Vernalization Strategies to Enhance Production of Annual Globe Artichoke

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SUMMARY. Annual production of globe artichokes (*Cynara scolymus* L.) requires vernalization of the plants, either through cold treatment of transplants or from natural temperature conditions in the spring. Studies were conducted in upstate New York, to determine if artificial vernalization treatments could be achieved by earlier planting dates. Initial trials evaluated two varieties used for annual production in other parts of the country—'Imperial Star' and 'Green Globe Improved'. Transplants were set in the field with or without a vernalizing cool treatment, to determine the extent of natural vernalization achieved under New York conditions. 'Imperial Star' produced slightly higher marketable yields than 'Green Globe Improved' in 2 years of trials. Vernalization treatment increased the number of plants producing buds and the marketable yields, when transplants were set after 15 May. Natural vernalization was achieved and cold treatment before transplanting did not improve yields of plants established in early May. At later planting dates, vernalizing transplants increased the number of plants producing apical buds (largest) by about 20%, yet over 57% of

nonvernalized plants of each variety produced buds within the season. Average bud sizes did not vary with vernalization treatment. A similar number of days from transplanting to first bud harvest (69 to 75 days) was noted regardless of planting date and size of tran.

Growers in the northeastern United States are continuously searching for potential new crops to diversify production and fill niche markets. Annually produced globe artichoke is one potential crop that can be grown in the northeastern United States and Canada using new varieties developed for annual production, such as 'Imperial Star' (IS) (Schrader and Mayberry, 1992) and 'Green Globe Improved' (GGI) (Hill and Maynard, 1989). Both of these varieties have been evaluated in other parts of the country and demonstrated production of high quality buds (Baggett et al., 1982; Bryant, 1993; Husain and Stewart, 1996; Welbaum, 1994). Annual production requires a vernalization regime, in order to initiate the edible flower bud (capitulum) production (Harwood and Markarian, 1968). Imperial Star has been shown to have a lower vernalization requirement than GGI. After 205 h of less than 10 °C (50 °F), 85% of IS plants produced buds, compared to 25% of GGI (Welbaum, 1994).

Vernalization has been induced in globe artichokes by stratifying seed (Gerakis et al., 1969; Hill and Maynard, 1989) or by exposing transplants to a cold treatment in a controlled environment or cold frame (Hussain and Stewart, 1996). A viable alternative in the northeastern United States would be to establish transplants earlier in the spring when average temperatures are above freezing but less than 18.5 °C (65 °F), to achieve natural vernalization. Extended cold temperatures (less than 10 °C) at too early a planting date, however, may slow plant establishment. Three experiments with globe artichoke were conducted over 2 years (1997 and 1998) and at two locations in upstate New York (Homer C. Thompson Research Farm, Freeville, and East Ithaca Research Farm, Ithaca). These studies explored yield differences by variety, efficacy of both natural and controlled vernalization techniques, and overall potential to produce artichokes in upstate New York.

Materials and methods

TRANSPLANT PRODUCTION. Details on artichoke variety, transplant production, and field establishment schedules for both years are provided in Table 1. Seeds of IS (Santa Maria Seeds Inc., Santa Maria, Calif.) and GGI (Pine Tree Garden Seeds, New Gloucester, Maine) were sown in 128-cell [25-cm³ (1.5-inch³)] plastic trays filled with a peat-based medium on 2 April 1997. After 3 weeks, plants were transplanted into 918-cm³ (56-in³) pots [diameter 10 cm (4 inch)] and grown for an additional 6 weeks. At transplanting, plants had an average of seven leaves, with a longest leaf length of 25 cm (10 inch). In 1998, IS seeds were sown on 18 March and 24 March, and for the variety trial, seeds of IS and GGI were sown on 8 April. After 3 weeks, these plants were transplanted to 50-cell [90-cm³ (5.5-inch³)] trays. By using a smaller soil volume, transplants were smaller than those grown in 1997 and had an average of five leaves, but production time was reduced by 2 weeks. In both years, plants received 400 mg·L⁻¹ (ppm) N fertilizer on a weekly basis, using a formulation of 15N-2.1P-12.5K. Plants were grown in a glass-covered greenhouse with supplemental overhead lighting (HID metal halide) to provide a light intensity of 400 to 450 μmol·m⁻²·s⁻¹ photosynthetic photon flux (PPF) for a 14 h photoperiod. Air temperatures were maintained at 24°C day/18.5°C (75/65 °F) night.

VERNALIZATION. In both years, some transplants received a vernalization treatment just before field establishment (Table 1). A growth chamber (model GEL 511-38; Sherer-Gillett, Marshall, Mich.) with 13 °C (55 °F) day and night air temperatures and fluorescent light (300 to 350 μmol·m⁻²·s⁻¹ PPF for 14-h photoperiod) was used to supply the cool treatment. Transplants were maintained in this chamber for 19 d in 1997, to ensure adequate cool temperature exposure for both varieties. In 1998, only 6 d of vernalization (same conditions as 1997) were used, due to the lower vernalization requirement for IS (Welbaum, 1994). Plants used in the 1998 variety trial were not vernalized.

FIELD ESTABLISHMENT, HARVESTING AND OVERWINTERING. The soil type at East Ithaca was an Arkport fine sandy loam (coarse-loamy, mixed, active, mesic Lamellic Hapludalf) and at Freeville, a Howard gravelly loam (loamy-skeletal

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Table 1. Varieties, location of experiments and scheduling for transplant and field production of artichokes.

Year	Varieties ²	Location ³	Seeding date	Transplant to larger pot or cell size ^x	Vernalization treatments	Transplant to field
1997	GGI, IS	EI	2 Apr.	23 Apr.	None vs. 19 d at 13 °C	6 June
1998	IS	EI, FV	18 Mar.	17 Apr.	None vs. 6 d at 13 °C	7 May
	IS	EI, FV	24 Mar.	24 Apr.	None vs. 6 d at 13 °C	15 May
	GGI, IS	FV	8 Apr.	29 Apr.	None	18 May

²GGI = Green Globe Improved, IS = Imperial Star.

³Location of field experiments were EI = East Ithaca or FV = Freeville.

^xIn 1997, 3-week-old seedlings were transplanted to 918-cm³ (56-inch³) pots. In 1998, same age seedlings were transplanted to 90-cm³ (5.5-inch³) 50-cell plastic trays.

mixed semic Glossoboric Hapludalf). A portion of the fertilizer was broadcast and incorporated at each site before planting. In 1997, 106 kg·ha⁻¹ (95 lb/acre) of N, 24 kg·ha⁻¹ (21 lb/acre) of P, 44 kg·ha⁻¹ (39 lb/acre) of K fertilizer was applied at East Ithaca. In 1998, 112 kg·ha⁻¹ (100 lb/acre) of N, 25 kg·ha⁻¹ (22 lb/acre) of P, 46 kg·ha⁻¹ (41 lb/acre) of K at East Ithaca and 102 kg·ha⁻¹ (91 lb/acre) of N, 45 kg·ha⁻¹ (40 lb/acre) of P, 85 kg·ha⁻¹ (76 lb/acre) of K at Freeville was applied. Transplants were established on bare ground plots on June 6, 1997, using 0.6 m (2 ft) in-row and 1.5 m (5 ft) between-row spacing, and 14 plants per plot. For 1998 plantings, raised beds were formed (1.5 m, 5 ft apart on center) and a single drip line was buried [5 cm (2 inch) deep and off center of bed]. The bed was covered with a silver reflective mulch of 1 mil [0.001 inch (0.0254 mm)] thickness, Clark Agricultural Plastics, Va.) to reduce potential aphid infestations (observed in the 1997 trial). Plants were transplanted on two dates, 7 and 15 May 1998 (Table 1). Plants were spaced 0.6 m (2 ft) apart in rows, and there were 12 plants/plot. Irrigation was applied through a drip system in all studies. Additional nitrogen was added through the drip irrigation system during the growing season [1997, 67 kg·ha⁻¹ (60 lb/acre) of N; 1998, 100 kg·ha⁻¹ (89 lb/acre) of N at East Ithaca and 84 kg·ha⁻¹ (75 lb/acre) of N at Freeville]. No pesticides were applied in any of the experiments.

In 1997, buds were harvested, sorted and weighed based upon position on the flowering stalk—the primary being the terminal and the first and largest bud produced, secondaries being the next buds produced from axials below the terminal. In 1998, harvest methods were modified to sort buds according to California artichoke industry size standards (De Vos, 1992),

and buds within each class were weighed. This change was made because artichoke buds are usually sold on a size basis. Marketable artichokes were graded according to four size classes; 18s = 18 buds/22 lb carton and larger than 4.5 inch (114 mm), 24s = 4 to 4.5 inch (102 to 114 mm) diameter, 36s = 3.5 to 4 inch (89 to 102 mm) diameter, and the rest bulked as 48s = 3 to 3.5 inch (76 to 89 mm) diameter.

In all three field trials, randomized complete block design was used, with three replications. Results for early and marketable yields, percent of plants producing primary buds (1997) and size distribution of all buds were analyzed for statistical differences among treatments.

In 1998, plants were left in the field after the last harvest, to determine the potential for overwintering artichoke crowns. In early November, tops were mowed within 15 cm (6 inch) of the soil surface, and crops mulched with 15 cm (6 inch) of straw. In May 1999, fields were evaluated and no surviving plants were found.

Results and discussion

Both IS and GGI produced high quality artichokes without any vernalizing treatments when grown in New York, over 2 years of experiments (Table 2 and 3). Marketable yield of IS was slightly higher in 1997 (Table 2) and significantly higher than GGI in 1998 (Table 3). These varieties varied in the number of plants producing buds, regardless of the vernalization treatment. An average of 86% of IS plants and 71% of GGI plants produced buds after an early June planting date (Table 2). There was no difference in the average weight or the size distribution of buds between the two varieties (Table 2 and 3), similar to results from previous evaluations of these two varieties (Welbaum, 1994).

Despite smaller size transplant and

earlier planting date used in 1998, a similar number of days to first bud production was observed over both years; there were 69 d between transplanting and the first bud harvest in 1997 and 72 to 75 d in 1998, for both varieties. In trials in Quebec, a similar days to first harvest was reported (Husain and Stewart, 1996), whereas in Virginia, first buds for both varieties were harvested after 91 d (Welbaum, 1994). Higher mean temperatures in Virginia may have contributed to the slower vernalization, potential devernization of the plants when temperatures exceeded 32 °C, and a delay of bud harvest by 20 d compared to plants grown in New York (Gerakis et al., 1969). Bud quality under these higher temperatures could be compromised as well (Welbaum, 1994).

The effect of vernalization on artichoke yield varied by planting date. There were no interactions detected for variety response (Table 2). At later planting dates, such as early June, vernalization treatment resulted in a 30% increase (significant difference) in the percent of plants producing a primary bud, indicating that local temperatures in upstate New York were not cool enough to induce flowering in all plants (Table 2). Imperial Star has a lower vernalization requirement than GGI, contributing to the yield differences observed in the 1997 trial (Table 2). In unvernized plants, 74% of IS and 57% of GGI plants produced buds, in contrast to vernalized plants, for which 98% of IS and 86% of GGI produced buds (Table 2). In Virginia, an average of 55% of all plants produced buds after a mid-May planting date but none produced buds after a 7 June planting date (Welbaum, 1994). Vernalization significantly increased the yield of primary and secondary buds after a June planting date, in 1997 (Table 2). However, after May planting dates in 1998 (Table 4), there was no

Table 2. Marketable yield, average size, and size distribution of artichokes grown at East Ithaca, N.Y., 1997.

Treatment	Early yield ^z (g/plot) ^y	Marketable yield (g/plot)	Plants producing primaries ^x (%)	Yield of primaries (g/plot)	Avg primary wt (g) ^w	Yield of secondaries (g/plot)	Avg secondary wt (g)
Variety							
Green Globe Improved	821	3079	71	798	160	2281	123
Imperial Star	838	3455	86	1018	170	2437	129
Vernalization treatment							
None	477	2727	65	808	174	1920	140
Pretransplant	1182	3806	92	1008	159	2798	121
Variety × vernalization							
Vernalized							
Green Globe Improved	1025	3666	86	947	158	2719	117
Imperial Star	1338	3947	98	1070	157	2877	119
Unvernalized							
Green Globe Improved	616	2492	57	649	162	1843	98
Imperial Star	337	2963	74	966	187	1997	146
Main effects ^v							
Variety	NS	NS	0.05	0.05	NS	NS	NS
Vernalization	0.05	0.05	0.01	0.05	ns	0.05	0.05
Variety × vernalization	NS	NS	NS	NS	NS	NS	NS

^zEarly yields include all mature buds from first three harvest dates before 1 Aug.

^y8.35 g/plot = 1 oz/plot.

^xPrimary buds are terminal buds produced first in season, and are generally the largest produced by the plant. Secondaries develop from next axials of flower stalks.

^w28.35 g = 1 oz.

^vNS = nonsignificant; 0.05, and 0.01 represent the level of statistical significance using the F test.

Table 3. Early, total and marketable yield of artichokes grown in Freeville, N.Y., in 1998. Transplants were not vernalized before field planting.

Cultivar	Yield (g/plot) ^z					
	Early ^y	Total	Marketable	Size 18 ^x	Size 24	Size 36
Green Globe Improved	400	4767	3363	515	399	385
Imperial Star	872	7240	6111	296	1075	977
Significance of main effects ^w	NS	NS	0.05	NS	0.05	NS

^z28.35 g/plot = 1 oz/plot.

^yEarly yields include all mature buds from first three harvest dates before 1 Aug.

^xBud size class description: 18 = >4.5 inches (114 mm), 24 = 4.5 to 4.0 inches (102 to 114 mm), 36 = 4.0 to 3.5 inches (89 to 102 mm).

^wNS = nonsignificant; 0.05, and 0.01 represent the level of statistical significance using the F test.

difference in overall bud size distribution (size classes) of vernalized compared to nonvernalized plants. All IS plants (vernalized and nonvernalized) produced buds in 1998, indicating that natural vernalization was achieved by earlier planting dates compared to the 1997 trial.

A significant interaction was detected between vernalization and planting date in 1998 (Table 4). For those plants established at the second planting date (15 May), vernalization improved the marketable yield of bud production compared to the same treatment applied to the early planted crop (Fig. 1). Daily maximum air temperatures were considerably lower the week following the first transplant date (7 May) compared to temperatures after the second date, at both Freeville [20 vs. 27 °C (68 vs. 81 °F)] and East Ithaca [20 vs. 26 °C

(68 vs. 79 °F)]. These warmer temperatures after the second plant date may have contributed to less uniform natural vernalization and bud production.

Vernalization increased early yield in 1997 by 60% (Table 2). Transplanting by 6 May increased early yields by 22% compared to the 15 May planting, and vernalization of transplants significantly increased early bud production by 25% (Table 4). This data suggest that while vernalization may require special handling and additional expense to the grower, uniformity of primary bud production will be improved, even after early to mid May planting dates in upstate New York. The induction of earlier production also resulted in significantly more small artichokes (tertiary buds) to be produced later in the season (data not shown).

The significant differences in productivity were found between the two locations of trials. Early and marketable yields were higher at the East Ithaca location than at Freeville. The soil types at both locations were well drained; East Ithaca was an Arkport fine sandy loam and at Freeville was a Howard gravelly loam. An additional 34 kg·ha⁻¹ (30 lb/acre) of N was applied at East Ithaca over the 1998 season. This additional nitrogen, however, would not be expected to contribute to this magnitude of yield increase (Husain and Stewart, 1996). Mean air temperatures were similar across both locations [23 °C (73 °F)], from June through August, and similar to the previous 5 year average.

Growers who are considering production of artichokes in the northeastern United States should vernalize trans-

Table 4. Early, total and marketable yield of artichokes grown in Freeville and East Ithaca, N.Y., in 1998.

Treatment	Yield (g/plot) ^z				
	Early ^y	Marketable	Size 18 ^x	Size 24	Size 36
Location					
Freeville	1913	7505	227	1262	2894
East Ithaca	4312	9573	329	2541	3321
Vernalization					
None	2658	7906	347	2028	2780
Pretransplant	3567	9172	209	1774	3436
Plant date					
6 May	3501	8415	185	2086	2980
14 May	2724	8663	371	1716	3234
Significance of main effects ^w					
Location	0.01	0.05	NS	0.01	NS
Vernalization	0.01	NS	NS	NS	NS
Plant date	0.01	NS	NS	NS	NS
Interactions					
Location × vernalizing	NS	NS	NS	NS	NS
Location × plant date	NS	NS	NS	NS	NS
Vernalizing × plant date	NS	0.05	NS	NS	NS
Vernalizing × plant date × location	NS	NS	NS	NS	NS

^z28.35 g/plot = 1 oz/plot.^yEarly yields include all mature buds from first three harvest dates before 1 Aug.^xBud size class description: 18 = >4.5 inches (114 mm), 24 = 4.5 to 4.0 inches (102 to 114 mm), 36 = 4.0 to 3.5 inches (89 to 102 mm).^wNS = nonsignificant; 0.05, and 0.01 represent the level of statistical significance using the F test.

Fig. 1. Influence of vernalization treatment provided to artichokes planted on two dates in 1998. Black bars represent marketable yield per plot from plants receiving no pretransplant vernalization treatments. White bars represent yield from plants receiving a vernalization treatment of 6 d of cool treatment in a growth chamber at 13 °C (55 °F) and 350 $\mu\text{mol m}^{-2}\text{s}^{-1}$ photosynthetic photon flux for 14 h. Standard error bars for the means are provided. 28.35 g/plot = 1.0 oz/plot.

plants if early uniform bud production is desired. This might be achieved either by use of a cold frame or cool greenhouse or by transplanting before 15 May. Artichoke transplants are sensitive to hard frosts, so some earlier planting dates may require use of row covers. To schedule production of both large and medium size buds over the season, later planting dates should also be consid-

ered. In these cases, controlled vernalization of transplants would be recommended to ensure a high percentage of plants producing buds. Another strategy being tested is the application of gibberellic acid to induce bud formation in annual artichokes (Schrader, 1994). 'Imperial Star' produced higher marketable yields in 2 years of trials, when grown from vernalized or nonvernalized

transplants, and is recommended for use in the northeastern United States.

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