Developing a sustainable automated spring frost cycling protection method in cranberry production

Final Report for GNE12-040

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Grant Recipient: UMass Cranberry Station
Region: Northeast
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Project Information

Summary:

Cranberry frost protection is a necessary practice in cranberry production to reduce losses due to spring frost damage. In the spring of 2013 and 2014, an experiment was conducted in southeast Massachusetts to evaluate two most common frost protection practices, conventional (CONV) and automated intermittent irrigation (AI). We hypothesized that automated intermittent (cycling) irrigation provides significant water, fuel and environmental benefits, relative to the conventional method. The objectives of this study was to (i) assess the effectiveness of CONV and AI methods in protecting buds against spring frost damage and (ii) quantify the amount of water applied under each method. Cranberry buds for cultivars 'Stevens', 'Howes' and 'Early Black' (EB) were collected from various beds protected by AI and CONV methods and evaluated for bud damage by dissecting under the microscope. Cranberry beds were monitored throughout the season for flowering density using a 15.2cm diameter ring. Fruit yield was estimated using 25 × 25 cm quadrat and water use was recorded at each irrigation event for each method. Water savings of 35% per night were observed in AI relative to CONV. Minimal damage was observed across cultivars before the occurrence of frost nights. Most damage was observed in mid-season at 13% EB and 8% for Stevens. For Howes, the differences were not significant, indicating that both methods were equally effective in frost control. There were no significant differences between spring frost control methods for upright density count, berry count and berry yield. Significant cultivar differences were observed for the yield. Fruit yield in 2014 were significantly higher than those obtained in 2013, with Stevens under cycling consistently being the highest, followed by Howes, also under cycling and EB under conventional being the lowest.

Introduction:

Sprinkler irrigation systems are the main means of protecting cranberry against frost damage in southeastern Massachusetts (MA), where cranberry production contributes largely to the economy in the state (USDA-NASS, 2014).There are currently two major methods for using sprinklers in spring frost protection of cranberries in southeastern Massachusetts: (1) conventional and (2) intermittent (cycling). In the conventional (CONV) approach, irrigation water is applied starting at a temperature above the critical or tolerance temperature of the buds, continued through the night, and stopped the following morning once the temperature has risen one to three degrees above the critical temperature. In the automated, intermittent irrigation (AI) approach, the programmed starting trigger temperature is similar to that used in CONV but the system would be programmed to shut down as soon as the temperature rose to a pre-determined set point above the frost tolerance. The system then restarts when the temperature drops back to the starting or selected secondary trigger temperature, with several cycles throughout the night. Since the pumps do not run continuously, it has been suggested that AI is more economic and efficient than CONV, using less water and fuel. However, there is a need for rigorous field testing, evaluation and monitoring of automated cycling under various conditions to demonstrate the effects on bud damage, relative to the conventional method.

Project Objectives:

The objectives of this project were to:

1. Evaluate the efficacy of automated irrigation cycling for cranberry spring frost protection by assessing cranberry buds for frost damage following frost events across frost protection methods.
2. Evaluate the effect of spring frost protection methods on plant density and fruit yield.
3. Quantify the amount of water applied and fuel used during the evaluated cycling protocols for both mild and severe spring frost events and compare to water use in a non-cycled protocol.
4. Synthesize the information gathered and distribute it to growers to encourage better water and land stewardship.

Cooperators

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Research

Materials and methods:

This study was conducted in southeastern MA using commercial cranberry beds with ‘Stevens’, ‘Howes’ and ‘Early Black’ cultivars and was arranged as a split-plot repeated measures design where bogs represented main plots while strips of cultivars were sub-plots. Sites which were using cycled automated irrigation approaches as well as those using the conventional method of frost protection were selected, both with the start set point of 3-4?F above tolerance of the least hardy cultivar. Those bogs were monitored for the 2013 and 2014 frost seasons and field assessments conducted in April, May and June.

Bud damage: Cranberry buds were collected on several dates throughout the season (Table 1), including a collection done prior to the beginning of the season to confirm whether or not there was prior damage to the buds. At the onset of frost events, collection was then done 24 hours after a frost event and buds brought to the laboratory, about 50 buds per bed Bud assessment focused on looking for internal damage by dissecting the buds under a microscope and performing a visual damage assessment (Image 1).

Flower and berry count: These were assessed using a 15.2cm diameter ring placed randomly on a bed and the number of flowering and vegetative uprights counted and recorded. For the berry count, the number of berries per upright was counted within the ring. The procedure was replicated four times per bog. Yield estimate: At the end of the season, yield estimates were measured by collecting berries from a 25 × 25 cm quadrat (Image 2), also placed randomly within each bed and replicated four times. The berries were sorted to separate the rotted fruit from the usable ones which were weighed and recorded. The yield estimates were presumed to be a more accurate and reliable measure of yield compared to either the upright density count or berry count.

Water use: Flow meters were connected to the discharge pipe from the pump (Image 3) to measure accurately the volume of water used during each frost event. Flow volume readings were taken from the pump before and after frost events to allow us to compare water use between conventional and cycling irrigation.

- Flow meter

- Bud collection dates
- Bud damage images
- Sampling fruit yield

Research results and discussion:

Water Use: Using flow meters installed on irrigation mains, water use for each frost protection method was recorded. There were generally more frost events in 2013 than 2014 and therefore more water used for frost protection in 2013. Most water savings were obtained under the automated cycling in both years, with as much as 35% less water usage under AI per night relative to CONV method. Mild and short nights with some fluctuating temperatures resulted in water savings for cycling irrigation, probably due to the ability of the irrigation pumps to stop running above the temperature threshold and cycle on and off while the conventional kept running even when it was not necessary, thereby wasting water and fuel. Intense frost nights that lasted longer than 10 hours resulted in similar amounts of water use under both methods, since temperatures were consistently low throughout the night (Fig 1). On average, conventional frost protection used 477 gallons/acre of water per frost night while AI used only 167 gallons/acre per frost night. That equates to 310 gallons/acre saved by using AI relative to CONV resulting in 35% water savings per night. This is consistent with a preliminary report. This study has clearly validated water savings associated with the use of a cycling protocol in both years of spring frost protection (Table 2). These savings are significant and should be considered when choosing a frost protection method.

Bud damage: The 2013 spring season had more than 25 frost nights forecast in the MA cranberry region while the 2014 season only had about 10. For samples assessed prior to the beginning of the season, there was minimal bud damage observed under both methods for the two years of the project. The benchmarking sites had highest bud damage at 6% for Stevens under conventional while Early Black (EB) only had 2% damage for either method (Fig 2). By mid-season, bud damage levels had increased to a high of 13% for EB under AI and 8% for Stevens under AI (Fig 3), but we observed the damage on only one or two floral initials. A typical cranberry bud has four to six floral initials; therefore the undamaged floral initials were expected to survive. The end of the season was characterized by less frequent frost nights, with mild and moderate temperatures. At that time, damage was relatively low, with the highest being 5% and 4% respectively, for Stevens and EB under AI (Fig 4) while Howes had no differences.

Yield data: There were no significant differences between the two methods with regards to the number of flowering uprights per unit area, but we found significant differences between cultivars ($p < 0.0056$). In addition, most uprights could provide photoassimilates for only two berries per upright, which is the average number that we noted across different sites. Yield estimates were made on data collected at the end of the season, in the months of September and October. Again, significant differences were only observed between cultivars, in both years, with the automated intermittent irrigation giving yields similar to conventional irrigation.

However, fruit yield in 2014 were significantly higher than those obtained in 2013, with Stevens under cycling consistently being the highest, followed by Howes and EB the lowest (Table 3). Stevens is a robust cultivar with large berry size and does not seem to have been affected by the mid-season damage incurred under AI. In conclusion, use of cycling irrigation is equally effective in cranberry bud protection, with the added advantage of water savings and therefore environmental sustainability and longevity of irrigation equipment.

- Water savings
- Cranberry bud damage prior to frost
- End of season bud damage
- Yield estimates
- Water use for select dates
- Mid-season cranberry bud damage

Research conclusions:

This study has an impact on the cranberry growers in southeastern MA. Equipped with the knowledge that the automation method of irrigation, with cycling, equally protects cranberry buds against frost damage, growers will get an opportunity to re-evaluate their frost protection and management practices. Moreover, from the study, water savings associated with cycling, are hard to ignore and will promote environmental sustainability and reduced tear and wear to the irrigation equipment. Although hard to quantify, the lesser the run times of the irrigation pumps, the lesser the fuel consumption and its associated emissions.

Participation Summary

Education & Outreach Activities and Participation Summary

PARTICIPATION SUMMARY:

Education/outreach description:

Jeranyama, P., F. Ndlovu., J. Sack, A. Ward, M. Hegedus, B. Jeranyama and C. Kennedy. 2014. Potential Water and Energy Savings in Cranberry Frost Cycling. Oral presentation by Peter Jeranyama at the Annual Cranberry Management Update Meeting, Radisson Hotel, Plymouth Habor, MA (15th January 2014)

Ndlovu, F., P. Jeranyama., C.J. DeMoranville and M. DaCosta. 2014. Spring Frost Control Methods and their Effectiveness in Preventing Bud Damage for Selected Cranberry Cultivars. Oral presentation by Faith Ndlovu at the Northeastern Division of the American Society for Horticultural Science Conference. Philadelphia, PA. Jan. 6-8, 2014. (abstract)

Ndlovu, F., P. Jeranyama., C.J. DeMoranville. 2013. Automated Intermittent Frost Cycling Effect on Cranberry Bud Damage and Water Usage. Oral presentation by Faith Ndlovu at the University of Massachusetts Amherst, Graduate student seminar series (24th Oct 2013)

Project Outcomes

Project outcomes:

Farmer Adoption

Most growers have indicated an interest in AI due to the lucrative profits that it brings. Conversely, a follow up survey showed the growers who cycled, found it more beneficial on mild frost nights when tolerance was only slightly below tolerance and did not cycle on extremely cold nights where there was a higher risk of bud damage and are likely to keep cycling