Title: Identifying critical temperature ranges of strawberry flower buds and blossoms for different types of cold conditions and seasonal growth stages

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Objectives:

1) Determine whether "critical temperature ranges" as opposed to a set "critical temperature," are more applicable to frost and frost/freeze protection management decisions under varying types of cold conditions, including relatively dry atmospheric moisture levels that prevail in black frosts and many frost/freezes
2) Determine strawberry blossom sensitivity to "ice crystal" formation even when air temperatures may exceed 30^{o} F (the standard critical temperature for strawberry open blossom stage)
3) Determine the hardiness levels of strawberry floral buds (non-emerged and emerged – where appropriate) removed from the field at 4 growth stages: new leaf growth, pre-bloom, 10% and 50% bloom

Justification:

Regardless of whether a strawberry grower uses row covers or sprinkler irrigation, it is vital to have reliable critical temperature information. Currently, the industry is being advised of the following critical temperature information for strawberries (Poling et al., 2005):

Tight Bud: 22.0^{o}F (-5.5 ^{o}C)
Popcorn: 26.5^{o} F (-3.0 ^{o}C)
Open Blossom: 30.0^{o} F (-1.1 ^{o}C)

Under a single night of frost protection in March 1985, Perry and Poling (1986), identified a critical temperature of 26.4 F (-3.1^{o}C) for two stages of blossom development (essentially the same for popcorn and open blossom). But, this research by Perry and

Poling (1986) never really led to any specific changes in strawberry cold protection strategies, and most growers are still unconvinced that open blossoms can survive temperatures lower than 30° F (-1.1° C). While most growers agree that it is good to learn about conditions under which tissue injury can occur, they ultimately feel that the risk is too great to adopt a lower critical temperature value for their deciding whether they need to frost protect or not (personal communication with Dr. Marvin Pritts, Cornell Universtiy). The fact remains, however, that over 50% of the industry in North Carolina has now adopted row covers as an alternative technology to sprinkler irrigation for frost protection, and for these growers it is of more than "academic interest" to know the true "critical temperature" of a strawberry blossom. If, for example, a manufacturer states that a 1 oz/sq yd row cover can provide 4-5 °F cold protection, it is important to know whether we are dealing with a critical blossom temperature of 30.0° F, 28 ° F, or possibly lower?

Methodologies:

A no cost extension of SRSFC grant 2007-03 was granted on 29-Nov-07 due to equipment problems encountered at the NCSU Phytotron with chambers not being able to reach the freezing points specified in the original proposal. By December 2007, one chamber was repaired, and we were allowed to evaluate temperatures down to 24.8 ° F (– 4 ° C), but not any lower due to concerns about possible equipment damage. Frigo plants of Chandler were then ordered in the early new year from Lassen Canyon, Redding, CA, and these plants were potted at two different dates (late Jan. and early Feb.) and then were grown in the Dept. of Horticultural Science/Plant Pathology glass greenhouses attached to Marye Anne Fox Science Teaching Laboratory. These plants started to reach the open bloom stage in mid-March 2008. Freeze trials were then initiated in mid-March and continued through the month of April 2008. The main objective of our study was to identify a critical temperature, or range of temperatures, for "open" strawberry flower blossoms of Chandler in a growth chambers with relative humidity of about 60%.

From March 18 through April 30 there were 15 separate cold chamber freezing runs made at night, and we made 3 runs at each of these temperature minimums: 30.2 ° F (– 1 ° C), 28.4 ° F (– 2 ° C), 26.6 ° F (– 3 ° C), and 24.8 ° F (– 4 ° C). Additional runs down to – 2 ° C were also made to get more detailed information about what we felt may be a true "critical temperature" somewhere between – 2 ° C and – 3 ° C.

We used 96 plants per nightly run (off-peak time for energy conservation) and these plants were distributed in 8 carts (12/cart) in a 1.2 x 2.4 m growth chamber. Plants were placed in the chambers at 17:00, and the nightly runs were from about 19:00 to 6:30 with the chambers programmed to reach a set point – 1 ° C, – 2 ° C, – 3 ° C, or – 4 ° C in the final 30 minutes, and were removed by the PI each early morning at 6:30. Cooling was at a relatively gradual rate to reflect the rate of cooling in the field, and temperature drop charts were generated by the Phytotron staff for each run. All 96 plants were individually assessed the following mid-afternoon (after 14:00) for blossom and leaf injury. In our visual rating scale, 1 = no damage, 2 = leaf damage, 3 = blossom damage and 4 = frozen (dead) plant. Humidity and dry bulb temperatures were recorded by individual Watchdog sensors placed in each of the 8 carts. We also placed thermocouples in close proximity to the blossoms of 12 plants (1 in each cart) for each of the nightly runs; these temperature readings helped us to identify the temperature gradients in the chamber as well as providing temperature information (every minute) at the level of the potted plants. Additional thermocouples were positioned at the same approximate height of open blossoms at a distance of ~5 cm from the blossom for an air temperature recording in the immediate area of the bloom (Figure 1).

Fig. 1. This photo shows the position of the thermocouple sensor relative to an open blossom (~5 cm); the inflorescence on the plant to the right was injured. The low of about -2.0 ^{o} C was reached at 6:00 (photo taken on 25-Apr-08 at 14:00).

Test modification relative to objective 1. It was not possible to have access to a second chamber with higher relative humidity (near 80%) for objective 1.

Testing problems relative to objective 2. It was not possible in this study to undertake objective 2, as the "frost simulator" chamber was not working. We hope to have it restored in early 2009, and we anticipate conducting this experiment at that time. <u>We can then provide the SRSFC with a follow-up progress report on objective 2 in fall 2009.</u>

Not possible to do testing of objective 3. For the purpose of investigating objective 3, we cannot be sure when the NCSU Phytotron will again have the capability to lower temperatures into the range of – 8 ^{o} C (17.6 ^{o} F). Cooling to temperatures as low as – 8 ^{o} C, or – 9 ^{o} C (15.8 ^{o} F), is required to conduct cold hardiness evaluations of strawberry floral buds. We have field experience indicating that hardy floral buds may survive temperatures into the upper teens. The Director of the NCSU Phytotron, Carole Saravitz, Ph.D., is currently working to secure needed funds (from the state) to restore these freezing capabilities in the future. It is doubtful that this capability will exist in 2009.

Results:

Air temperature gradients. We identified air temperature gradients within the freeze chamber that caused differences of nearly 1 ^{o} C between carts, depending on location. We observed plants in the front corner areas of the chamber that would reach – 2.0 ^{o} C (the target temperature), but in the back middle area, minimum temperature recordings were often close to – 3 ^{o} C at 6:00 even though the entire chamber was set to reach a minimum of only – 2.0 ^{o} C. Watchdog temperature and humidity sensors located in each cart helped us to document these temperature gradients (Fig. 2).

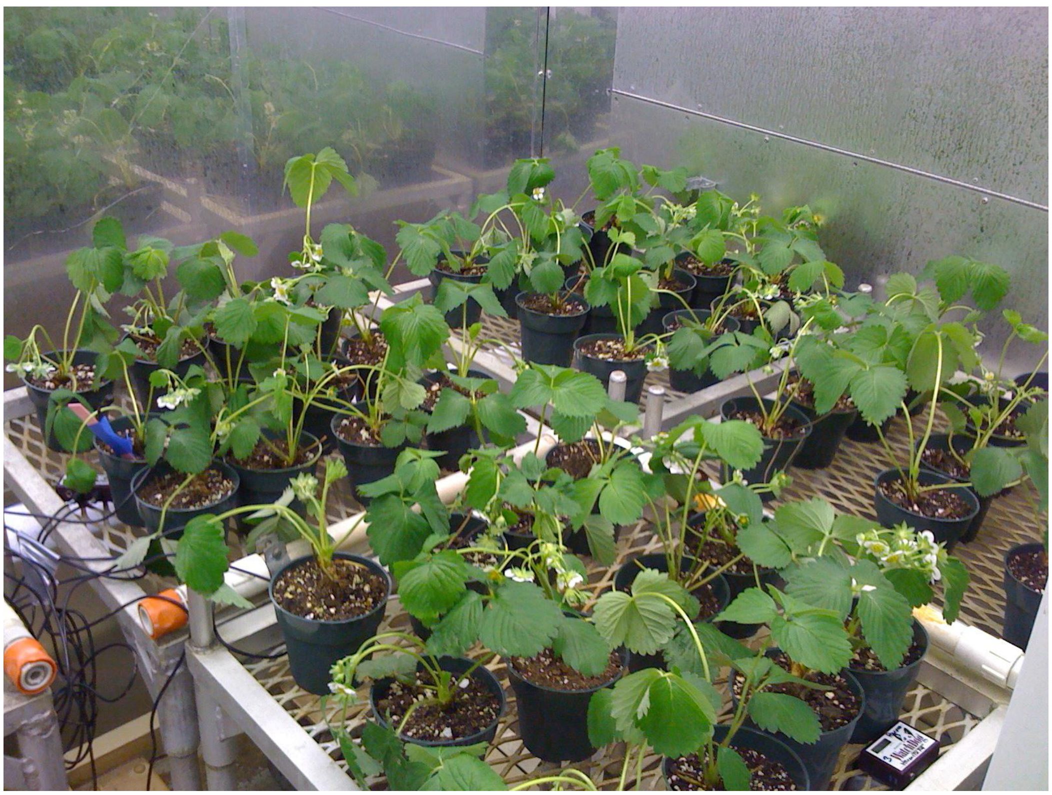

Fig. 2. Air temperature gradients within the chamber were identified with the use of Watchdog sensors located on each cart. In this photo the plants on the cart in the immediate foreground had slightly less injury than plants in back of the chamber. Within an hour after removing the plants from the chamber, most of the "drooping plants" became upright and were uninjured. Our statistical model designed by Dr. Stephen Stanislav, Dept. of Statistics, NCSU, was able to take these temperature gradient effects into account.

Statistical analysis and finding that a critical temperature of 28.0 ° F (– 2.2 ° C) for the open blossom may be more appropriate to use for strawberry row cover cold protection

Our work showed that no floral or vegetative injury occurs at 30.2 ° F (– 1 ° C), and this was the case for each of 3 runs at this temperature minimum. We also learned from 3 runs at 28.4 ° F (– 2 ° C), 26.6 ° F (– 3 ° C) and 24.8 ° F (– 4 ° C), that there is minimal risk of blossom injury at 28.4 ° F. Using SAS Multinomial Logistic Regression, we also determined that plants are 14 times more likely to receive cold injury at 26.6 ° F than at 28.4 ° F. In addition, strawberry plants at the open blossom stage are 47 times more likely to receive injury at 24.8 ° F than 28.4 ° F. From these findings we can say that the "old recommendation" of a critical temperature of 30.0 (– 1.1 ° C) is not accurate, and under drier atmospheric conditions that do not favor "ice crystal" formation (white frost), we learned that open blossoms may supercool to as low as 26.4 ° F (– 3.1 ° C).

Blossom Supercooling Potential

As more and more strawberry growers switch to row covers as their primary means of spring frost protection, it is important for us to better understand the potential for blossom supercooling (when blossoms drop below their normal freezing points and do not freeze) in a "non-irrigated" dry condition. In the table below we show blossom injury levels by location within the chamber for a freeze run down to 28.4 ° F (– 2 ° C) that was made on 4/25/08 – 4/26/08. From this data it is very important to note that several blossoms survived temperatures as low as 26.4 that were located in carts 4, 5, 6 and 8 (Table 1). Also, another blossom in cart 7 survived an exposure to 27.2 for 22 minutes (Table 1).
From this data you can also see evidence of this chamber's temperature gradient. For example, 28.9 is the min. temp. in Cart 1 vs. 26.4 min. temp. in Cart 5, or a difference of 2.5 ° F (1.4 ° C).

Table 1. An additional run at 28.4 ° F (– 2 ° C) in the NCSU Phytotron that shows the potential for strawberry blossom supercooling under humidity levels that did not "ice crystal" formation (the table shows the minimum temperatures recorded within each cart, and also for individual blossoms with thermocouples placed within 5 cm of the blossom

4/25/08 – 4/26/08

	Location	Min. Temp. recorded and min.	Injured/Non-injured plants
Cart 1	Front right corner	28.9 (30 min)	0/12 (0%)
Cart 2	Back right corner	28.1 (30 min)	0/12 (0%)
Cart 3	Front middle right	27.2 (5 min)	2/10 (20%)
Cart 4	Back middle right	27.2 (36 min)	3/9 (25%)
Cart 4 (blossom a)		26.4 (35 min)	Blossom survived
Cart 5	Front middle left	27.2 (28 min)	2/10 (20%)
Cart 5 (blossom b)		26.4 (36 min)	Blossom survivied
Cart 6	Front middle back	26.4 (27 min)	2/10 (20%)
Cart 6 (blossom b)		26.4 (37 min)	Blossom survived
Cart 7	Front left corner	NA	0/12 (0%)
Cart 7 (blossom c)		27.2 (22 min)	Blossom survived
Cart 8	Back left corner	27.2 (35 min)	1/11 (8%)
Cart 8 (blossom a)		26.4 (36 min)	Blossom survived

Conclusions:

Having reliable, research-based critical temperature thresholds for the open blossom strawberry stage can help growers decide whether cold protection with row covers is likely to be successful under different cold conditions. At this point in our research, it would appear that strawberry growers should be taking protective measures for any weather forecast of temperatures at the canopy level of below 28.0 ^{o} F (– 2 ^{o} C). Also, it is very interesting to report how little, or no damage occurred to blossoms that were exposed to temperatures as low as of 26.4 ^{o} F (– 3.1 ^{o} C) for approximately 30 minutes under humidity conditions that did not favor "ice crystal" formation. These findings of blossoms that survive to 26.4 ^{o} F (– 3.1 ^{o} C) are consistent with field research work by Perry and Poling (1986). Additional studies in the future will be required to more fully assess the potential for strawberry blossoms to supercool under floating row covers, as well as to document the potential for blossom injury at significantly higher temperatures when relatively humidity is high enough to favor "frost" formation (Wisniewski, M. 2007).

Impacts:

Out of this research project has evolved a new understanding of the critical temperature of an open strawberry blossom in atmospheric conditions that do not favor "ice crystal" formation, and the data show that neither blossom or vegetative injury occurs until temperatures drop below 28.0 ^{o} F (– 2.2 ^{o} C). This information will likely have little practical impact on grower decision-making with regard to overhead irrigation, and growers will be advised to continue to use a wet bulb temperature of 30.0 ^{o} F (– 1.1 ^{o} C) to initiate cold protection. However, this research clearly establishes that strawberry blossoms may supercool to 26.4 ^{o} F (– 3.1 ^{o} C) under atmospheric conditions that do not favor "frost" and this information is critically important to decision-making with regard to row cover protection.

Literature cited:

Perry, K. B. and E. B. Poling. 1986. Field observation of frost injury in strawberry buds and blossoms. Adv. Strawberry Prod. 5:31-37.

Poling, E.B., Gerard Krewer, and J. Powell Smith. 2005. Southeast Regional Strawberry Plasticulture Production Guide http://www.smallfruits.org/SmallFruitsRegGuide/index.htm

Wisniewski, M. 2007. Using infrared thermography to study freezing in plants. HortScience 42:795. (abstr.).