Influence of Short-term Cyclic Cold Temperature Stress on Muskmelon and Honeydew Yield

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Summary. **Muskmelon (*Cucumis melo*) seedlings are transplanted in late winter or early spring before last frost date to ensure early yields; however, this makes them very vulnerable to temperatures cycling between almost freezing and optimal temperatures. To simulate temperature alternations that may occur after field transplanting, 'Athena', 'Sugar Bowl', 'Eclipse' muskmelon, and 'Tesorro Dulce' honeydew (C. melo) transplants were subjected to 2 ± 1 °C (35.6 ± 1.8 °F) in a walk-in cooler and then to 29 ± 5 °C (84.2 ± 9.0 °F) in a greenhouse before field planting. In 1998, transplants were exposed to 2 °C for 9 to 54 hours, and for 9 to 81 hours in 1999. 'Athena' and 'Sugar Bowl' yielded less early melons in both years, whereas 'Eclipse' and 'Tesoro Dulce' early yields were only reduced in 1999. Total yields of 'Athena' decreased linearly in both years with 10% yield reduction occurring with 12 to 21 hours of cold stress. Total yields of 'Sugar Bowl' decreased linearly in both years with 11 to 18 hours of cold stress causing 10% yield reduction in 1998 and 1999, respectively. Therefore, early planting before last frosts of all these muskmelon and honeydew cultivars should be done with caution since reductions in early yields are highly probable.**

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Early harvests are of primary importance to muskmelon and honeydew growers, since the demand for melons reaches its peak during early summer months, making grower profits more lucrative. In order to ensure early harvests, the melons need to be planted into the field in late winter in March in coastal South Carolina before last frost dates. Although research has demonstrated that early planting of cucurbits can be achieved with transplants (Norton, 1968), plastic mulches (Nettles, 1968), and rowcovers (Hemphill and Mansour, 1986), early production of muskmelons in South Carolina is still limited by cold air and soil temperatures at the time of transplanting.

Muskmelons are native to tropical and southern Africa (Bates and Robinson, 1995), and are very susceptible to low temperatures. When exposed to near freezing temperatures, cucurbits may develop symptoms of low temperature injury, consisting of stunted growth, decreased yield, increased susceptibility to pathogens, necrosis on the plant tissue, or the death of the plant (Risse et al., 1978; Tachibana, 1982; Tanczos, 1977).

Although some research has been carried out to investigate the effects of low temperatures on muskmelon growth (Dunlap, 1986; Mitchell and Madore, 1992; Reyes and Jennings, 1994; and Risse et al., 1978) there is no information available on the effects of low temperatures imposed at transplanting on muskmelon yield, except our own. In our previous study, we found that the yield of 'Athena' muskmelon decreased linearly as seedlings were exposed to 2 °C with durations ranging up to 81 h (Korkmaz and Dufault, 2001). In that study, we only tested one muskmelon cultivar and no honeydew cultivars and it was unknown whether other muskmelon cultivars and honeydew would behave in a similar way. Therefore, our objective in this study was to determine the long-term effects of short-term cold stress at transplanting on the yield of three commercially popular muskmelon cultivars and one honeydew cultivar.

Materials and methods

'Athena', 'Sugar Bowl', and 'Eclipse' muskmelon and 'Tesoro Dulce' honeydew seeds from Syngenta Seed Co. (Salinas, Calif.) were planted with the radicle pointing down for uniform placement in 5.1 cm (2 inches) deep cells 57 cm^3 (3.5 $inches^3$) (Hummert Int., Earth City, Mo.) filled with Metro Mix 300 growth medium (Grace Sierra Co., Milpitas, Calif.) on 21 Apr. 1998 and 14 Apr. 1999. The flats were covered with plastic sheets to retain the moisture and placed in a germination room at 32 °C (89.6 °F) for 2 d then moved into a greenhouse where they were kept under natural photoperiod and day/night 29 ± 5/20 ± 5 °C (84.2 ± 9.0/68.2 ± 9.0 °F). Seedlings were watered as needed and fertilized twice with 50 $mg{\cdot}L^{-1}$ (ppm) of 20N–8.6P–16.6K water-soluble fertilizer.

Transplant cold stress started on 11 May 1998 and 30 Apr. 1999 and all treatments ended on 17 May 1998 and 9 May 1999. Seedlings were exposed to 2 °C for 9 h for 1, 2, 4, and 6 d in 1998 and for 1, 2, 4, 6 and 9 d in 1999. Plants were moved into dark walk-in coolers during the night hours, exposed to cold temperatures for 9 h (from 2100 to 0600 HR), and then returned to a warm greenhouse. The total cumulative exposure to 2 °C ranged from 9 to 54 h in 1998 and from 9 to 81 h in 1999. All cold stress treatments were timed to terminate on the same day to provide same-day field planting. The control plants remained in the greenhouse without exposure to cold temperatures. There were a total of five treatments in 1998 and six treatments in 1999. The experimental treatments were replicated three times in 1998 and four times in 1999 and all trays were arranged in a randomized complete block design in the greenhouse.

After completion of cold stress and after all risk of ambient cold stress had passed, 15 transplants from each treatment per replication were hand-transplanted into the field on 17 May 1998 and 10 May 1999. The soil type was Yonges loamy fine sand, an Aquic Hapludult. Soil tests were taken from respective fields each year before planting and fertilized with N, P, and K at 179.3, 76.2, and149.1 $kg{\cdot}ha^{-1}$ (160, 68, 133 lb/acre), respectively, according to soil test recommendations. The field was limed with Ca and Mg at 149.1 and 89.7 $kg{\cdot}ha^{-1}$ (133 and 80 lb/acre), respectively, from dolomitic limestone in both years. Beds on 1.8-m (6 ft) centers were fumigated with 75% methyl bromide and 25% chloropicrin at the rate of 459.5 $kg{\cdot}ha^{-1}$ (410 lb/acre) and mulched with 1.25-mil [0.03175-mm-thick (0.00125-inch)] black plastic. Treatment plots which were arranged in a randomized complete-block design consisted of one row, 4.6 m (15 ft) long and contained 15 plants. The plots were irrigated as needed using tensiometers [20 cm (7.9 inches) deep] at 15% moisture depletion to signal the start of a 1-h irrigation cycle. Crop protectants were applied with pesticides based on standard commercial recommendations (Cook, 1996).

The muskmelons and honeydews were harvested seven times in 1998 and eight times in 1999 at a minimum 3/4 slip stage. In 1998, fruit were harvested on 17, 20, 22, 24, 27, 29, and 31 July. In 1999, harvests were made on 30 June, and 2, 6, 9, 12, 14, 16, and 19 July. On the last harvest, all fruit were stripped from all plants. Harvests were grouped into four seasons as follows: early (harvests 1 and 2), middle (harvests 3 and 4), mid-late (harvests 5 and 6), and late (harvests 7 and 8) (only harvest 7 in 1998). Each fruit was weighed and graded as marketable or cull according to USDA standards (U.S. Dept. of Agriculture, 1978). Fruit that were <0.68 kg (1.5 lb) or misshapen were classified as culls.

Data were analyzed by harvest season and also pooled over the entire harvest season each year to determine the effects of cold temperature stress on earliness and total productivity, respectively. Polynomial regression analysis was performed between yield variables and total hours of cold exposure to determine the significance and strength of relationships. We chose a 10% yield reduction as the maximum tolerable yield reduction permissible before yield reduction was considered unacceptable commercially. To calculate the amount of cold exposure resulting in a 10% yield loss, the intercept of the regression equation was considered to be the yield of noncold-stressed plants. If the yield of any treatment was <90% of noncold stressed plants, that particular treatment suffered a 10% yield reduction. The same procedure was used to determine the tolerance level for 20% yield reduction, in the case that a 10% tolerance level is considered too stringent.

Results

COLD STRESS VERSUS EARLINESS. Exposure to 2 °C for as little as 18 h, significantly reduced the early yield of 'Athena' and 'Sugar Bowl' in both years and 'Eclipse' and 'Tesoro Dulce' only in 1999 (Table 1). Since cold stress did not significantly affect early fruit size of any cultivar in either year (data not shown), the early yield reductions were due to fewer melons produced per plant. 'Athena' and 'Sugar Bowl' plants exposed to 2 °C for increasingly longer times produced fewer fruit per plot, which reduced the early yields linearly in both years. 'Athena' early yields decreased 69% in 1998 and 73% in 1999 compared to control plants with 54 and 81 h of cold stress, respectively. Similarly, 'Sugar Bowl' early yields were

Table 1. The relationship between cold stress hours and early yield[z] of muskmelon and honeydew cultivars.

Cold stress (h)	'Athena' Fruit/plot (no.)		'Athena' Yield[y] (kg/plot)		'Eclipse' Fruit/plot (no.)		'Eclipse' Yield[y] (kg/plot)		'Sugar Bowl' Fruit/plot (no.)		'Sugar Bowl' Yield[y] (kg/plot)		'Tesoro Dulce' Fruit/plot (no.)		'Tesoro Dulce' Yield[y] (kg/plot)	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
0	5.3	5.3	14.3	10.0	3.7	1.3	11.1	2.9	2.3	3.1	7.0	6.8	5.0	2.8	17.1	6.6
18	3.3	5.0	8.6	11.6	3.3	1.5	9.2	3.6	1.3	0.8	3.3	1.3	4.3	2.0	17.6	5.1
36	1.7	3.0	4.9	7.2	2.0	1.3	5.5	2.8	0.7	0.3	1.6	0.8	3.7	1.0	12.5	1.9
54	1.7	2.0	4.5	4.7	2.0	0.3	7.1	0.5	0.0	0.5	0.0	1.5	3.3	1.3	14.4	2.6
81	---[x]	1.5	---	3.1	---	0.0	---	0.0	---	0.0	---	0.0	---	1.0	---	2.8
Regression																
Significance	L	L	L	L	NS	L	NS	L	L	L	L	L	NS	L	NS	L
R^2	0.67	0.30	0.65	0.46	---	0.20	---	0.23	0.47	0.35	0.47	0.31	---	0.22	---	0.20
P	0.001	0.01	0.001	0.02	0.07	0.05	0.14	0.03	0.01	0.007	0.01	0.01	0.11	0.03	0.27	0.05

[z]Early yield is sum of the first two harvests.
[y]1.0 kg = 2.20 lb.
[x]Treatment not used in 1998.

Table 2. The relationship between cold stress hours and total yield of muskmelon and honeydew cultivars.

Cold stress (h)	'Athena' Fruit/plot (no.)		'Athena' Yield[y] (kg/plot)		'Eclipse' Fruit/plot (no.)		'Eclipse' Yield[y] (kg/plot)		'Sugar Bowl' Fruit/plot (no.)		'Sugar Bowl' Yield[y] (kg/plot)		'Tesoro Dulce' Fruit/plot (no.)		'Tesoro Dulce' Yield[y] (kg/plot)	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
0	17.0	25.0	46.6	54.0	15.0	19.3	50.4	51.1	17.7	26.8	46.7	52.1	12.3	18.0	39.1	40.1
18	13.3	22.3	41.9	51.8	13.3	18.0	45.1	46.4	14.7	22.8	39.0	42.1	11.3	15.0	38.9	31.0
36	12.7	20.5	34.5	46.5	12.3	16.3	40.4	40.3	11.0	20.8	29.4	41.5	10.7	14.5	32.7	31.7
54	10.0	17.3	28.9	39.7	10.3	16.0	34.4	38.6	9.7	19.5	23.5	37.5	8.0	12.5	29.5	26.7
81	---[y]	14.5	---	32.1	---	12.0	---	29.4	---	15.0	---	27.4	---	11.0	---	23.8
Regression																
Significance	L	L	L	L	NS	NS	NS	NS	NS	NS	L	L	NS	NS	NS	NS
R^2	0.11	0.08	0.24	0.12	---	---	---	---	---	0.12	0.11	---	---	---	---	
P	0.05	0.009	0.03	0.02	0.21	0.16	0.22	0.10	0.24	0.06	0.05	0.04	0.06	0.08	0.19	0.09

[z]Yield is the sum of early, mid, mid-late, and late harvest seasons. 1.0 kg = 2.20 lb.
[y]Treatment not used in 1998.

affected so severely in both years that plants exposed to the greatest number of cold stress hours did not produce any early fruit. Although 'Eclipse' and 'Tesoro Dulce' early yields were not significantly affected in 1998, 'Eclipse' plants in 1999 did not produce any early fruit with 81 h of cold exposure and 'Tesoro Dulce' early yields linearly decreased 58% with 81 h of cold in 1999 compared to the controls.

Cold stress versus total yield. Cold stress did not affect average fruit size of any cultivar in either year (data not shown). The number of 'Athena' fruit per plot decreased linearly by 58% and 42% as cold stress hours increased which, in turn, reduced total yields linearly by 36% and 41% in 1998 and 1999, respectively (Table 2). Although in both years cold stressed 'Sugar Bowl' plants at the seedling stage produced statistically similar number of fruit in all cold treatments, total yields decreased 50% in 1998 and 47% in 1999. 'Eclipse' and 'Tesoro Dulce' yields decreased by as much as 42% and 41% respectively, with increasing hours of cold stress in both years; however, this was not significant at $P = 0.05$ level. Additionally, cold stress had no affect on mid, mid-late, and late season yields of all cultivars in either year (data not shown). Moreover, cold stress did not affect cull yield of any cultivar in either year.

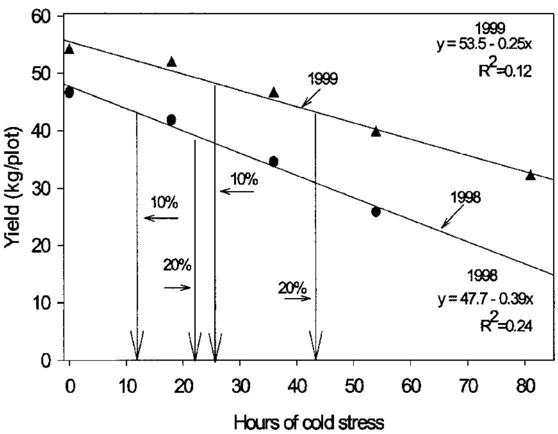

Fig. 1. Relationship between total cold hours and 'Athena' muskmelon total yield in 1998 and 1999. Regression analysis was performed on harvest season means (N = 12 in 1998 and 16 in 1999). 1 kg = 2.2 lb.

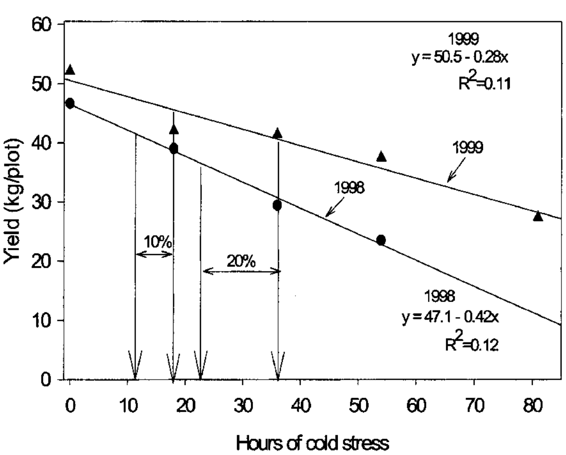

Fig. 2. Relationship between total cold hours and 'Sugar Bowl' muskmelon total yield in 1998 and 1999. Regression analysis was performed on harvest season means (N = 12 in 1998 and 16 in 1999). 1 kg = 2.2 lb.

Discussion

According to Jenni et al. (1996), minimum soil temperature for muskmelon growth is 12 °C (53.6 °F) while growth proceeds linearly with air temperatures averaging between 15 and 25 °C (59 and 77 °F). Severe muskmelon fruit or leaf tissue damage occurred when plants were exposed to constant temperatures ranging from 5 to 15 °C (41 to 59 °F) (Mitchell and Madore, 1992) and plant growth was very minimal when root temperatures were maintained below 12 °C (53.6 °F) (Risse et al., 1978).

Hassell (1979) reported that exposing 2-week-old 'Gold Star' muskmelon seedlings to 1 °C (33.8 °F) during the night time (9 h) for 8 d reduced yield 19% compared to plants exposed to 18 °C (64.4 °F) during nights. Korkmaz and Dufault (2001) found that plant development slowed and growth reduced on 'Athena' muskmelon at transplanting stage by exposure to 2 °C for as much as 81 h. This persisted until harvest and severely reduced early and total yields. Further, they stated that exposure to 2 °C for as little as 21 h caused 10% yield reduction. These results are confirmed by our findings in the present study that 12 to 21 h of exposure to 2 °C caused 10% reduction in 'Athena' total yield (Fig. 1). Similarly, 'Sugar Bowl' yields also decreased by 10% with 11 and 18 h of cold stress in 1998 and 1999, respectively (Fig. 2). The strength (R^2) of the relationships between cold stress hours and the yield of these two cultivars were low due to two reasons: 1) variation caused by uncontrolled factors in the environment were assumed to contribute to experimental error such as climate, pests, etc. which diluted the potency of treatment effects and 2) we expected that it would be difficult to expect a seedling stress to have a major impact on final yield statistics (high R^2) months after imposition of cold stress. The expression of a seedling stress is progressively lessen as time proceeds and recovery occurs gradually. In our study, we feel that to still detect a significant relationship between a transitory seedling stress and yield months after the stress was imposed, however, is still noteworthy even though the magnitude of R^2 is quite low.

The concept of using a particular probability level (usually 5%) as a critical value to test hypotheses is sometimes an oversimplification of a complex issue, and if a 10% difference in yield is considered economically important, using a more liberal P-value may be justified (Marini, 1999). Although 'Eclipse' yield decreased 32% and 42% and 'Tesoro Dulce' yield decreased 25% and 41% in 1998 and 1999, respectively, the mathematical relationship between cold stress and yield was nonsignificant at 5% probability level. Yield reductions of this magnitude are very important from a grower's point of view since they may seriously reduce grower's profits.

We found that earliness of all the cultivars studied was significantly reduced in 1 year ('Eclipse', Tesoro Dulce') or both years ('Athena', Sugar Bowl) by cold stress. Earliness is of great importance commercially and a strong risk exists for early planting these cultivars under cold field conditions. These cultivars should not be planted in late winter unless the unit price for earlier muskmelon and honeydew warrants and compensates for yield loses highly probable as an aftermath of cold stress.

Literature cited

Bates, M.D. and R.W. Robinson. 1995. Cucumbers, melons, and watermelons, p. 89–97. In: J. Smartt and N.W. Simmonds (eds.). Evolution of crop plants. 2nd ed. Longman, Essex, England.

Cook, W. 1996. 1996 Agricultural chemical handbook. Clemson Univ. Coop. Ext. Serv. Pub. EC 670.

Dunlap, J.R. 1986. Influence of soil temperature on the early growth of three muskmelon cultivars. Scientia Hort. 29:221–228.

Hassell, R.L. 1979. The effects of low temperature on the growth of muskmelon and watermelon plants. MS thesis. Cornell Univ., Ithaca, N.Y.

Hemphill, D.D. and N.S. Mansour. 1986. Response of muskmelon to three floating row covers. J. Amer. Soc. Hort. Sci. 111:513–517.

Jenni, S., D.C. Cloutier, G. Bourgeois, and K.A. Stewart. 1996. A heat unit model to predict growth and development of muskmelon to anthesis of perfect flowers. J. Amer. Soc. Hort. Sci. 121:274–280.

Korkmaz, A. and R.J. Dufault. 2001. Developmental consequences of cold temperature stresses at transplanting on seedling and field growth and yield: II. Muskmelon. J. Amer. Soc. Hort. Sci. 126:410–413.

Marini, R.P. 1999. Are nonsignificant differences really not significant? HortScience 34:761-762.

Mitchell, D.E. and M.A. Madore. 1992. Patterns of assimilate production and translocation in muskmelon (*Cucumis melo* L.). II. Low temperature effects. Plant Physiol. 99:996–971.

Nettles, V.F. 1968. Planting and mulching studies with cucurbits. Proc. Fla. State Hort. Sci. 76:178–182.

Norton, J.D. 1968. Effects of field seeding and transplanting on earliness, quality, and yield of cantaloupe varieties. HortScience 3:175–177.

Reyes, E. and P.H. Jennings. 1994. Response of cucumber (*Cucumis sativus* L.) and squash (*Cucurbita pepo* L. var. *melopepo*) roots to chilling stress during early stages of seedling development. J. Amer. Soc. Hort. Sci. 119:964–970.

Risse, G., P. Carnillon, J.C. Rode, and M. Auge. 1978. Effect de la temperature des racines sur la croissance de jeunes plantes de diverses varietes de melon (*Cucumis melo* L.). Ann. Agron. 29:453–473.

Tachibana, S. 1982. Comparison effect of root temperature on the growth and mineral nutrition of cucumber cultivars and figleaf gourd. J. Jpn. Soc. Hort. Sci. 51:299–308.

Tanczos, O.G. 1977. Influence of chilling on electrolyte permeability and oxygen uptake in leaf discs of thermophilic *Cucumis cativus.* Physiol. Plant. 41:289–292.

U.S. Dept. of Agriculture. 1978. United States standards for grades of watermelons. Doc. 77-35621. U.S. Dept. Agr. Wash., D.C.