The Connecticut Agricultural Experiment Station, New Haven

Yield and Quality of Witloof Chicory (Belgian Endive) Grown Using Weighted Insulation

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SUMMARY

In winter, roots of witloof chicory were forced in an unheated barn basement using heating cables to maintain a constant temperature of 65F. Forcing with a 4-inch thick sand-peat mixture covering the planted roots was compared to forcing with 6-inch insulation batts covering the roots and weighted with sandbags to apply 1 lb pressure to each developing chicon. Roots of early-maturing cultivars were harvested and directly planted (25 roots/ft^2) in the forcing bed while roots of mid-to-late maturing cultivars were stored 3-7 weeks at 32-34F before forcing.

In six forcings with unstored roots, the average weight of Grade 1 trimmed chicons grown with the sand-peat cover was 3.5 oz compared to 4.1 oz in trimmed chicons grown with weighted insulation. The increase in average weight of chicons grown with weighted insulation was related to the decrease in trim loss (18% for sand-peat cover vs.13% for weighted insulation). The average total yield of trimmed chicons in six forcings with sand-peat cover was 5.4 lb/ft^2 compared to 6.3 lb/ft^2 in forcings with weighted insulation.

In 10 forcings with roots stored 3-7 weeks, the average weight of Grade I trimmed chicons grown with the sand-peat cover was 4.1 oz compared to 4.5 oz in trimmed chicons grown with weighted insulation. Trim loss under sand-peat cover averaged 16% compared to 12% under weighted insulation. Less trim loss in forcings under weighted insulation produced a greater total yield (6.2 lb/ft^2) compared to the sand-peat cover (6.0 lb/ft^2).

In six forcings with unstored roots, Grade 1 chicons averaged 94% under both forcing techniques. In 10 forcings from roots stored 3-7 weeks, Grade 1 chicons averaged 79% under both forcing techniques. The quality of chicons from stored roots declined because some roots became over-mature during storage.

Economic benefits increase in forcing with weighted insulation compared to forcing with sand-peat covers. Total costs of material (\$4.76/ft^2) and labor (\$3.80/ft^2) in forcings with sand-peat cover are \$0.66/ft^2 greater that the total costs of material (\$5.22/ft^2) and labor (\$2.68/ft^2) in forcings with weighted insulation. With greater total yield from forcings with weighted insulation, net return is \$3.35/ft^2 greater than the net return from sand-peat cover or over \$80.00 for each 3 X 4-foot forcing cell.

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Witloof chicory, known in the United States as Belgian endive, is grown extensively in Western Europe where it is consumed in great quantities. It was discovered in the late 1800's by a Belgian farmer who stored a pile of chicory roots in the dark over winter for use as a coffee substitute. He found that the roots, whose tops were severed, began to re-grow a small head whose pale yellowish-white leaves were mild tasting. Following perfection of the quality of witloof chicory at the Brussels Botanical Garden, it began to be exported to the United States in 1911 (Sokolov 1985). Consumers here discovered that the pale yellow head, called a chicon, had great culinary diversity. It could be cooked as an entree or in soups or eaten raw in a salad or served as an hors d'oeuvre with a dip.

Traditionally in Europe, witloof chicory was grown in winter in darkened sand-covered beds at a constant temperature and humidity. Three weeks after planting the roots, the chicons were exhumed from the sandy overburden, cleaned, and shipped to market. The weight of the sandy overburden compressed the leaves into a tightly-furled head. In the past 30 years, however, production in Europe shifted to hydroponic forcing, a more efficient procedure. Although initial cost of hydroponic forcing is high, efficiency in planting the roots and harvesting the chicons created an economic advantage and allowed year-round commercial production.

CURRENT OUTLOOK

The rise in popularity of witloof chicory is demonstrated by imports from Belgium increasing from 440 tons in 1976 to 2025 tons in 1998 (Anon. 2000a). Total imports in 1998 were 3580 tons with Belgium, the Netherlands, and Italy the major exporters. The high cost of production in Europe began a shift in production in 1999 to South America where 143 tons were imported from Chile and Guatemala. Commercial production in the United States was confined to New York State but experimental tests were also conducted in Florida (Maynard and Howe 1986). I demonstrated that witloof chicory could be grown in Connecticut on diverse soils and, in winter, mature roots could be forced to form chicons of marketable quality (Hill 1987, 1988). In trials from 1985-1987, witloof chicory was grown in two environments, traditional plantings in an unheated barn with sand-peat cover, and uncovered plantings in a forcing room where optimum temperature (60-65F) and humidity (95%) were maintained.

In the traditional European forcing of witloof chicory, roots were deeply buried with a sandy cover and the re-growth exhumed and trimmed at considerable cost of labor and wasted trimmings. Cultivars have been developed whose chicons are more tightly furled and can be forced hydroponically to save labor costs. Hydroponic forcing requires controlled temperature and humidity, and initial cost is high, often beyond the means of growers who seek winter income.

Tan and Corey (1990) demonstrated that the quality of witloof chicory can be improved in hydroponic forcing using polyurethane foam and application of pressure on the growing chicon. Because hydroponic forcing is impractical in unheated buildings when temperatures fall below 60F in winter, Tan and Corey's method was modified to produce marketable chicons in an unheated barn, using a sand-peat mixture for planting the roots and weighted insulation to maintain heat in the forcing bed and envelop the chicons as they grew under pressure.

In this Bulletin, I report comparative yield and quality of chicons from nine cultivars and their trim losses in forcings from 1992-1999 under traditional methods with a sand-peat cover and under weighted insulation. I will also discuss management techniques to efficiently produce marketable witloof chicory.

MATERIALS AND METHODS

Production of roots for forcing. Roots were grown at Lockwood Farm, Mt. Carmel on Cheshire fine sandy loam, a loamy upland soil with moderate moisture holding capacity. Graded seed of witloof chicory was obtained from several domestic and Dutch seed companies. The nine cultivars provided an array of maturity to accommodate forcing from November through February under the two management techniques. They included:

Early: Monitor, Toner, Turbo
Early to middle: Flash, Conrad
Middle: Totem, Roelof (Red)
Late: Rinof, Radio

Field management. Witloof chicory requires adequate phosphorus, potassium, and magnesium to produce quality roots (Kruistum and Buishand 1982). Accordingly, the soil was fertilized with 150 lb/A P_2O_5 (supplied as triple superphosphate at 570 lb/A), 300 lb/A K_2O (supplied as muriate of potash at 445 lb/A) supplemented with 140 lb/A MgO (supplied as magnesium sulfate at 860 lb/A). Nitrogen fertilizer is generally excluded to prevent excessive top growth in the field and to discourage unfurling of the outer leaves of the chicon during forcing. Nitrogen supplied by decaying organic matter in the soil is usually sufficient for field growth.

Seeds were planted by hand July 3-10 to ensure that the roots of early-maturing cultivars would mature in late fall and allow sufficient cool treatment (vernalization) for direct forcing without placing them in cold storage (Hill 1988). The rows were placed 36 inches apart to allow cultivation by a rototiller. Plants were thinned 4 inches apart within the rows, producing a plant density of 43,000 plants/A. For commercial production, spacing between rows is 18 inches, producing a plant density of nearly 90,000 plants/A. In previous cultivar trials with narrower spacing between rows, weeds were controlled with Pronomid (Kerb 50W at 3 lb/A) applied immediately after seeding and watered in.

In late September, roots of witloof chicory were sampled for maturity. Sample roots were split in half lengthwise and the fingernail-size white patch just below the crown was examined. At maturity, the white tissue is 1/4 to 3/8 inch thick. Roots with patches thinner than 1/4 inch are immature and will not produce tightly furled chicons (Anon 1984). Roots with patches thicker than 3/8 inch are over-mature and produce chicons of poor quality with numerous subsidiary crown shoots. The optimum root diameter is 1-1/4 to 2-1/4 inches.

Roots of early-maturing cultivars, used for direct forcing, were harvested from mid-October to mid-November. The leaves were severed about 1 inch above the root crown and the roots trimmed to 8 inches. Roots less than 1 inch diameter and those excessively forked were discarded. The trimmed roots of Flash, Monitor, Toner, and Turbo, having received adequate chilling the field, were re-planted directly in the forcing bed.

Storage of roots. Trimmed roots of Flash, Rinof, Radio, Roelof, Totem, and Turbo, stored in wire mesh boxes to ensure ventilation, were placed in cold storage at 32-34F. Roots of Rinof and Radio, destined to be stored more than 60 days, were dipped in a 10% bleach solution to control soft rot bacteria. During cold storage, the roots became vernalized and flower induction was initiated. Vernalization may take 4-8 weeks in middle and late-maturing cultivars (Huyskes 1961).

Forcing of roots. All forcing was done in the basement of an unheated barn. Daily air temperature fluctuated less than 2 F but the average temperature declined from 55 F in mid-November to 46 F at the end of February. Electric heating cables were buried in the sand-peat mixture beneath the roots to maintain the optimum temperature (65 F) in the bed.

The forcing bed, 8 X 3 X 1.5 feet, was partitioned into two 4 X 3 X 1.5-foot cells. The inner walls of each cell were lined with 1-inch thick styrofoam sheets to conserve heat and the entire two-cell bed draped with a 4-mil black plastic sheet to exclude light. The planting media in both cells was 10 inches of unfertilized 1:1 sand:peat mixture into which the heating coil was placed in a serpentine fashion about 2 inches from the bottom of the bed. Up to 200 roots were planted in each cell utilizing the innermost section of the cell. Outermost roots were about 6 inches from the styrofoam lining to avoid edge effects. The roots, planted at close spacing, provided a density of 25 roots/ft^2. The roots were planted to their crowns using a dibble to make the holes. After planting, the sand-peat mixture was watered thoroughly until water dripped from the cell. In one cell, another 4 inches of 1:2 sand:peat mixture was added above the root crowns. The overburden was also watered thoroughly. In the other cell, the root crowns were covered with a sheet of Reemay (spunbonded polyester) to form a permeable barrier above the root crowns and then 6-inch batts of insulation to provide heat retention and a cushion for the growing chicons. Next, a 3 X 4-foot sheet of plywood was placed over the insulation batts to support bags of sand that applied 1 pound of pressure/root (Tan and Corey 1960).

Chicons from roots re-planted directly from the field were harvested after 18-21 days. Chicons from roots stored 3-7 weeks were harvested after 28-30 days. Stored roots partially wither if storage humidity is lower than 95%. After re-planting in the forcing bed, turgor is regained in several days before the chicons begin to grow.

In the cell with the sand-peat cover, whole plants were exhumed and the chicons cut from the roots. The chicons were trimmed to remove unfurled leaves and those with sand and peat particles adhering to the outer leaves. In the cell with weighted insulation, the chicons were cut directly from the roots in the bed and unfurled leaves trimmed. The chicons and trimmings were weighed and the chicons graded. Grade 1 chicons weighed more than 2.5 ounces and had length/diameter ratios less than 3.0. Grade 2 chicons weighed 1.5-2.5 ounces or had length/diameter ratios greater than 3.0. Deformed chicons (generally from over-mature roots) and those weighing less than 1.5 ounces were discarded.

YIELD AND QUALITY OF CHICONS

Yield. The forcings throughout the study were divided into two segments, those whose roots were unstored and those whose roots were stored at 32-34 F for 3-7 weeks. In six forcings with unstored roots, the average weight of Grade 1 chicons grown with a sand-peat cover was 3.5 ounces compared to 4.1 ounces in six forcings with weighted insulation. The increase in weight/chicon in forcings with weighted insulation is mostly related to a decrease in trim loss. The average trim loss in forcings with the sand-peat mixture was 18% compared to 13% in forcings with weighted insulation. In forcings with weighted insulation, 1-3 unfurled leaves were trimmed while 3-5 outer leaves coated with adhering sand and peat particles were trimmed in forcings with the sand-peat cover. The sand and peat particles cannot be completely removed by washing because some particles are imbedded behind the outer leaves. Washing also increases the risk of storage losses of chicons due to bacterial or fungal infections that may become established on moist surfaces.

The greater average weight/chicon in forcings with weighted insulation produced a greater average total yield/ft^2. The average total yield in six forcings with the sand-peat cover was 5.4 lb/ft^2 compared to 6.3 lb/ft^2 with weighted insulation, a 17% difference. Among the cultivars whose roots were unstored, the total yield of Monitor was 0.9-1.2 lb/ft^2 above average in two forcings (Dec 92 and Nov 99) under the sand-peat cover and 0.6-0.8 lbs/ft^2 above average under weighted insulation. Total yield of Flash was also 0.3-0.5 lb/ft^2 above average in two forcings (Dec 92 and Nov 99) under sand-peat cover. In one forcing (Dec 92) under weighted insulation, total yield of Flash was 9.7 lb/ft^2, the greatest yield among all cultivars in either treatment. In the December 1999 forcing under sand-peat cover, trim loss of Totem, exceeding 20%, was due to the development of bacterial rot that spotted the outer two layers of leaves and required extra trimming.

In forcings with roots stored 3-7 weeks, differences between the two treatments were less dramatic. In 10 forcings, the average weight/chicon grown under sand-peat cover was 4.1 ounces compared to 4.5 ounces with weighted insulation, a 10% difference (Table 1). Trim losses in 10 forcings under sand-peat cover averaged 16% compared to 12% under weighted insulation. Less trim losses in forcings under weighted insulation produced a greater average yield of 6.2 lb/ft^2 compared to 6.0 lb/ft^2 under the sand-peat cover.

Comparing average chicon weights in forcings with unstored roots vs. stored roots, we observed that average chicon weights from stored roots were 0.6 ounces greater under sand-peat cover and 0.4 ounces greater in stored roots under weighted insulation, differences of 17% and 11% respectively. The differences in average chicon weight with unstored vs. stored roots is probably due to the differences in cultivars used. With the exception of Flash and Turbo, whose roots were either stored or unstored, the other cultivars were segregated by maturity. The cultivars used in direct forcing were mostly early-maturing ones. The mid-to-late maturing cultivars were harvested 1-2 weeks later for storage. The roots were thicker and produced somewhat larger chicons.

Among the cultivars whose roots were stored, Radio had the greatest average weight under sand-peat cover (5.6 ounces) and weighted insulation (6.0 ounces) compared to all others. These heavy average weights/chicon produced the greatest yields/ft^2 under both treatments, 7.0 lb/ft^2 and 8.3 lb/ft^2, respectively. In 1999, Roelof was probably harvested too late and the roots were somewhat over-mature. The rough, hairy roots that were mostly 2 inches in diameter, produced chicons that were not tightly furled. Although secondary shoots did not emerge from the root crown during forcing, a sign of over-maturity, the chicons were less compact than chicons of other cultivars. Under the sand-peat cover, trim wastes exceeded 20%. Trim waste of Totem also exceeded 20% due to the development of bacterial decay on the outer leaves in chicons grown under sand-peat cover.

Quality of chicons. We shall now compare the quality of chicons produced under sand-peat cover and weighted insulation. In six forcings of unstored roots with the sand-peat cover, an average of 97% of chicons were Grade 1, and 2% were Grade 2 (Table 2). In six forcings of unstored roots with weighted insulation, an average of 91% of chicons were Grade 1 and 7% were Grade 2. Decrease in the average percent of Grade 1 chicons under weighted insulation was attributed to a decrease in the quality of early-maturing Turbo chicons which tended to be less compact as developing internal sprouts widened the spaces between concentric layers of outer leaves. The roots of Turbo, harvested in early December, were slightly over-mature but the decline in the quality of the chicons was not observed in the companion forcing with sand-peat cover.

In 10 forcings of roots stored 3-7 weeks with the sand-peat cover, an average of 86% of chicons were Grade 1 and 10% were Grade 2. In 10 forcings of roots stored 3-7 weeks with weighted insulation, 72% of chicons were Grade 1 and 18% were Grade 2. Comparing chicons produced from stored vs. unstored roots, it is apparent that storage reduced

Table 1. Average weight of chicons, trim losses and average yield of trimmed witloof chicory chicons grown in forcing beds covered with a sand-peat mixture compared to beds covered with weighted insulation.

	Sand-peat mix				Weighted Insulation			
	Avg. wt/ Oz.		Trim loss %	Yield lb/ft^2	Avg. wt/ Oz.		Trim loss %	Yield lb/ft^2
	Grade 1	Grade 2	Grades 1+2	Grades1+2	Grade 1	Grade 2	Grades 1+2	Grades1+2
UNSTORED ROOTS								
Toner	2.7	1.9	18	4.0	2.7	1.9	19	4.1
Turbo	3.0	1.6	15	4.6	2.6	1.6	19	3.3
Flash	3.7	--	16	5.7	6.4	--	8	9.7
Monitor	4.0	--	16	6.2	5.2	--	11	8.0
Flash	3.9	--	21	5.9	3.4	1.5	11	5.7
Monitor	3.9	2.2	21	6.0	4.6	--	10	7.2
AVG.	3.5	1.9	18	5.4	4.1	1.7	13	6.3
ROOTS STORED 3-7 WEEKS								
Flash	4.0	2.3	14	5.3	5.4	3.9	16	5.8
Rinof	3.8	1.8	12	5.8	4.8	3.9	14	7.0
Turbo	3.7	3.0	17	5.6	4.7	3.2	12	4.2
Flash	3.8	1.8	17	5.8	3.7	--	15	5.7
Flash	4.1	2.9	12	6.2	4.7	--	7	7.3
Flash	3.8	--	17	5.7	3.7	--	15	5.6
Flash	4.1	2.4	12	6.2	4.0	1.9	6	5.1
Totem	4.1	3.1	22	6.1	4.6	4.9	16	6.7
Roelof	3.9	4.6	20	6.3	3.3	4.1	14	5.9
Radio	5.6	2.0	16	7.0	6.0	4.6	9	8.3
AVG.	4.1	2.4	16	6.0	4.5	2.6	12	6.2

Table 2 Quality of roots grown in uncovered beds covered with sand-peat mix compared to those grown with weighted insulation.

		Sand-peat mix			Weighted Insulation		
	Forcing Period	Grade 1	Grade 2	Unmar-ketable	Grade 1	Grade 2	Unmar-ketable
UNSTORED ROOTS		%	%	%	%	%	%
Toner	Dec. 91	91	7	2	92	8	0
Turbo	Dec. 91	98	7	0	63	31	6
Flash	Dec. 92	100	0	0	97	0	3
Monitor	Dec. 92	100	0	0	98	0	2
Flash	Nov. 99	98	0	2	96	0	2
Monitor	Nov. 99	96	2	2	100	0	0
AVG.		97	2	1	91	7	2
ROOTS STORED 3-7 WEEKS							
Flash*	Jan. 92	83	12	5	61	12	12
Rinof	Jan. 92	94	6	0	82	13	5
Turbo*	Feb. 93	89	10	1	34	35	31
Flash	Dec. 94	95	4	1	94	2	4
Flash	Jan. 97	95	2	3	98	1	1
Flash	Jan. 97	95	0	5	97	0	3
Flash	Jan. 98	91	9	0	78	8	14
Totem	Dec. 99	84	14	2	76	16	8
Roelof	Dec. 99	56	40	4	33	67	0
Radio	Jan. 00	78	6	16	70	24	6
AVG.		86	10	4	72	18	10

* Roots were over mature

the percentage of Grade 1 chicons under both sand-peat cover and weighted insulation. Storage also increased the average percentage of unmarketable chicons from 2% to 10% in forcings with weighted insulation. This is related to an increase in the number of roots that became over-mature in storage. Prime examples are seen in forcings of Flash (Jan 1992) and Turbo (Feb 1993) whose roots are clearly over-mature. Both are early-maturing cultivars whose quality would have improved if they were forced earlier from unstored roots. Among the cultivars used in forcings from roots stored 3-7 weeks, Roelof produced only 33-57% Grade1 chicons in both forcing techniques. Although 2-inch diameter roots predominated, there was little evidence of over-maturity (development of internal sprouts). The chicons from these roots, however, were not tightly furled. Chicons from roots with smaller diameters (1.25-1.5 inches) were smaller but more tightly furled.

Among the cultivars used in forcings with stored roots, Flash provided consistently high percentages of Grade 1 chicons under both forcing techniques.

MANAGEMENT

Planting and harvesting. If seeds are planted in early July, the roots grow to optimum diameter (1.25-1.75 inches) by early fall. At this time, the early-maturing cultivars have been vernalized (subjected to cool temperatures to initiate reproductive growth) which allows direct forcing of early-maturing cultivars without storage. Mid-maturing and late-maturing cultivars require 3-7 weeks of cold storage to complete vernalization. Plantings in May produce mature roots in September but sufficient exposure to vernalizing temperatures may not have occurred and cold storage is required to complete the task. Longer storage periods may also reduce the numbers of Grade 1 chicons. Plantings in early-May in cool soil may prematurely vernalize the roots and cause them to bolt during the warm summer months. Plants that bolt are unfit for forcing.

Cultivars. Among the early-maturing cultivars used for direct forcing, Monitor and Flash produced a high percentage of Grade 1 chicons that were above-average in weight/chicon and total yield/ft^2 under both sand-peat cover and weighted insulation. Toner also produced 90% Grade 1 chicons, but the average weight/chicon and total yield/ft^2 were below average.

Among the cultivars whose roots were stored 3-7 weeks, chicons of Flash exceeded 90% Grade 1 in four of five forcings with sand-peat cover and three of five forcings with weighted insulation. In one forcing, quality diminished because the roots were over-mature. The chicons of Flash were average in weight and total yield/ft^2 under both forcing techniques. Although the percentage of Grade 1 chicons of Radio were slightly below the average, the average weight/chicon and total yield/ft^2 were well above average. The percentage of Grade 1 chicons of Roelof (red leafed) was below average under both forcing techniques but its uniqueness in providing color to salads without adding bitterness, merits further investigation.

Forcing with unstored vs. stored roots. There are two distinct advantages of direct forcing with unstored roots. First, storage costs are eliminated. If the grower has cold storage facilities, costs are reduced to the electricity needed to maintain the storeroom at 32-34F for 2-3 months. Renting commercial storage space is usually prohibitive. Second, the percentage of Grade 1 chicons from unstored roots is greater than the percentage of Grade 1 chicons from stored roots irrespective of forcing technique.

One negative feature of unstored roots is that the yield of chicons/ft^2 is slightly less than the yield/ft^2 from stored roots under both forcing techniques. Using only unstored roots limits one's options to early-maturing cultivars whose vernalization period is short and can occur in the field. Mid-maturing and late-maturing cultivars must be stored to complete vernalization. The harvest and forcing period of early-maturing cultivars is usually in late October through early December. Although roots can be harvested in early December (barring frozen ground) the root crowns may become injured by freezing temperatures with a subsequent decline in chicon quality. If the exposed portion of the root crown freezes, it may become the focal point of soft-rot bacteria in the forcing bed. Rotting of roots in the forcing bed requires replacement of the sand-peat mixture before another crop is planted. Occasional frost may also injure the outer leaves of plants in the field, but these are usually pruned from the root crown before placing in storage.

Forcing with sand-peat cover vs. weighted insulation. Several benefits accrue by forcing with weighted insulation. First, the trimmed chicons are heavier and the total yield/ft^2 is greater compared to chicons grown with sand-peat cover. With unstored roots, the average increase in total yield/ft^2 is 0.9 lb greater with weighted insulation; with stored roots 0.2 lb greater. The increased total yield is mostly due to the decrease in trim loss of chicons grown with weighted insulation.

Second, economic benefits also improve in forcing with weighted insulation. Debits and credits of each forcing system are shown in Table 3. The variable costs are materials used in forcing and electricity needed to maintain a temperature of 65F throughout the forcing period. Several variable costs are common between both forcing systems. They include cost of 10 inches of sand-peat mixture (1:1) into which the roots are planted and the heating cables to maintain a constant temperature in the bed. Electric use was metered throughout the winter of 1992. The number of kilowatt hours (kwh) expended varied according to the ambient temperature in the basement of the unheated barn. In November, with an average air temperature of 55.1F, electric use was 1.17 kwh/day for the 24-ft^2 bed. In December, with the average air temperature of 49.1F, electric use was 1.91 kwh/day for the 24-ft^2 bed. In January, with an average air temperature of 46.6F, electric use was 2.83 kwh/day for the 24 ft^2 bed. For an average forcing period of 25 days, the cost of electricity ranged from \$0.18/ft^2 to \$0.40/ft^2. An average cost of \$0.30/ft^2 was chosen for electrical use in the budget.

Other variable costs include 4 inches of sand-peat cover (1:2 mixture) in one cell and the cost of the Reemay barrier, insulation batts, and plywood in the other cell.

Labor costs common to both forcing systems include time spent mixing and filling each cell with the sand-peat mixture, planting the roots, and trimming the chicons. In the system with sand-peat cover, the cost of mixing and emplacement of the cover is added. Current labor costs in 1999 have been estimated to be \$8.50/hour according to labor statistics by the New England Agricultural Statistics Service (Anon. 2000b).

From Table 3, total variable costs (materials) are estimated to be \$4.76/ft^2 for forcing with a sand-peat cover and \$5.22/ft^2 for forcing with weighted insulation. Although initial cost of materials for weighted insulation is \$0.46/ft^2 greater than for the sand-peat cover, cost of the insulation batts, Reemay barrier and plywood can be amortized over several years because of their durability for repeated use. Total labor costs for forcings with sand-peat cover are \$3.80/ft^2 compared to \$2.68/ft^2 for weighted insulation. Savings in labor in forcing with weighted insulation are elimination of mixing and emplacement of the sand-peat cover (\$0.35/ft^2) and more efficient harvesting and trimming (1.5 hours/200 chicons vs. 2.25 hours/200 chicons for sand-peat cover).

Assuming that all harvested chicons are sold at an average retail price of \$2.99/lb the gross return for weighted insulation is \$2.67/ft^2 more than the gross return for sand-peat cover. Subtracting the total costs of materials and labor, the net return for forcings with weighted insulation is \$3.35/ft^2 more than the net return for forcings with the sand-peat cover or over \$80.00 for each 3 X 4-foot forcing cell.

The net returns reported in Table 3 are comparisons between the two forcing systems. The net returns do not take into account the cost of field production of roots or the storage costs of mid- to-late maturing cultivars. These costs however, would be constant for both forcing systems.

The only negative feature of forcing with weighted insulation was the reduction in the percentage of Grade 1 chicons, 6% from unstored roots and 14% from roots stored 3-7 weeks. Grade 2 chicons, however, are commonly found in imported 10-pound boxes of chicons sold at retail and are not separated by a price differential.

In summary, forcing with weighted insulation reduced trim loss and increased economic value of the crop compared to forcing with sand-peat covers. It also reduced the cost of harvesting and trimming to prepare the chicons for market. This system is adaptable to forcing in unheated structures compared to hydroponic forcing whose set-up and maintenance costs are high and limited to heated structures.

Table 3. Comparative budgets for forcing sand-peat cover vs. weighted insulation in 3 x 4 foot beds. Costs and returns are per square foot.

	Sand peat/cover	Weighted insulation
Common variable costs		
Sand + peat for planting	1.02	1.02
Heating cables	2.90	2.90
Electricity @ 0.14/kwh	0.30	0.30
Uncommon variable costs		
Sand + peat for cover	0.54	
Reemay barrier		0.25
Insulation batts		0.39
Plywood		0.36
Total variable costs	4.76	5.22
Labor costs @8.50/hr		
Filling cell and planting 200 roots	1.06	1.06
Emplacement of sand + peat cover	.35	
Emplacement of weighted insulation		.02
Harvesting and trimming chicons	2.39	1.06
Total labor costs	3.80	2.68
Total costs (material + labor)	8.56	7.90
Gross returns @2.99/lb	16.15	18.84
	5.4lb	6.3lb
NET RETURNS	7.59	10.94

REFERENCES

Anon. 1984. Instructions for growing and forcing chicory (witloof). Enza Zaden. Enkhuizen, Holland. 4p.

Anon. 2000a. 1998 U.S. vegetable imports, chicory, witloof, fresh. ERS - USDA Jan. 2000. 4p.

Anon. 2000b. 1999 Farm labor. February Ag. Review. New England Agricultural Statistics Service. USDA. 4p.

Hill, D.E. 1987. Witloof chicory (Belgian endive) trials - 1985. Conn. Agr. Exp. Sta., New Haven. Bull. 843. 8p.

Hill, D.E. 1988. The chicories: witloof (Belgian endive) and radicchio. Conn. Agr. Exp. Sta., New Haven. Bull. 859. 12p.

Huyskes, J.A. 1961. Witlooftrekken zonder dekgroud. Tuinbouw. 24:297-300.

Kruistum, G. von and Tj. Buishand. 1982. Teelt en trek van witloof (Cultivation and forcing of witloof). Handbook No. 12. Proefstation AGV Lelystad, Holland. 100p.

Maynard, D.N. and T.K. Howe. 1986. Evaluation of specialty crops for production in west central Florida. Proc. Fla. State Hort. Soc. 99:293-300.

Sokolov, R. 1985. The redheaded newcomer. Natural History. 4/85:35-37.

Tan, Y.T., and K.A. Corey. 1980. Technique for improving marketable yield of hydroponically forced witloof chicory. HortScience 25:1396-1398.