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Water Savings for Potato Production Using Center Pivot Irrigation in Southwest Florida

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Seepage irrigation is the most widely used irrigation system for potato production in Florida but is inefficient in water use. To evaluate the potential water-savings under center pivot, field trials were conducted on a commercial potato farm in Parrish, FL, where both center pivot and seepage irrigation systems were compared side by side. The irrigation water usage, potato yield and quality were compared between the two irrigation systems in the 2012–13 growing season at two locations. Two 20-foot rows were used for tuber yield measurement. Our results showed no significant difference in tuber yields and leaf greenness between seepage and center pivot irrigation. The total water applied for seepage irrigation and center pivot irrigation ranged from 24 to 36 inches and 9 to 15 inches, respectively. Center pivot irrigation used 35% to 75% less water and had high water use efficiency compared to seepage irrigation. In addition, after two freeze events of 2013, better foliage coverage, greener plants, and less freeze damage were found under the center pivot system. More research is required to fully evaluate the potential of switching from conventional seepage irrigation to overhead irrigation.

Potato production is extremely sensitive to soil water availability. In Florida, seepage irrigation as a conservative irrigation strategy is the predominant practice and has lasted for decades. With seepage irrigation, the water table in field is controlled at a depth just below the plant root zone by either adding or removing water from the field. It is likely to cause over-irrigation, poor soil aeration, lower yields, increased disease problems, low tuber quality (Makani, et al., 2010), and nutrient leaching problems (Shock et al., 2007).

Although irrigation management has been proven to be a valuable best management practice, there has been limited work in investigating the use of alternative irrigation methods that lead to more efficient use of irrigation water. Overhead irrigation (center-pivot) has greater water-use efficiency (Alva et al., 2012) compared to seepage irrigation (Simonne et al., 2002). The combination of overhead irrigation with irrigation scheduling and fertilization management has been successfully used for potato production in other parts of the country (Miller and Spoolman, 2011). Due to the lower irrigation volume applied, higher soil water storage is expected, which may reduce runoff from the field after a rain event.

The specific objectives of this study were to: 1) evaluate how much water could be saved by using center pivots; and 2) compare the effects of overhead and seepage irrigation systems on potato growth and development, whole plant physiology, tuber yield, and quality.

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Methods and Materials

Study site

Trails were conducted on a commercial potato farm in Parrish, Florida in the 2012–13 growing season. Two potato production farms (Farm 1–2) were selected. Each farm had two treatments including seepage and center pivot. In total, there were 16 plots.

Two varieties were used including one chipping potato 'Atlantic', and one fresh table potato 'Red LaSoda'. The varieties and planting and harvesting dates are listed in Table 1. The rate of inorganic fertilizer (N, P, and K) application for chipping potato was 750 lb/acre with N-P-K composition of 9-15-20 at preplant, 500 lb/acre 21-0-18 at emergence, and 250 lb/acre 21-0-21 as a side dress at layby. For fresh table potato, fertilizers were only applied at preplant and emergence at the same composition and rates as chipping potatoes. In addition, 500 lb/acre gypsum was also used at emergence for fresh table potato.

Field measurements

Before planting, water flow meters (WMX101-600 6 Inch Magnetic Flow Meter, Gold River, CA) were installed at the inlet of each seepage area. The water usage for center pivots was recorded using a Water Specialties Propeller Meter (McCormeter Inc., Hemet, CA) that was set up by the Southwest Florida Water Management District. Four rain gauges (Model # BAR206_RGR126, Oregon Scientific, Tualatin, OR) were installed at each of the treatments on the two farms to investigate the contribution of rainfall to water usage. The reference evapotranspiration (ET) rates during the growing season were estimated from Florida Automated Weather Network (FAWN) <http://fawn.ifas.ufl.edu/> station located at Balm, FL. Water use efficiency (WUE) in this study was calculated as the yield

Table 1. Trial designs in 2012–13 growing season.

Farm	Irrigation	Variety	Acreage	Planting Date	Date
1	Seepage	Red LaSoda	10	12/18/12	4/11/13
	Center Pivot	Red LaSoda	130	12/11/12	4/11/13
2	Seepage	Atlantic	120	12/10/12	4/11/13
	Center Pivot	Atlantic	300	12/28/12	4/11/13

per unit of water. When we only considered irrigation water, it was called irrigation WUE. When considering both the rainfall and irrigation water, it was called overall WUE.

$$WUE\ (lb/inch) = \frac{Yield}{WU}$$

To evaluate the water status of the potato crops, 30 healthy potato leaves in the second and third rows of each of the fourplots were randomly selected to measure leaf greenness with a portable SPAD-502 leaf chlorophyll meter (Minolta, Japan). At harvest, two 20-foot rows were manually harvested for each of the 16 plots.

There were two freeze events in 2013, i.e., 17 Feb., and 8 Mar. To evaluate the freeze damage, 10 plants in each plot were randomly chosen and all of the healthy leaves and damaged leaves of each plant were counted to calculate damage percentage.

Statistic analysis

One-way analysis of variance (ANOVA) was conducted in JMP version 10 (SAS Institute Inc.). Student's t-test was used for evaluation of significance in potato yields, freezing damage, and leaf greenness between the two irrigation systems. Results were considered significant at $P < 0.05$.

Results and Discussion

Leaf greenness is a measurement of leaf chlorophyll content which responds to water stress (Fanizza et al., 1991). In our study, leaf greenness varied with different times during the growing season (Table 2). It is not clear whether center pivot irrigation had a negative or positive effect on leaf greenness based on our results.

During the two freeze events, seepage plots showed higher freeze damage, but only significantly higher in the second freeze event (Table 2), suggesting probable frost protection by center pivot compared to the center pivots. It has been reported that overhead irrigation, mostly sprinkler irrigation systems, can provide frost protection (Jorgensen & Norum, 1991; Hochmuth et al., 1993; Jorgensen et al., 1996). The principle behind this protection needs to be further explored.

There was no significant difference in potato yield between the two irrigation systems (Table 3). Water usage included two sources, i.e., irrigation water and rainfall. All the seepage plots at the two farms consistently showed greater water usage compared to those at the center pivot plots (Table 3). The center pivot saved 75.3% and 35.2% water compared to the water applied in seepage for the fresh table potato and chip potato, respectively. Both overall WUE and irrigation WUE for center pivots were much higher than those for seepage plots (Table 3).

These water consumptions in seepage systems were 2 to 3 times greater than the reference evapotranspiration (ET_0) in Spring 2013 (10.2 inches, FAWN). As aforementioned, no significant differences in potato yields and leaf greenness were found between the two irrigation systems, suggesting center pivots have potential to save water without remarkable loss of potato yields.

Our study showed a promising perspective that center pivot can save water for potato production. However, multiple years of trials for different varieties of potatoes are needed to further evaluate the performance of center pivot in potato yields, crop physiology, and nutrient use efficiency.

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Table 2. Leaf greenness measured by a portable SPAD-502 leaf chlorophyll meter (Minolta, Japan) and freeze damage on 23 Feb. and 8 March 2013 (mean ± standard error, n = 4). Different letters denote significant difference by Student's t-test, $P < 0.05$.

		Leaf greenness		Freeze damage (%)	
Farm	Irrigation	9 Feb. 2013	23 Feb. 2013	23 Feb. 2013	8 Mar. 2013
1	Seepage	40.2 ± 1.9	37.1 ± 2.4 b	28.0 ± 7.6	28.0 ± 3.6 a
	Center Pivot	39.8 ± 2.6	46.6 ± 2.7 a	19.9 ± 4.0	14.3 ± 3.2 b
2	Seepage	47.0 ± 2.7	41.5 ± 4.3 b	1.1 ± 1.1	21.3 ± 7.2 a
	Center Pivot	49.8 ± 3.8	46.0 ± 4.2 a	0.0 ± 0.0	4.2 ± 3.4 b

Table 3. Potato yields (mean ± standard deviation, cwt/acre), water usage (inch water), and water use efficiency (WUE) between seepage and center pivot irrigation plots at the two farms during 2012–13 growing season.

Farm	Irrigation	Potato yield cwt/acre	Irrigation water (inch)	Rainfall (inch)	Water saving (%)	Irrigation WUE lb tubers/inch	Overall WUE lb tubers/inch
1	seepage	290 ± 44	35.6	2.2		905	853
	center pivot	264 ± 22	8.8	2.2	75.3%	3340	2683
2	seepage	270 ± 22	23.8	3.4		1262	1104
	center pivot	248 ± 14	15.4	2.2	35.2%	1780	1556

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