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Pre- and Postharvest Temperature Conditioning of Greenhouse-grown Sweet Basil

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***Abstract.*. Postharvest shelf life (defined by visual quality) of fresh, greenhouse-grown sweet basil (*Ocimum basilicum* L.) at 5 °C was only 3 to 4 d due to the appearance of chilling injury symptoms. Plants chill-hardened at 10 °C for 4 h daily (2 h at the end of the light period and 2 h at the beginning of the dark period) for 2 d, before harvesting and packaging, had ≈3 d longer postharvest life. Four- to 6-week-old plants were chill-hardened for 1 week at several periods during the day. Chill-hardening at the beginning of the day extended the average shelf life of cuttings from 4- to 5-week-old plants by 1 and 1.5 d, respectively. Shelf life either was decreased or not affected by the other periods of preharvest hardening. More importantly, postharvest chill-hardening of packaged sweet basil for 1 day at 10 °C in darkness before transfer to 5 °C increased average shelf life by 5 d. Good potential exists for postharvest chill-hardening of packaged sweet basil since this method is effective and convenient.**

Sweet basil, one of the most popular fresh herbs, is sensitive to chilling injury (CI). Joyce et al. (1986) reported that 5 to 7 °C is optimal for optimal for long-term basil storage, whereas Duke (1978) reported 7 °C to be the lower limit for field-grown basil. Lange and Cameron (1994) reported the presence of CI symptoms (darkened lesions and water soaking) at temperatures as high as 10 °C (after 7 d or more of storage) and recommended 15 °C for relatively long-term storage.

Commercially, fresh herbs are marketed either as potted plants or cuttings. Field- or greenhouse-grown plants and cuttings typically are harvested and shipped in mixed loads to retail markets. The majority of freshly harvested horticultural commodities are held at 5 °C for optimal storage life, but such temperatures in a mixed-load shipment cause problems for low-volume, chilling-sensitive crops such as sweet basil. Since chilling temperatures are often unavoidable, treatments to increase the tolerance of the tissue before chilling or to reduce the development of injury symptoms after chilling would be beneficial.

Conditioning, or holding sensitive tissue slightly above the critical chilling temperature for a short period, increases subsequent tolerance to chilling (Harding et al., 1957; Lyons, 1979; McColloch, 1962; Wheaton and Morris, 1967). Most conditioning research is on harvested fruits and vegetables. Harding et al. (1957) reported that exposure of grapefuit (*Citrus paradisi* Macf.) to 7 d at 10 or 15 °C prevented or significantly reduced CI during storage at 0 or 1 °C. Similarly, McColloch (1962) found that sweet peppers (*Capsicum annuum* var. *annuum* L.) exposed to 10 °C for 5 or 10 d had inhibited CI expression at 0 °C. Hetherington et al. (1983) found that corn (*Zea mays* Bonaf.) seedlings grown on a 16 °C day/6 °C night regime were more tolerant to chilling at 0 °C than plants grown at 20 °C day/15 °C night. We found no reports on preharvest intermittent exposures of herbaceous cuttings to a nonchilling temperature to prevent CI.

King et al. (1982) found that harvesting at the end of the day reduced CI to tomato (*Lycopersicon esculentum* Mill.) seedlings. We found that packaged basil cuttings harvested at 1800 HR had a longer shelf life than cuttings harvested at 0600 HR because of delayed CI symptoms (Lange and Cameron, 1994). If diurnal variation is a factor to consider with chilling tolerance, then this variation also might be a factor to consider during selection of a daily conditioning period.

The objectives of this research were to compare, in three separate studies, the CI response of sweet basil conditioned at 10 °C: 1) preharvest, with daily 4-h exposures; 2) preharvest and at several periods within the day; and 3) postharvest for 1 d.

Materials and Methods

Sweet basil seeds (Sieger Seeds, Imlay City, Mich.) were sown into 208-cell plug trays containing a commercial peat/perlite/vermiculite plug mix in consecutive experiments from 10 Oct. 1989 through 5 Feb. 1990. The basil seeds were germinated under an intermittent mist system at 24 °C day/20 °C night in a greenhouse with natural lighting only. Three seedlings were transplanted into each 11-cm (600 mL) plastic azalea pot and grown in the same greenhouse under natural lighting for 1 week. During the next 3 to 5 weeks, the plants received at least 12 h of light from natural and supplemental high-intensity discharge (HID) lighting (from 1600 to 2400 HR) and were fertilized weekly with 225 mM 20N–20P–20K.

In all three studies, basil shoots were harvested by cutting just below the third node from the apical meristem after about 6 weeks of growth. Each cutting contained six to eight leaves and weighed 4 to 6 g. Harvested shoots were placed in unsealed plastic bags at harvest and transported rapidly to the laboratory for packaging (≈22 °C). Two shoots (six to eight leaves each) were sealed in each 20 × 20-cm package constructed from 127-µm-thick, low-density polyethylene film (LDF 501; Dow Chemical U.S.A, Midland, Mich.) using a Magneta 620 heat sealer (Packaging Aids Corp., San Francisco, Calif.). Shoots with bruised or damaged leaves were not used. Four 26- 1/2-gauge needle holes (0.4 mm in diameter) were punched through each package to facilitate O_2 exchange. The entire harvesting and packaging procedure took fewer than 90 min (harvesting, 30 min; packaging, 60 min). Basil packages were held in darkness under black plastic, for the duration of postharvest storage.

Preharvest temperature conditioning (Expt. 1). Seventy, 6-week-old basil plants were placed into a growth chamber at constant 25 °C and 75% relative humidity (RH). Fluorescent lamps supplied 12-h photoperiods (0800 to 2000 HR) at 175 to 225 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Daily fertilization as described above occurred between 0800 and 1000 HR. After 1 week, 35 basil plants were moved to a chamber held at 25 °C, 75% RH for 20 h and 10 °C for 4 h (1800 to 2200 HR). Five cuttings were harvested at 1730 HR from each chamber (see harvesting methods) after 2, 4, 6, 8, 10, 12, and 14 d. Basil was inspected daily at 1400 HR and visually rated for the presence of necrosis. We considered CI to be present when 2% to 5% or more of the leaf area of the basil cuttings was necrotic. Shelf life was determined by the first occurrence of any necrosis on the leaf area of each package replication.

The experiment was conducted in Jan. 1990 and analyzed as a completely randomized design using SAS procedures analysis of variance (ANOVA) (version 6.0; SAS Inst., Cary, N.C.). The two factors (and corresponding levels) were seven durations and two temperature treatments with five replications per treatment combination.

Diurnal effect of preharvest temperature conditioning (Expt. 2). Four-, 5-, and 6-week-old basil was used in three consecutive replications. Each replication began with 1 week of growth chamber conditioning as described

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above. After the first week, 20 plants were moved to each of four growth chambers programmed to precondition the plants at 10 °C for 4 h (0400 to 0800 HR, 0800 to 1200 HR, 1600 to 2000 HR, or 2000 to 2400 HR). Lighting was supplied from 0800 until 2000 HR each day. Plants were maintained as described above. After 1 week, the plants were harvested at 1500 HR and 100 packages were placed in 5 °C storage by 1630 HR. The control group consisted of plants that remained at 25 °C until harvest and were stored at 5 °C. All basil shoots were evaluated visually for the extent of CI symptoms as described above. Each replication was performed similarly, beginning Feb. 1990 and ending in Mar. 1990. The experiment was analyzed, as noted, as a randomized complete-block design blocked over harvest age of the basil. The only factor was period of chill-hardening during the day; 20 replications per treatment were used.

Postharvest temperature conditioning (Expt. 3). Five-week-old greenhouse-grown basil plants were harvested without preconditioning and packaged as previously described. The packaged basil cuttings were either chill-hardened in darkness at 10 °C for 1 d before 5 °C dark storage or were stored immediately after harvest in 5 °C dark storage. The experiment was performed during Dec. 1989 in two consecutive replications. Data from both replications were combined and analyzed as a completely randomized design in a one-way ANOVA. There were 10 total replications for each temperature treatment.

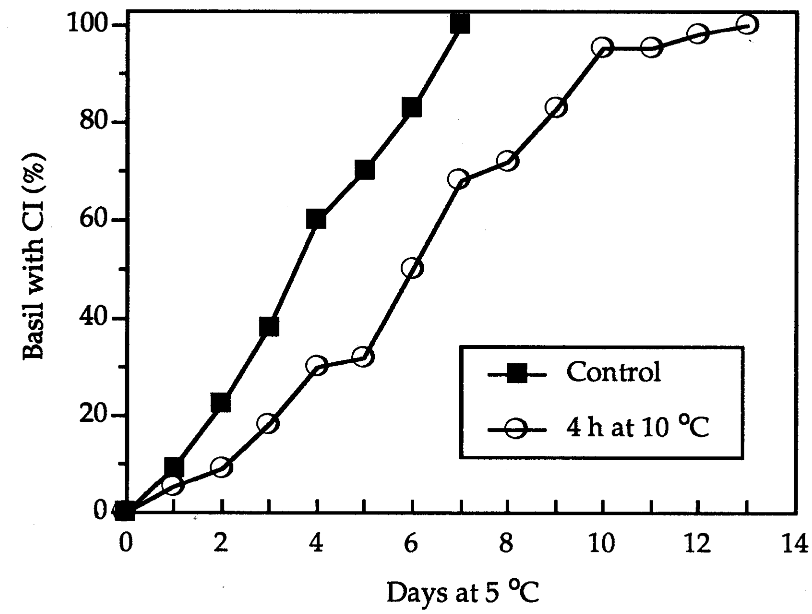

Fig. 1. Effect of preharvest intermittent cooling at 10 °C on the percentage of packaged sweet basil cuttings damaged by chilling injury when stored at 5 °C in darkness. Conditioned plants (○) were placed at 10 °C for 4 h daily. Control plants (■) were held at constant 20 °C. Each point represents 35 packaged cuttings averaged over 2 to 14 d of conditioning. The effect of conditioning was significant at $P \leq 0.0001$, CV = 48%.

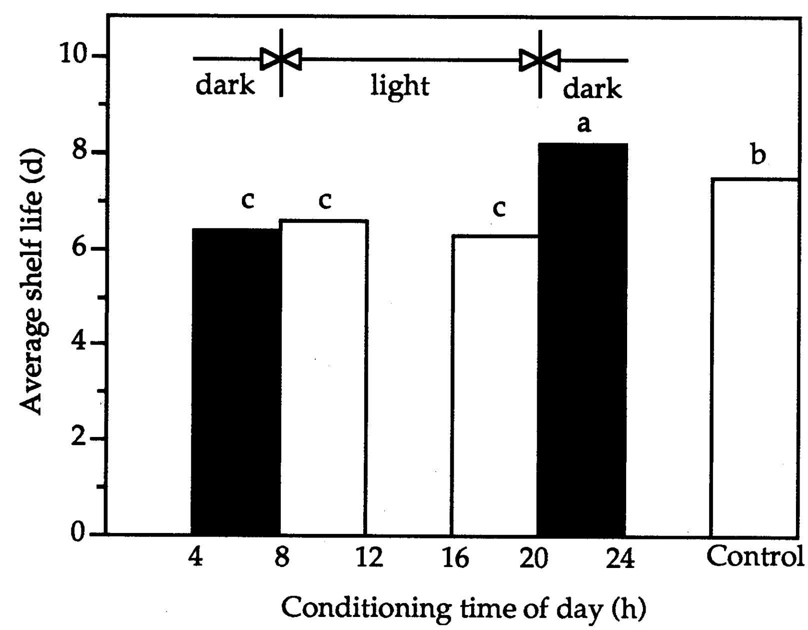

Fig. 2. Effect of preharvest intermittent cooling at 10 °C for 4 h daily at four times of day on the chilling injury response of sweet basil cuttings. Control plants were held at constant 20 °C. Each bar represents 60 packaged cuttings from three combined replications. Arrows signify periods of light and darkness. The effect of period of conditioning was significant at $P \leq 0.0001$, CV = 29%. Treatment means were separated by Duncan's multiple range test at a significant level of $\alpha = 0.05$.

Results

Symptomatic CI on sweet basil was delayed when 5-week-old basil plants were conditioned before harvest at 10 °C (4 h·day^{-1} for 2 d) (Fig. 1). There was no additional, significant benefit with an increase in conditioning period (from 4 to 14 d), so the data from all the conditioning durations were averaged. The shelf life of the conditioned cuttings was twice as long as for the unconditioned cuttings (6 vs. 3 d). All of the nontreated cuttings had CI damage by 7 d of storage as opposed to 13 d for the conditioned basil cuttings. The average shelf life of conditioned basil was 6.5 d, ≈3 d longer than that of the control cuttings at 3.7 d (significant to $P \leq 0.0001$). The coefficient of variability (CV), defined as the ratio of population variability to the mean, was 48%.

Although the average shelf life was significantly increased, the range of shelf life data (over all durations) was 1 to 12 d for the conditioning treatment and 1 to 7 d for the control.

Basil tissue conditioned during the beginning of the dark period and stored at 5 °C had an average shelf life of 8.2 d, ≈1 day longer than that of the control cuttings (Fig. 2). At other periods during the day, conditioning caused a small but significant decrease in average shelf life ($P \leq 0.0001$) compared to that of the controls (not conditioned). The oldest tissue was consistently the most tolerant to chilling over all periods of conditioning (data not shown). Six-week-old basil cuttings had an average shelf life that was extended by less than a day (from 7.5 d) over 4- and 5-week-old basil (to 6.9 and 6.4 d, respectively).

The CV for Expt. 2 was 29%, which was 60% less than that in Expt. 1. In Expt. 2, the average shelf life of 5-week-old control cuttings was higher (7.1 d) than that of similar controls (3.7 d) in Expt. 1. One possible explanation for this shelf life difference could be due to production of basil under longer days in February through March relative to January.

Postharvest conditioning of 5-week-old basil plants for 1 d at 10 °C delayed the subsequent onset of CI symptoms at 5 °C (Fig. 3). Of the cuttings stored for 1 d at 10 °C, 20% were undamaged by the 18th day of storage. Nontreated cuttings were all damaged after 10 d.

One day of storage at 10 °C significantly extended ($P = 0.0064$) the average shelf life of basil (10.4 d) when compared to the nontreated controls (5.4 d) (detailed data not shown). The CV of this third experiment was 46%, which was similar to that of Expt. 1.

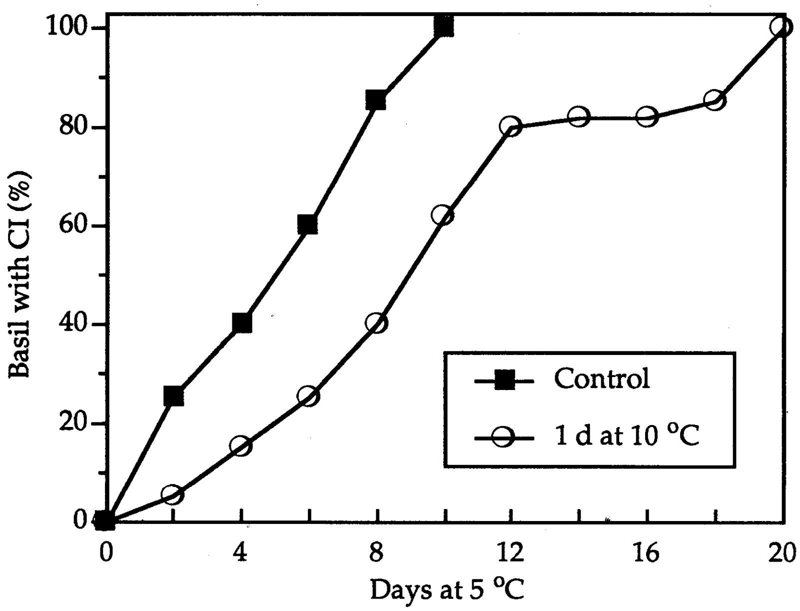

Fig. 3. Effect of postharvest conditioning for 1 day at 10 °C (in the dark) on the percentage of sweet basil cuttings damaged by chilling injury in storage at 5 °C in darkness. Conditioned packaged cuttings (O) were placed at 10 °C for 1 d prior to storage at 5 °C. Control packaged cuttings were held at constant 5 °C in the dark. Ten observations were combined from two experiments. The effect of conditioning was significant at $P \leq 0.0001$, cv = 46%. The treated cuttings were in storage longer than the controls because of the extra day at 10 °C.

Discussion

Preharvest conditioning of basil at 10 °C for as little as 2 d delayed CI by an average of 3 d (Fig. 1). Preharvest conditioning at 7.5 °C for more than 2 d caused increased susceptibility to CI symptoms. Similarly, Kader et al. (1974) found that vegetable plants exposed to chilling temperatures in the field or during handling had increased susceptibility to additional injury when exposed to chilling storage temperatures. Thus, choosing the proper temperature and duration for conditioning requires careful consideration.

The best time for preharvest conditioning was between 2000 to 2400 HR (beginning-of-dark treatment). All other periods negatively affected the onset of CI and the related shelf life (Fig. 2), possibly due to increased CI sensitivity at certain periods of the day. These results were in agreement with those of King et al. (1982) in which tomato seedlings were the most CI-sensitive when chilled during the early morning hours. Lange and Cameron (1994) similarly reported that it is least damaging to apply low temperatures to seedlings or cuttings at the end of the day rather than the early morning hours. Basil cuttings conditioned preharvest during the beginning-of-dark period lasted significantly longer than those conditioned during all other periods. King et al. (1988) reported that carbohydrate reserves are highest in tomato seedlings during the end-of-light (1600 to 2000 HR) and beginning-of-dark (2000 to 2400 HR) periods and that diurnal chilling sensitivity was inversely proportional to the levels of carbohydrates. CI may have been reduced in basil tissue conditioned at the end of the day, due to the presence of higher levels of carbohydrates during this period. The end-of-light treatment showed no positive effect on the conditioning of basil. In maize, light can exacerbate CI in the field (Miedema, 1982). Possibly, conditioning at 10 °C in the presence of light preinduced CI in the basil cuttings.

Postharvest conditioning of basil at 10 °C for only 1 d delayed the onset of CI symptoms by 5 d. Harding et al. (1957) and McColloch (1962) found that 7 to 9 d of exposure to 10 °C effectively reduced CI symptoms in grapefruit and bell pepper, respectively. Postharvest conditioning looks promising because of the effectiveness of conditioning at 10 °C for only 1 d. In addition, this technique is simple and practical.

The CI response of the sweet basil population was highly variable, as was expressed by the high cvs in the three experiments. As previously reported (Lange and Cameron, 1994), high plant-to-plant variability was common in all experiments. Special efforts were made to standardize selection of cuttings and production methods, but the variation may be due to genetic differences in the seed lot or other factors.

Wang (1990) reported that the effectiveness of conditioning is affected by maturity of the commodity. In Expt. 2, the basil was blocked by age, which was a significant factor ($P \leq 0.0001$). The older the tissue, the more tolerant it was to CI. The age of cuttings was difficult to standardize within a given experiment due to nonuniform germination rates within the seed crop.

Chilling injury (at 10 °C and below) most likely will be encountered during shipping, handling, and retail display of sweet basil. Basil is a minor crop; therefore, it is shipped and marketed with commodities that have optimum storage temperatures that are damaging to chilling-sensitive crops. Both, pre- and postharvest temperature manipulations alleviated CI. In earlier work, we showed that harvest time was an important determinant of postharvest life; the best results were with basil harvested during the end-of-light period (Lange and Cameron, 1994).

A possible solution to large losses caused by CI might be to harvest in the late afternoon or early evening and then store chilling-sensitive leafy crops for 1 d at 10 °C before refrigerated shipment at 5 °C.

Literature Cited

Duke, J.A. 1978. The quest for tolerant germplasm, p. 1–61. In: G.A. Jung and M. Stelly (eds.). Crop tolerance to suboptimal land conditions. Ser. ASA Spec. Publ. No. 32.

Harding, P.L., M.J. Soule, and M.B. Sunday. 1957. Storage studies on Marsh grapefruit. U.S. Dept. Agr. Res. Serv. Mktg. Res. Rpt., AMS-202.

Hetherington, S.E., R.M. Smillie, A.K. Hardacre, and H.A. Eagles. 1983. Using chlorophyll fluorescence *in vivo* to measure the chilling tolerances of different populations of maize. Austral. J. Plant Physiol. 10:247–249.

Joyce, D.C., M.S. Reid, and P. Katz. 1986. Postharvest technology of fresh horticultural crops. Coop. Ext., Univ. of Calif., Issue 58.

Kader, A.A., J.M. Lyons, and L.L. Morris. 1974. Postharvest responses of vegetables to pre-harvest field temperature. HortScience 9:523–525.

King, A.I., D.C. Joyce, and M.S. Reid. 1988. Role of carbohydrates in diurnal chilling sensitivity of tomato seedlings. Plant Physiol. 86:764–768.

King, A.I., M.S. Reid, and B.D. Patterson. 1982. Diurnal changes in the chilling sensitivity of seedlings. Plant Physiol. 70:211–214.

Lange, D.D. and A.C. Cameron. 1994. Postharvest shelf life of sweet basil (*Ocimum basilicum*). HortScience 29:102–103.

Lyons, J.M. 1979. Strategies for altering chilling sensitivity, p. 179–202. In: H. Mussell and R.C. Staples (eds.). Stress physiology in crop plants. Wiley, New York.

McColloch, L.P. 1962. Chilling injury and alternaria rot of bell peppers. U.S. Dept. Agr. Mktg. Res. Rpt. 536:1–5.

Miedema, P. 1982. The effect of low temperature on *Zea mays*. Adv. Agron. 35:93–96.

Wang, C.Y. 1990. Alleviation of chilling injury of horticultural crops, p. 281–302. In: C.Y. Wang (ed.). Chilling injury of horticultural crops. CRC Press, Boca Raton, Fla.

Wheaton, T.A. and L.L. Morris. 1967. Modification of chilling sensitivity by temperature conditioning. Proc. Amer. Soc. Hort. Sci. 91:529–533.