J. Amer. Soc. Hort. Sci. 126(4):410–413. 2001.

Developmental Consequences of Cold Temperature Stress at Transplanting on Seedling and Field Growth and Yield. II. Muskmelon

Ahmet Korkmaz[1] and Robert J. Dufault[2]
Clemson University Coastal Research and Education Center, Department of Horticulture, Clemson University, 2865 Savannah Highway, Charleston, SC, 29414-5332

Additional index words. *Cucumis melo*, Cucurbitaceae, cucurbits, chilling stress

Abstract. **For the earliest yields of spring melons, muskmelon [*Cucumis melo* L. (Reticulatus Group)] fields in the southeast United States may be transplanted in late winter before the last frost date. Seedlings may be exposed to cold temperatures cycling between almost freezing and optimal for weeks before warm weather predominates and such exposure may reduce later growth and yields. To test whether cold stress may reduce growth and yield, 'Athena' muskmelon seedlings were subjected to cold stress at 2 ± 1 °C then transferred to a greenhouse at 29 ± 5 °C before field transplanting. In 1997, cold exposure durations were 3, 6, or 9 h and were repeated (frequency) for 1, 3, 6, or 9 d before transplanting. In 1998, duration levels were not changed but frequencies were 3, 6, or 9 d. In 1997, as cold stress increased, seedling shoot and root fresh and dry weights, height, leaf area, and leaf chlorophyll content decreased linearly, but shoot carbohydrates decreased curvilinearly and stabilized with ≈54 hours cold stress. In 1998, all seedling growth characteristics except leaf chlorophyll content decreased linearly as cold stress exposure increased. Leaf chlorophyll content decreased curvilinearly as cold stress increased to 36 h, but leveled off with more hours of cold stress. Even 1 week after transplanting, plants exposed to cold stress for up to 81 h continued to transpire more than control plants. In both years, vining (date first runner touched the ground) and male and female flowering were delayed significantly with increasing cold stress, but fruit set was affected only in 1998. Cold stress in 1998 delayed earliness with early fruit weight and number per plot decreasing as cold stress exposure increased. Total yields decreased linearly in both years as cold stress increased with 21 to 32 hours causing 10% yield reduction in 1997 and 1998, respectively. Results indicate a potential risk exists for yield reduction if 'Athena' muskmelon is planted weeks before last frost dates.**

Muskmelons [*Cucumis melo* (Reticulatus Group)] are native to the African tropics and the optimum air temperature for growth ranges from 20 to 32 °C, with 18 and 35 °C considered the minimum and maximum for growth, respectively (Bates and Robinson, 1995). Melon seedlings are very sensitive to low temperatures, which can severely impair growth. Species, exposure temperature and duration, and plant growth stage interact mediating the response of a plant to low temperatures (Wolk and Herner, 1982). Although climatic conditions during summers in the southeast United States are ideal for muskmelon growth, to insure early harvests, melons are often field planted in early March before the last killing frost. Once the seedlings have been planted in the field, they may be exposed to temperatures cycling between chilling and optimal for weeks before temperatures finally reach optimum for melon growth. Therefore, it is hypothesized that exposure of muskmelon seedlings to low temperatures may delay flowering, fruiting, and possibly reduce early and total yields and fruit quality. Previous work has shown that cold temperatures reduce the growth of muskmelon (Risse et al., 1978) and watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] (Bradow, 1990). However, little is known about temperatures alternating repeatedly from cold to warm and how these stresses affect melon seedling growth, earliness, and yield. Therefore, the objectives of this study were to 1) determine the long-term effects of short-term cold stress at transplanting on muskmelon seedling growth, earliness, yield, and fruit quality, and 2) establish the hours of cold stress necessary before significant yield reductions occur.

Received for publication 5 July 2000. Accepted for publication 2 Apr. 2001. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
[1]Former graduate student.
[2]Professor.

Materials and Methods

The experimental approach and cold stress treatments for conducting this study were identical to previous work on watermelon (Korkmaz and Dufault, 2001) except for the following differences. 'Athena' muskmelon seed (Rogers Brothers Seed Co., Salinas, Calif.) were sown in seedling trays on 1 May 1997 and 4 May 1998. Imposition of cold stress started on 20 and 19 May and ended on 29 and 28 May 1997 and 1998, respectively. The younger control plants were planted 9 d later than the older control on 10 May 1997 and 13 May 1998. Seedling growth data were taken 29 May 1997 and 28 May 1998. In the field experiment, the soil type, fertility, fumigation, irrigation, and pest management practices were the same as described previously for a watermelon study (Korkmaz and Dufault, 2001). Control plants and cold stressed seedlings were hand-transplanted into each field plot on 29 and 28 May in 1997 and 1998, respectively, after all risk of ambient cold stress had passed. The treatment plots consisted of one row, 4.5 m long, containing 15 plants separated by 0.3 m within rows and were replicated four times in 1997 and six times in 1998 in a randomized complete block design. Seedling data collection on shoot and root dry weight (DW), leaf area, sucrose content, height, chlorophyll content, and early field growth data on transpiration, flowering and fruiting were collected in the same manner as in the previously cited watermelon study (Korkmaz and Dufault, 2001). In 1997, muskmelons were harvested eight times at full slip (23, 25, 28 and 30 July, and 1, 4, 7, and 12 Aug.). In 1998, seven harvests were made (17, 20, 22, 24, 27, 29, and 31 July). On the last harvest, all fruit were stripped from each plant. Each fruit was weighed and graded as marketable or cull according to USDA standards (U.S. Dept. of Agriculture, 1978). If fruit were <0.6 kg and misshapen, they were classified as cull. Harvests were grouped into four "seasons" as follows: Harvests 1 and 2 were "early", harvests 3 and 4 were "mid", harvests 5 and 6 were "midlate", and harvests 7 and 8 were "late" (only harvest 7 in 1998). Fruit quality measurements were taken on randomly selected subsamples from each treatment of three fruit in 1997 (one from the first three harvests) and five fruit in 1998 (one from first five harvests). The fruit were cut open and length and width were measured. Soluble solids were measured with a hand-held refractometer on a sample cut from the center of each fruit. Data analyses were the same as described for the previous watermelon research (Korkmaz and Dufault, 2001).

Results

Cold stress vs. transplant growth. Duration and frequency of cold stress significantly affected seedling growth similar to that reported for watermelon (Korkmaz and Dufault, 2001), but by harvest, neither factor significantly affected yield. However, if duration and frequency treatment levels were combined to produce total cumulative cold stress treatments, their effects influenced growth and muskmelon yield and only these data will be presented.

In 1997, shoot fresh weights (FWs) (Fig. 1A) and DWs (Fig. 1C), height, leaf area (Fig. 1B), and chlorophyll (Fig. 1F) decreased linearly as cold stress increased from 0 to 81 h; however, the strength of these relationship (R^2) was weak, probably as a result of large amounts of variation in individual seedling growth response in cell packs to cold, reducing the R^2 precision. Root FW (Fig. 1E) and DW (Fig. 1G) also decreased linearly as exposure to cold increased from 0 to 81 h. With longer exposure, the plants became visibly chlorotic with shoot sucrose content (Fig. 1H) decreasing curvilinearly as cold stress increased to 54 h but leveling off with longer cold stress.

Plant response in 1998 was similar to 1997 with a few exceptions. In 1998, increasing replications from four to six increased the strength of R^2 values between cumulative cold hours and seedling growth variables (Fig. 1). All variables except leaf chlorophyll content (Fig. 1F), decreased linearly as cold stress increased from 0 to 81 h. Leaf chlorophyll content decreased curvilinearly as cold increased to 36 h without further change with greater exposure to cold stress.

Cold stress vs. early field growth, early and total yields, and fruit quality. In both years, transpiration rate increased linearly as cold stress increased from 0 to 81 h (Fig. 2A). The R^2 values in transpiration were low and probably due to differences in sampling day temperatures that lessened the effect of cold. In 1997, increasing cold stress from 0 to 81 h linearly delayed vining (Fig. 2D), male (Fig. 2B) and female flowering (Fig. 2C) about 5, 7, and 5 d, respectively, but fruit set were unaffected (Fig. 2E). In 1998, all variables increased linearly with increasing hours of cold stress. Plants exposed to 81 h of cold stress vined about 3 d later than the older control plants. Male and female flowering and first fruit set occurred 12, 6, and 5 d later than the controls, respectively, after cold exposure of 81 h.

Early yields were affected by increasing hours of cold stress only in 1998 and not 1997 (Fig. 3). Cumulative cold hours increasing from 0 to 81 h in 1998 decreased linearly average early fruit weight (Fig. 3A) and number of fruit per plot (Fig. 3B), resulting in a linear reduction of early yields (Fig. 3C).

Total number of fruit (Fig. 4A) and total weight per plot (Fig. 4B and C) decreased linearly with increasing hours of cold stress; however, average fruit weight summed over all harvest periods was unaffected by cold stress in both years (data not presented). Since the effect of harvest season was con-

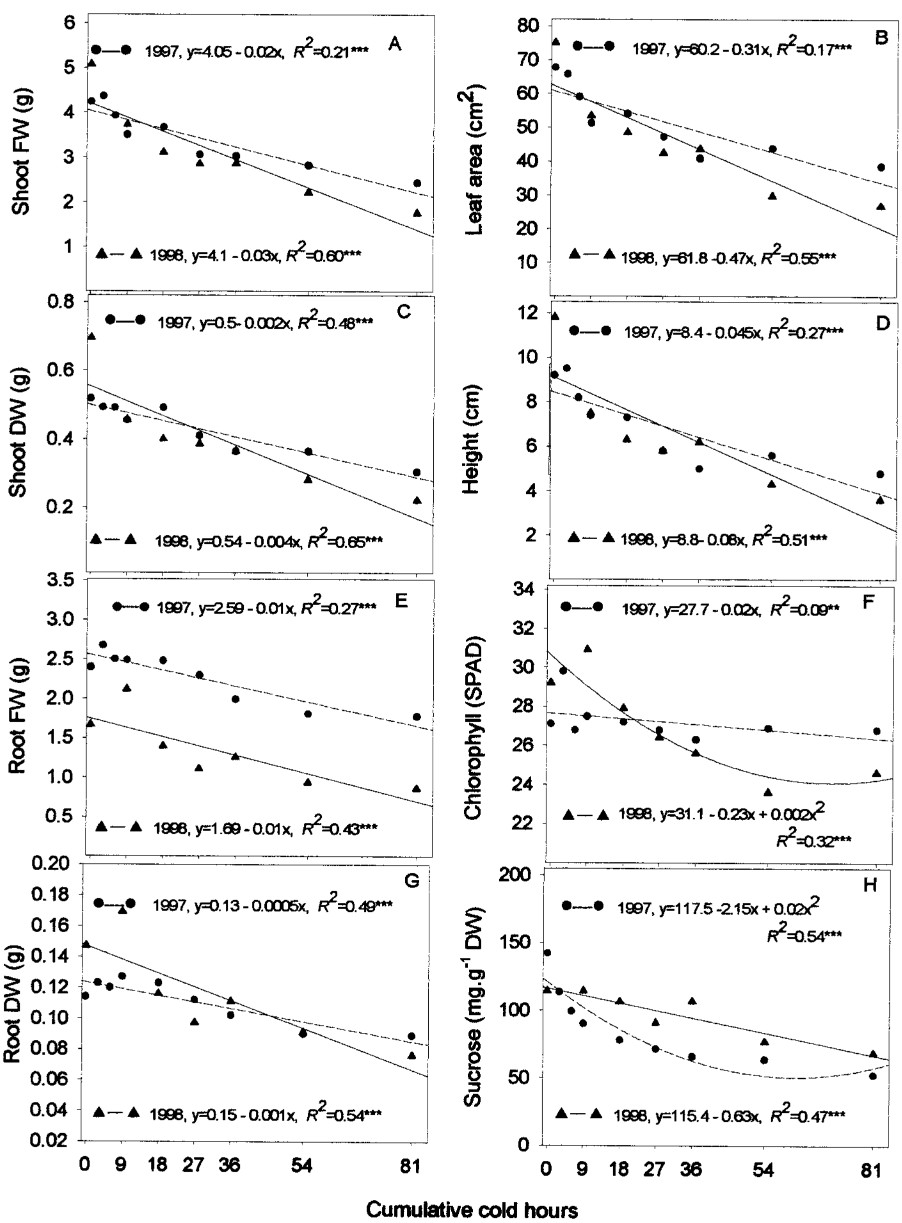

Fig. 1. Relationships between cumulative cold hours and muskmelon seedling growth variables measured 27 ds after seeding. (**A**) Shoot fresh weight (FW), (**B**) leaf area, (**C**) shoot dry weight (DW), (**D**) height, (**E**) root FW, (**F**) chlorophyll, (**G**) root DW, and (**H**) sucrose. Regression analysis was performed on individual seedling data (n = 32 in 1997 and 48 in 1998). ***Significant at $P \leq 0.001$.

founded in the variation attributable to the cold stress with these variables, the R^2 values were reduced. Similar to results reported for watermelon (Korkmaz and Dufault, 2001), both older and younger controls yielded similarly in both years with older control plants tending to yield more than the younger control plants.

Cold stress did not increase the production of cull fruit in either year. Additionally cumulative cold stress did not affect fruit length and diameter in either year, but soluble solid content of the fruits decreased linearly in 1997 with increasing cold stress from 0 to 81 h (data not presented).

Discussion

Exposure to cold stress up to 81 h significantly reduced muskmelon seedling growth in both years with the severity intensifying as exposure increased. Others workers have reported similar observations as a result of cold damage on muskmelon (Mitchell and Madore, 1992), and other cucurbits including cucumber (*Cucumis sativus* L.) (Bulder et al., 1987; Reyes and Jennings, 1994; Tanczos, 1977), watermelon (Hassell, 1979), and squash (*Cucurbita pepo* L.).

Field growth of muskmelon in both years was significantly delayed with increasing cold stress hours, but the response differed slightly each year. Flower initiation for most plants is temperature dependent. In the present study, heavy rains and cooler temperatures during flowering in 1997 (Table 1) may have reduced bee activity and pollination, permitting cold-stressed plants to set fruit at the same time as the control plants. In 1998, however, the weather was very conducive for muskmelon growth. Similarly, Dunlap (1986) reported that soil temperatures > 21 °C accelerated female flowering and fruit set of 'TAM-UVALDE' muskmelon. Furthermore, Hassell (1979) reported that exposing 'Gold Star' muskmelon seedlings to day/nights of 27/10 °C for 8 d delayed flowering by 4 d compared to those exposed to 27/18 °C. In our study, growth differences as a result of cold stress during the seedling stage were still measurable by the time of fruit set although they decreased progressively as the growing season progressed. Cold stress significantly delayed earliness in one of 2 years with fruit weight, fruit number, and early yields decreasing with increasing cold stress in 1998 (Fig. 3). Total yields over all harvest seasons decreased linearly in both years with increasing hours of cold stress. In 1997, 21 h of cold stress caused 10% yield reduction (Fig. 4B), but in 1998, 32 h of cold stress caused similar results (Fig. 4C). Furthermore, yields decreased by 20% with 43 to 65 cold stress hours in 1997 and 1998, respectively. We also reported similar findings with watermelon with yields decreasing 10% with 38 to 40 h of cold stress (Korkmaz and Dufault, 2001); however, muskmelon apparently is more susceptible than watermelon to long-term effects of short-term cold stresses in the seedling stage.

This study also revealed that transplant age significantly affected yield in both years. Twenty-six-day-old noncold-stressed plants yielded more than 17-day-old noncold-stressed transplants. NeSmith (1994) reported similarly that muskmelon transplant age did not affect early or total yields. In another study, NeSmith (1993) found that 30-day squash transplants yielded more than 10-day old transplants.

The significant relationship between total fruit yield and cumulative hours of cold stress suggest that 'Athena' muskmelons should not be planted in the field if there is a high probability of prolonged low temperatures. Early planting of this cultivar should be avoided, since 21 or more hours of cold stress reduced yield by at least 10% in 1 of 2 years.

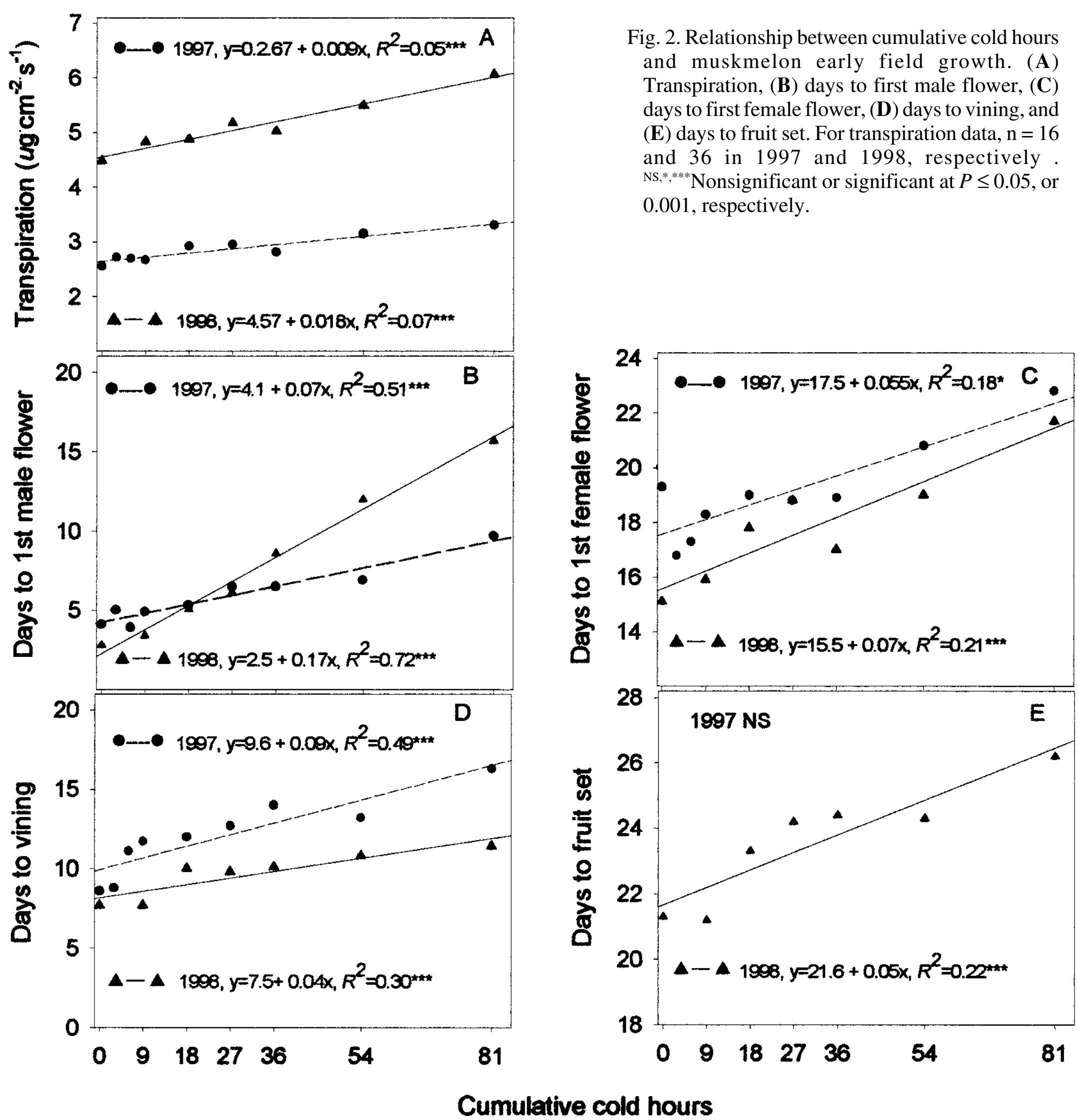

Fig. 2. Relationship between cumulative cold hours and muskmelon early field growth. (**A**) Transpiration, (**B**) days to first male flower, (**C**) days to first female flower, (**D**) days to vining, and (**E**) days to fruit set. For transpiration data, n = 16 and 36 in 1997 and 1998, respectively . NS,*,***Nonsignificant or significant at $P \leq 0.05$, or 0.001, respectively.

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 Scientific & Tech, Essex, U.K.

Bradow, J.M. 1990. Chilling sensitivity of photosynthetic oil-seedlings. J. Expt. Bot. 41:1595–1600.

Bulder, H.A.M., P.H.R. Van Hassellt, and P.J.C. Kuiper. 1987. The effect of temperature on early growth of cucumber genotypes differing in genetic adaptation to low-energy conditions. Scientia Hort. 31:53–60.

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.

Korkmaz, A. and R.J. Dufault. 2001. Developmental consequences of cold temperature stress at transplanting on seedling and field growth and yield. I. Watermelon. J. Amer. Soc. Hort. Sci.126(4):404–409.

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.

NeSmith, D.S. 1993. Transplant age influences summer squash growth and yield. HortScience 28:618–620.

NeSmith, D.S. 1994. Transplant age has little influence on yield of muskmelon (*Cucumus melo* L.). HortScience 29:916.

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.

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

U.S. Dept. of Agriculture. 1978. United States standards for grades of melons. U.S. Dept. Agr., Wash., D.C.

Wolk, W.D. and R.C. Herner. 1982. Chilling injury of germinating seeds and seedlings. HortScience 17:169–173.

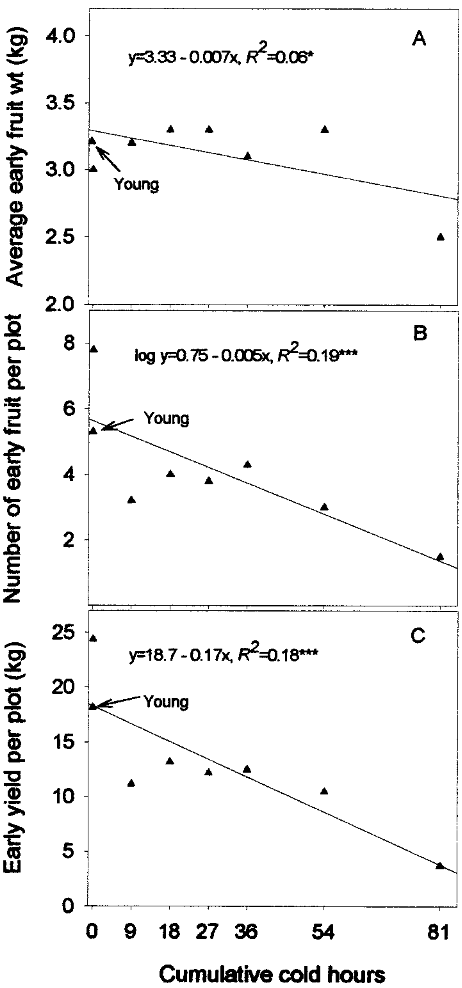

Fig. 3 (**above**). Relationship between cumulative cold hours and muskmelon early yield variables in 1998. (**A**) Fruit weight, (**B**) fruit number, and (**C**) yield. Only data from older control plants were included in the regression analysis; however, data for the younger control plants are also shown for comparison purposes. *,***Significant at $P \leq 0.05$ or 0.001, respectively.

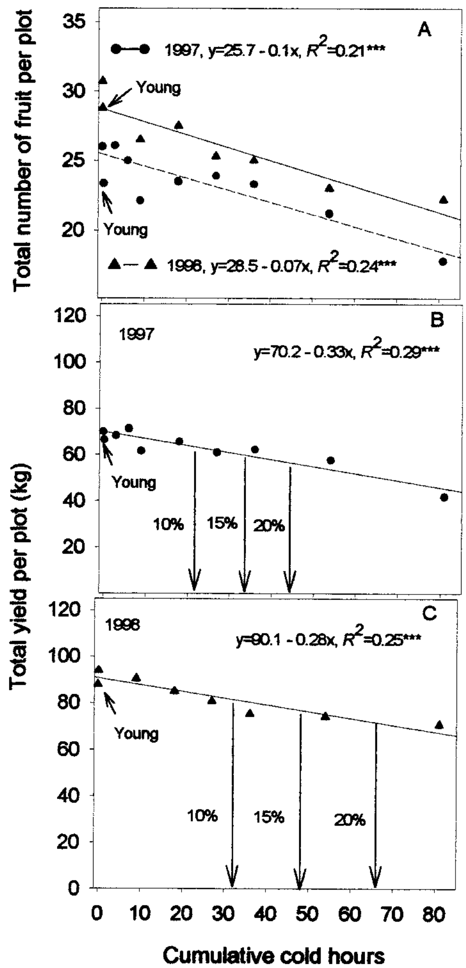

Fig. 4. Relationship between cumulative cold hours and muskmelon (**A**) total fruit number and total yield for (**B**) 1997 and (C) 1998. Only data from older control plants were included in the regression analysis; however, data for the younger control plants are also shown for comparison purposes. Regression analysis was performed on replication means (n = 9 in 1997 and 7 in 1998). ***Significant at $P \leq 0.001$.

Table 1. Summary of weather data for 1997 and 1998 growing seasons of muskmelon at the Clemson University Coastal Research and Education Center, Charleston, S.C.[z]

	May		June		July		August
	1997	1998	1997	1998	1997	1998	1997
Rainfall (mm)	0	0	343	76	216	173	17
Temperatures (°C)							
Extreme minimum	15.0	20.0	10.7	11.6	17.7	20.5	15.6
Mean minimum	15.9	20.8	19.4	22.4	22.2	23.8	20.4
Extreme maximum	28.3	31.7	32.7	37.8	35.5	36.6	31.6
Mean maximum	27.0	31.0	28.3	34.4	32.0	33.8	30.0
Mean	21.7	26.1	23.8	28.3	27.2	28.8	25.3

[z]Data represent only the days the experiment was conducted in the field.