Frost Protection Irrigation for Florida Peaches: Economic Considerations[1]

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Highlights

- For Pasco, Polk, and DeSoto Counties, the number and duration of frost events were determined for the past few seasons following the precision frost protection approach based on temperature as it relates to petal and bloom stages, along with wind speed, as recommended in Extension publications by the University of Florida (based on research at the Washington State University).
- The number and duration of frost events were then determined again for the same seasons using 32°F as the relevant critical temperature and by observing the wind speed without consideration for the petal and bloom stages. This is assumed to reflect the uniform frost protection irrigation approach frequently followed by peach producers in Florida.
- For both precision and uniform approaches, for the nights with temperatures below the critical levels, the duration of frost events was assessed as the number of hours from the hour when the average temperature dropped below 33°F (start of the event) and the hour when the average wet bulb temperature raised above 33°F (end of the event).
- On average for the production season, farmers following the uniform approach run frost protection irrigation for approximately 9 hours longer in comparison with the farmers following the precision approach.

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- Assuming a 0.3-inch-per-hour water application rate, the area of 20 acres served by one pump at 8.5 gallons per hour of diesel use, and the cost of $2.50 per diesel gallon, producers can save $200 per pump per production season following the precision approach (or $10 per acre per season).
- The savings in particularly cold production seasons (such as 2009/10) can be more than $1,000 per pump (or $50 per acre).
- In addition to the money savings, changes in frost protection irrigation can translate into reductions in water withdrawals, with the estimated average difference between the two approaches being 76 thousand gallons per acre per season.
- An important limitation is the use of the precision approach developed by the researchers from the state of Washington. While these recommendations are used in Extension publications by the University of Georgia and the University of Florida, additional Florida-based research is being conducted to tailor these recommendations to Florida's peach varieties and production conditions. Such research is currently conducted by the UF Horticultural Sciences Department.

Introduction

Peach production in Florida is growing in importance. Annually, Florida produces 4.5 million pounds of peaches with an estimated value of $6 million (Olmstead and Morgan 2013). While the total peach acreage in Florida is significantly smaller than in California, South Carolina, or Georgia, the industry is growing rapidly. In just five years (2007 to 2012), the number of farms growing peaches in Florida rose by 162 percent (to 380 farms), while the acreage increased by a staggering 426 percent (from 234 to 1,231 acres) (USDA 2012). As shown in Table 1, three counties account for more than 50 percent of total peach acreage in Florida: Polk, Pasco, and DeSoto Counties. Harvesting of Florida peaches usually begins in April/May, well before that of other states. This unique market window allows the prices for Florida peaches to be high (i.e., approximately $1.25 per pound as compared with $0.80 per pound received by producers in the other southeastern states) (Morgan and Olmstead 2013; Olmstead et al 2011).

Reduction in peach production costs would allow producers to increase the net revenues. While irrigation costs are relatively small in comparison with the costs of other production inputs (Olmstead and Morgan 2013), more efficient water use and reduction in water withdrawals have a significant additional benefit (USGS 2010): they contribute to the protection and restoration of lakes and streams in the region (e.g., Eagle Lake and Lake McLeod in Polk County, and Moon Lake in Pasco County, which show reduced water levels) (SWFWMD 2015). In addition, use of the most efficient strategies reinforces the public image of farmers as innovators and environmental stewards.

Frost Protection Irrigation

Peach buds, flowers, and young fruits can be damaged by low temperatures. Overhead irrigation is generally used to prevent such damage (Figure 1). The underlying principle for overhead irrigation for freeze protection is that as water turns to ice it releases heat, so as long as water is applied continuously, the rate of application is appropriate, and the wind is weak, the plant temperature will remain near 32°F (Olmstead et al. 2013).

Figure 1. Frost protection irrigation for peaches (Source: UF/IFAS/ICS)

The decision to turn on the irrigation system for frost protection depends on the plant's susceptibility to cold, and different stages of peach bud development are susceptible to frost damage at different temperatures. Most Extension researchers (Murray 2011; Olmstead et al. 2013; Riger and Lockwood undated) base their frost protection recommendations on the research conducted at Washington State University (Ballard and Proebsting 1978). Generally, flower buds that have just begun to swell can withstand temperatures at 18°F, flowers at full bloom can withstand temperatures at 27°F, and young fruits can withstand temperature at 28°F (Figure 2). These critical temperatures result in an approximately 10 percent bud or flower kill after 30 minutes of frost exposure (Ballard and Proebsting 1978). Since peach production requires pruning and thinning, this 10 percent loss of buds and flowers would generally have no negative effect on the marketable yield.

	Swollen Bud (First Swell)	Calyx Green	Quarter-Inch Green (Calyx Red)	Pink (First Pink)	First Bloom	Full Bloom	Post-bloom
10%	18	21	23	25	26	27	28
90%	1	5	9	15	21	24	25

Figure 2. Critical temperatures (°F) at which 10% and 90% bud kill occurs after 30 minutes exposure (Source: Murray 2011)

Despite these recommendations regarding susceptibility to frost damage at different bud and flower stages, some producers apply frost protection irrigation uniformly for Pink, First Bloom, Full Bloom, and Post-bloom stages (with no or limited protection applied for Swollen Bud, Calyx Green, and Calyx Red stages), switching the irrigation system on when temperature is predicted to drop below 32°F. There are several reasons to explain why producers irrigate at higher-than-recommended temperatures: lack of experience (with peaches being a relatively new crop for most Florida producers), concern that the weather forecast given by meteorologists may not coincide with local temperatures, a need to account for the time necessary to start the frost protection irrigation when the air temperature is dropping sharply, reduction in plant temperature right after the start of the irrigation (due to evaporative cooling), and desire for a margin of safety in frost protection.

The aim of this document is to estimate how altering frost protection irrigation decisions to follow the critical temperatures for different bud stages can save peach producers pumping costs and reduce water use. University of Florida researchers are developing decision support tools to address the producers' concerns listed above, and to assess the potential impacts of changes in frost protection irrigation practices to better account for frost susceptibility during different bud and flower stages.

Method and Data

While peach blooming time can vary from year to year, we considered the period from the end of December to mid-January as the typical blooming period and divided this period into equal intervals to account for different bud and flower stages. For each stage, Table 2 reports the critical temperature recommendations for the precision approach (25°F–32°F) and the uniform approach (32°F). The precision approach accounts for differences in frost susceptibility. In the uniform approach, irrigation is turned on at the same temperature without consideration for the bud development stages. In reality, there is a range of practices, and some producers might turn on irrigation at 35°F, while others might wait until 31°F temperatures.

Average hourly temperature, web bulb temperature, and wind speed data for Polk, Pasco, and DeSoto Counties were collected from the Florida Automated Weather Network (FAWN) online database (FAWN 2015) and used to determine the duration of frost events given the precision and uniform approaches. Specifically, for each production season and the dates corresponding to the bud development stages (Table 2, column 2), hourly average air temperature was compared to the critical temperatures given for the precision approach (Table 2, column 3). If the air temperature was at or below the relevant critical temperature, the corresponding hour was counted toward frost protection irrigation. The hours with average wind speeds above 10 miles per hour were disregarded since protection irrigation would be ineffective. Furthermore, it was assumed that in the nights with temperatures below the critical levels, irrigation systems are turned on at 33°F, and once the irrigation system is turned on, it stays on until the air temperature rises to 33°F, as measured by both dry bulb and wet-bulb thermometers (Harrison et al. 1972; Jackson et al. undated).

For the uniform approach, we counted the number of frost protection irrigation hours using a similar method but referring to the critical temperatures reported in column 4 of Table 2. We focused on events where the air temperature falls to 33°F and continues falling (so that at some point, the temperature drops below 32°F).

The relevant data (air temperature, wind speed, and the wet bulb temperature) were available for three production seasons in Pasco County (2012–2015), and eight production seasons for Polk and DeSoto Counties (2007–2015). Moreover, in Polk County, two FAWN weather stations were available to download the weather data.

The frost event durations per season defined using precision and uniform approaches were then used to estimate the cost of water pumping. Diesel costs were determined using the 2015 cost of farm diesel fuel (EIA 2015a, b). Table 3 illustrates a peach farm setup with one water pump serving approximately 20 acres, delivering 2.7 thousand gallons of water per minute and using 8.5 gallons of diesel per hour.

Results and Discussion

The end result was that producers can save on pumping costs and reduce water use by altering frost protection irrigation. As expected, the average frost protection irrigation duration was significantly longer for the uniform approach compared with the precision approach (columns 3–5 in Table 4). Producers using the uniform approach were estimated to frost-protect for an average of 17 hours per season (i.e., approximately 2 cold nights per season). In turn, producers using the precision approach were estimated to frost-protect for only 7 hours per season (i.e. approximately 1 cold night per season). On average, the difference between the uniform and precision approaches was 9 hours.

There is significant variation in frost protection irrigation needs from season to season and from location to location. For example, the 2009/10 season was particularly cold, so producers employing the uniform approach were estimated to frost-protect for about 60 hours (i.e., about 6 or more nights). In contrast, for the precision approach, the duration of frost protection irrigation was 9 to 30 hours (i.e., about 1 to 3 nights). Thus, estimated reduction in frost protection irrigation was 36 to 48 hours, depending on geographic location. In contrast, no difference between the uniform and precision approaches was observed for warm seasons (such as 2014/15 in Polk and DeSoto Counties) and for seasons when cold spells happened in February–March after blooming was over (such as 2014/15 in Pasco County).

It was estimated that Florida peach growers would save on diesel costs if they followed the precision approach (see column 6 in Table 4). These savings were considerable for cold seasons, such as 2009/10 and 2010/11. For example, in Polk County, the estimated difference between the precision and uniform approach in 2009/10 was approximately 50 hours of irrigation, and $50 per acre. For a pump serving 20 acres, this translated into a diesel cost savings of approximately $1000 per pump. Not all examples were this extreme. For example, in Polk County, no difference in pumping costs for the two approaches was observed for the seasons of 2012/13, 2013/14, and 2014/15. Nonetheless, for the three counties considered, the average difference in the diesel costs for frost protection irrigation pumping between the two approaches was $10 per acre per season. For a pump serving 20 acres, these savings amount to $200 per pump per season.

It is also important to recognize that there is a significant amount of water saved each time a grower chooses to forego irrigation (see column 7 in Table 4). On average, the difference in water use for the two approaches is estimated at 75.6 thousand gallons per acre per season. For a pump serving 20 acres, this translates into 1.5 million gallons per season.

There are significant variabilities in frost protection practices among growers, including the types of water pumps used and the criteria to make the decision of when to turn the pumps on or off. These variabilities are not considered in the study. This study does not account for the variability in bloom times among years, locations, or varieties. This study also does not consider the effect of alternative frost protection strategies on yield. Riger and Lockwood (undated) state that "several factors can influence the actual temperature at which [frost] injury occurs [for instance] buds on weak trees cannot tolerate the same temperatures as those from healthy trees [and] conditions leading up to the cold event influence hardiness." It can be added that susceptibility to cold can depend on the peach variety. Hence, while losses in buds and flowers do not necessarily mean losses in harvestable yields, additional research on this topic is needed, particularly focusing on Florida varieties and production conditions.

Conclusions

Peach growers who account for cold hardiness of various bud and flowering stages (as opposed to the uniform approach) for frost protection can save money on diesel fuel and can also save significant volumes of water. The estimated annual savings range from $0 per acre to approximately $50 per acre per season, with the average per season of approximately $10 per acre. For a water pump serving 20 acres, this translates into approximately $200 per season. Estimated water use reduction is more 75.6 thousand gallons per acre per season, on average. During colder seasons, growers can expect even higher savings.

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Table 1. Selected Florida peach production statistics (2012)

Geographic region	Number of farms		Area (acres)	
	Total number	Percent of state total	Total number of acres	Percent of state total
Florida—total	380	100%	1,231	100%
Top peach-producing counties in Florida				
DeSoto	7	1.8%	95	7.7%
Pasco	16	4.2%	109	8.9%
Polk	38	10.0%	459	37.3%
Total for the three counties	61	16.1%	663	53.9%
Source: USDA (2012)				

Table 2. Peach bud stages and critical temperatures, given precision and uniform approaches to frost protection irrigation

Bud development stage	Dates	Critical temperatures frost protection irrigation (°F)	
		Precision approach*	Uniform approach
First pink	Dec 27–Jan 01	25	32
First bloom	Jan 02–Jan 06	26	32
Full bloom	Jan 07–Jan 10	27	32
Post bloom	Jan 11–Jan15	28	32
Fruit	Jan 16–Apr 30	32**	32

* Sources: Ballard and Proebsting (1978); Riger and Lockwood (undated).
** Assumed to be the same as growers' practice.

Table 3. Assumptions made in the study to characteriize peach farming practices

Assumptions	Value
Area served by one water pump, acres	20.00
Water pump capacity, thousand gallons of water per minute	2.70
Water application rate for frost protection, inches per hour	0.30
Water application rate for frost protection, thousand gallons / (acre*hour)	8.10
Water pump diesel use, gallons of diesel per hour	8.50
Diesel cost, $/gallon	$2.50
Diesel cost per hour per pump, $/hour	$21.25
Cost of water pumping per acre per hour, $/(hour*acre)	$1.06
Cost of water pumping, $/thousand gallons of water	$0.13

Table 4. Frost protection irrigation per production season

County (location)	Production season	Frost irrigation duration (hours)		Difference between the uniform and precision approaches		
		Precision approach	Uniform approach	Frost irrigation duration (hours)	Frost protection irrigation cost ($/acre)	Frost protection water use (1000 gallons/acre)
(1)	*(2)*	*(3)*	*(4)*	*(5)=(4)-(3)*	*(6)=(5)*$1.06*	*(7)=(5)*8.10th.gal.*
Pasco	2012/13	11	11	0	0.0	0.0
(Dade City)	2013/14	16	16	0	0.0	0.0
	2014/15	11	11	0	0.0	0.0
Polk	2007/08	0	11	11	11.7	89.1
(Lake Alfred)	2008/09	31	31	0	0.0	0.0
	2009/10	30	66	36	38.2	291.6
	2010/11	0	34	34	36.0	275.4
	2011/12	0	9	9	9.5	72.9
	2012/13	0	0	0	0.0	0.0
	2013/14	0	0	0	0.0	0.0
	2014/15	0	0	0	0.0	0.0
Polk	2007/08	0	7	7	7.4	56.7
(Frostproof)	2008/09	6	6	0	0.0	0.0
	2009/10	9	57	48	50.9	388.8
	2010/11	0	18	18	19.1	145.8
	2011/12	0	3	3	3.2	24.3
	2012/13	0	0	0	0.0	0.0
	2013/14	7	7	0	0.0	0.0
	2014/15	0	0	0	0.0	0.0
DeSoto	2007/08	0	0	0	0.0	0.0
(Arcadia)	2008/09	37	37	0	0.0	0.0
	2009/10	23	60	37	39.2	299.7
	2010/11	6	32	26	27.6	210.6
	2011/12	0	23	23	24.4	186.3
	2012/13	4	4	0	0.0	0.0
	2013/14	8	8	0	0.0	0.0
	2014/15	0	0	0	0.0	0.0
Average		7.4	16.7	9.3	9.9	75.6