UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 309

EXPERIMENTS IN THE CULTURE AND FORCING OF WITLOOF CHICORY.

(FRENCH ENDIVE)

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URBANA, ILLINOIS, MAY, 1928

SUMMARY

Witloof chicory, known on the market as "French endive," is a high-priced salad plant, large quantities of which are imported from Belgium and France. Since this plant can be grown successfully in Illinois and forced thruout the winter months, it should prove of special interest to home gardeners as well as to commercial growers.

In these experiments Witloof chicory was grown and forced at Urbana, Illinois for four years, both indoor and outdoor methods being used. Attempts to force the roots in the field without removing them from the place where they were grown were successful in producing a marketable crop, but the special care required to keep the roots from freezing before they were forced and the disproportionate amount of labor involved made this method impractical.

Planting the seed about June 15 outdoors produced the largest proportion of roots of best forcing size. The large roots resulting from the planting made in May produced many compound heads which were unmarketable, and small roots from the July plantings produced light yields.

Equally good crops were obtained from roots dug while in an active growing condition and forced immediately, from roots dug and forced as soon as growth had ceased in the fall, and from roots held dormant in storage before being forced.

A temperature between 28° and 45° F. was satisfactory for storing the roots. When stored over five months there was a tendency for seed stalks to develop instead of heads during the forcing of the roots. Freezing killed the roots.

Choice chicory heads were obtained when the roots were bedded in brown silt loam in boxes with an 8-inch covering of sand and kept at a temperature of about 70° F. Lower temperatures resulted in slow growth, while temperatures above 80° F. were likely to induce rot. Other coverings used were sawdust, sandy soil, and muck, all of which proved inferior to sand as a material thru which to force growth.

EXPERIMENTS IN THE CULTURE AND FORCING OF WITLOOF CHICORY

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INTRODUCTION

Witloof chicory is known in this country principally from its use as a high-priced fancy salad served in the big hotels and cafes under the name of "French endive." Altho little known in this country, it has been grown for centuries in Europe. Large quantities are produced in Belgium and France, particularly in the vicinity of Brussels and Paris, and it is from this region that most of the supply for the American market is imported.

Thus far the demand for Witloof chicory has been principally in the larger markets; but there seems to be a good opportunity for expanding the demand as the crop becomes better known. Many markets depend upon the imported product and are inadequately supplied. The crop is grown to a limited extent in New York, New Jersey, and Pennsylvania. A few Illinois growers are producing it successfully, but not in sufficient quantities to supply the demand.

This delicious salad plant would doubtless find a greater place in home gardens also if the ease with which it can be produced were more generally realized. The fact is that it can be grown in home gardens and the roots forced in the winter with greater assurance of success and less care and expense than are required for many other salad crops, such for instance as head lettuce. Grown in this way, it produces a fresh, crisp salad thruout the winter months when other fresh vegetables are unavailable. Home gardeners who take pride in extra-fancy products will find especial pleasure in growing for their own tables this delicious salad crop which is served as a delicacy in exclusive restaurants and clubs.

Best Varieties for Forcing

There are several varieties of chicory and it is important to secure the true Witloof chicory for forcing. Botanically it belongs to the species *Cichorium intybus* Linn. It is closely related to and sometimes confused with the species *Cichorium endivia* Linn., which includes the common garden endive. The two species are distinct, however, and it is important that their differences be recognized if one is to be sure to secure the correct species and variety for forcing. Confusion is often caused by the fact that Witloof chicory is known on the market almost exclusively by the term French endive, and many seed catalogs are likewise listing Witloof chicory by the incorrect term French endive.

Of the species *Cichorium intybus* Linn., there are several varieties in commerce. Likewise the wild chicory, a common roadside weed in Illinois, belongs to this species. Altho this wild chicory can be forced, it produces a small head of very bitter flavor.

The large-rooted Brunswick is a commercial variety which has very deeply cut leaves divided somewhat like those of a dandelion and spread horizontally. With this spreading habit of growth it produces a loose, spreading head, and consequently is not desirable for forcing.

FIG. 1.—A PLANT OF TRUE WITLOOF CHICORY

Note the wide, smooth leaves, thick midrib, and erect habit, which is typical of the growth of the plant in the field.

This variety is grown principally for its large roots, which are sliced, roasted, and ground and used as a coffee substitute. Another large-rooted variety used principally as a coffee substitute is the Magdeburg. This has smooth-edged leaves which stand erect, thus making it suitable for forcing, particularly to form what is known as barbe-de-capucin. To produce barbe-de-capucin the roots are forced in a dark

place without confining the tops. A loose-headed top develops, composed of long, slender, blanched leaves as shown at A, Fig. 4, page 448. Any of the varieties may be used to produce barbe-de-capucin but the improved varieties such as Magdeburg and Witloof are sweeter and less bitter.

The true Witloof variety is said to be a selection of the Magdeburg, but it is characterized by wider, smoother-edged leaves, with

FIG. 2.—CHICORY GROWING IN FORCING BOXES

The above growth is characteristic of the compact, firmly closed, well-blanched heads produced under proper forcing conditions. This shows a section thru the forcing box after the sand thru which the heads have grown has been removed. For home use boxes like this holding about two dozen heads each are satisfactory.

wider, thicker midribs, and a more erect habit of growth. These characteristics make it specially suitable for forcing, since they result in a blanched head which is more compact and solid and less bitter than other varieties.

Methods of Forcing

Practices in the forcing of this crop differ slightly, but commercial and home gardeners all follow the same principles. In general, the mature roots are transplanted to a compact space (boxes) where the temperature can be controlled. A layer of sand about 8 inches deep is then filled in above the crowns and the growth is forced thru this sand. The weight of the sand causes the shoots to develop into a firmly closed, compact head, which is blanched to a creamy white as shown at B, Fig. 4. As soon as the tips of the shoots appear at the surface of the covering layer of sand, the heads are ready to harvest. Fig. 2 shows the characteristic growth obtained under forcing conditions. If allowed to grow in the light, the leaves turn green and become bitter.

For home use a box (Fig. 2) that will hold about two dozen roots and is sufficiently deep for the 8-inch layer of sand, makes a satis-

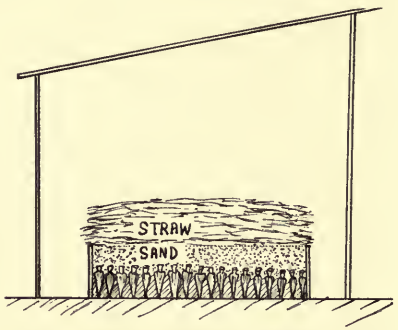

FIG. 3.—AN INEXPENSIVE FORCING SHED

The roots are bedded vertically on the floor in shallow bins or beds, and sand or light soil is filled in above the crowns. The beds may be covered with a deep layer of straw or the shed may be heated to forcing temperature.

factory place in which to force this crop. Two or three boxes started at intervals of a week or ten days will maintain a constant supply for home use. The boxes may be placed in the basement during the forcing period.

In forcing on a commercial scale, large beds may be used on the cellar floor or in a root cellar, or under greenhouse benches.

Inexpensive sheds may also be used for forcing the crop. In this case the roots are bedded vertically on the floor of the shed in shallow bins or beds. Sand or light soil is then filled in above the crowns, as shown in Fig. 3. The beds, then, may be covered with a deep layer of straw or the shed may be heated to the forcing temperature.

Another method is to force the roots in outdoor trenches or beds. A modification of this plan is to force the roots right in the row where

they have grown. This was done as part of the work in this experiment and the method was discarded as impractical (see page 459).

For the market the heads should be carefully cleaned and graded and packed in paper-lined boxes or baskets holding about ten pounds each. One large grower uses boxes measuring 5 by 11 by 18 inches, which hold 14 to 15 pounds when packed. Retailers prefer small packages and can handle the crop to better advantage in small lots.

Object of These Experiments

The object of these experiments was to secure information in regard to the best methods of producing Witloof chicory in Illinois. The points specifically studied were the following:

1. The best time to plant seed from which to grow roots for forcing.
2. The advantages, if any, of a rest period for the roots before they are forced.
3. The effect of freezing the roots before forcing them.
4. The best method of storing the roots for forcing late in the winter or spring.
5. The best temperature for forcing the roots.
6. The best size of roots for forcing.
7. The practicability of growing more than one crop from the same roots.
8. The practicability of forcing the roots in the field without removing them from the row.
9. The difference in the growth produced when the roots are forced thru sand and when forced thru other materials.

CONDITIONS OF EXPERIMENT

Planting of Seed and Care of Roots

In these tests Witloof chicory was grown in the experimental gardens of the Department of Horticulture at Urbana during the seasons 1921 to 1924 inclusive, and the roots were forced during the following winters.

The seed was sown on various dates from May to July on a brown silt loam soil in rows 3 feet apart, thus allowing for horse cultivation. The seedlings were thinned to about 6 inches apart in the row.

Cultivation.—The plants were given ordinary cultivation thru the growing season, and each year the roots were dug late in October or November. The tops were cut off at the time the roots were dug. After experience gained the first season, when some of the tops were cut too short, an effort was made to cut off the tops about 2 inches above the crown. These were removed with a single stroke of a butcher knife. Likewise, after the first season all overgrown roots (over 2¼ inches in diameter) and all roots that had produced seed stalks were discarded at digging time.

Forcing Boxes.—All of the roots except those forced in trenches were forced in boxes. These boxes were of various sizes but of suffi-

cient height so that after the roots were bedded vertically in soil in the boxes, 8 inches of sand could be filled in above the crowns.

Experience showed that the boxes must be substantially built; otherwise the side pressure of the sand causes the sides to bulge or break. A box 20 inches high, 12 inches wide, and 16 inches deep, inside measurements, is about as large as can be handled conveniently in pouring off the sand when a crop is ready to harvest. One of this size holds about 30 roots. Fig. 2 shows one of the forcing boxes with the side removed and the sand poured off when a crop was ready to harvest. The long tips of the roots are of no value in forcing. Consequently these were cut off, making the roots a uniform length of 8 inches. In bedding the roots, they were placed vertically about an

FIG. 4.—TYPICAL SPECIMENS OF THE FORCED PRODUCT OF WITLOOF CHICORY

(A) Loose head and long slender leaves known as barbe-de-capucin produced by forcing the roots in darkness without a covering layer of sand above the crowns; (B) extra fancy grade, called French endive on the market; (C) No. 1 market grade; (D) too small for market but good for home use.

inch apart, with the crowns at the same level and with soil filled in around them to the level of the crowns. They were then thoroly watered.

Watering.—It was found that if the soil around the roots is thoroly watered at the time the roots are bedded, no additional watering is necessary to produce the crop. During the first season the boxes were watered at frequent intervals during the forcing period by pouring the water on the covering layer of sand. Considerable rot developed in the heads growing up thru the moist sand. The next season a pipe was thrust thru the sand, and water was poured into the pipe so that the water flowed out at the level of the soil. This reduced the amount

of rot. In the next two seasons the soil was thoroly soaked at the time the roots were bedded, and no additional watering was given. Sand was not filled in above the crowns until a day after they had been bedded and watered. This kept the sand dry and practically controlled the rot.

Grading the Crop

In all of the lots in which yield records were taken the same standards were used in grading the product. Two marketable grades were made, namely "extra fancy," and "No. 1." The extra fancy grade included only large, firm, well-blanched heads of very compact growth. The No. 1 grade included heads that were slightly smaller, or less compact, but which were well blanched and free from blemish or rot. Typical extra fancy heads are shown at B, Fig. 4, and typical No. 1 heads are shown at C, Fig. 4.

A comparison of the average weight per head of each grade of the different lots would seem to indicate considerable variation and lack of uniformity in grading. However, the extra fancy heads in each lot were distinctly superior. That is, the grading was based on the size, shape, and solidity of the heads and represented definite standards in appearance, and the grades were quite uniform between the lots.

It should be noted in records of yields that the longer the forcing period the greater was the average weight per head. This result might naturally be expected, as the longer time would give the slower growing heads a chance to fill out more and raise the general average. Each lot was harvested when several shoots had grown thru the covering layer of sand. In some cases it was found that a few shoots had grown unusually fast and would indicate that the lot was ready to harvest when in reality the majority of the roots in the lot had not attained maximum growth. Consequently harvesting at this time resulted in a lower average weight per head.

RESULTS OBTAINED

June 15 Best Planting Time

The time of planting the seeds to grow roots for forcing is of considerable importance. If the seed is sown too early it will result in the development of a large percentage of overgrown roots that produce seed stalks or compound heads. Roots of this type are worthless for forcing. On the other hand, if the seed is sown too late in the season, the roots will be too small to develop a maximum forcing crop.

The best time for planting was determined by the growth at digging time. Each season as the roots were dug, a representative portion of a row was critically examined, the size and maturity of 200 "field run" roots was noted, and the percentage of desirable and of worthless roots recorded. The results showed that planting the seed

about June 15, which gave about a four months' growing period, produced the largest proportion of roots of best forcing size and a low percentage of seed stalks (Table 1). Planting in May resulted in a large proportion of overgrown roots and the development of seed stalks; and planting in July resulted in a larger proportion of small roots. This is in accordance with the experience of most growers in this region and in the East, the majority of whom recommend planting about June 15.

Rest Period of No Advantage

To determine whether or not a rest period is necessary before the roots can be forced satisfactorily, 50 medium-sized roots were dug from the field on October 2 and again on October 16, while they were

TABLE 1.—WITLOOF CHICORY: RELATION OF PLANTING DATE TO SIZE OF ROOTS PRODUCED[1]

(200 roots examined for each planting date)

Planting date	Undersized roots: less than 1 inch	Medium-sized 1 to 1¾ inches	Large roots: 1¾ to 2¼ inches	Overgrown roots: over 2¼ inches	Seed stalks
	perct.	*perct.*	*perct.*	*perct.*	*perct.*
May 15, 1921	13	34	37	16	22
June 24, 1922[2]	19	49	23	9	14
July 2, 1923[2]	23	44	27	6	11
	(Less than ¾ inch)	(¾ to 2 inches)		(Over 2 inches)	
June 14, 1924	14	67		19	3
		(¾ to 1¾ inches)		(Over 1¾ inches)	
July 1, 1924	19	48		33	1

[1]During the first three seasons these roots were graded in four sizes. In the last season only three grades were considered, namely: (1) too small for forcing, less than ¾ inch; (2) good forcing size, ¾ inch to 2 inches; and (3) overgrown, over 2 inches. Thru an error the upper limit of the good forcing size was reduced in the July planting in 1924. Consequently the proportionate amount of overgrown roots was increased. A thin stand probably also increased the proportion of overgrown roots in this planting.

[2]Irrigated. It may be assumed that irrigation promoted growth and increased the size of the roots.

still in an active growing condition, and were forced immediately (Lots 19 and 20). By November 10 the growing season was over and all roots were dug. Two lots (Nos. 21 and 22) were stored at 31° F. for later forcing.

This test was repeated the next season by digging and immediately forcing 50 actively growing medium-sized roots on October 1 (Lot 37) and a similar lot on October 15 (Lot 38). These were compared with two lots (Nos. 39 and 40) from the main crop which was

dug on November 19 and kept dormant in cold storage for later forcing.

All lots were forced in a warm greenhouse. A comparison of the yields (Table 2) clearly shows that a rest period is unnecessary before Witloof chicory roots can be forced successfully. The roots may be taken from the field in an active growing condition and immediately forced, or with equal success the roots may be matured and kept in a dormant condition before forcing. The yields and the time required for forcing are approximately the same with or without a rest period.

Roots that had an extra long rest period, it should be noted, had a tendency to produce seed stalks. This is shown subsequently in Lots 5 to 8 inclusive.

Freezing Fatal to Witloof Chicory Roots

Before some plants, such as rhubarb, can be forced successfully it is first necessary to freeze the roots to break the rest period. In order to determine whether or not freezing would result in physiological changes in chicory that would stimulate growth as is the case with rhubarb, some roots were subjected to freezing temperatures.

Fifty roots of the 1921 crop (Lot 12, Table 3) were covered with soil and placed in cold storage at a temperature of zero for two weeks. When these roots were removed from cold storage, they were thawed out slowly in a cool cellar. As they thawed, they became watery and soft and it was found that the entire lot was killed.

This test was repeated with 50 roots of the 1924 crop (Lot 50, Table 3). In this case the storage temperature was 10° F. for two weeks. The result was the same; all the roots were killed by the freezing.

Another lot of roots, Lot 27, was not dug in the fall (of 1922), but was left in the field unprotected from freezing. After severe freezing weather, hot manure was heaped over the row to force the roots, but no growth resulted. A similar lot of roots left in the row but protected from freezing (Lot 28, page 459) was forced successfully when hot manure was heaped over the row. Furthermore Lots 9 and 10, placed in outdoor trenches and mulched to protect them from freezing, were forced successfully when hot manure was heaped over the trench. Lot 29, in an outdoor trench not protected from freezing, was a total loss.

These results clearly indicate that freezing is fatal to Witloof chicory roots.

Successful Storage Requires Moderate Temperatures

In order to extend the marketing period of Witloof chicory over several months, it is necessary to store the roots or keep them in a dormant condition until needed for forcing.

TABLE 2.—SHOWING THAT A REST PERIOD FOR WITLOOF CHICORY IS NOT NEEDED BEFORE ROOTS CAN BE FORCED SUCCESSFULLY

(50 medium-sized roots in each lot, forced in warm greenhouse)

Lot	Date roots were dug	Date forcing commenced	Length of forcing period	Length of rest period	Yields of heads					
					Extra fancy		No. 1		Total marketable	
					Number	Av. wt.	Number	Av. wt.	Number	Av. wt.
	1922		*days*	*days*		*oz.*		*oz.*		*oz.*
19	Oct. 2	Oct. 2	16	0	16	3.8	20	2.7	36	3.2
20	Oct. 16	Oct. 16	14	0	13	4.0	18	2.8	31	3.3
21	Nov. 10	Dec. 21	20	42	12	4.9	14	2.8	26	3.8
22	Nov. 10	Jan. 10	19	61	15	4.2	19	2.9	34	3.5
	1923									
37	Oct. 1	Oct. 1	15	0	18	3.3	23	2.6	41	2.9
38	Oct. 15	Oct. 15	15	0	16	4.3	27	2.8	43	3.3
39	Nov. 19	Dec. 20	14	31	23	3.4	13	2.1	36	2.9
40	Nov. 19	Jan. 19	20	61	20	3.6	22	2.6	42	3.1

TABLE 3.—COMPARISON OF METHODS OF STORING ROOTS OF WITLOOF CHICORY
(Medium-sized roots in each lot)

Lot	Storage conditions	Storage period	Forcing period	Number of roots	Yields of heads					
					Extra fancy		No. 1		Total marketable	
					Number	Av. wt.	Number	Av. wt.	Number	Av. wt.
		days	*days*			*oz.*		*oz.*		*oz.*
20	Forced immediately	0	14	50	13	4.0	18	2.8	31	3.3
38	Forced immediately	0	15	50	16	4.3	27	2.8	43	3.3
1	Forced immediately	0	16	30	12	3.4	12	1.9	24	2.7
12	Cold storage, 0° F.	15	Roots killed	50	0	0	0	0	0	0
50	Cold storage, 10° F	15	Roots killed	50	0	0	0	0	0	0
51	Cold storage, 28° F	150	22	30	11	4.2	9	1.9	20	3.1
39	Cold storage, 31° F	31	14	50	23	3.4	13	2.1	36	2.9
21	Cold storage, 31° F	42	20	50	12	4.9	14	2.8	26	3.8
2	Cold storage, 31° F	60	18	30	15	3.6	9	2.1	24	3.0
3	Cold storage, 31° F	90	18	30	14	3.1	11	2.1	25	2.7
4	Cold storage, 31° F	120	20	30	18	3.4	3	2.3	21	3.2
5	Cold storage, 31° F	150	23	30	13	3.9	6	2.5	19	3.5
7	Cold storage, 45° F	150	23	30	15	3.3	2	2.5	17	3.2
30	Cellar, about 53° F	150	25	30	0	0	0	0	0	0
9	Outdoor trench, shallow	90	28	50	19	3.8	11	2.2	30	3.2
29	Outdoor trench, shallow	120	Roots killed	50	0	0	0	0	0	0
10	Outdoor trench, deep	90	28	100	46	4.2	21	2.3	67	3.4

Various experiments were tried in order to determine the best method of storing the roots so that they could be forced late in the season. In each case the roots were covered with soil to protect them from drying out or shriveling. Several lots were left for one to five months in cold storage at 31° F. Other lots were stored at a temperature of 45° F., and one lot at 28° F. Another lot was left in a cellar at a temperature of about 53° F., and a few lots were kept in outdoor pits protected from freezing. These lots were all forced in the warm greenhouse except the lots in pits, Lots 9 and 10, which were forced outdoors.

For convenience of comparison, the yields secured from roots stored in various ways are listed in Table 3. These results indicate that the roots may be stored successfully, either in outdoor trenches or in boxes in cold storage, at a temperature sufficiently low to prevent growth, but not low enough to freeze. Experience with Lot 51 indicates the freezing temperature of chicory roots is below 28° F., while a temperature of 10° F. is fatal, as shown in Lot 50. That 45° F. is sufficiently low to prevent growth is shown by Lot 7; and that growth will occur at 53° F. is shown by five lots, No. 30 in Table 3 and Nos. 13, 23, 41, and 53 in Table 4.

Because of the satisfactory results secured in storing the roots at 31° F. and the availability of storage space at this temperature (apple-storage temperature) all of the remaining lots, except as otherwise noted, were so stored.

The fact that seed stalks developed in a number of heads after being stored five months (Lots 5, 51, 7, and 30) would seem to indicate that if the roots are held in storage too late in the season they attain an age or stage of maturity following which they are likely to produce seed stalks.

In Lot 30, stored in a cellar at about 53° F., growth started followed by rot, or at least the old stubs rotted away. However, the roots were plump. Eighty small, slender heads were produced from this lot, none of which were marketable. The total weight of the heads was only 2 pounds 3 ounces, and many of them had seed stalks in the center.

In Lot 9 the roots were bedded upright in a trench outdoors with 2 inches of sand above the crowns. As freezing weather came, a mulch of old manure was heaped over this trench. At the start of the forcing period, the old manure was removed and hot, fermenting manure was heaped over the roots to a depth of 3 feet. At this time a part of the trench was opened and it was found that from 2 to 3 inches of growth had occurred after the roots had been placed in the trench. The growth was stocky but had one unfavorable feature—most of the heads were bending over as tho turning back from the cold. Apparently they had started an upright growth and later turned down. This peculiar growth did not occur in Lot 10. In that lot the roots were bedded upright in

the trench outdoors and 8 inches of sand filled in above the crowns; this was mulched to protect it from freezing. In both Lots 9 and 10 the forcing period was lengthened by the fact that a cold wave, with sub-zero weather, occurred shortly after the hot manure was placed over the trenches to start growth; this cooled the manure and retarded growth.

In Lot 29 the roots were bedded upright in a shallow trench and only 2 inches of sand was filled in above the crowns. No effort was made to protect this lot from freezing. At the time the hot manure was heaped over the trench to start the forcing, it was found that the roots were frozen in the soil. No growth resulted, the roots having been killed by the freezing.

Roots Best Forced at About 70° F.

In order to determine the best temperature for forcing, roots which had been kept in cold storage for two months at 31° F. were bedded in forcing boxes and placed in the following temperatures and locations: (1) A basement having a constant temperature of about 53° F.; (2) a cool greenhouse having a night temperature of about 50° F. and day temperatures of 60° to 65° F.; (3) a greenhouse having a night temperature of 55° and day temperatures of 65° to 70° F.; (4) a warm greenhouse having a night temperature of 65° and day temperatures of 75° to 80° F.; (5) a tunnel containing heating pipes having a constant temperature of 85° to 90° F. Medium-sized roots were used in each case and were forced in each of these temperatures during the four forcing seasons (Table 4).

In each season the lot forced in the warm greenhouse (average temperature about 70° F.) was superior to the other lots, both in percentage of marketable heads and in average weight of marketable heads; and in all four seasons the largest yields of marketable heads were produced at this temperature. The results clearly indicate, however, that Witloof chicory is not very exacting in regard to forcing temperature providing it is not too high; 85° F. or above is too hot for healthy growth. All lots forced at this temperature were a total loss because of rot. It appears that the higher the forcing temperature the larger is the yield, providing the temperature does not exceed 80° F. An average temperature of about 70° F. proved to be the optimum forcing temperature in these experiments.

Medium-Sized Roots Best for Forcing

To determine the best size of roots for forcing, those grown during the first season were graded into the following sizes based on the largest diameter: (1) *very small,* diameter ⅜ to ¾ inch; (2) *small,* diameter ¾ to 1 inch; (3) *medium,* diameter 1 to 1¾ inches; (4) *large,* diameter 1¾ to 2¼ inches; (5) *very large,* diameter over 2¼ inches.

TABLE 4.—YIELDS OF WITLOOF CHICORY PRODUCED AT DIFFERENT FORCING TEMPERATURES
(Medium-sized roots in each lot)

	1921	1922	1923	1924	
(1) Basement: constant temperature 53° F. Lots	13	23	41	53	Average
Percentage of marketable heads	72	56	60	68	64
Average weight of marketable heads, ounces	2.7	2.6	3.1	2.8	2.8
Forcing period, days	18	19	20	18	..
(2) Cool greenhouse: night 50° F., day 65° F. Lots	14	24	42	54	Average
Percentage of marketable heads	60	70	57	66	63
Average weight of marketable heads, ounces	2.6	2.8	3.1	2.9	2.8
Forcing period, days	18	19	20	18	..
(3) Medium greenhouse: night 55° F., day 70° F. Lots	..	25	43	55	Average
Percentage of marketable heads	..	64	62	72	66
Average weight of marketable heads, ounces	..	2.8	2.9	3.1	2.9
Forcing period, days	..	19	20	18	..
(4) Warm greenhouse: night 65° F., day 80° F. Lots	2	22	40	52	Average
Percentage of marketable heads	80	68	84	76	77
Average weight of marketable heads, ounces	3.0	3.5	3.1	3.2	3.2
Forcing period, days	18	19	20	18	..
(5) Heating tunnel: constant temperature 85° to 90° F. Lots	15	26	44	56	Average

Each lot forced in the heating tunnel was a complete loss. Lot 56 made a quick growth but was a total loss from rot.

The next two seasons the roots were graded on the same scale, except that roots smaller than ¾ inch in diameter or larger than 2¼ inches were discarded. The test of comparative sizes was not continued into the fourth season. For this season all roots under ¾ inch or over 2 inches in diameter were discarded at digging time, as in the second and third seasons, and the remaining roots were not subdivided but were classed together as one forcing grade.

Roots of each size were forced each year both in the cool and in the warm forcing house.

The yields show conclusively that medium-sized roots (1 inch to 1¾ inches in diameter) are by far the best size for forcing (Table 5). In fact in each comparison each year, both in the cold and in the warm temperatures, the medium-sized roots made the best showing, considering quality of heads as well as weight. Altho heavier total yields were produced by the large roots, most of the weight was from compound heads or from large clumps of small pencil-like heads which were unmarketable (Fig. 5).

FIG. 5.—TYPICAL HEADS PRODUCED BY ROOTS OF DIFFERENT SIZES

(A) Unmarketable compound heads produced by extra large roots; (B) extra fancy heads from medium-sized roots; (C) small heads from small roots. The head at the extreme right is below market grade.

In some cases the small roots produced a more marketable product than the large roots. In general, they produced heads that were firm and of high quality but too small for the extra fancy grade.

It should be noted from Table 5 that the yields produced by roots of each size were slightly heavier in the lots forced in the warm house than they were in lots of similar size forced in the cool house; which is further evidence of the advantage of a temperature of about 70° F.

TABLE 5.—RELATION OF SIZE OF WITLOOF CHICORY ROOTS TO YIELD OF MARKETABLE HEADS

(30 roots in each lot)

Lot	Size of roots	Extra fancy heads		No. 1 heads		Total marketable heads	
		Number	Av. wt.	Number	Av. wt.	Number	Av. wt.
				Cool forcing temperature			
	1921		*oz.*		*oz.*		*oz.*
16	Small[1]	2	3.1	17	1.8	19	1.9
14	Medium[2]	11	3.4	7	1.8	18	2.6
17	Large[3]	10	3.7	4	2.4	14	3.4
18	Very large[4]	7	4.3	2	2.2	9	3.8
	1922						
31	Small	2	3.3	23	2.0	25	2.1
24	Medium	11	3.4	10	2.2	21	2.8
32	Large	9	4.5	6	2.3	15	3.6
	1923						
45	Small	5	3.2	17	1.9	22	2.2
42	Medium	12	3.6	5	1.8	17	3.1
46	Large	10	3.5	3	2.1	13	3.2
				Warm forcing temperature			
	1921						
6	Small	4	3.2	17	2.1	21	2.3
2	Medium	15	3.6	9	2.1	24	3.0
8	Large	11	4.0	3	2.0	14	3.6
11	Very Large	7	3.6	3	2.2	10	3.2
	1922						
33	Small	0	0	20	2.2	20	2.2
34	Medium	17	3.9	7	2.3	24	3.4
35	Large	9	4.1	4	2.2	13	3.5
	1923						
47	Small	2	3.4	17	2.2	19	2.3
48	Medium	18	3.9	8	2.4	26	3.4
49	Large	9	4.1	2	2.2	11	3.8

[1]Small roots: ¾ to 1 inch maximum diameter.
[2]Medium roots: 1 to 1¾ inches maximum diameter.
[3]Large roots: 1¾ to 2¼ inches maximum diameter.
[4]Very large roots: over 2¼ inches maximum diameter.

Roots Cannot Be Forced Successfully a Second Time

In producing one head of Witloof chicory under forcing conditions, the food material stored in the root is not nearly exhausted. An effort was made, therefore, to use this remaining food material to produce additional yields, but the tests clearly indicate that a second crop of marketable heads cannot be produced from the same roots.

In Lots 3 and 21, each of which included 30 medium-sized roots, the heads were cut about half an inch above the crown when the first crop was harvested. This was done so as to avoid injuring the central bud. The heads cut in this manner, however, fell apart readily and could not be marketed satisfactorily, since they must remain intact to sell to advantage.

Having harvested the crop in these lots without disturbing the roots, 8 inches of sand was again filled in above the roots to force them a second time. Altho new growth developed, no marketable heads were produced. Instead of one large head to a root, a cluster of small shoots of no market value developed from the peripheral buds.

In Lots 2 and 20 the heads of the first crop were cut at the base in the usual way except that the roots were not disturbed. These heads, being harvested intact, were of marketable grade (Table 3). Sand was again filled in above the roots and they were forced a second time. The second growth consisted of a cluster of small shoots from each root and was of no market value.

In Lots 1 and 22 the crops were harvested in the usual way without disturbing the roots. For the second forcing, the roots were placed in darkness under conditions suitable for producing barbe-de-capucin. The layer of sand was not replaced. A light crop resulted, which was satisfactory for home use but of doubtful market value except where barbe-de-capucin is desired. It would therefore seem useless to try to force the roots a second time. The best-yielding roots may be kept in a dormant condition after forcing and planted out in the following spring to produce seed. The roots may also be used for stock feeding but may produce an unpleasant flavor in the milk if fed to milk cows.

Forcing Roots in Field Not Practical

If Witloof chicory roots could be successfully forced in the field where they grow, the labor of digging and transplanting them to the forcing beds would be eliminated. To determine the practicability of such a method, the roots in a section of a row in Lots 27 and 28 were left in the ground and the tops trimmed off this row 2 inches above the crowns at the time the other roots were dug. Eight-inch boards were then stood on edge on each side of the row, with 6 inches between the boards. This space between the boards and above the crowns was then filled with 8 inches of sand. Old manure was heaped over the row to prevent freezing. When ready for forcing, hot fermenting manure was heaped over the row. In very cold weather about 30 inches of manure was needed. This enormous amount of manure used in proportion to the number of roots covered would not be practicable on a commercial scale.

Lot 28, consisting of 15 feet of a row which had been protected from freezing, produced 14 extra fancy heads having an average weight

of 3.9 ounces and 11 No. 1 heads having an average weight of 2.6 ounces. Lot 27, which was not protected from freezing, was a total loss.

In addition to the extravagant amount of manure required to force the roots in the field, this method required a large amount of labor to maintain the proper forcing temperature. In very cold weather an extra amount of manure had to be heaped over the row, and when the weather moderated the covering layer had to be opened a little to prevent excessive heating. Likewise, hot spots in the manure required frequent attention. Furthermore it was difficult to note the progress of the forced growth, for the rate of growth varied with weather conditions and it was necessary to dig thru the manure layer at frequent intervals to determine it.

Considering all of these factors, it is evident that altho the roots may be forced in the field without removing them from the row, it is more practical to dig the roots and force them in a more compact area.

Sand Proves Best Material for Forcing Cover

All the roots used in the foregoing experiments were forced thru a covering layer of sand, but in four other lots different materials were used in place of sand for comparison, and in four lots no covering was used. In each case the roots were bedded in soil in the usual way, the difference being only in the 8-inch covering above the crowns.

In Lots 57 and 58 sawdust was used instead of sand for the covering layer. There were 30 medium-sized roots in each lot. No extra-fancy heads were produced and only 8 No. 1 heads. These had an average weight of 2.1 ounces. Altho a quick growth occurred thru the sawdust, the low yield of marketable heads apparently was due to the fact that the sawdust was not heavy enough to exert the pressure which is needed to develop solid and compact heads. The loose, open heads were greatly inferior to heads forced thru sand. A second disadvantage of sawdust was that it slightly flavored the blanched leaves.

In Lot 59 a sandy soil, made by mixing 1 part of sand to 4 parts of loam, was used instead of pure sand for the covering layer. The 30 medium-sized roots in this lot produced 12 extra-fancy heads having an average weight of 3.2 ounces, and 9 No. 1 heads having an average weight of 2.4 ounces. Altho this may be considered a fairly satisfactory yield, there was more rot in this lot, and it was more difficult to dig out and to clean the heads.

In Lot 60 muck soil was used for the covering layer. It was thought that such a light, porous soil would make a satisfactory covering layer. This lot, however, was a total loss from rot. When the origin and source of muck soil (reclaimed swamp land) is considered, it may be expected that such soil will often contain organisms that will cause rot. Likewise such loose, light covering material can not be expected to produce a compact head.

Lots 36, 61, 62, and 63 were forced in darkness without any covering layer above the crown. These produced barbe-de-capucin; that is, the growth consisted of loose clusters of long, slender, blanched leaves, as shown in A, Fig. 4. They were similar in texture and flavor to the compact heads but much less attractive in appearance. Because of such characteristics a market is difficult to find for this product. For home use, however, the growing of barbe-de-capucin has an advantage; the covering layer of sand being omitted, the forcing boxes are easier to handle. If only the larger leaves are picked off at each harvest, a continuous growth may be secured for several weeks from the same roots.

For a marketable crop of Witloof chicory, sand is undoubtedly the best material for covering the roots for forcing.

CONCLUSIONS

1. Witloof chicory should be sown about June 15 in Illinois in order to secure the largest proportion of roots of best forcing size.

2. The roots do not require a rest period before being forced. They can be forced equally well when dug in an active growing condition, when dug and forced immediately after growth has ceased in the fall, or if kept dormant a few months.

3. Freezing is fatal to Witloof chicory roots. The roots do not freeze at 28° F., but at 10° F. they are killed by freezing.

4. The roots may be stored successfully for several months, either in outdoor trenches or in boxes in cold storage at a temperature sufficiently low to prevent growth but above the freezing temperature. A temperature between 28° and 45° F. is satisfactory. If stored too long (five months or more) they are likely, when forced, to develop seed stalks, which make the heads unmarketable.

5. Witloof chicory roots are not very exacting in regard to the temperature for forcing. Temperatures of 55° to 80° F. may be used. Low temperatures result in slower growth, producing in the same period a slightly smaller head. The optimum forcing temperature is about 70° F.

6. Medium-sized roots, that is, roots with a maximum diameter of 1 inch to 1¾ inches, produce the heaviest yields of marketable heads. Large roots produce compound heads which are unmarketable, and small roots produce small yields.

7. Altho the production of one crop does not exhaust the food material stored in the roots, it seems impossible to secure additional marketable yields by repeating the forcing.

8. Altho the roots can be forced in the field without removing them from the row, it is more practical to dig them and force them in a more compact area.

9. Sand makes the best covering material thru which to force the growth to produce firm, compact heads.