# Optimizing Sprinkler Irrigation for Cold Protection in Strawberries

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**Abstract.** *Sprinkler irrigation has been used effectively for cold protection in strawberries. While an application rate of 0.25 inches per hour is recommended to protect plants from cold damage, the effectiveness of alternative rates for adequate protection has not been studied. The objective of this study was to determine the effect of varying sprinkler supply pressure and spacing on strawberry yield and quality under freeze conditions. Five treatments were evaluated using sprinkler irrigation, two system pressures: 50 and 30 psi, and two sprinkler spacings: 48 ft. and 40 ft. The experimental design was a complete randomized block design with three replications and repeated measurements. Initial results showed significant yield differences between the irrigated treatments and the control. Recovery capability from the cold events among the irrigated treatments did not differ significantly. Only irrigated treatments showed a linear increase in the yield after each cold event.*

**Keywords.** Cold protection, Sprinkler irrigation, Strawberries, Variable pressure.

# Optimizing Irrigation for Cold Protection in Strawberries

## Introduction

The United States of America is the largest strawberry producing country in the world. Florida is the second largest strawberry-harvesting state, where 10 to 15 percent of the total U.S. crop is produced (FAOSTAT, 2011). Hence, strawberries represent an important crop for this state, where, the strawberry growing season occurs during the winter; therefore, plants can suffer cold damage when the air temperature falls to critical levels.

Irrigation is the primary method used for fruit, vegetable and nursery cold protection. Particularly, sprinkler irrigation has been used effectively for cold protection in strawberries for several decades (Locascio et al., 1967). In recent years, due to the unusual number of cold events, the ground water supplies have been stressed by the large volumes of water withdrawn in order to protect the plants from cold damage in the Dover/Plant City region.

Overwatering plants can cause several problems such as resource depletion, nutrient leaching, and increased plant diseases. The critical situation presented in this area provoked the need to create best management practices on water use.

Current cold protection recommendations are based on 1960's modeling for citrus nurseries and it is not clear if these recommendations are for advective (i.e., windy) or radiative freeze events. An application rate of 0.25 inches per hour (in $h^{-1}$) is recommended to protect the plants from freeze damage; however, the effectiveness of alternative rates for freeze protection have not been tested. Lower sprinkler application rates may provide adequate cold protection and result in less pumping required.

## Latent heat

Latent heat is the chemical energy stored in the bonds that join the water molecules together, which is converted to sensible heat when water condenses, cools or freezes, increasing the temperature of the surrounding environment (Snyder, 2000b). The heat released through fusion is 80 calories per gram or 0.32 BTU and the temperature when water is freezing will be close to 32 ºF, even though the surroundings may be colder. Therefore, an equilibrium temperature state will be established as long as the mixture of water and ice is present and the temperature remains close to 32 ºF (Harrison et al., 1987). Under the latent heat transfer principle, the heat loss from the plant to its immediate environment is substituted by the sensible heat and the heat of fusion associated with the water, providing protection to the plants from frost or freeze damage using sprinkler irrigation (Harrison et al., 1987).

## Critical temperatures and cold damage

*"A "frost" is the occurrence of an air temperature of 32 °F or lower, measured at a height of between 1.25 and 2.0 m (4.1 and 6.6 ft.) above soil level, inside an appropriate weather shelter"* (Snyder and de Melo Abreu, 2005). Some avoidance factors (e.g. supercooling and concentration of ice nucleating bacteria) might provoke a freezing of the water within plants. *"A "freeze" occurs when extracellular water within the plant freezes (i.e. changes from liquid to ice).*

Damage on the plant tissue depends on some tolerance factors (e.g. solute content of the cells) (Snyder and de Melo Abreu, 2005).

When extracellular ice forms inside of the plants, the frost event is converted into a freeze event. However, freeze injury is present when an irreversible physiological condition occurs causing death or malfunction of the plant cells after falling below a critical value (Snyder and de Melo Abreu, 2005). This temperature varies within varieties and species at the same temperature and phenological stage. Critical temperatures for strawberries are defined in Table 1.

Table 1. Strawberry critical temperatures at different crop stages calculated using dew point and wet bulb temperatures (°F). Table used to determine turn-on and turn-off times for the AC treatment irrigation system.

| | Strawberry critical temperature at | | | |
|---|---|---|---|---|
| Crop stage | Tight bud | Popcorn | Fruit | Open blossom |
| | Critical temperature or Wet bulb temperature (ºF) | | | |
| Dew point (°F) | 23 | 28 | 29 | 31 |
| 32 | - | - | - | - |
| 31 | - | - | - | 31.0 |
| 30 | - | - | - | 31.7 |
| 29 | - | - | 29.0 | 32.3 |
| 28 | - | 28.0 | 29.6 | 32.9 |
| 27 | - | 28.6 | 30.2 | 33.5 |
| 26 | - | 29.2 | 30.8 | 34.0 |
| 25 | - | 29.7 | 31.3 | 34.6 |
| 24 | - | 30.2 | 31.8 | 35.1 |
| 23 | 23.0 | 30.7 | 32.3 | 35.6 |
| 22 | 23.5 | 31.2 | 32.8 | 36.1 |
| 21 | 24.0 | 31.7 | 33.3 | 36.6 |
| 20 | 24.4 | 32.1 | 33.7 | 37.0 |
| 19 | 24.9 | 32.6 | 34.2 | 37.5 |
| 18 | 25.3 | 33.0 | 34.6 | 37.9 |

Adapted from (Snyder, 2000).

## Sprinkler irrigation for cold protection

Drip and sprinkler irrigation are the two systems used to produce strawberries in Florida. Sprinkler irrigation is typically used by Florida growers for crop establishment during 10 to 14 days after transplanting for between 12 and 14 hours per day giving an approximately of 16-24 inches (Santos et al., 2010). In addition, sprinklers are used for frost protection.

## Objectives

The objective for this study is determination of the effect of varying sprinkler supply pressure and spacing on strawberry yield and quality under freeze conditions.

## Materials and Methods

This study was conducted from September 2011 to April on the 2012 at the Plant Science Research and Education Unit near Citra, Florida. Pre-formed planting beds were established (28 in. wide at the base, 24 in. wide on the top, and 10 in. high) on an Arredondo Sand soil with 0.5% organic matter and pH of 6.2. Soil was fumigated with methyl bromide/chrolopicrin (50/50, v/v) and after, beds were covered with black high-density polyethylene mulch 1.25 mm thickness. Pre-plant fertilizer 10-10-10 at 400 lb/ac was used. Fertilization and pest control was done according to the requirements of the crop (Botts et al., 1995). Fertigation was applied through a 5/8 inch drip tape line 10 ml thickness with 12 in. emitter spacing with a flow rate of 0.5 gallon a minute per 100' of tape buried 1 inch. The experimental area was equipped with WR-32 brass impact sprinklers aluminum arm with 9/64" nozzles with 4.07 gpm at 50 psi (Wade Rain Inc., 2007) for frost protection and crop establishment. These are the most common sprinklers used by growers. The cultivars used were: 'Strawberry Festival' and 'Treasure'. Bare-root strawberry transplants were planted in double rows 12 ft. apart. After transplanting, overhead irrigation was used for 9 hours for the first 14 days to ensure plant establishment.

### Treatments

The strawberry field experiment tested a set of 5 treatments with 3 replications, totaling 15 plots (Table 2). Each plot had five planted rows 16 to 24 linear ft. WR-32 brass impact sprinklers altering irrigation system pressure and sprinkler spacing were tested. The pressures under evaluation were 50 and 30 psi, and the sprinkler spacings tested were 48 ft. by 48 ft. and 40 ft. by 40 ft.

Table 2. Treatments evaluated. Field experimental project. Citra, Florida. Fall 2011- Spring 2012.

| Treatment | Sprinkler | Pressure (psi) | Spacing (ft.) | Control |
|---|---|---|---|---|
| 50 psi | WR-32 | 50 | 48 x 48 | Manual |
| 30 psi | WR-32 | 30 | 48 x 48 | Manual |
| AC | WR-32 | 50 | 48 x 48 | Automated |
| NO | No sprinklers | Non frost protected | NA | None |
| 40*40 | WR-32 | 50 | 40 x 40 | Manual |

A system pressure of 50 psi was evaluated using sprinkler spacings of 48 ft. and 40 ft. on center (50 psi and 40*40 treatments correspondingly). The 30 psi system pressure was evaluated using 48 ft. spacing (30 psi treatment). Irrigation for these treatments was activated at 34 ºF using a thermostat directly connected to a valve, mimicking a grower turning on the system at this temperature. Another treatment with 48 ft. spacing was implemented so that frost protection was determined by dew point temperature using wireless temperature sensors (AC treatment). Frost protection continued for all irrigated treatments until the temperature exceeded 34 ºF. The control treatment (NO) did not receive frost protection. The experimental design was a split-plot design with three replications.

## Yield

The experiment contained 15 plots. The harvest area (H) for all plots consisted of 12 linear ft. of plants in the middle three planted rows whereas the remaining areas of the plot were considered guard row areas (GR) (Fig. 1).

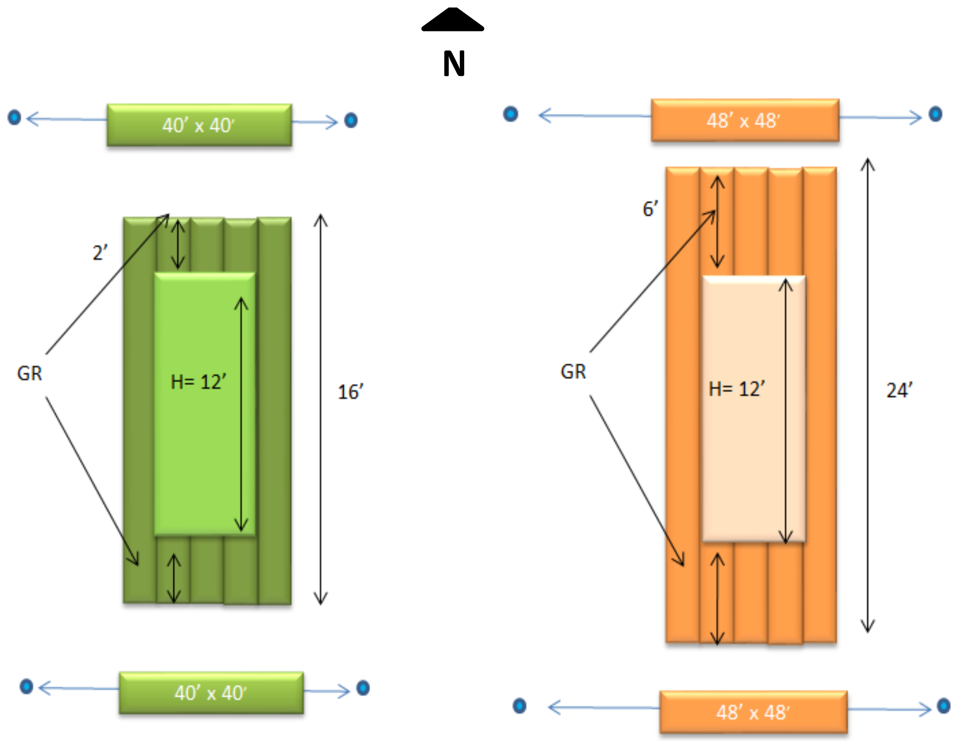


Figure 1. “Cultivated” and “Harvest” areas description.

## Temperature

Two different temperature sensors were used to record air temperature in the field: thermocouples and wireless temperature sensors.

### 1. Thermocouples

The air temperature in the field was recorded using cooper-constantan thermocouples placed within each plot. Temperature was measured below the plant canopy at 1.4 in., above ground, within the plant canopy at 6.3 in., and above the plant canopy at 11.8 in. These thermocouples were connected to 6 dataloggers or “temperature stations”. The temperature data recorded was slightly different at each plot. Therefore, the cold events were defined using the data from temperature station 1, this being the station that generally showed the most extreme cold effect (i.e. temperatures below 34 ºF for the longest periods of time).

“Cold events” were defined as periods when temperature station 1 showed temperatures consistently below 34 ºF more than 2 hours. Later in the document, “freeze events” were defined and analyzed according to the "physiological critical temperature" of strawberries, which was found to be 31 ºF. This is the temperature below which damage occurs to the "open blossom" stage of the crop (Table 1).

**2. Wireless temperature sensors**

The automated controlled treatment (AC) irrigation was activated at a critical temperature derived from Table 1. Air temperature and relative humidity were recorded by wireless sensor devices placed in each treatment plot which were used to calculate an average dew point (DP). Irrigation for cold protection began once the temperature reached a dynamic value, determined using the critical temperature for an open blossom (31 ºF) and the average DP. Table 1 was used to determine the temperature at which irrigation should be turned on. Using this method, the irrigation system was programmed to shut off when temperature exceeded 36 ºF.

## Data Analysis

Initial results for cold protection includes minimum leaf temperatures, air temperature, and other climatic data recorded in the strawberry field during the period of November 2011 to March 2012. During every cold event, average minimum air temperature was determined for each plot. Other climatic data such as minimum air temperature at 60 cm, minimum DP temperature and average wind speed was obtained from the Florida Automated Weather Network (FAWN) archived weather data at the station located in Citra, Fl.

### Amount of water applied for cold protection

Typically, strawberry growers turn on the irrigation for cold protection about a temperature of 34 ºF approximately. Therefore, for this study, the 50 psi treatment (48 x 48 ft. spacing) with irrigation activated by a thermostat at a temperature below 34 ºF represents a “grower practice” for comparison. The 50 psi treatment was used as a benchmark against which the water savings of all other treatments was measured.

The AC treatment irrigation was activated during 10 cold events while the irrigation for the other treatments; controlled by the thermostat, was activated during 16 events.

The amount of water applied per treatment during the cold events is described in Table 3. The 40*40 treatment resulted in the highest irrigation amount. It used a total of 2,821,255 gallons per acre, representing a 44% extra water application. The AC treatment applied 90,932 gallons less than the 50 psi, representing a 5% of water savings. The 30 psi treatment saved 439,883 gallons during the cold events, this being a 22% of water savings.

Table 3. Amount of water applied during the cold events and percent water savings per treatment (compared to 50 psi treatment). Citra, Fl. Fall 2011- Spring 2012.

| Treatment | Pressure (psi) | Irrigation (gal applied)* | Gal/ac | Water savings (gal/acre) | Water Savings (%) |
|---|---|---|---|---|---|
| AC | 50 | 296,454 | 1,868,016 | 90,932 | 5 |
| 50 psi | 50 | 310,885 | 1,958,948 | - | 0 |
| 30 psi | 30 | 241,076 | 1,519,064 | 439,883 | 22 |
| NO | - | - | - | 1,958,948 | 100 |
| 40*40 | 50 | 310,902 | 2,821,255 | -862,307 | -44 |

* Total irrigation (gal) applied on the three plots of the treatment, over all cold events.

## Freeze events according to the crop stage critical temperature (30 °F)

The physiological critical temperature was defined as 30 °F, this being the critical temperature below which damage occurs to the “open blossom” stage of the crop (Table 1). Only eight freeze events presented temperatures below physiological stage critical temperature (30 °F). All of them were freeze protected (AC and “grower practice” (thermostat-controlled) irrigation). A comparison between treatments during the critical temperature freeze events, with the 50 psi treatment as the water saving benchmark is described in Table 4. AC used 226,181 gal/acre extra water, or 15% more than the “grower practice”. Reducing the pressure to 30 psi resulted in 22% water savings (335,461 gal/acre). The 40*40 treatment increased the water use by 44% applying 657,608 gal/acre more than 50 psi treatment.

Table 4. Amount of water applied during the physiological critical temperature events (<30 ºF) and percentage of water savings per treatment (compared to “grower practice” (50 psi)). Citra, Fl. Fall 2011- Spring 2012.

| Treatment | Pressure (psi) | Irrigation (gal applied) | Gal/acre | Water savings (gal/acre) | Water Savings (%) |
|---|---|---|---|---|---|
| AC | 50 | 272,980 | 1,720,102 | -226,181 | -15 |
| 50 psi | 50 | 237,085 | 1,493,921 | - | 0 |
| 30 psi | 30 | 183,848 | 1,158,461 | 335,461 | 22 |
| NO | 0 | - | - | 1,493,921 | 100 |
| 40*40 | 50 | 237,099 | 2,151,529 | -657,608 | -44 |

## Strawberry yields

Strawberries were harvested twice per week from December 2011 until March 2012. However, for the results of the statistical analysis yield was weighted in order to have an equal number of days between the harvests. The weighted marketable weight for a total of 23 harvests during the period of December 2011 to March 2012 is shown in Figure 3. The “grower practice” irrigation (thermostat controlled) was triggered for 16 cold events, while automatic control irrigation (AC) was triggered for only 11 cold events. Statistical analysis was performed taking into account the recovery of the treatments after each cold period.

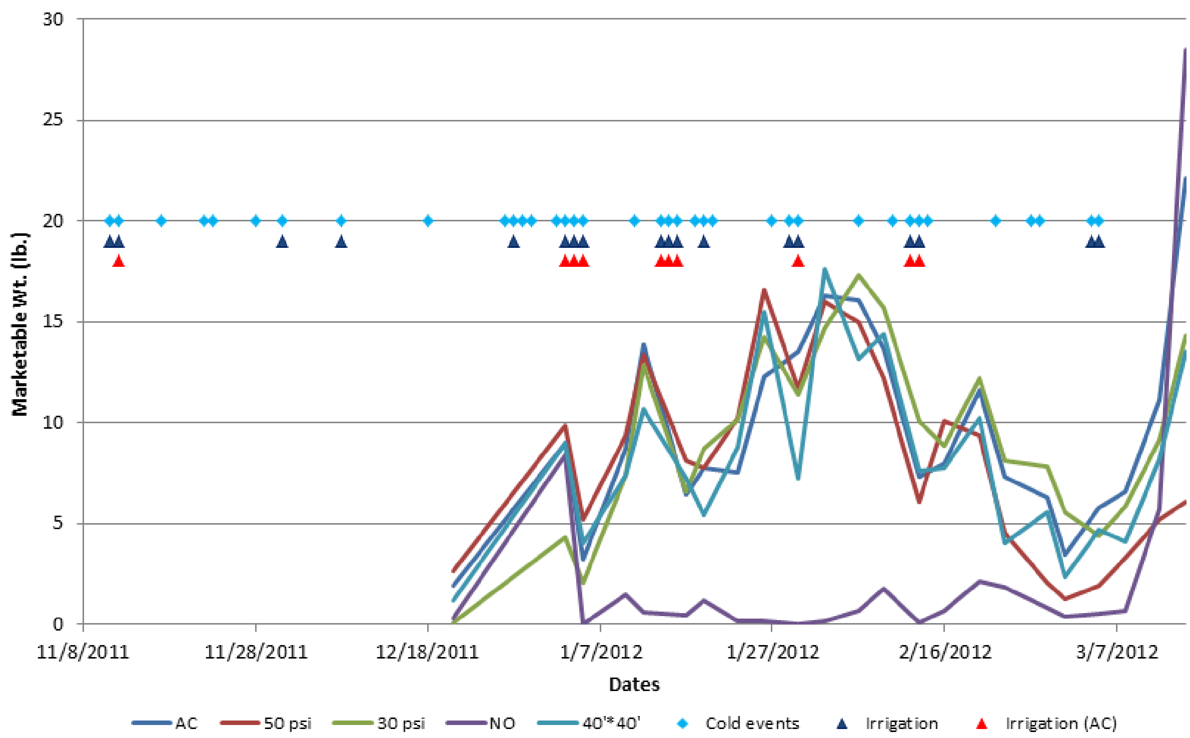


Figure. 3. Weighted marketable weight per treatment (lb.). Irrigation for freeze protection during the cold events. Citra, Fl. Fall 2011 – Spring 2012.

Initial results showed significant yield differences between the irrigated treatments and the control (non-irrigated, NO) (Fig. 3). Yield and volume applied during cold events for each treatment were compared to the 50 psi treatment.

The non-irrigated treatment showed significant differences from the 50 psi treatment. It was affected by the initial cold events and thus produced very low marketable weights during the whole harvesting period. AC and 40*40 both showed only slight differences in yield compared to 50 psi. However, the 30 psi treatment achieved water savings of 22% without a large effect on yield throughout the harvesting period, and even it gave a slightly higher yield at the middle and at the end of the harvest period.

Average yield was analyzed using the Least Square Difference method of Bonferroni ($LSD_{Bon}$ = 0.2310), shown in Table 5. The average yield of the non-irrigated treatment was significantly different from the other treatments for all pairwise comparisons (NO, AC, 50 psi, 30 psi and 40*40) (Table 6).

Table 5. $LSD_{Bon}$ value for comparison of average treatment yield.

| Cold Period | TOTAL |
|---|---|
| $t_{Bon}$ value | 3.83 |
| DF MSE | 8 |
| MSE (Error 1) | 0.00544 |
| # of Contrasts | 10 |
| # of Rep | 3 |
| $LSD_{Bon}$ | 0.2310 |

The cold events occurring between December 2011 and March 2012 were grouped into a total of 5 recovery periods based on the cold's effect on yield during those periods. This was done in order to evaluate the recovery of the treatments after each cold period. $LSD_{Bon}$ results comparing the NO treatment (control) versus the irrigated treatments (AC, 50 psi, 30 psi and 40*40) are shown in Appendix 1. The non-irrigated treatment mean was 66.4% lower on average during the 5 recovery periods ($LSD_{Bon}$ NO greater than critical $LSD_{Bon}$ for each period).

For the irrigated treatments, significant differences were found only for recovery period 5 (Table 6) when 30 psi treatment showed 50%, 44% and 77% higher yields than 40*40, 50 psi and NO treatments correspondingly during harvest 17, and 74% and 89% higher yields than 50 psi and NO treatments during harvest 18. In contrast, 50 psi obtained the lowest mean yield for the last harvest (February 28$^{th}$) and it was 74% and 63% significantly lower than 30 psi and 40*40 respectively (Table 7). Irrigated treatments always showed a linear increase in the yield after each cold event, but that was not observed in the control treatment.

Table 6. Average yield $LSD_{Bon}$ results for all pairwise comparisons (NO, AC, 50 psi, 30 psi and 40*40).

| Treatment | | Diff according to | | | | |
|---|---|---|---|---|---|---|
| | Means (lb.) | 30 psi | 40*40 | 50 psi | AC | NO |
| 30 psi | 1.39 | 0.00 | -0.15 | -0.16 | 0.05 | -1.02* |
| 40*40 | 1.25 | | 0.00 | -0.01 | 0.20 | -0.87* |
| 50 psi | 1.23 | | | 0.00 | 0.21 | -0.86* |
| AC | 1.45 | | | | 0.00 | -1.07* |
| NO | 0.37 | | | | | - |

(*) Significant differences between treatments.

Table 7. $LSD_{Bon}$ results comparing the non-irrigated treatment (control) vs. the irrigated treatments (AC, 50 psi, 30 psi and 40*40) during recovery period 5.

| $LSD_{Bon}$ | 0.4810 | | | | | |
|---|---|---|---|---|---|---|
| Harvest | # 17 | Diff according to | | | | |
| | Average Means (kg.) | 30 psi | 40*40 | 50 psi | AC | NO |
| 30 psi | 1.22 | - | b | b | a | b |
| 40*40 | 0.61 | | - | a | a | a |
| 50 psi | 0.69 | | | - | a | a |
| AC | 1.10 | | | | - | b |
| NO | 0.28 | | | | | - |
| | # 18 | 30 psi | 40*40 | 50 psi | AC | NO |
| 30 psi | 1.18 | - | a | b | a | b |
| 40*40 | 0.84 | | - | b | a | b |
| 50 psi | 0.31 | | | - | b | a |
| AC | 0.95 | | | | - | b |
| NO | 0.13 | | | | | - |

Different letters denote significant differences between treatments

Table 8 shows the $LSD_{Bon}$ results comparison within irrigated treatments (AC, 50 psi, 30 psi and 40*40) during recovery period 5. Recovery capability from the cold events among the irrigated treatments differs significantly only for recovery period 5. The least recovery was showed by the 50 psi treatment which presented 44% significantly lower yields than 30 psi during harvest 17. During harvest 18, 50 psi obtained 74%, 63% and 67% significantly lower yields than 30 psi 40*40 and AC treatments respectively (Table 8).

Table 8. $LSD_{Bon}$ results comparing the irrigated treatments (AC, 50 psi, 30 psi and 40*40) during cold period 5.

| $LSD_{Bon}$ | 0.5190 | | | | |
|---|---|---|---|---|---|
| Harvest | # 17 | Diff according to | | | |
| Treatment | Average Means (kg) | 30 psi | 40*40 | 50 psi | AC |
| 30 psi | 1.22 | | b | b | a |
| 40*40 | 0.61 | | | a | a |
| 50 psi | 0.69 | | | | a |
| AC | 1.10 | | | | |
| | # 18 | 30 psi | 40*40 | 50 psi | AC |
| 30 psi | 1.18 | | a | b | a |
| 40*40 | 0.84 | | | b | a |
| 50 psi | 0.31 | | | | b |
| AC | 0.95 | | | | |

Different letters denote significant differences between treatments

## Conclusion

Sprinkler irrigation effectively protected strawberries from cold damage. Initial results showed significant yield differences between the irrigated treatments and the control. Recovery capability from the cold events among the irrigated treatments did not differ significantly. Irrigated treatments always showed a linear increase in the yield after each cold event, but that was not observed in the control treatment. No yield differences between the irrigated treatments (AC, 50 psi, 30 psi and 40*40) were found; however, water usage differences were found within them. The 30 psi treatment achieved water savings of 22%, which could reduce water use by 439,883 gallons per acre of crop per season without affecting yield. Therefore, a total of 25 billion gallons of water could be saved considering the 57,470 acres of strawberries harvested in Florida in 2011. Further investigation will be done this year to repeat the experiment.


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## References


Botts, D.A., C.K. Chandler, M.D. Dukes, M.L. Lamberts, A.W. MacRae, E. McAvoy, J.W. Noling, S.M. Olson, M. Ozores-Hampton, N. Peres, J.F. Price, R.N. Raid, P.D. Roberts, B. Santos, E.H. Simonne, S.A. Smith, C.A. Snodgrass, W.M. Stall, D.D. Sui, G.E. Vallad, S.E. Webb, A.J. Whidden, S. Zhang and L. Zotarelli. 1995. The vegetable production handbook for Florida 2010-2011. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida., Florida, Gainesville.

FAOSTAT, F.S.D. 2011. Crops production. 2010. Also at http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Harrison, D.S., J.F. Gerber and R.E. Choate. 1987. Sprinkler irrigation for cold protection. Florida Cooperative Extension Service, Gainesville, Florida.

Locascio, S.J., D.S. Harrison and V.F. Nettles. 1967. Sprinkler irrigation of strawberries for freeze protection. Florida Agricultural Experiment Stations Journal 2817:208-209,210,211.

Santos, B.M., T.P. Salame-Donoso, C.D. Stanley, A.J. Whidden, C.A. Snodgrass and M.B. Henry. 2010. Cultural practices for vegetable and small fruit crops: Using kaolin clay to reduce sprinkler irrigation for strawberry transplant establishment. 2011. Also at http://edis.ifas.ufl.edu/hs1188

Snyder, R.L. 2000. Principles of frost protection. 2011. Also at http://biomet.ucdavis.edu/frostprotection/Principles%20of%20Frost%20Protection/PFPlong/PFPlong.pdf

Snyder, R.L. and J.P. de Melo Abreu. 2005. Frost protection: Fundamentals, practice and economics. Food and Agriculture Organization of the United Nations, Rome.

Wade Rain Inc. 2007. Wade rain: Sprinkler irrigation. 2007 product catalog. 2011. Also at http://www.waderain.com/pdfs/Wade-Rain-Catalog-2007.pdf

# Appendix

Appendix 1. $LSD_{Bon}$ results comparing the non-irrigated treatment (control) vs. the irrigated treatments (AC, 50 psi,30 psi and 40*40).

| Cold Period | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $t_{Bon}$ value | 2.74 | 2.74 | 3.04 | 2.74 | 3.04 |
| DF MSE | 20 | 20 | 10 | 20 | 10 |
| MSE (Error 2) | 0.1235 | 0.0547 | 0.1861 | 0.08753 | 0.03755 |
| # Contrasts | 4 | 4 | 4 | 4 | 4 |
| # Rep | 3 | 3 | 3 | 3 | 3 |
| $LSD_{Bon}$ within each cold period | 0.7862 | 0.5232 | 1.0708 | 0.6619 | 0.4810 |

Note: $LSD_{Bon}$ was calculated using Balanced ANOVA for average yield.

Appendix 2. $LSD_{Bon}$ results comparing the irrigated treatments (AC, 50 psi, 30 psi and 40*40).

| Cold period | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| tBon value | 2.93 | 2.93 | 3.28 | 2.93 | 3.28 |
| DF MSE | 20 | 20 | 10 | 20 | 10 |
| MSE (Error 2) | 0.124 | 0.055 | 0.186 | 0.088 | 0.038 |
| # of Contrasts | 6 | 6 | 6 | 6 | 6 |
| # Repetitions | 3 | 3 | 3 | 3 | 3 |
| $LSD_{Bon}$ per Time | 0.8407 | 0.5595 | 1.1553 | 0.7078 | 0.5190 |

Note: $LSD_{Bon}$ was calculated using Balanced ANOVA for average yield.