Galia Muskmelons: A Potentially Profitable Early-Season Crop for High Tunnels in the Central Great Plains

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High tunnels are low-cost season extension technology used for producing a diversity of horticulture crops (Lamont, et al., 2003). Specifically, high tunnels are passively vented, solar greenhouses covered with one layer of greenhouse plastic. Crops are grown directly in the soil beneath the high tunnel, and the only external connection is the drip irrigation system. In addition to accelerating crop growth and maturity, high tunnels protect the crop from a capricious environment where extremes in temperature, wind, rainfall, pests and light intensity can severely reduce marketable yields and quality. Using a high tunnel, crops can be harvested at peak horticulture maturity over a longer growing season because the crops are not weakened by insects, weeds or diseases.

The choice of which crops to grow within a high tunnel is based on market potential, economics, yield per plant and improved quality (Waterer, 2003). In a survey of high tunnel producers in the Central Great Plains, the dominant crops growers produced within high tunnels were tomatoes, peppers, salad greens (lettuce, spinach, etc.) and cucurbits, respectively (Jett and Carey 2006). Most high tunnel producers in the Central Great Plains use high tunnels for 1-2 crops per year and desire early season harvest of high-value warm-season vegetables. Each crop occupies the high tunnel for approximately 4 months or one-third of each calendar year. While early season tomatoes may be the dominant crop grown within high tunnels in the Central Great Plains, growers are interested in diversifying their production with other warm-season crops that can be double cropped or rotated with tomatoes and peppers. There is a premium price for early, muskmelons in the Midwest, and many specialty melons are becoming increasingly popular with consumers (Simon et al., 1993).

Galia muskmelons (*Cucumis melo* L. var. r*eticulatus*) are green-fleshed melons with a yellow, netted rind, high soluble solids and a robust aroma that are adapted to warm, dry growing environments (Karachi, 2000). Although not widely found in U.S. markets, they are very popular in Europe, and production has been evaluated in Florida within passively vented greenhouses (Cantliffe, et al., 2002; Rodriguez, et al., 2002). Rainfall during flowering and fruit formation significantly lowers quality of Galia melons, and they should be harvested at the vine-ripe stage for maximum quality (Cantliffe, et al., 2002). Hochmuth et al. (1998) noted less cracking of Galia muskmelons when grown in protected culture versus the field in Florida. High tunnels may provide an optimal environment for growing Galia muskmelons in the Central Great Plains.

Muskmelons are susceptible to chilling injury at temperatures between 41-59F (Mitchell and Madore, 1992). There are several production practices that are used to protect muskmelons from low temperature stress and increase early yields. Transplants can significantly increase early, marketable yield of muskmelons relative to direct seeding (Wiedenfeld et al., 1990). Spunbonded and perforated, polyethylene row covers used in combination with black plastic mulch significantly increased early and total marketable yield of muskmelons (Waterer, 1993; Hemphill and Mansour, 1986; Loy and Wells, 1982; Wiebe, 1973). Water is a very efficient collector of radiant energy. Water-filled polyethylene tubes have been shown to reduce greenhouse heating costs by accumulating energy during the day and releasing heat during the night time (Pavlou, 1990). The use of water-filled poly tubes in conjunction with clear plastic mulch and nonperforated polyethylene rowcovers significantly increased early yield of field-grown muskmelon in Quebec, Canada (Jenni, et al., 1998). Many of these techniques have been evaluated in the field environment but have not been evaluated in concert with a high tunnel. The objective of this research project was to evaluate the production and economic potential of early-season Galia muskmelons within a high tunnel and to determine which combination of season extension practices is the most effective in accelerating early harvest in the Central Great Plains.

Materials and methods

High tunnel structures and plot establishment

Three freestanding, Quonset high tunnel units (Stuppy Greenhouse Manufacturing, Kansas City, MO) were constructed in early March 2002 at the University of Missouri Bradford Research and Extension Center near Columbia, MO (lat. 90’11”W, long. 38’37” N). Each high tunnel was covered with a single layer of greenhouse grade, 6-mil (0.006-inch thick) polyethylene plastic (K-50, Klerk’s Plastic Manufactures, Inc., Richburg, South Carolina). The dimensions of each high tunnel were 12 feet (wide) x 36 feet (long) x 12 feet (high) with each arch spaced 4 feet apart. The high tunnels were oriented in a north-south direction with 10 feet between each high tunnel. Temperature and humidity were managed by manually rolling-up the sidewalls or removing two end wall panels from each end of the high tunnel. Whenever air temperatures inside the high tunnel exceeded 95°F, the sidewalls were rolled up to lower temperature and humidity.

The soil within each high tunnel was a Mexico silt loam.6 with a pH of 6 which was tilled and formed into raised beds 6 inches high x 24 inches wide beginning in mid-

March 2004 and 2005. Each high tunnel accommodated 5 rows of raised beds on 48-inch centers. Preplant fertilizer (13N-5.7P-11K) was top-dressed and incorporated into each raised bed at a rate of 12 ounces/1000ft^2 nitrogen (N), 40 ounces/1000 ft^2 potassium (K_2O) and 40 ounces/1000ft^2 phosphorus (P_2O_5) (Jett, 2006). Calcium nitrate (15.5N-0P-0K-19Ca) was fertigated at a rate of 20 ounces/1000ft^2/week commencing 2 weeks after seeding or transplanting and continuing through harvest.

Black, embossed plastic mulch (3 ft width) was laid over each raised bed. Each row was irrigated with one, 8-mil [(0.008-inch) T-Tape (T-Systems International, San Diego, CA)] plastic drip tube with drippers spaced on-center 12 inches apart. Irrigation was scheduled using a tensiometer placed 12 inches deep in the center of each bed (Jett, 2004).

Transplants versus direct seeding within a high tunnel

'Galia 152' (Hazera Genetics, El Segundo, CA) was chosen for this experiment based on performance in cultivar trials (Shaw et al., 2001). In early February of 2004 and 2005, 'Galia 152'seeds were planted in the greenhouse in 72 cell, 1.75 inch square, 2.75 inches deep, polystyrene trays (Speedling, Sun City, FL) filled with a moistened, soilless mix (Pro-Mix BX, Premier Brands, Yonkers, NY) and allowed to grow for 6 weeks before transplanting within each high tunnel. The plants were fertilized once per week with a 20N-8.7P-16.6K (Peter's 20-20-20 water-soluble fertilizer) containing 200 ppm N. The transplants were watered as needed.

The minimum temperature for muskmelon seed germination is 60°F (Maynard and Hochmuth, 1997). When the soil temperature at the 2 inch depth equaled or exceeded this temperature level, the plants or seeds were planted within the high tunnel. To evaluate direct seeding within a high tunnel, 2 seeds of 'Galia 152' were hand-seeded approximately 0.75 inches deep and 24 inches apart in 2-inch diameter planting holes on each raised bed. After emergence, the muskmelons were thinned to one vigorous seedling per hill. Six-week-old ‘Galia 152’ melon transplants were planted at the same spacing. Both seeding and transplanting occurred on 30 March 2004 and 2005. Cultural practices consisted of standard recommendations for growing melons within a high tunnel (Jett, 2006).

Row covers and water bags

Immediately after seeding and transplanting, low tunnels were fashioned using wire hoops (#9 gauge) covered with 2 layers of lightweight, spunbonded polypropylene rowcover (0.55 oz/yd^2; AG-19; Agribon Inc., Mooresville, NC). The rowcovers remained on the plants continuously until anthesis, defined as the time when the first perfect muskmelon flower was observed. After anthesis, the rowcovers were held in reserve in the event of a frost event

Water was evaluated as a solar collector that could increase the microclimate temperature around each muskmelon plant rather than as a technique to effect the air temperature within the entire high tunnel structure. Two, 1 gallon Ziploc storage bags (2 mil thickness) holding 8 lbs of water per bag were filled with water and placed on either side of each planting hole immediately after planting or seeding. Since the muskmelons were spaced 24 inches apart and each raised bed was 24 inches wide, 1 gallon of water occupied each square foot of bed space. Initially a 3 inch diameter polyethylene water tube was used but was discarded after discovering the tube leaked water and failed to remain stationary on the raised beds.

To facilitate harvest, the muskmelon vines were trellised using a 79-inch-high, plastic, mesh trellis (Johnnys' Selected Seeds, Albion, ME) supported by tensile wire and metal posts. The vines were not pruned, and each lateral was trained or directed to grow on the trellis using plastic vine clips.

Experimental data

Treatments consisted of combinations of two planting methods, transplanting (TRP) and direct seeding (DS), with or without spunbonded rowcovers (RC) and with or without water bags (WB). Individual plots were one raised bed, 8 feet long and containing 4 muskmelon plants. Treatments were randomized within each of the 3 high tunnels. Replicated air temperature was recorded 18 inches above the crop canopy using Hobo H8 data loggers (Onset Computers, Bourne, MA) in 2005. Temperature was measured under row covers, (with or without water bags), within the high tunnel as well as the ambient air temperature. Temperature was logged hourly and averaged to determine average daily temperature.

Since muskmelons require physical transfer of pollen from staminate to perfect flowers to set fruit, honeybee (*Apis mellifera* L.) colonies were placed 300 ft from the high tunnels to facilitate pollination. In 2005, small bumblebee (*Bombus impatiens* Cresson) colonies (Koppert Biological Systems, Ann Arbor, MI) containing approximately 150 bees per colony were placed within each high tunnel on 10 April to aid in pollination after it was determined honeybees were not entering the high tunnels in sufficient numbers to pollinate early, perfect flowers in 2004.

Thirty days after flowering, most muskmelons hanging on the trellis were supported with mesh,onion sacks cradled around the fruit and secured to the trellis. Fruits were harvested at full slip twice per week and individually weighed beginning 22 June 2004 and 15 June 2005. Fruits weighing less than 2 lbs were categorized as unmarketable. Harvest continued until 31 July of each year.

Economic analysis

Over the course of this research project, production inputs including specific cultural practices pest management and labor required to grow and harvest Galia muskmelons within high tunnels were recorded. Variable costs include all inputs used to grow the crop each season plus harvesting and marketing costs while fixed costs included all costs that remained constant regardless of the level of production such as prorated costs of the high tunnel, depreciation on machinery, depreciation on irrigation equipment, taxes and insurance. These data were used to develop an enterprise budget for a single, 4-month crop of Galia muskmelons within a high tunnel to compare production systems. Gross revenue was calculated based on average yields of melons with each production system. Wholesale muskmelon prices were recorded at the Central Missouri Produce Auction in Versailles, MO each year of this study. Additional price information for Galia melons as recorded from the New York Terminal Market (USDA, 2004). A sensitivity analysis was performed for a range of yields and melon prices.

Statistical analysis

The experiment was a randomized complete block design with three blocks (high tunnels). Data were analyzed using analysis of variance (ANOVA) and orthogonal contrasts (SAS Institute, 2003).

Results and discussion

Effect on air temperature

Throughout most of the vegetative growth in 2005, high tunnels maintained an average temperature of 60.4°F compared with an outside temperature of 53.1°F (Figure1). These temperatures are consistent with research conducted at Penn State where the average temperature difference between a single-layer, plastic high tunnel and the outside was 7.6°F (Lamont, et al., 2003). The addition of 2 layers of rowcovers increased the average microclimate temperature by 5.1°F (65.3F), while row covers combined with thermal water bags increased the microclimate temperature by 6.2°F (66.5°F). Photosynthesis and anthesis of Galia muskmelons is reduced when temperatures decrease below 65°F (D. Cantliffe, Personal Communication).

High tunnels alone generally don't provide significant frost protection but may protect against chilling temperatures. Minimum temperatures within a high tunnel eventually equilibrate with the outside temperature as was observed in Kansas during March (Kadir, et al., 2006) (Figure 1). Ambient temperatures did not decrease below 32°F in 2004. However, 24 April 2005 a frost event occurred, and the air temperature within the high tunnel was < 32°F for 5h and < 41°F for 11 h. Muskmelons with only a rowcover had microclimate temperatures <32°F for 1h and <41°F for 9h. The combination of rowcovers and thermal water bags, however resulted in 0 h below 32°F and <41°F for only 6 h. While foliar symptoms of chilling injury were observed on control plants, no plant loss occurred in either 2004 or 2005. However, sustained exposure to air temperature <41°F can result in lethal chilling injury to muskmelon plants (Jenni, et al., 1998).

Excessively high daytime temperatures can reduce vine growth of muskmelons and offset advantages of the high tunnel. Maximum microclimate temperatures were highest using the rowcover and thermal water bag combination, but did not exceed 104°F, the temperature threshold for muskmelons (Jenni, et al., 1996)

Effect on early marketable yield

In the Central Great Plains, early harvest of muskmelons before 4 July can be very profitable since local field production does not usually commence until mid-July. Perfect flowers were first observed on 28 April 2004 and 30 April 2005 with transplanted Galia melons supplemented with thermal water bags and row covers. In 2004, very few honeybees were active because of cool weather and failed to enter the high tunnels and pollinate these early, perfect flowers. As a result, early yield of some treatments was reduced (Table 1).

Transplanted Galia muskmelons had significantly greater early yield in 2005 relative to direct seeded melons (Table 1). At least one marketable melon per plant was harvested before 4 July 2005. Direct seeded melons did not flower until 14 May 2004 and 8 May 2005 resulting in a much later harvest. In both years of this study, rowcovers did not accelerate early harvest when used within a high tunnel. Rowcovers seemed to be most valuable in protecting melons from low temperature chilling injury. When used with thermal water bags, the rowcovers are very effective in retaining stored, solar heat resulting in early flowering and harvest. Almost 3 melons per plant were harvested before early July 2005 using these inputs.

Thermal water bags undoubtedly increased soil temperatures, but when used without a rowcover, did not significantly increase early marketable yield. Plants which had only waterbags showed no signs of chilling injury relative to the controls (data not shown).

Effect on total marketable yield

Fruit quality was excellent with most melons averaging 14° brix regardless of treatment. Due to the longer harvest period, transplanted melons had a significantly higher total season yield in both years of this study. Direct seeded Galia muskmelons averaged 1.2-1.9 melons per plant while transplanted muskmelons averaged 2.4-2.6 melons per plant. Despite earlier flowering and harvest of transplanted melons, average fruit mass did not differ with planting method. In both years, fruit mass averaged 3.8 lbs across all treatments.

In a commercial high tunnel, which is typically 2500 ft^2, approximately 300 muskmelon plants can be planted. If each plant yielded 3 marketable fruits, 900 Galia muskmelons can be harvested per high tunnel. In 2004, inadequate pollination delayed early fruit set on transplanted Galia melons with rowcover and thermal waterbags. Transplanted melons produced only 20-25% of their total yield before early July in 2004, but in 2005, more than 50% of the total yield was early. Given adequate density of pollinators in 2005, 86% of the total marketable yield of transplanted melons with rowcover and thermal water bags was harvested before 4 July.

Table 1. Marketable yield of Galia muskmelons grown within a high tunnel combined with inputs to accelerate harvest.

Treatment	Early yield				Total marketable yield			
	fruits/plant		*lbs/plant*		*fruits/plant*		*lbs/plant*	
	2004	*2005*	*2004*	*2005*	*2004*	*2005*	*2004*	*2005*
DS	0.0	0.8	0.0	3.5	2.0	1.9	4.3	8.4
DS+RC	0.2	0.6	0.8	2.5	1.5	0.8	6.4	3.0
DS+WB	0.5	0.8	2.5	3.3	2.9	1.3	12.8	5.3
DS+WB+RC	0.4	0.5	1.9	1.7	1.0	0.7	4.5	2.2
TRP	0.7	1.0	2.7	3.9	1.8	2.3	7.8	8.4
TRP+ RC	0.2	0.8	0.6	3.7	1.9	2.0	7.0	7.9
TRP+WB	0.3	1.0	0.9	3.7	2.7	1.9	9.6	7.1
TRP+WB+RC	0.5	2.7	2.1	9.7	3.8	3.2	15.2	11.6
Treatments	NS	**	NS	**	**	**	**	**
Orthogonal contrasts								
TRP vs DS	NS	**	NS	**	**	**	**	**
TRP+WB+RC vs. TRP	NS	**	NS	**	NS	NS	NS	NS
WB vs. NWB	NS	NS	NS	NS	NS	NS	**	NS
RC vs. NRC	NS	NS	NS	NS	NS	NS	NS	NS

TRP=Transplanted; DS=Direct Seeded; RC=Row cover; WB=(Thermal) water bag

*Significant at P≤0.05.

Economic analysis

The wholesale price range for muskmelons was \$1.75/melon for early-season (mid-June) cantaloupes at the local produce auction and \$3.20/melon at the New York Terminal Market. However, retail price for Galia melons often ranges between \$3-5/melon (Shaw et. al., 2004). Although some treatments affected date of harvest, total marketable yield did not exceed 4 melons/plant (1.9 lbs/ft^2) in either year of this study. In Florida, yields of Galia melons grown in nutrient culture within greenhouses have reached 5 fruits/plant (Cantliffe et al., 2002).

Some itemized variable costs were considered optional such as pruning, trellising and the use of thermal water bags for heat retention around the young plants. Pruning Galia melons reduces excessive vegetative growth and is performed by removing laterals up to the ninth node (Rodriguez et al., 2004). Trellising makes harvesting the melons easier. Using these inputs increased preharvest production costs by approximately \$100/1000ft^2 (Table 2). Items such as black plastic, trellising, and vine clips can be re-used for a succeeding crop of tomatoes peppers or cucumbers.

Labor accounted for 35-42% of the total variable costs associated with growing high tunnel Galia melons. However this is about 50% of the labor required to grow, harvest and market high tunnel tomatoes (Jett, 2004). Harvest and marketing labor was 20% of the total labor required.

Fixed costs were approximately \$0.10/ft^2 and included such items as yearly structure costs, insurance and depreciation (Table 2). Most high tunnel structures have an average structure cost of \$1.00-1.25/ft^2. Shaw et al., (2004) reported an average fixed cost of

$0.61/ft^2 and structure cost of $1.75/ft^2 for passive vented greenhouses used for Galia melon production in Florida.

Total revenue was calculated based on a range of yields per plant and market prices per melon. Wholesale prices were never lower than $1.75/melon for early-season melons in either year of this study. The sensitivity analysis was performed for three production systems: direct seeded, transplanted, and transplanted with all inputs including thermal water bags for heat retention.

Direct seeding melons decreases production costs slightly, but early-season yields are significantly less relative to transplanted melons in the high tunnel (Table 4). Thus, lacking the early-season price premium, average prices received by producers may be lower. Since direct seeded Galia melons produced an average yield of 2 melons/plant (0.9lbs/ft^2), the price must be at least $3.50/melon for profit to occur (Table 4). With transplanted melons, average yields were approximately 3 melons/plant with a significantly higher percentage of melons being harvested before early July. Thus, melons must sell for at least $2.50/melon for profit to occur (Table 4). When transplanting is combined with other optional inputs, early and total marketable yield is increased. Transplants plus all the additional inputs resulted in a total yield of approximately 3-4 melons/plant (1.4-1.9 lbs/ft^2). Given this level of yield, market prices must be $2.00-2.50/melon for profit to occur using these inputs.

Conclusions

Galia muskmelons are a potentially profitable warm season crop for high tunnel production in the Central Great Plains. Galia muskmelons can be rotated or double cropped with popular high tunnel vegetables such as tomatoes, peppers and lettuces.

Production practices which increase microclimate temperature and early growth such as using transplants, row covers and thermal water bags will increase both early and total marketable yield. The increased yields will offset the increase in production costs. Wholesale prices may not be high enough for a significant profit to occur. Most high tunnel producers in the Central Great Plains market their produce via local farmers' markets where a price premium for vine-ripe early muskmelons may be attained. In addition, high tunnels enable Galia melons to be grown using less pesticides which may further increase the price premium.

Table 2. High tunnel muskmelon budget (120 muskmelon plants per 1000 ft^2).

Production expense	Unit	Quantity	Price	Labor (rate/h)	Type[z]	Hours	Total costs ($)
Variable Costs							
Preplanting							
Soil test	**Complete high tunnel**		7.50	8.00	M	0.5	11.50
Major tillage			5.00	8.00	M	0.5	9.00
Rototill			3.00	8.00	M	0.5	7.00
Raised bed formation				8.00	M	3.0	24.00
Fertilizer and lime	lb.	50	5.00	8.00	M	0.5	9.00
Plastic mulch	linear ft.	245	4.90	8.00	M	1.5	16.00
Irrigation drip tape	linear ft.	245	4.00	8.00	M	0.5	8.00
Plant costs							
Transplants (excluding seed)	plants	120	12.00	8.00	M	1.5	24.00
Seed	seed	120	5.40				5.40
Starter solution		lb					1.00
Planting				8.00	M	2.0	16.00
Production costs							
Insecticide			42.00	8.00	M	1.5	54.00
Fungicide			16.00	8.00	M	2.0	32.00
Irrigation/fertigation	ft^2	1000	37.00	8.00	M	5.0	87.00
(Pruning)[z]				*8.00*	*M*	*3.0*	*24.00*
(Trellising)	*linear ft.*	*245*	*22.05*	*8.00*	*M*	*3.0*	*46.05*
(Plant clips)							*19.20*
(Support bags for fruits)	*mesh bag*	*240*	*0.25*	*8.00*	*M*	*1.5*	*72.00*
Fuel and oil							2.50
Plastic, crop removal				8.00	M	3.0	24.00
Pollination -bees	hive	1	65.00				65.00
Row covers	linear ft.	250	32.50	8.00	M	1.0	40.50
(Thermalwater bags)	*1-gal bag*	*240*	*0.10*	*8.00*	*M*	*4.0*	*56.00*
Wire hoops		50	28.00	8.00	M	0.5	32.00
Temperature mgt.				8.00	M	5.0	40.00
Harvesting costs							
Picking				6.00	H	5.0	30.00
Postharvest costs							
Boxes	box	30	0.75				22.50
Marketing costs							
Packaging/delivery				6.00	H	3.0	18.00
Total Variable Costs							**690.05**
Total Variable Costs (including optional inputs)							***795.65***
Total Fixed Costs							**103.87**
Total Costs							**793.92**
Total costs (including optional inputs)							***899.52***

M=Manager labor; H=Hired labor. [z]Optional inputs are in italics.

Table 3. Fixed costs for a 2000 ft^2 high tunnel in muskmelon production.

Item	Cost ($)	Years used	Yearly costs ($)
Land charge/rent	100.00	NA[z]	100.00
High tunnel structure	3000.00	10	300.00
Plastic covering	300.00	3	100.00
Wire hoops	40.00	5	8.00
Row cover	20.00	4	5.00
Fertilizer injector	300.00	10	30.00
Interest on land and buildings	20.00	NA	20.00
Taxes on land and buildings	10.00	NA	10.00
Interest on machinery	10.00	NA	10.00
Depreciation on machinery	10.00	10	10.00
Depreciation on irrigation equipment	10.00	5	10.00
Interest on irrigation equipment	5.00	NA	5.00
Insurance	5.00	NA	5.00
Total fixed costs per year			**613.00**
Area portion for 1000 ft^2			**306.50**
Yearly portion used for melons			**103.87**

[z]NA=not applicable.

Table 4. Net revenue for high tunnel Galia muskmelons per 1000 ft^2 (120 plants).

Price/melon ($)	**Yield/plant (no.)**			
	2	**3**	**4**	**5**
A. Transplanted				
1.75	-433.92	-253.92	-73.92	106.08
2.00	-313.92	-73.92	166.08	406.08
2.50	-193.92	106.08	406.08	706.08
3.00	-73.92	286.08	646.08	1006.08
3.50	46.08	466.08	886.08	1306.08
4.00	166.08	646.08	1126.08	1606.08
B. Direct Seeded				
1.75	-409.92	-229.92	-49.92	130.08
2.00	-289.92	-49.92	190.08	430.08
2.50	-169.92	130.08	430.08	730.08
3.00	-49.92	310.08	670.08	1030.08
3.50	70.08	490.08	910.08	1330.08
4.00	190.08	670.08	1150.08	1630.08
C. Transplanted + All inputs[z]				
1.75	-539.52	-359.52	-179.52	0.48
2.00	-419.52	-179.52	60.48	300.48
2.50	-299.52	0.48	300.48	600.48
3.00	-179.52	180.48	540.48	900.48
3.50	-59.52	360.48	780.48	1200.48
4.00	60.48	540.48	1020.48	1500.48

[z]Trellising, pruning, vine clips, thermal water bags.

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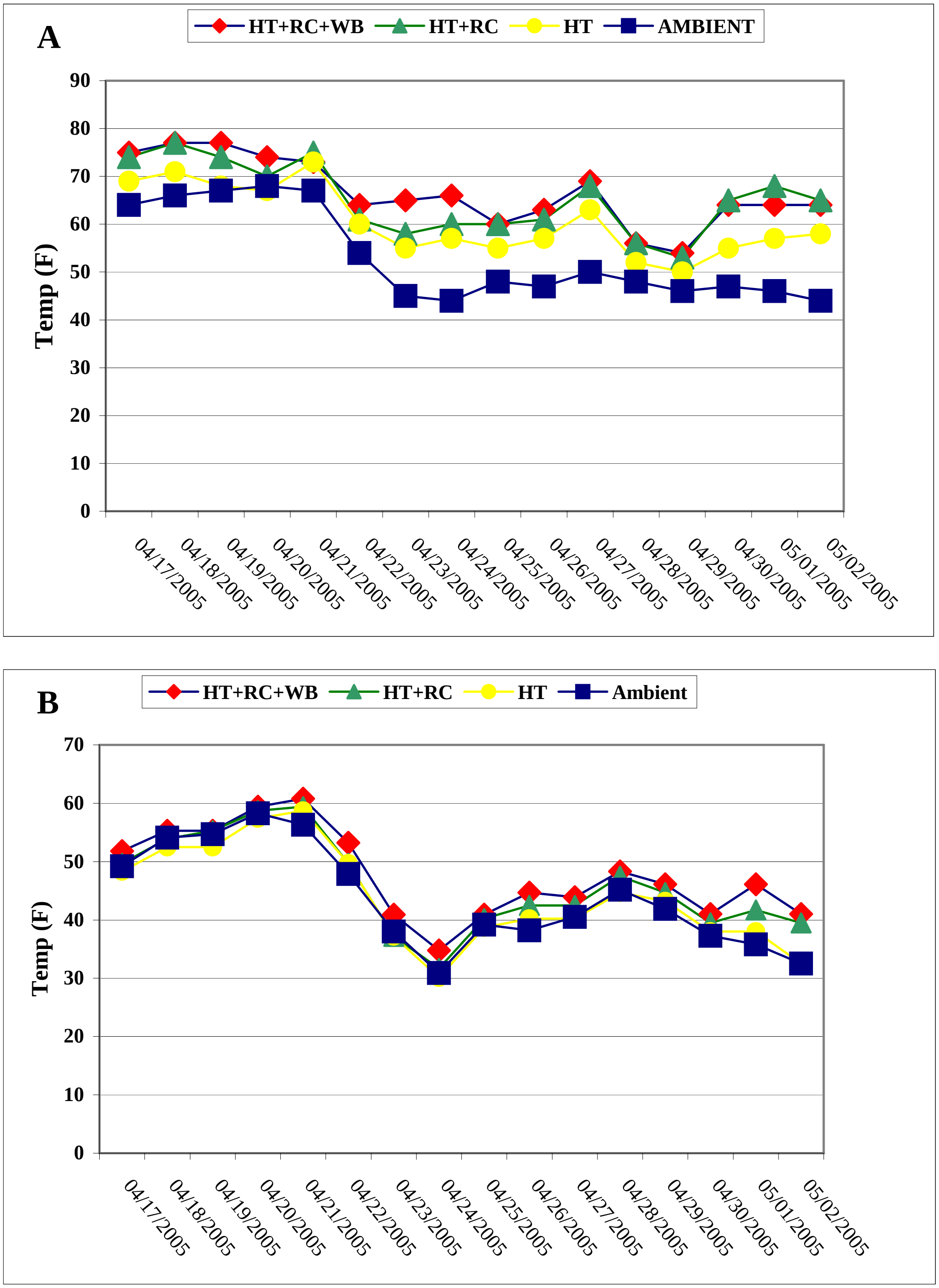

Figure 1. Effect of using high tunnels, rowcovers, and thermal water bags on microclimate average temperature (A) and minimum (B) temperatures for Galia muskmelons.