.

Among the most advanced agricultural tribes at the coming of the whites were the Iroquois of western New York. Parker (*93, p. 105, 106*) was not able to find any evidence that these people cultivated the artichoke, but he says that it often grew spontaneously in the alluvial land of their cornfields and was eaten raw or roasted for their camp dinners or husking parties. "Some women became especially fond of them," he wrote, "and were called 'artichoke eaters,' a term which survives to-day among the Seneca." It was then apparently knocking at the door of Indian agriculture very much as it is at ours to-day, and had never become an important cultivated plant to the Indian.

Its initial reception by the Europeans was enthusiastic, if we may judge by the praise given by men who wrote of it. Its "marvelous" productivity and its general usefulness are often recounted. It may well be doubted if this interest was ever widespread or that it reached the mass of the peasantry in any country. After a few years of enthusiasm its novelty wore off for its new acquaintances, and it is not now an important human food anywhere.

It has never lacked admirers, however, and when war or famine have laid heavy hands on humanity the question as to why more use is not made of this insistent producer is always raised. Toward the end of the Thirty Years' War, Thuringia largely fed what men and animals were left on the Jerusalem artichoke. The popular and horticultural press showed increased discussion of this plant at the time when Ireland suffered from the potato disease in the middle of the last century, also when French vines were dying from phylloxera, and during and following the World War.

Europe generally has taken the crop more seriously than America has. Seed catalogues from Scandinavia to Spain list it, and most of the careful scientific work on the plant in the past has been European; yet too often the attitude of the European cultivator has been that of the American Indian. Since it could so well take care of itself, not much care has been bestowed on it. The plant has been put into out-of-the-way corners, where the only attention given to it was to harvest the tubers when wanted. When treated in this way it will give small harvests of small tubers.

In France alone has the crop been large enough to be given statistical treatment, which began in 1903. The figures are given in Table 1.

TABLE 1.—*Acreage and yield of Jerusalem artichokes in France*

[Compiled from Statistique Agricole Annuelle, Ministère de l'Agriculture, Paris]

Year	Acres	Pounds per acre	Year	Acres	Pounds per acre	Year	Acres	Pounds per acre
1903	267,000	14,037	1911	247,000	11,746	1919	259,000	9,215
1904	245,000	9,828	1912	254,000	14,420	1920	284,000	8,345
1905	245,000	12,502	1913	274,000	14,430	1921	278,000	9,431
1906	230,000	6,672	1914	270,000	14,718	1922	288,000	10,314
1907	237,000	8,808	1915	208,000	11,265	1923	301,000	9,540
1908	232,000	14,030	1916	206,000	12,449	1924	315,000	14,280
1909	250,000	14,048	1917	250,000	12,014	1925	324,000	17,060
1910	240,000	15,429	1918	248,000	9,207	1926	330,000	11,081

It is of interest to note that artichokes lost very little ground during the war. Potatoes in France lost 16 per cent of their acreage from 1914 to 1920.

The map of Jerusalem-artichoke acreage in France shows that the plant is grown mainly in the region bordering the corn section to the north. It coincides with a part of the region of heaviest potato production.

The United States has never planted any very great acreage to the Jerusalem artichoke. No American statistics of the crop have been found. It has been recommended mainly for feeding hogs, but it has had to compete with another native American product for that purpose—Indian corn or maize—and in that competition it has been outclassed. The regions of its greatest use for this purpose are outside the best maize-growing sections. The South and the Pacific Northwest probably grow more than other sections do.

USEFULNESS OF THE PLANT

All parts of the plant may be used for feed, forage, human food, or for manufactured articles. Some French investigators suggest the use of the stalks for fuel and of the pith for holding material for free-hand cutting of sections for the microscope. Some of its uses are considered in the following paragraphs.

AS FEED AND FORAGE FOR LIVESTOCK

The most extensive use that has yet been made of the Jerusalem artichoke is as feed and forage for livestock. Nearly all of the French crop of 2,750,000 tons (in 1925) was used for feeding cattle, sheep, hogs, and horses. This use in France was well started half a century ago. A writer in the American Agriculturist in 1866 (*1*) speaks almost jestingly of the Frenchman's enthusiasm for this "root" which "everyone remembers that he used to dig in the old garden, and as a boy used to crunch and consider good." Prieur (*98*) in 1869 and Delagarde (*44*) in 1871 tell of its being extensively used for fattening cattle in Charente and Vienne, two Departments of France where it is now an important crop. Beeves fattened on artichoke were killed in April, and with very satisfactory results. Jerusalem artichokes were often fed to lambs, and it is asserted that lambs could be thus fattened with the addition of oat straw. In

France these artichokes are not so frequently fed to hogs, and when so fed they are usually cooked. Gouin (*56*) says that hogs may be fed 10 to 13 pounds a day with 9 to 10 pounds of kitchen refuse and 1½ pounds of peanut cake. For 10-weeks pigs he recommends 6½ to 9 pounds of cooked Jerusalem artichoke, one-fifth of a pound fish meal, and half a pound of peanut cake. In the south of France the artichokes are also fed to work horses. They are not extensively used in any other European country.

In the United States but little careful work has been done to determine the feeding value of Jerusalem artichokes. They have been recommended for feeding hogs and have been more used for this than for any other purpose. Apparently hogs have usually been allowed to harvest the tubers as needed.

The Oregon Agricultural Experiment Station in 1898 published a bulletin, Feeding Artichokes to Pigs (*53*). The experiment therein reported was based on one-eighth of an acre, which was estimated to have yielded at the rate of 740 bushels of tubers to the acre. Six pigs were weighed in on October 22 and were kept on the plot until December 11. They were fed 756 pounds of mixed wheat and oats, and they gained 244 pounds. If it takes 5 pounds of grain to make 1 pound of gain, as this bulletin estimates, then the plot of artichokes was responsible for 93 pounds of this gain, or an acre of artichokes at this rate would give 744 pounds of pork. No other feeding experiments on which to check these results are available.

Evvard and others (*50*), working in 1925 at the Iowa Agricultural Experiment Station, conclude that it does not pay to "hog up" Jerusalem artichokes unless some use can be made of the tops for forage.

F. D. Coburn (*25, p. 112–116*), in his treatise on Swine Husbandry, published in 1877, praises the Jerusalem artichoke very highly and gives examples of farmers who successfully use it.

The late Joseph C. Sibley, of Franklin, Pa., had probably used the plant as extensively as anyone in recent years. He found it to be satisfactory for feed for nearly all the animals of his farm (*109, 110, 111*).

In addition to the tubers, the stems and leaves may be used for forage. In regions where maize does not grow well, sunflower is used for silage and for forage. Jerusalem artichoke stems in Europe are sometimes cut and cured as corn stover is handled in the United States, and they are sometimes used to fill silos.

Mottet (*87*), writing in 1926, complains that the stems and leaves are too often neglected as a source of forage. He compares the food value of the tubers with that of the stems and leaves, as shown in Table 2. His analyses show that the parts of the plant above ground are richer in three of the food substances but much poorer in starches. He says that the tops of Jerusalem artichokes weigh from 9 to 14 tons green weight per acre. The variety Fuseau, grown and recommended by Vilmorin-Andrieux, of Paris, as a garden vegetable, is especially recommended as producing a very heavy yield of forage. Mottet recommends cutting while the stems are green and succulent, and he asserts that repeated cuttings can be made for soiling.

TABLE 2.—*Comparative food value of stems and leaves and of tubers of Jerusalem artichoke, as shown by analyses by Hottet (87)*

Parts of plant	Constituents (per cent)			
	Fat	Protein	Pectin	Starch (inulin)
Stems and leaves	0.38	2.54	5.47	1.90
Tubers	.11	2.10	3.10	13.30

In Hungary sheep and hogs for many years have been allowed to forage on the tops and tubers of Jerusalem artichoke.

The agricultural experiment station of the State of Washington counts sunflower silage as 90 per cent of the value of corn silage. Jerusalem artichoke, being not quite so coarse in stem as sunflower, and having a greater number of slender branches, should make a slightly better silage. It is, of course, necessary to take tuber formation into account when cutting the tops for silage; and the best period for cutting, so that the crop of tubers shall not be lessened too much, is still a subject for study. (See U. S. Dept. Agr. Tech. Bull. 514.)

AS A WEED ERADICATOR

Jerusalem artichoke makes so dense a shade as to smother most competing plants. Schribaux (*106*), writing in 1917, gives as one of the important reasons for wider use of this plant that it would eradicate weeds from the neglected soils of France. He states that two years of its culture, or one year if it is given good help with a hoe, will clear soil of quack grass. The United States Department of Agriculture has recently received a letter from a correspondent at Des Moines, Iowa, who reports that the plant is very successful in overcoming quack grass.

FOR ALCOHOL MANUFACTURE

The tubers have been investigated as a source of alcohol. Du Mont (*47*) in 1877 estimated a yield of 60 to 100 liters per long ton of tubers. In the artichoke-growing region in France, alcohol factories in recent years have worked up some of the crop.

FOR HUMAN FOOD

The Jerusalem artichoke has had a varied history as a human food. When first introduced into Europe it was accepted with great enthusiasm, but within less than 20 years after its introduction into England Parkinson complained that even the poor people despised it. It is very doubtful if the "poor people" had ever accepted it. Lauremberg, writing in 1632 (*72, p. 131*), gives five very good recipes for the preparation of the tubers for the table, and it would be possible at present to collect a considerable list of published recipes. The vegetable must everywhere have devotees who continue to use it, but nowhere is it an important human food.

Newman (*91, p. 157–158*), writing in 1855, says that Jerusalem artichokes were formerly more extensively used, but adds: "The supposition, however, having obtained credence that these were very unhealthy, tending to produce flatulency and dyspepsia, has almost sunk them to oblivion." Miller, in the Gardener's Dictionary, 1771 (*84*), mentions the same objections to their use.

Much work has been done, without success, in an attempt to find in the digestive tract of the higher animals an enzyme similar to inulase, which will work on inulin, and some writers have concluded that the plant has very little value as food on this account. Bierry (*11*), in 1910, introduces his paper with the remark: "Inulin is a good food; many beeves are fattened on it." Yet he finds no digestive enzyme capable of working on inulin. The general conclusion seems to be that the conversion of inulin into levulose is performed in the stomach by the acids of the gastric juice. Surplus inulin which passes into the intestine may, therefore, in the absence of a proper digestive enzyme, undergo bacterial decomposition, with gas formation.

A test of the digestibility of Jerusalem artichoke was made by the Food (War) Committee of the Royal Society of England in 1918.[3] A standard diet containing 1 pound of potatoes was fed to three persons for five days, analyses of feces being made for the last three days. This was followed by a five-day test with the same diet having a pound of Jerusalem artichoke tubers substituted for the potatoes. The whole diet furnished 3,000 calories per day, 375 of which was derived from potatoes or from artichokes. The results showed that for the first period an average of 96.8 per cent of all the energy in the diet was absorbed, as against 96.1 per cent for the second period.

They give the following summary of results:

> It will be seen that the data show somewhat marked individual variations. In the case of one subject (B) the substitution of artichokes for potatoes had practically no effect at all upon the availability of the dietary. In a second subject (A) the effect was more noteworthy, though not considerable; in the third (C) it was marked.
>
> The experiment as a whole shows that artichokes are probably less well utilized than potatoes, but it shows, nevertheless, that they possess real value as human food.
>
> Potatoes and artichokes each contributed 12½ per cent to the energy contained in the respective diets. Taking the average of three subjects, the increased loss of energy in the feces of the artichoke period as compared with the potato period was 23 calories per individual per day—only 0.8 per cent of the calorie value of the whole diet.
>
> It is of course impossible to decide what is the absolute digestibility of the artichoke from an experiment in which it yielded a comparatively small proportion of the whole food value of the diet. It can not, however, be eaten by most people in quantities much larger than those chosen for the experiment without the occurrence of flatulence. In the case of subject C, who, as will be seen from the figures, digested even the potato dietary less well than the other subjects, the consumption of a smaller proportion of artichokes would, to judge from later experience, have led to relatively better utilization.
>
> The experiment shows that when eaten in reasonable quantities artichokes can replace so well-tried a food as the potato in a not unsatisfactory manner, and have a food value which is certainly not to be neglected in a time of shortage.

[3] A copy of private and confidential report No. 40, issued by the Royal Society, Mar. 11, 1918, over the signature of F. Gowland Hopkins, professor of biochemistry, Cambridge, "The artichoke as a source of carbohydrate," was furnished to the Department of Agriculture by United States Senator R. B. Howell.

It seems certain that ordinary methods of cooking will give opportunity for a considerable amount of inulin to be changed to levulose during the cooking process.

Root and Baker (*101*) conclude that diabetics can use both levulose and inulin to a much greater extent than ordinary sugar and starch. Even with the insulin treatment there is need for foods that the patient can tolerate, but the medical profession is by no means in accord in its attitude toward the Jerusalem artichoke for diabetics.

RECIPES [4]

The Jerusalem artichoke is rated as a low carbohydrate food, presumably on account of the low availability of its carbohydrates to the human digestive system. Hence it is of some interest to diabetics. It is popular if cooked so as to retain the flavor.

Preparation.—The tubers which grow wild are often small and irregular, and therefore tedious to pare or scrape. Both for this reason and because of their very mild flavor, baking in their own skins is one of the best methods of cooking. They must be well scrubbed with a stiff brush.

Baked Jerusalem artichokes.—Bake in skins 30 to 60 minutes according to size in a slow oven. They may be served in the skins and eaten with butter. Or they may be scraped out with a fork and spoon, mashed, and seasoned with salt, pepper, and a little butter or a very little cream. They should be sweet and piquant in flavor, if properly handled.

Boiled Jerusalem artichokes.—The Jerusalem artichokes may be boiled in their skins and peeled afterwards. This is one of the best ways of preserving flavor. If pared before boiling, the vegetable should be thinly sliced, very little water should be used, and it should be boiled down almost dry at the close. Small tubers may cook tender in 15 to 20 minutes. Season with butter or cream, salt, pepper, and a little lemon juice or nutmeg if liked. The flavor is much enhanced by cooking in milk or in a good meat broth. Or boil with a tablespoon of minced carrot and a teaspoon of minced onion to each pound of tubers. Or use minced chives, shallot, leek, or celery.

Serve the boiled vegetable in cream or other well-seasoned sauce. Or bake in cream sauce with a sprinkle of grated cheese. Or fry it with chopped leeks, celery tops, or parsley in a little butter, adding white sauce later if desired.

Jerusalem artichokes en casserole.—Pare, place in baking dish whole or sliced, cover closely and bake in slow oven till done, or about one-half to one hour, removing the cover of the baking dish toward the close if necessary to dry out excess moisture. Season with butter, salt, and pepper. Add grated cheese or buttered crumbs or both, when liked.

Fried Jerusalem artichokes.—Pare, slice very thin, soak 30 minutes in cold water. Dry between towels, drop into very hot oil or lard (at 400° F.), fry to a crisp chip. This method brings out sweetness and flavor very well. These chips if properly made are usually judged superior in flavor to those made from potatoes.

Jerusalem artichokes in salad.—The fresh texture of the tubers makes them very desirable in salads, and they could probably be used acceptably in certain other dishes like chop sueys and chow mein. From this point of view they are very similar to the Chinese water chestnuts. In using them in salads, peel, slice thin, and dice; serve alone on lettuce leaves mixed with water cress, or as a part of a vegetable salad composed of tomatoes, cucumbers, onions, peppers, and radishes, or in other combinations. Serve preferably with French dressing.

Quick Jerusalem artichoke soup.—Heat 4 cups of milk in a double boiler, add 1 tablespoonful of flour creamed in 2 tablespoonfuls of butter. Lift out, place directly over the fire, and let cook to a boil to thicken. Add 2 cups of grated raw artichokes, 1¼ teaspoons salt, one-half teaspoon grated onion, and one-half teaspoon chopped parsley. Let heat through for 5 minutes and serve.

Puree of Jerusalem artichoke.—Boiled tubers may be used in the preparation of puree. Prepare and cook just as you would puree of potato. Jerusalem artichokes give a surprisingly good flavor to soups of this type.[5]

[4] Prepared by the Bureau of Home Economics.
[5] Adapted from Sibley (*101*).

Fried Jerusalem artichokes.—Left-over boiled tubers may be mashed, formed into patties, dipped in egg and crumbs, and fried in deep fat or sautéed in butter.[8]

Jerusalem artichoke surprise.—Pare the tubers, cut lengthwise into pieces approximately three-fourths inch in size. Dip in egg and crumbs, and again in egg and crumbs until thoroughly coated. Fry in deep fat, until certain that the pieces are thoroughly done. The fat must not be too hot or the crumbs will burn before the artichoke is completely cooked. Place on soft paper in a pan, put in the oven a short time in order that the fat may be absorbed.[8]

DISADVANTAGES TO BE OVERCOME

Altogether the various uses and the hardiness and productiveness of the plant have made enthusiastic advocates of most investigators. A very frequent conclusion to a paper on the study of *Helianthus tuberosus* is the suggestion that it should be used much more extensively than it is, and sometimes an attempt is made to explain its lack of popularity. It will be worth while to recount some of these reasons, and possibly to suggest means of overcoming them.

The Jerusalem artichoke is handicapped by being regarded as a competitor of the potato, both being tubers, and when cooked it is always compared with that vegetable. This is not a just comparison, since the two are very distinct in composition and character. In flavor and food value it is much more suggestive of the globe artichoke and salsify, members of its own family, than it is of potatoes. There should be no competition between the two. The Jerusalem artichoke has probably lacked the active and long-continued campaign for its popularization to which the potato has been subject. It is easy to forget that a century and a half ago horticultural Europe was in the midst of an earnest discussion as to whether potatoes were worth growing, Cobbett in England asserting that anyone who advocated their cultivation was not a patriot. Their merits had to be insisted upon and fought for foot by foot. The peasantry in places were subsidized to induce them to grow and use potatoes, so hard was it to change food and agricultural habits. It is of interest, too, to note that France in 1920 grew many more hectares of Jerusalem artichoke than she grew of potatoes in 1820.

Besides these difficulties which might accompany any new agricultural plant, there are a number of peculiarities to which agricultural practice may be adjusted so as to minimize them or even to nullify them as disadvantages.

Probably first in these characters is the rapid loss of water when the tubers are exposed to the air. Decaisne (*42*) in 1880 pointed out that they lack the corky layer which covers the potato. This causes the tubers to shrivel on exposure to the air, and makes it difficult for a grocer to handle supplies in the same way as potatoes. However, tubers were stored in burlap bags in a cold cellar at Washington from November, 1925, to March, 1926, without shriveling or other difficulty. The temperature never got quite to freezing but was always cold. The tubers are also liable to storage rots, especially to sclerotium diseases. Some varieties seem to hold up better than others, and there may be storage temperatures at which this fungus would be quiescent. The French writers agree, however, that the tubers are very difficult to keep by any common storage methods. This has had much to do in deciding the geography of the crop in

[8] Adapted from Sibley (*111*).

France. They are planted where the winter is mild enough for them to be harvested as needed. As may be said about many phases of our knowledge of the Jerusalem artichoke, this subject is still a fertile field for investigation.

Its second character to be considered is its hardiness, which has given it the reputation of being a weed. Exotic plants which persist only when they are properly planted and cared for are commonly cultivated as farm and garden crops. Clovers and forage grasses become naturalized, but they succumb when plowed under. The Jerusalem artichoke is a native plant grown as a crop in its home region, where it has won its way in the keenest competition for the richest lands. In the United States many farmers in the rich alluvial valleys and on the prairies of the Mississippi Valley are all too well acquainted with Jerusalem artichoke. There are valley lands subject to overflow which have grown corn continuously for well over a century. If they grew *Helianthus tuberosus* at the beginning it is probably growing there yet. The Indian-corn farmers' practice is not adapted to the eradicating of the plant. The cultivation of corn ceases when the crop is "laid by," usually by the middle of July. Thus the underground tuber may have had its stalks cultivated off or broken one to three times, but it

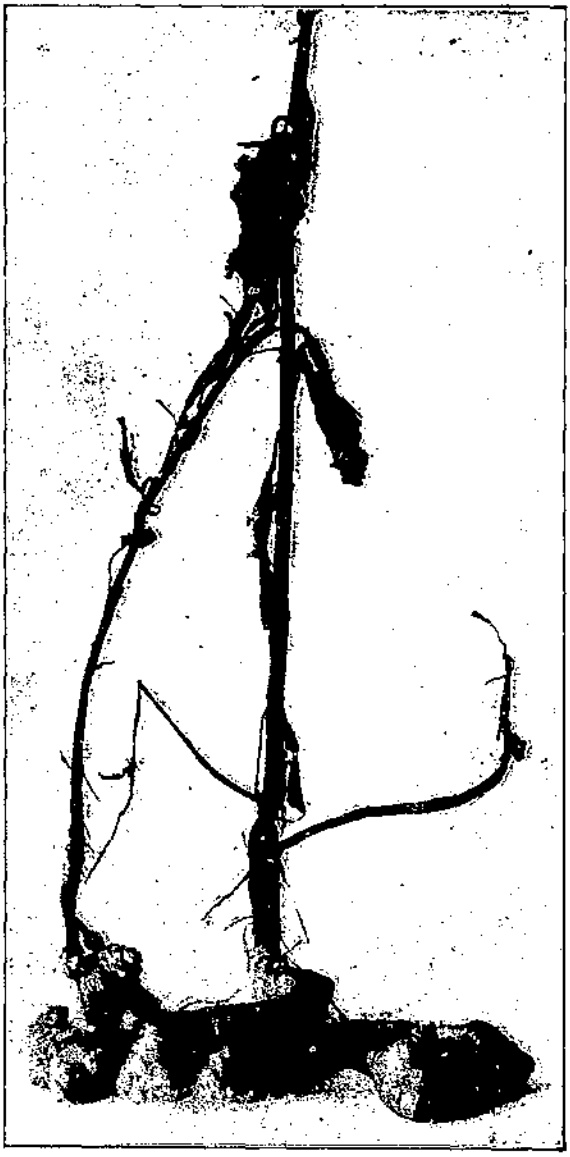

FIG. 3.—A plant of white Jerusalem artichoke grown from Australian tubers planted the middle of August near Washington, D. C. The stem was not more than 18 inches high and did not bloom

will not have lost power to grow. When the year's cultivation is over it is still able to send a shoot to light and air. It is well able to grow under the light shading of the Indian-corn crop, and it may be able to reach a height of 2 or more feet before frost. It will make a good crop of tubers (fig. 3) and will be in good condition to continue its growth the next year and in succeeding years. This experience in limited corn-growing regions has given the plant an undeserved reputation as a weed, since such continuous corn culture is very limited in extent.

Where Indian corn is grown in rotation with forage grasses and small grains, however, the Jerusalem artichoke loses all its terrors as a weed. The writer is acquainted with a farm in the Miami Valley of southwestern Ohio where there is a strip of valley land bordered by a county road which has been located for about a century. In the dense bluegrass sod on this roadside is to be found here and there a plant of Jerusalem artichoke. It has never been a weed in cultivated crops in the adjoining fields, at least not in the last half century. It must be remembered, also, that in France the annual plantings of more than 300,000 acres are mostly in a rotation.

The proper time at which to attempt the destruction of this plant is when the mother tubers are exhausted and before the new crop is formed. If the plants are allowed to grow freely, the old tuber will be about spent by the latter part of June at Washington, D. C. The new tubers begin to branch out in the last half of July, but it may be some time before they can be used for propagation. If then, after free growth, the plant is cut in midsummer, it will be largely destroyed at one operation.

This is usually what happens in French rotations, some of which are as follows: (1) Jerusalem artichoke, (2) oats, (3) clover, (4) wheat. The stems growing in the oats are of no serious disadvantage and are harvested with the crop, adding value to the oat straw when cured. When the clover crop is cut the succeeding year the artichoke is completely destroyed. Another rotation is (1) Jerusalem artichoke, (2) spring vetch, (3) wheat, (4) oats. The vetch and artichoke are harvested together. A six-year rotation is sometimes followed on better lands: (1) Jerusalem artichoke, (2) oats, (3) clover, (4) wheat or rye followed by turnips, (5) potatoes, (6) wheat or rye and turnips.

Another way to avoid the weed menace is to keep the same piece of ground continuously in Jerusalem artichoke. Villeroy (*119*) in 1869 recounted his experience with about two-fifths of an acre of ground which he had had in this crop for 40 years. After digging he plowed and harrowed, picking all the tubers obtainable. The plot was then immediately lined off and planted, and all volunteer plants were treated as weeds in the next year's cultivation. He manured the plot every other year and got an annual yield at the rate of about 6 tons of tubers to the acre. He intended to keep up the plan while he lived. There are records of other fairly satisfactory continuous culture plantings in France. This method, if successful, would be an anomaly to the best farm practice, and it is probably not the best way. After all, it seems strange to count as a disadvantage the tendency of a valuable plant to grow too well. This character at least promises well for the ease and certainty of a crop when wanted.

Another objection often raised to the tubers as vegetables is their irregular shape. This characteristic is probably less marked as the culture is carried north into a short growing season, and it can be controlled to a considerable extent by cultural methods. In a planting of any size the tubers are always much rougher in the outer rows, where growth is unrestrained by competition; therefore a small garden plot with full sun on one side of nearly all the plants will give much rougher tubers than will be found in the middle of a larger plot. Vilmorin-Andrieux, Paris seedsmen, have put out a variety Fuseau ("the spindle") which bears elongated tubers much smoother than the ordinary sorts.

Many varieties, in fact most of them, scatter their tubers in the soil more widely than potatoes as grown near Washington, D. C. There is very great difference in varieties in this regard, and the best can probably be improved upon in future selections.

Another character peculiar to the Jerusalem artichoke among field plants is its reliance on length of day for tuber formation. It will not form tubers during the long days of summer, but will make tubers and blossoms only when the days become shorter toward fall. When placed in an artificially shortened day in 1925 at Washington it bloomed, formed tubers, and died by midsummer.[7]

At Washington any variety of potato may be planted in very early spring or in the latter half of June. These crops will ripen in corresponding season, making an early and a late crop of potatoes. Jerusalem artichoke was planted in late March in 1925, and through cold storage of tubers this planting was continued at short intervals to August 15. The yield varied, but the whole set of plantings formed tubers at the same time. It therefore appears that with our present varieties of Jerusalem artichoke there can be only one crop in a year. This point of difference is possibly no disadvantage, yet it throws the harvest into late fall or very early spring, when soils are most apt to be in poor condition for handling. Frequently there are seasons when it would be a decided advantage to have at least part of the crop mature a month earlier than at present.

Where hogs are allowed to harvest the crop this lateness of tuber formation is often harmful, especially on heavy soil, which may be puddled to its very great injury by the hogs in uprooting the tubers.

The foregoing seems to be a fairly full statement of the points wherein agricultural practice may be required to specialize to fit the Jerusalem artichoke if it becomes worth while to grow the crop extensively. None of the adjustments seem difficult to make.

ADAPTATION AND CULTURE

REGIONAL ADAPTATION

The Jerusalem artichoke is apparently adapted for growing over a large part of the world's surface. It is known and grows luxuriantly in all of Europe. Perry (*95, p. 44*) found it being grown in the Loo Choo (Nansei) Islands. It is planted in India and throughout the temperate regions of the Southern Hemisphere in New Zealand, Australia, South Africa, Argentina, and Chile. It has recently been tried at all the experiment stations in Alaska, where it promises to

[7] The test of Jerusalem artichoke in the artificially shortened day was made by H. A. Allard, of the Bureau of Plant Industry, United States Department of Agriculture.

be a valuable forage addition to the crops of that region. In latitudes equal to its native habitat, or higher, it grows much as has been described, setting its crop of tubers just before frost. In tropical regions where all days are short there is yet need of exact knowledge. Piper (*97, p. 409*) tells of a disappointing experience with it in the Philippines, although other reports from these islands are not so discouraging. Freeman and Williams (*52, p. 8*), writing in 1918 at Trinidad under the urge of the slogan "Food will win the war," call it an excellent substitute for the potato, which is not discussed in their paper. They advise planting in succession at intervals of six weeks through the rainy season, when "a supply can be obtained for the greater part of the year." Macmillan (*79, p. 314*), writing in Ceylon in 1925, says that it is there one of the most successfully cultivated of Temperate-Zone vegetables. He states that it reaches about one-half the height attained in temperate regions and that it matures its tubers in about four months.

Experience at Washington, D. C., leads to the conjecture that in the uniformly short days of the Tropics its growing season would shorten and that two crops or a succession of crops could be grown. What this length of growing season is for different varieties and what effect the shorter length of day may have on yield and tuber composition are not known.

SOILS

The Jerusalem artichoke is adapted to all soils except those too wet. It will give a better account of itself in poor soils than will other root and tuber crops. It is called in France "the poor-soil beet" and is largely planted in soils which would return little in potatoes and nothing at all in beets. Schwerz (*107*) says that "the Lord in His bounty has not forgotten poor sandy soils, for He gave them the Jerusalem artichoke and spergula." One decided advantage of sandy soil is that the tubers do not carry so much adhering earth at harvest time. Under extreme conditions in heavy clay soil this has been known to make up 40 per cent of the harvest. Jerusalem artichokes repay good culture in good soil as abundantly as any crop.

FERTILIZER

French and German literature contains reports of a number of fertilizer experiments which are fairly agreed that potash is an important addition to most soils for maximum returns. Chemical fertilizers are applied in addition to 10 to 14 tons of stable manure per acre.

PLANTING

Planting may be done in the fall at harvest time, or at any time when the soil can be worked until growth begins in the spring. Probably early spring planting is somewhat better, if the soil is heavy.

No report of experiments on planting distance is at hand. The spacing should vary in accordance with the latitude. In the northern peninsula of Michigan, where the plants reach 6 feet in height and do not flower, they may be planted closer than at Washington, D. C., where they often grow 10 feet high and have a corresponding spread. Vilmorin recommends rows 2½ to 3 feet apart and a spacing of 12 to 14 inches in the row. Brétignière (*18, p. 176–200*) recommends

rows 25 to 30 inches apart and plants spaced 12 to 20 inches in the rows and says that 20 to 26 bushels are required to plant an acre.

For field culture at Washington a spacing between rows of one-fifth of a rod (3.3 feet), with the plants 18 to 20 inches in the row, has been found to be very satisfactory. The spacing given for Indian corn through the Corn Belt would be well adapted to artichoke. In variety trials at Washington the plants have been spaced in rows two-fifths of a rod (6.6 feet) apart and have been planted seven or eight plants to the rod of row. When so planted on good soil they have fully occupied the space and completely shaded the soil, and for some varieties the distance was none too great to avoid the mingling of tubers from adjacent rows.

The planting of whole tubers of the smaller sizes has been found very satisfactory, 6 or 7 bushels being needed to plant an acre. The larger tubers can well be cut into pieces, as for potatoes, when the planting would be at the rate of 5½ to 6 bushels to the acre. (See U. S. Dept. Agr. Tech. Bull. 514.)

CULTIVATION

Because of its strong-growing, wide-branching habit and its large heavy leaves, the Jerusalem artichoke is doubtless the most easily cultivated tuber or root crop to be found in the Temperate Zone. No handwork is needed, and after July 1 the planting will overshadow and kill any weeds. Mounet (*88*) recommends ridging the plants when they are 8 inches high, which is more necessary if the soil is damp in winter; otherwise the tubers are apt to rot in the wet soil.

HARVESTING

There is nowhere available any exact record of the cost of harvesting. A large part of the crop in the United States has been harvested by hogs. In France the tubers are dug as needed, probably by hand, and are fed shortly after digging. Sibley (*110*) reported that he had no difficulty in digging the crop with a potato digger. With some of the present-day varieties with shortest tuber stems it would surely be possible to obtain a large proportion of the tubers with this machine. There is one essential difference in habit between potatoes and Jerusalem artichokes which it may be necessary to take into consideration in the matter of machine digging. The potato vine is weak and often has died before harvest. The artichoke stems are strong, and growth continues to the time of harvest. Potato tubers thus readily separate from the stems and fall apart, while the artichoke tubers form a large mass at the base of the stem, intertwined with the roots, from which they are not easily separated. More work is thus required in picking artichoke tubers from the furrow than in the case of potatoes. Artichoke tubers are much more subject to damage in handling than potatoes.

YIELD

So few exact data are available in this country that not much can safely be said as to the yield of Jerusalem artichokes. In France records are more reliable, but they probably can not be applied entirely

to American conditions. The figures for average yield given earlier (Table 1, p. 7) show the returns year by year since 1903. Brétignière (*18*) gives the average production of France for the decade 1911–1920 as 12,280 pounds per acre. The corresponding figure for potatoes is about 6,700 pounds. For several reasons it would not be worth the time to try to estimate from these figures the probable yields in the United States if the crop were grown extensively. (1) In France this yield is made on soils so light that they are usually not planted to potatoes. In the United States it will probably be desirable to give the best soils to the artichoke crop. (2) France is farther north than the United States will probably grow artichokes, and her crop may be lower on this account. The same author says that French poorer continuous-culture plantings give from 7,200 to 10,800 pounds per acre, the good cultures 13,500 to 21,500 pounds per acre, and that often 27,000 pounds per acre is exceeded in the best. Mounet (*38*) in 1925 says that with the same opportunity and culture their yield will equal that of forage beets.

As to yields in the United States, there is surprisingly little that can be said. The method of growing for hogs has not lent itself to yield statistics. Usually any figures given are estimates, and these are often in bushels of unstated weight. Sometimes, too, a small plot has been grown in a garden, and the yield has been calculated up to an acre basis. This is a very unreliable procedure and usually overstates the crop, because gardens are usually more fertile than fields and a small plot exposed to sunlight on all sides is not a fair sample on which to compute the yield of an acre. An example of this sort of statistics is found in the Patent Office Report for 1879 (*118, p. 490–491*). There had been a distribution of "Red Brazilian" artichokes from Washington, apparently in one-quarter peck lots, and returns from 12 States were published. Ohio reported that the 2 quarts produced 6 bushels of tubers, which was probably not calculated. The reports from other States ran all the way from 500 bushels per acre from Pennsylvania to 4,000 bushels per acre from California. Bulletin 54 of the Oregon Agricultural Experiment Station (*53*) estimated its planting to yield 740 bushels per acre at 60 pounds per bushel; this would amount to 22 tons of tubers per acre.

The most valuable figures from the experimental plantings near Washington, D. C., are based on a quarter of an acre planted in 1925. This was at the Arlington Experiment Farm, Rosslyn, Va., on the "flats," where the soil has been pumped in from the river. This plot would be called good cornland, but had had no manure. The growth was good, though a windstorm in August had partially uprooted many of the plants. This plot produced at the rate of 14 tons of clean tubers per acre. The soil was decidedly wet, and there was much adhering earth. All was weighed; then selected samples were washed and the whole tared for soil, which amounted to 28.7 per cent of the whole harvest.

Predictions are hazardous, but the writer believes that, given the same opportunity, Jerusalem artichokes will probably yield as heavily as sugar beets. (See U. S. Dept. Agr. Tech. Bull. 514.)

STORAGE

There is much yet to be learned in regard to safe storage. Sibley reports that he windrowed the tubers and then with a turning plow

threw earth over them. They were not more than 6 inches deep in the windrows. The soil covering was not heavy, and the whole mass of tubers was frozen during the winter. They could be thawed before feeding. These tubers would all have been in growing condition at planting time in the spring, since freezing while under the soil does not harm them.

DISEASES AND PESTS

In both European and American literature the Jerusalem artichoke is described as a plant almost without important enemies. However, in developing an intensive crop plant from the wild in the native region of the plant there is the possibility that when large quantities are grown some of its hereditary enemies, before unnoticed, may become important pests. The culture of the artichoke in the United States has not so far been intensive enough to test this possibility. The comparatively large cultures in France are away from the plant's former pests.

During the experience with the crop near Washington no pests of apparent importance have developed. The most injurious disease is sclerotium, which makes a storage rot. This is as troublesome in France as here. Becker (*5, p. 907–910*) notes that *Puccinia helianthi* is at times a serious pest and recommends burning the tops and a change of location. A planting at the Arlington farm, on ground which had produced a crop in 1925, was badly infected by this rust in 1926, and the yield was materially reduced.

Insect larvæ of an undetermined pyralid moth have been found in the tubers at Washington, but so far they do not promise to be of any practical importance.

There would seem to be no more reason to fear trouble from pests than with other crops.

VARIETIES

The question of varieties of Jerusalem artichoke seems to be as little understood as any phase of the subject. There is also much misconception. Apparently the main error is the idea that our present-day varieties are the product of long-continued and careful breeding.

Cockerell (*28*) in 1919 gives descriptions of seven forms with Latin trinomials, and says "it is practically certain no wild form has tubers as large as the cultivated ones." Lesourd (*75*) in 1920 reviews the varieties in European trade and adds four other types described by Cockerell, and remarks that this makes in all eight varieties to show for three centuries of work on the plant.

Neither of these writers realized that probably the wild types to be found in the native range of the plant are to be listed by the hundred thousands and that there are now probably hundreds of desirable varieties to be found in the wild. Of the varieties mentioned by Lesourd, only three or four are the product of man-sown seed, and all the remainder are the gift of nature and unimproved by man. Also, if technical trinomial names are to be given to all the forms which can be described, the adjective vocabularies of both the Latin and Greek languages will be exhausted before even a good beginning is made.

This conception of varieties is based on the study of European literature of the subject, on several years' varietal study, most intensive

in 1924 and 1925, and on one year's growing of seedlings. The variety plantings at the Arlington farm now include upward of 160 numbers, in which, however, there are many duplicates. They were built up in the following manner:

Since the Jerusalem artichoke is not native to Europe, and since it does not seed in the countries on that Continent where most grown, it was thought that only a few varieties would be found in Europe. Also European seedsmen usually list the plant under a varietal name. Dealers were selected in France, Germany, Sweden, Italy, England, Scotland, Ireland, New Zealand, Australia, and Argentina, and orders were placed with them. Shipments were received from all the European orders and from two Australian firms. These represented only a few forms.

Since the artichoke is native to the United States, the list of catalogues was carefully searched, and 80 dealers in the United States and 5 in Canada were found who listed Jerusalem artichoke. It was very rare for any varietal name to be used in these catalogues, yet it was conjectured that many types might be in the trade. Accordingly, orders were sent to all firms in the United States and Canada quoting Jerusalem artichoke. Forty-three orders were delivered from the United States and three from Canada. These represented a considerable number of different varieties.

The Vilmorin-Andrieux Seed Co., of France, very courteously sent from its breeding grounds 20 unnamed seedlings which seemed most worthy for trial.

In the fall of 1924 the writer had an opportunity to spend one day in November along three creeks in Preble County, Ohio. Fourteen sorts were collected in this way, two of which would make fairly successful varieties. (Fig. 4.) Ten varieties were also sent in from various parts of the United States by persons who had become interested in the new developments regarding the artichoke. A few collections were made in 1925, and the department has about 50 selections from its 1925 seedlings.

From these various sources the varieties propagated in the department's experiments were acquired. Nearly all of the 1925 numbers were replanted in 1926, even when it was very certain that they were duplicates of other numbers. It is not the purpose to give in this publication full descriptions of the different varieties on hand, though it will be possible to make some general observations and to give the chemical composition of all of the numbers grown in 1925.

The European varieties will be considered first. Meunissier (*81*) in 1922 says that it seems very probable that the type called Ordinaire (common) by European seedsmen is the form first introduced from Massachusetts to Europe. If this is true, it would seem likely that it furnished the plants for Colonna's illustration. (Fig. 1.) It is very floriferous at Washington, D. C., and it has colored tubers. There seems to be no record as to the source of the first European introduction; it might have come from the St. Lawrence region, from New England, or even from as far south as Virginia. It seems to have been a variety grown by the Indians. Almost certainly this variety originated from self-sown seed.

The varieties originating from seed in Europe are Patate (a seedling of 1889), Piriform (a seedling of 1903), Fuseau (a seedling of 1913), and probably the variety called Rose. The source of the seed

from which these varieties were grown is not known. A letter from Vilmorin-Andrieux states that the seed which produced Fuseau came from Egypt and was of unknown parentage.

The variety called White Improved in Europe and French White or Giant French White Improved in the United States has had an interesting history. The name was first brought out by Sutton & Sons, seedsmen in England, in 1891. Apparently it was the first white-skinned variety to be sold in Europe, and it was acclaimed as a great improvement over all existing forms. Vilmorin-Andrieux received it from England, so the American name can only mean that we may have bought it from France, not that the French had any hand in its origination. For that matter Sutton did not grow it as a seedling but purchased it from P. H. Pierce, of St. Dunstan's Nursery, Canterbury, England, December 24, 1889. Walter R. Pierce,

FIG. 4.—Tubers of a wild variety collected on Four Mile Creek, Preble County, Ohio, November 24, 1924. In size and smoothness these are good forms

writing to the Sutton firm January 11, 1919, says: "I raised the white Jerusalem artichoke from a tuberous rooted Helianthus which a friend of mine (Doctor Brodie) imported from abroad. It may have come from South America with a lot of other specimens he received, but I believe it came from Holland." (Lacaita, *71*.) This might seem to be the end of the trail. No assertion is made that Mr. Pierce grew this variety as a seedling, though his letter might be so interpreted but for the fact that *Helianthus tuberosus* rarely blooms in England and does not set seed there.

Taking up the trail in the United States, it is of interest that of the 43 purchases made by the department from American seedsmen in 1925 there were more samples of this variety than of any other. Some of these may trace back to England or France, but it is doubtful if all do.

There is a plot of this variety at McMillan, Mich., which traces to a purchase from a Rockford, Ill., seedsman in 1896. It might already have been imported from England, but this is doubtful. The catalogues of that period of the firm selling it make no claims to introduction.

While Europe was not acquainted with white Jerusalem artichokes prior to the Sutton introduction, they are frequently mentioned in American publications before 1891. Probably the most interesting reference is in the work on Field and Garden Vegetables of America, published by Fearing Burr in 1863 (*20, p. 34*). He says:

> For a long period there was but a single variety cultivated or even known. Recent experiments in the use of seed as a means of propagation have developed new kinds, greatly varying in their size and color, possessing little of the watery and insipid character of the heretofore grown Jerusalem artichoke, and nearly or quite equaling the potato in excellence.

He then proceeds to a description of varieties. He tells of purple-skinned, red-skinned, and yellow-skinned artichokes, all of which were improved sorts. Of the purple he says: "A French variety, produced from seed. Tubers purplish rose color; flesh drier when cooked, and finer flavored than the white variety." Under Common White his description reads: "Tubers larger and often irregular in form; quality watery and somewhat insipid. It is unfit for boiling, but is sometimes served baked or roasted. It makes a very crisp and well-flavored pickle." Of course, we have no proof that Burr's "Common White, the only variety known for a long period," was the one now called White Improved, though his incomplete description is accurate for that variety so far as it goes. The department's variety trial includes a number of white varieties, and any of them may be the Common White of Burr. But since the White Improved or Giant French White is most widely distributed over the country now, it seems most likely to be the older type. This much at least seems certain—the French Improved White is not a man-sown seedling. It may, of course, trace back to Indian cultivation, or it may be a form obtained from the wild more recently.

The tubers of this Helianthus are the swollen ends of underground stems or runners. The portion of stem which is swollen usually amounts to from 5 to 10 internodes. The reduced leaves, appearing as scales, are much more conspicuous than in the potato. These scales in the tuber are opposite and make four well-defined rows on the sides. The growing aerial stems as they first emerge from the tubers bear opposite leaves for several internodes, usually becoming alternate in the upper portion of the stems. These underground stems branch extensively, so that one runner may bear a considerable number of tubers.

The uneven surface of Jerusalem artichoke tubers is due to a cause exactly opposite to that for the usual roughness of potato tubers. In the uneven potato the "eyes" or buds are sunken below the level of the surface of the tuber. In the smooth Jerusalem artichoke tuber the "eyes" are even with the surface, and in the uneven tuber they protrude above it. Potatoes sometimes exhibit this same form of tuber, usually spoken of by growers as caused by "second growth." It may be partly because of this form of tuber that the weight per bushel in France is given as about 52 pounds.

During the period 1906–1908 a form of tuberous-rooted Helianthus was exploited in Europe as a very valuable plant for garden and forage. It was called Helianti, also American salsify. It proved to be very similar to a large proportion of the seedlings produced by most varieties, with long runners, slender tubers, and giving a low yield.

A very similar form was exploited in this country in 1846 and 1847 under the name of Tennessee hog artichoke (*126, 127*).

TABLE 3.—*Analyses of Jerusalem artichokes grown at Arlington Experiment Farm, Rosslyn, Va., 1925*

Accession No.	Weight of tuber (grams)	Constituents (per cent)			Ratio of levulose to total sugar	Accession No.	Weight of tuber (grams)	Constituents (per cent)			Ratio of levulose to total sugar
		Total sugar	Levulose	Glucose (by difference)				Total sugar	Levulose	Glucose (by difference)	
27039	5	18.95	17.55	1.20	0.926	27007	73	13.20	10.20	2.94	.773
26338	16	18.25	16.49	1.76	.903	27008	37	15.33	12.14	3.19	.792
27540	66	15.52	13.60	1.83	.882	27009	23.5	12.62	9.88	2.74	.782
27541	12	21.10	19.47	1.63	.923	26994	29	14.21	11.65	2.56	.819
27571	40	18.78	16.37	2.51	.867	26995	27.6	16.32	12.90	3.42	.790
27584	50	15.90	13.35	2.55	.840	26996	24.5	12.98	9.99	2.99	.770
27585	82.4	13.82	11.90	1.92	.861	26997					
27586	7.3	18.09	17.00	1.09	.943	26998	27	13.92	10.98	2.94	.789
27632	32	12.81	10.70	2.11	.834	26999	40	14.84	12.14	2.70	.819
27096	30.5	10.63	14.75	1.88	.887	27000	38	13.96	10.83	3.13	.775
27097	22.5	16.71	14.24	2.47	.852	27001	19	16.35	13.64	2.71	.834
27098	24	16.45	14.15	2.30	.860	26986	17	11.34	8.64	2.70	.762
27119	23	15.13	12.90	2.23	.852	26987	36	13.60	10.96	2.64	.806
27206	23.6	16.90	14.25	2.65	.843	26988					
27218	22.5	17.45	15.23	2.22	.873	26989	27.5	14.17	11.25	2.92	.794
27320	36.5	18.14	15.22	2.92	.839	26990	09	13.21	10.22	2.99	.773
27478	4.5	19.11	17.17	1.94	.908	26991	23.5	12.79	9.72	3.07	.759
27088	38	14.25	12.41	1.84	.871	26992	41	14.32	12.04	2.28	.841
27089	22.5	15.16	12.77	2.39	.842	26993	32.5	13.54	10.74	2.80	.793
27090	23.5	14.61	11.95	2.66	.818	26978	45	12.15	9.11	3.04	.750
27091	22	14.71	12.56	2.15	.854	26979	44	13.78	10.97	2.81	.796
27092	24	15.99	13.35	2.64	.835	26980	51	13.32	10.34	2.98	.776
27093	23.5	17.27	14.81	2.46	.858	26981	18	12.48	9.30	3.18	.746
27094	33	17.35	15.26	2.09	.879	26982	68	13.36	10.28	3.10	.769
27095	53	16.77	13.40	3.37	.799	26983	84	13.50	11.26	2.24	.834
27080	84	17.85	15.56	2.29	.872	26984	42.5	15.61	13.29	2.32	.851
27081	58	15.10	12.55	2.55	.831	26985		12.76	9.67	3.09	.757
27082	27	16.05	14.29	2.36	.858	26938	32	12.90	9.71	3.19	.752
27083	48	16.58	14.53	2.05	.876	26939	28.5	13.22	10.09	3.13	.763
27084	26	18.31	15.97	2.34	.872	26940	9.5	17.42	14.34	3.08	.823
27085	10	16.83	14.11	2.72	.838	26941	3.5	16.46	13.40	3.06	.814
27086	25	17.12	14.06	3.06	.822	26942	33	11.88	9.06	2.82	.763
27087	16	19.05	16.56	2.49	.870	26943	32	15.40	13.04	2.36	.847
27034	35	14.06	11.43	2.63	.812	26944	28	13.70	10.50	3.20	.767
27035	31	16.47	13.74	2.73	.834	26977	31	12.51	9.68	2.83	.773
27036	40	18.54	15.98	2.56	.862	26929	7.5	17.10	15.14	1.96	.886
27048	32	14.89	12.51	2.38	.840	26930	10	18.15	15.21	2.94	.839
27049	55	15.45	12.42	3.03	.804	26931	0.5	16.89	14.62	2.27	.866
27050	24	14.94	11.82	3.12	.791	26933					
27079	63	18.01	14.79	3.22	.821	26934	5.5	17.16	15.49	1.67	.903
27020	31	16.36	14.11	2.25	.862	26935	10	17.08	14.48	2.60	.848
27021	29.5	15.89	13.08	2.81	.823	26936	11	16.14	13.10	3.04	.812
27022	32.5	14.26	11.66	2.60	.818	26722-1	20	16.11	13.09	3.02	.812
27023	28	13.40	10.74	2.66	.801	26921	13	18.17	15.94	2.23	.877
27024	60	13.31	10.21	3.10	.767	26922	11.5	17.69	15.72	1.97	.888
27025	27.5	13.60	10.89	2.80	.795	26923	8.5	17.98	16.68	1.30	.928
27026	52	17.32	14.90	2.42	.860	26924	8.5	15.32	13.27	2.05	.866
27027	39.5	14.62	11.80	2.82	.807	26925	8.5	17.06	14.93	2.13	.875
27010	64.5	13.20	10.84	2.36	.821	26926	23	17.35	14.17	3.18	.816
27011	31.5	14.74	11.67	3.07	.792	26927	8.5	19.09	15.76	3.33	.826
27012	65	14.10	11.66	2.44	.827	26928	7	19.46	15.71	3.75	.808
27013	22	13.71	10.55	3.16	.769	26920	12	18.95	16.30	2.65	.860
27014	29	14.49	11.74	2.75	.809	26725	9	20.57	17.84	2.73	.868
27015	9.5	19.18	17.29	1.89	.902	26720	11	20.48	17.76	2.72	.866
27016	7	21.89	19.56	2.33	.894	26718	27.5	19.26	15.14	4.12	.786
27019	43	13.69	11.11	2.58	.812	26719	24.5	16.03	12.94	3.09	.807
27002	47.5	12.69	10.36	2.33	.816	26722	20	17.17	13.84	3.33	.805
27003	23.5	15.64	13.40	2.24	.857	26724	42	17.14	13.73	3.41	.801
27004		14.11	10.96	3.15	.777	26721	43	14.56	11.36	3.20	.781
27005	30	13.81	10.34	2.47	.748	26723	25	15.29	12.01	3.28	.786
27006	28.5	15.78	12.40	3.38	.785						

ANALYSES SHOWING SUGAR YIELD OF THE TUBERS

Analyses showing the sugar production of about 120 numbers of Jerusalem artichoke grown at the Arlington Experiment Farm are given in Table 3.[5] These analyses were made on samples from the crop of 1925 and were made in the fall of that year, at harvest time. The average weight of tubers shown is the average in the sample sent for analysis; it may not be representative in each case, as no particular pains were taken to dig an average sample. The size of the figure in the levulose column is significant, as is also the last column, showing the ratio of levulose to total sugar.

SELECTION AND BREEDING

So far as can be learned, only one firm has engaged in growing Jerusalem artichoke seedlings—Vilmorin-Andrieux & Co., of Paris, France. This firm has been growing seedlings since 1809, when Philippe-André L. de Vilmorin announced at the April 18 meeting of the Société d'Agriculture du Department de la Seine that he had found that seedling growing furnished "a means of regenerating the race, if there should be need, and perhaps of obtaining varieties as interesting as had already been obtained for potatoes." His son, Louis L. de Vilmorin, continued the work and on April 20, 1831, presented a memoir to the same society, showing the variations to be obtained, and that the plant could be improved. He presented to the Société Impériale et Centrale d'Agriculture at its meeting on March 4, 1857, a collection of 28 varieties, one representing the original type with 27 seedlings produced by his father and himself. Doubtless it is this collection of which Fearing Burr wrote in 1863. Henry L. de Vilmorin continued the same work and frequently published his results. During his lifetime the edition of the Vegetable Garden, which was translated by William Robinson in 1885, was issued (*122*). This work contains the following summary of attempts at improvement of the artichoke:

> Experiments made with the view of raising improved varieties from seed have hitherto been attended with very unsatisfactory results. From one of these experiments we obtained a variety with yellow tubers which have a finer and more agreeable flavor than the common kind, but the plant is far less productive. This variety may answer as a kitchen-garden plant, but is not suitable for extensive or field culture.

The work was continued by Philippe L. de Vilmorin, who grew seedlings extensively, and the firm has now very extensive plantings. In Table 3, showing analyses of varieties grown in the department's tests, there are 17 varieties with large tubers having a possible levulose production of more than 12 per cent. Five of Vilmorin's 20 unnamed seedlings reach a place in this list. The careful and persistent work of this seed firm has been much hindered by the fact that the plant very rarely seeds in France, even in the southern part. Part of the seed used was produced in Corsica. The firm at present conducts its breeding work on Jerusalem artichokes in Morocco. Its list of 20 seedlings furnished for the department's trials is a very variant and interesting lot. Aside from this work, no reference is found of any attempts at seedling production.

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[5] These analyses are published here by the courtesy of the Bureau of Standards, United States Department of Commerce. The analyses were made by R. F. Jackson and W. B. Chase of the polarimetry section.

It is extremely doubtful whether the American Indians grew any seedlings. They must have carried forms of the plant north of its natural seeding range, but so far as improvement is concerned they probably took the plant entirely as they found it.

A brief account of the experience of the Department of Agriculture with one year's seedling growing can be given here. Seed which had been saved from seven varieties in the crops of 1923 and 1924 was planted March 18, 1925, in flats in the greenhouse. Between 1,200 and 1,300 seedlings were grown, which were first potted from the seed flats and later were planted out with spacing of 6.6 by 3.3 feet. These seedlings might very well have been regarded as so many perfectly good species, so far as their make-up is concerned. They varied extremely in all characters. To take the character of flowering as an example, the planting varied from exceedingly floriferous to those which made no flowers at all, some not even showing a bud at time of frost. Some flowered early. Some set a heavy crop of seed. Some, though flowering heavily, set scarcely any seed. The blossoms varied in shade of yellow color, in size, in shape, in width of ligule, in expansion of flower, in color of surrounding bracts; in fact, it is more than a mere rhetorical statement to say that no two of them were alike. An observer unaccustomed to seeing slight differences would have come to this conclusion after a few minutes of examination of the planting.

Forty-nine seedlings have been saved out of the whole lot for second-year trial, and there will probably not develop more than one or two really good sorts. These 49 seedlings represent three parents, but mostly are from one, which has been discussed above as White Improved.

No record has been found that anyone has done any crossing of types.

IMPROVEMENT PROBLEMS

It is plain, then, that the Jerusalem artichoke is an undomesticated plant. There are no varieties which deserve the name "improved" in the sense that human beings have done anything to improve them, excepting in the seedlings grown by the house of Vilmorin. These do not as yet have any influence on the varieties grown in America. Moreover, the process of seed sowing which that firm has followed has been occurring naturally throughout the range of the plant in the United States on a scale immeasurably greater than any human agency could hope to attain. The Vilmorins have doubtless grown seedlings by many thousands, but the plant itself has grown them by the hundred millions, with a much broader basis of hereditary characters to juggle with, since at least the earlier work in Europe was based on seedlings from one variety.

What, then, are the characters desirable to be combined into the Jerusalem artichoke of the future? If the United States is to grow the plant more extensively, the success of the crop will depend on economic adjustments. The basis of selection will be an attempt to find the type which can most cheaply produce inulin.

It must be capable of being harvested by machinery. The underground runners must be short, and the tubers must be close enough around the base of the stem to be handled by potato-digging machines.

It must be productive.

It must be as high as possible in inulin content.
It is desirable to get some earlier maturing varieties in order to lengthen the harvest season.

How can these characters and varieties best be obtained? Obviously, the first thing to do is to take advantage of the naturally sown seedlings (fig. 4), either direct from their wild habitat or from farms and gardens where these wild plants have been grown. The region north of the seeding range of the plant will probably prove as good hunting ground as can be found, since whatever is growing in these regions has probably been taken there by white or Indian cultivators, and so has been selected as worth growing. When more is known about seeding habits of the best varieties, crossing should be done, for if a good first-generation cross is obtained it is then immediately available for growing. The breeding problem will be that of sugar cane rather than of the sugar beet, in that the plant is propagated vegetatively. In this work of improvement there will be room for many collectors and for many hybridizers.

This searching among wild plants for desirable forms is not quite enough, however, even in the way of seedling growing and selection. There may be excellent agricultural types with characters which would not allow them to reach maturity as wild plants but which might be of no disadvantage in a crop plant. The only way to be able to study these is to grow the seedlings.

SUMMARY

There is increased interest in the Jerusalem artichoke from the possibility of its serving as a source of levulose by a careful process of crystallization, and as a source of carbohydrates for making alcohol.

It is American in origin, but has been used and studied more in Europe.

It can be used for human food, stock feed, and alcohol manufacture, but its true value for these purposes is not known.

It has an undeserved reputation as a weed because of its hardiness, but by proper rotation and cultural practices it can be kept under control.

It is desirable to get types which are earlier and smoother and which cluster close to the stems.

The culture of the Jerusalem artichoke is very similar to that of corn and is no more expensive, except harvesting, which is probably somewhat more costly than that of potatoes.

Selection is on the basis of sugar cane rather than of sugar beets.

All the American varieties are almost certainly wildings, picked up by the Indians or by the whites from the forests. The most promising improvement work will be further exploration of wild types.

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