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Evaluation of Belgian Endive (*Chicorium intybus*) as an Alternative Vegetable Crop[1]

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ABSTRACT

Belgian endive (*Chicorium intybus*) is one of those crops that can grow with residual nitrogen and has relatively few pest problems. Presently, little is known on the culture of this crop in the United States, particularly in Virginia and the Mid-Atlantic region. The objectives of this study were: 1) to determine the effect of planting date on the root production of selected endive cultivars and 2) to determine the efficiency of two methods of forcing for chicon (a forced leaf head used as a vegetable) production. Three cultivars (Bea, Flash, and Zoom) were planted in 1990 at three planting dates (June 20, July 19, and August 13) in a split-plot design with four replications at Randolph Research Farm of Virginia State University, Petersburg, Virginia. Highly significant differences ($P < 0.01$) were observed for number of seedlings, usable and unusable roots, and total fresh root weight among the planting dates. Results have indicated that planting endive cultivars around July 19 would produce better suited root stock for chicon production than planting on either June 20 or August 13 planting dates. Results from both Phase I and II productions indicate that the two late maturing cultivars Bea and Flash were better adapted to Virginia edaphic and climatic conditions and to hydroponic forcing than was the middle early cultivar, Zoom. Similarly, Flash produced 41% and 51% more chicon weight than did either Bea and Zoom in the soil method of forcing. However, the chicon quality from the hydroponic method of forcing was better than that from the soil method.

INTRODUCTION

As fresh fruits and vegetables have become more important in the American diet, growers are finding that American tastes are often varied; different ethnic groups and different areas of the country demand different varieties of fruits and vegetables. Innovative marketing strategies are often the secret to selling niche type fruits and vegetables to these specialized markets.

In an effort to increase agricultural diversification opportunities for small scale farmers in Virginia, new alternative crops that have market demand have to be explored. One of the more promising alternative crops is Belgian endive also known as chicory. In the United States 80% to 90% of the consumption of Belgian endive is presently being imported. A conservative estimates of endive's value is approximately $5.0 million per annum (Whitney and Corey, 1988).

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Belgian endive requires little nitrogen fertilization, and has relatively few pest problems. Its planting and harvesting do not coincide with that of other field crops; and it is in demand as shown by increase in consumption. The endive is an attractive vegetable, which can be prepared in many ways and utilizes relatively little production input compared to other crops (Anon., 1985). Production of endive occurs in two phases: root (Phase I) and chicon or marketable head (Phase II). Producers who wish to produce just the roots can sell them to hydroponic growers for Phase II production. The chicons then can be sold to wholesalers, chain stores, and food service markets. It is projected that in Phase I production, endive roots would bring \$0.02 to \$0.04 each, depending on quality and availability, and a producer could expect to gross \$ 3,000.00 to \$ 4,500.00 ha^{-1}. In Phase II production, the chicons can sell from \$10.00 to \$17.50 wholesale per 4.55 kg box^{-1}. Through food service accounts, a 4.55 kg box^{-1} retails for \$19.00 to \$40.00 box^{-1}. In addition, endive roots are potential sources of various sugars (Chubey and Dorrel, 1977). Since most of the endive presently consumed in the United States is imported, local endive could be marketed at competitive prices. However, several major cultural concerns must be addressed before it can be commercially grown successfully.

Presently, little is known about the culture of endive as a crop in the United States. As a wild plant it is found in Europe, in North Africa, and in Siberia to the Baikel-Lake. Botanists have divided the family Chicorium in two species. One of them is the *Chicorium intybus*, about which this study is concerned.

Endive was discovered in the mid-nineteenth century by a Belgian farmer who advertently left chicory roots in the dark over winter (Hill, 1987; 1988). In the spring, these roots had begun to re-sprout and produced the chicory heads, which are now a popular vegetable in many countries. Its rise in popularity is demonstrated by the fact that imports from Belgium have increased nearly seven-fold, from 440 tons in 1976 to more than 3,000 tons in 1983, as reported by the United States Department of Agriculture. Today, endive is commonly found in markets with other salad greens rather than in its former display among gourmet vegetables.

Hill (1987; 1988; 1989) tested several imported endive cultivars for adaptability to Connecticut's soil, climate, and two methods of forcing. From these studies he concluded that endive can be successfully grown in diverse soils and in the climate of Connecticut, and during the winter mature roots could be forced to produce chicons.

Development of endive as a potential alternative crop provides a significant value to farmers. However, before it is recommended to growers, extensive studies should be done to provide information about all the essential cultural practices under Virginia's environmental conditions. The objectives of these studies reported here were: 1) to determine the effect of planting date on the yield and quality of root stock production of selected endive cultivars and 2) to determine the efficiency of two methods of forcing for chicon production.

MATERIALS AND METHODS

Seed Bed Preparation

Belgian endive is a crop that requires a fine, firm, and well-drained soil with a pH of 5.5 or higher. Based on soil test results, the fertilizers triple phosphate (P_2O_5) and potash (K_2O) were applied at rates of 150 and 30 kg ha^{-1}, respectively.

Nitrogen fertilizer was generally excluded, because too much nitrogen gives the crop luxurious leaf growth, an irregular crop density, relatively small roots, and loose chicons during forcing (Hill, 1987). To raise the soil pH to 6.3, lime was applied at the rate of 2,500 kg ha^{-1}. In the middle of June raised beds (approximately 75 cm apart, 20-23 cm in height and 30 cm across) were made and rolled to create a firm seedbed.

Planting

Experiment I: During the 1990 growing season, two late cultivars, Bea and Flash, and a middle early cultivar, Zoom were used. The experiment was arranged in a split plot design with date of planting as the main-plot and cultivar as the sub-plot. Each sub-plot in an experiment was replicated four times and consisted of six-beds; each bed in a plot had double rows 6 m long and 3.75 m wide. The three cultivars were planted on three separate dates (June 20, July 19, and August 13) on Abell sandy loam (fine loamy mixed, thermic Aquatic Hypridults) soil, with Nibbex precision planter. Spacing was 45 seeds per meter in double rows 7.5 cm apart; later the seedlings were thinned to 3 plants per meter. Immediately following planting, the preemergence herbicide, pronamide, was applied at 1.50 kg ha^{-1} and the plots were irrigated. Gramaxone at 0.5 kg active ingredient (ai) ha^{-1} was applied prior to the middle (July 19) and late (August 13) plantings. The postemergence herbicide sethoxydim was also applied at the rate of one kg ai ha^{-1} to control grass weeds. Plots were also hand weeded as needed. The plots were irrigated using sprinkle irrigation as needed. Seedling emergence was recorded two weeks after planting.

Experiment II: During the 1991 growing season, three cultivars (Bea, Flash, and Zoom) were planted in a randomized complete block design with four replications. Each plot in an experiment consisted of 8 beds (two rows per bed) each 6.1 m long and 4.25 m wide. The three cultivars were planted on 26 July 1991 at the Virginia State University (VSU), Randolph Research Farm similar to the procedures described in Experiment I.

Maturity determination

Immature roots will not produce the desired tightly furled chicons and overmature roots usually produce unmarketable multiple heads (Hill, 1988). Because endive takes as few as 90 days or as many as 120 days to mature, roots were tested for maturity periodically. Roots were randomly pulled from a meter-long row and immediately placed in plastic bags and transported to the laboratory. Roots were washed, cleaned, and separated according to the diameter size. Top roots <1.5 cm in diameter (unusable roots) were discarded; those >1.5 cm in diameter (usable) were kept for further processing. Ten roots were taken at random and weighed and cut cross-wise into a one-inch slice rings. The total weight of the sliced rings was recorded, and the rings were ovendried at 80°C. Root dry weight was taken at 24 and 48 h, and percent dry weight was calculated. The root dry weight for each planting date and cultivar was checked using the above procedure until 25 to 30 gram dry weight per root was obtained.

Harvesting

Experiment I and II

Phase I production: At maturity, roots from the four middle beds of each six-bed plot were harvested using a wing plow, which removed the roots from the ground at a depth of 30 cm on November 15, December 6, and December 12, for June 20, July 19 and August 13 planting dates, respectively. The roots were harvested and cut to a uniform length (15 cm); leaves were trimmed off to 2.5 cm above the crown. The total root weight was recorded and presented as total fresh weight kg ha^{-1}. Then roots were separated into <1.5 cm (unusable) and >1.5 cm diameter (usable) and were counted and recorded as number of roots ha^{-1}. Similarly, endive roots from Experiment II were harvested on December 9, 1991 using the procedure described in Experiment I.

Storage

Phase II production: The harvested roots from experiment II of each plot were placed in a chicken-wire cage and stored in a growth chamber located at the M. T. Carter Research Building of Virginia State University at $0 \pm 1^{o}C$ for 59 days. The roots were removed from cold storage and forced under two environmental conditions.

a) Hydroponic forcing- A table or trough that allowed for gravity flow of the solution was constructed. A pump that circulated the nutrient solution throughout the system was placed inside a 380 liter reservoir. A delivery line that allowed the solution to get to the upper end of the table was placed. A catchment pipe that delivered solution back to reservoir was also constructed. Boxes to hold roots were made from plastic coated wire. The bundle of roots (25-30) from each cultivar and replication were put in these boxes and then placed on the table with continuous flow of solution. The roots in the forcing table were allowed to equilibrate in water for 2-3 days. After three days Peters solution fertilizer with 20 N-20 P_2O_5-20 K_2O at the rate of 0.6 ml per liter of water was added in the reservoir tank and pumped into the table. The solution was continuously circulated to the roots and back to the reservoir where it was aerated to bring oxygen in and if necessary reheated. The roots were kept standing in approximately 3 cm of nutrient solution and never allowed to dry out. The forcing room was kept completely dark and the temperature and relative humidity were maintained at $18 \pm 2\ ^{o}C$ and at 80 ± 3, respectively (Kruistum and Buishand, 1982). The air temperature in the room was kept at 3 to 4 ^{o}C lower than the nutrient temperature by ventilation system. The first chicons were harvested sixteen days (March 16, 1992) after planting and at weekly intervals thereafter. The emerging chicons were severed from the roots, weighed and results are presented as kg ha^{-1}.

b) Soil Forcing- Five endive roots of each cultivar and replication were planted on February 29, 1992, in 5 liter-plastic pots containing a 75:25 (v/v) mixture of metro-mix 220 (W. R. Grace and CO.) and Baccto potting soil (Michigan Peat Co., P. O. Box 980129; Houston, TX 77098). There were five plastic pots for each cultivar and replication. The root stock and crowns were completely covered with soil. Immediately after planting the roots were watered and fertilized at the rate of 0.6 ml of Peters 20N-20P_2O_5-20K_2O per liter of water weekly. The pots were then placed in the same forcing room with the hydroponic forcing. On March 16, sixteen days after planting, the emerging chicons or marketable heads and their attached roots were uncovered, roots severed and the outer leaves trimmed to remove adhering soil. The chicons were weighed and presented as kg ha^{-1}.

Statistical Analysis: The data from Experiment I were analyzed as a split plot design and the data from Experiment II as a randomized complete block design. Means were separated using least significant difference (LSD) at the 5% probability level as described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Experiment I

Phase I production: Generally, germination and the subsequent seedling establishment of the cultivars were satisfactory. The analysis of variance showed significant ($P < 0.05$) differences for number of seedlings among the three planting dates. The mean number of seedlings for the late planting date was higher than early and middle planting dates. The middle planting date had more number of seedlings than the early planting.

Significant differences for unusable and usable roots were found among the planting dates. The late planting date produced 90% and 88% more unusable roots than the early and middle planting, respectively (Table 1). The middle planting date had 4% and 21% more usable roots than the early and late planting dates, respectively. These results indicate that planting endive cultivars between June 20 and July 19 would produce root stock more suitable for chicon production.

There were also significant differences for total root fresh weight among the three planting dates with the greatest fresh root weight obtained from early planting date. Although, the early planting date had the most root fresh weight and the least unusable roots, root size in early planting was too large to be used for forcing, because large roots produce multiple heads per root which are unmarketable. The middle planting date (July 19) appeared to be the best time to plant endive to produce ideal root size for forcing. Among the cultivars tested, we feel that Flash is the best choice for planting during July.

As we observed in our study, endive requires minimum management as compared to other vegetable crops. The crop performed well in poor soil with less than 1.5% humus content. Although we did not test the effects of nitrogen on root production in this study, we believe that low nitrogen is the key for good production. It is also observed to be relatively tolerant to drought. Because of its long tap root, it can absorb moisture as deep as 90 cm. All these facts show that endive is a low-input rotational crop which can be produced inexpensive in many areas of the United States.

Experiment II

Phase I production: Germination and the subsequent seedling establishment of the cultivars were very good. We did not observe any difference in germination among the tested cultivars. Similarly, the analysis of variance showed that there were no significant differences for roots <1.5 cm in diameter (unusable roots) among the tested cultivars (Table 2). However, significant differences for roots with >1.5 cm (usable roots) diameter were observed among the tested cultivars. The cultivar Zoom produced the lowest 52,097 mean usable root yield and Flash

TABLE 1. Mean number of unusable* and usable **roots, and total fresh root weight of Experiment I, 1990.

Cultivar	Planting date: June 20	July 19	August 13	mean ***
	Number of unusable roots ha^{-1}			
Bea	24,355	16,476	286,532	109,121
Flash	27,221	30,086	183,380	80,229
Zoom	20,057	37,249	233,526	96,944
Planting-Mean	23,879	27,937	234,450	---
$LSD_{(0.05)}$ for planting date = 51,769				
	Number of usable roots ha^{-1}			
Bea	131,088	143,266	118,911	131,088
Flash	161,338	184,813	121,060	155,737
Zoom	149,713	133,237	123,925	135,625
Planting-Mean	147,380	153,772	121,300	---
$LSD_{(0.05)}$ for planting date = 19,494				
	Total fresh root weight Kg ha^{-1}			
Bea	28,947	21,995	14,689	21,877
Flash	29,410	21,700	14,731	21,947
Zoom	26,263	19,200	13,847	19,770
Planting-Mean	28,207	20,965	14,422	---
LSD(0.05) for planting date = 5,326				

*Root diameter < 1.5 cm
**Root diameter > 1.5 cm
***Cultivar mean

the highest 188,582 (Table 2). The cultivars Flash outyielded Bea and Zoom by 60% and 72%, respectively, and Bea outyielded Zoom by 34%.

Phase II production: The second phase of chicon or marketable head production includes root storage and then forcing. During cold storage the roots become vernalized and flower induction is initiated (Hill, 1988). The term "forcing" includes planting, growing, and harvesting chicons (marketable heads). Successful storage of roots is the second measure of productivity. The roots of all cultivars from experiment II stored well. At least 95% of the roots of most cultivars remained viable for about 14 weeks after being placed in cold storage.

The production of chicon or marketable head (Phase II) in soil as well as in nutrient solution is very common in European countries. The development of

TABLE 2. Mean number of unusable* and usable ** roots of Experiment II, 1991.

	Number of roots ha^{-1}	
Cultivar	Unusable	Usable
Bea	46,930	79,222
Zoom	22,712	52,097
Flash	43,486	188,582
Mean	37,709	106,634
LSD (0.05)	N.S	47,823

* Root diameter <1.5 cm
**Root diameter >1.5 cm

multiple production systems for Belgian endive would give Virginia farmers additional flexibility.

a) Hydroponic forcing: Recently, growing lettuce, tomatoes, and cucumber hydroponically has been very successful at VSU. Similarly, culturing roots from different endive cultivars in hydroponic solution to produce quality chicon is receiving increasing interest among the VSU research scientists. Significant differences in chicon mean weight were observed among the cultivars hydroponically. The mean weights of Bea and Flash chicon were significantly more than those of Zoom in the soil but not in hydroponic forcing method (Table 3). There were no significant differences in chicon weight between Bea and Flash. The chicon mean weight for cultivars forced hydroponically was 8,821 kg ha^{-1} and ranged from 6,989 to 9,750 kg ha^{-1}. The cultivar Bea and Flash produced about the same amount of chicons, but their chicon weights were 28% higher than Zoom's. Results from both Phase I and II experiments indicated that the two late maturing cultivars Bea and Flash are better adapted to Virginia conditions and to hydroponic forcing than the middle early cultivar, Zoom.

b) Soil forcing: The cultivars forced in the soil responded somewhat similarly to the hydroponic forcing (Table 3). The overall cultivar chicon mean yield was 12,681 kg ha^{-1} and ranged from 10,616 to 16,069 kg ha^{-1}. The cultivar Flash produced 41% and 51% more chicon weight than did Bea and Zoom, respectively. Again, Flash seems to be well adapted to forcing in the soil. Therefore, farmers in Virginia could successfully grow Flash and force the roots either in hydroponic solution or in soil.

The overall mean weight of chicons that were forced in the soil were 43.8% heavier than those forced hydroponically. The increased chicon weight is attributed to an improved forcing techniques that maintained uniform temperature and humidity in the soil than compared to hydroponic (Table 3).

Even though we found no significant forcing x cultivar interaction, cultivars Bea, Zoom, and Flash produced 14%, 34%, and 39% more chicon weight in soil than in hydroponic forcing. However, the quality (pale yellow, tight, and attractive) of chicons forced hydroponically were better than those chicons forced in the soil, because of fungus *Pseudomonas margnalis* which discolored the chicons.

TABLE 3. Chicon (marketable head) yield from hydroponic and soil methods of forcing from Experiment II, 1991.

Cultivar	Forcing Methods: Hydroponic	Soil	Cultivar Mean
		$kg\ ha^{-1}$	
Bea	9,750	11,360	10,556
Zoom	6,989	10,616	8,803
Flash	9,725	16,069	12,897
Mean-Forcing-	8,821	12,681	---

LSD(0.05) : Forcing methods = 2,574, Cultivar = 3,152
Forcing Methods x cultivar interaction = N.S.

Several researchers have indicated that production of endive roots for forcing is simple and relatively inexpensive; however, storing and forcing roots require careful control of temperature and relative humidity to produce quality chicons that can compete with European imports. The VSU-grown chicons were judged equal in quality to imports, and the chicons from VSU were milder than imported chicons which had aged in transit. The information obtained from these experiments will be useful to growers. We have shown that cultivars Bea or Flash could be planted in eastern Virginia during the middle of July at 75 cm spacing between rows, and can be harvested during the first week of December. This crop is a low input vegetable crop that can be grown in rotation after small grain crops with no or minimal nitrogen fertilizer. This is a major advantage especially in those areas where there is a concern of groundwater contamination from synthetic fertilizers. It is also very efficient in resource allocation because planting and harvesting do not coincide with the schedules of other major field crops. In addition, the roots are potential sources of various sugars (Chubey and Dorrel, 1977).

It is apparent that endive is a potentially profitable crop to growers. Experimental studies in Virginia, Massachusetts, and Connecticut have shown that this crop can be grown successfully under the United States environmental conditions.

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