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Water Savings of Center Pivot Irrigation for Snap Bean Production in Southwest Florida

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Efficient use of irrigation water is imperative for efficient vegetable production. To evaluate the potential water savings of center pivot irrigation over conventional seepage irrigation for commercial snap bean production in southwest Florida, a field trial was conducted at a private farm during Spring 2014, where center pivot and seepage irrigation systems were compared. Fertilizer rates and application were identical for both irrigation systems. Results showed that the overall water usage of seepage irrigation and center pivot irrigation was 118,139 gallons per acre (gal/acre) (4.35 inches) and 50,090 gal/acre (1.84 inches), respectively. Center pivot irrigation saved 57.6% (68,049 gal/acre) of water. However, the snap bean yield was significantly higher in the seepage plot (14527.3 ± 709 lb/acre) than in the center pivot plot (8851.8 ± 281 lb/acre). Also, a significant decrease occurred in marketable yield under the center pivot irrigation system, which might be attributed to a possible increase of N leaching under overhead irrigation. This result suggests that the combination of fertigation and center pivot irrigation system might be an effective way to improve fertilizer use efficiency, yield, and reduce losses of nutrients to the environment.

Nationally, Florida ranks first in the production, acreage, and total value of fresh market snap beans (FDACS, 2011). The state's snap bean crop contributes 44% of the U.S. total in terms of production and 27.4% in terms of cash receipts (FDACS, 2011).

Seepage as a traditional irrigation method is widely used in Florida. It involves pumping a large volume of groundwater to maintain a high water table, resulting in low irrigation efficiency, poor soil aeration, higher soil salinity, and more plant diseases (Smajstrla et al., 2002, Makani, et al., 2010). In contrast, overhead irrigation (center pivot) has greater water-use efficiency (> 85%) than seepage irrigation (20% to 50%) (Simonne et al., 2002, Alva et al., 2011). Overhead irrigation systems have shown tremendous potential to improve water quality by reducing nutrient leaching associated with high irrigation volume applications and by allowing the injection of soluble fertilizer directly (fertigation) into the root zone (Miller and Spoolman, 2011, Singh et al., 2011).

The specific objectives of this trial were to 1) evaluate water usage reduction of overhead irrigation using center pivots as compared to seepage and 2) assess the effect of overhead and seepage irrigation systems on snap bean growth, whole plant physiology, yield, and quality.

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Methods and Materials

This trial was conducted on a commercial farm in Parrish, FL, from February to April 2014. There were four replications each for seepage and center pivot.

The snap bean variety was 'Caprice'. The application rate of inorganic fertilizer was 250 lb/acre with N-P-K composition of 18–0–18 at preplant (Olson and Simonne, 2012), identical for both irrigation systems. Based on our experience to keep nutrient in the root zone, one third of irrigation water was used for overhead irrigation. Thus, when we mentioned "center pivot" at the farm, it was actually a hybrid irrigation system including both center pivot and seepage. For hybrid "center pivot," irrigation the application rate for the pivot system was twice a week with 0.4 inches water per run, while the application rate for seepage was once every other week for 12 h from 7 pm to 7 am.

Field Measurements

Before planting, water flow meters (WMX101-600 6 Inch Magnetic Flow Meter, Gold River, CA) were installed at the inlet of seepage plots. The water usage for center pivot was recorded using a Water Specialties Propeller Meter (McCormeter Inc., Hemet, CA) that was set up by the Southwest Florida Water Management District. Two rain gauges (Model # BAR206_RGR126, Oregon Scientific, Tualatin, OR) were installed for the treatments, to investigate the contribution of rainfall to water usage and irrigation volume from the center pivot system. Soil moisture, temperature, and electrical conductivity sensors (5TE, Decagon

Table 1. Water usage for snap bean production in the Spring 2014 growing season.

Irrigation system	Area (acres)	Water usage			Water savings			Rainfall (inches)
		gallons	gal/acre	inches	gal/acre	gallons	%	
Seepage	10	1,181,392	118,139	4.35				5.87
Center Pivot	170	8,515,358	50,090	1.84	68048.9	11,568,330	57.6	

Devices, Inc., Pullman WA) were installed for each irrigation system to monitor soil volumetric water content (VWC, %) at five soil depths: 4, 8, 12, 20, and 28 inches. The data were recorded every hour with an Em50 digital/analog data logger (Devices, Inc., Pullman WA). At harvest, biomass, yield, and the diameter/length of 30 randomly selected snap beans were measure for each treatment.

Statistical Analysis

A one-way analysis of variance (ANOVA) was conducted using JMP version 10 (SAS Institute Inc.).

Results and Discussion

During this growing season, the cumulative rainfall was approximately 5.8 inches, contributing more than 50% of the total water usage. Table 1 showed that the water usage for seepage irrigation was 118,139 gallons per acre (gal/acre) while the water application rate for hybrid center pivot was approximately 50,090 gal/acre. Center pivot irrigation saved 57.6% (68,049 gal/acre) of water.

The volumetric water content (VWC) increased with soil depth, and moisture contents in the root-zone (top 12 inches) were greater for center pivot irrigation than for seepage irrigation. This result showed that center pivot irrigation maintained a better moisture status in the root-zone than seepage irrigation even though the center pivot irrigation system used much less water.

Snap bean yields of the seepage plots were significantly higher than for the center pivot plots. Specifically, the yields were 14527.3 ± 709 lb/acre and 8851.8 ± 281 lb/acre for seepage and center pivot plots, respectively. The difference between the two treatments might be resulted from the possible increase of N leaching under overhead irrigation. As most of the fertilizer was applied at the beginning of the growing season, it was susceptible to leaching as the growing season progressed. Thus, a more suitable fertilization program is required for the center pivot irrigation system.

At harvest, three plants were collected at each plot to measure the dry biomass of the stems, pods, and leaves; 30 beans were randomly selected from each plot to analyze their length and diameter. Table 2 showed that the dry weights for stems and leaves at the seepage plots were significantly higher than those at the center pivot plots. Also, the length of snap beans were greater at the seepage plots (12.3 ± 1.0 cm) than at the center pivot plots (11.8 ± 1.1 cm) (Table 3). No significant differences in the diameter of snap beans were observed between the two irrigation systems. The ratio of bean length to bean diameter (L/D value) is an important parameter for assessing bean appearance quality and is closely associated with bean size (Wijitha et al, 2003). For the seepage plots, significantly higher L/D ratios (16.0 ± 1.5 mm) were found compared to those at the center pivot plots (14.9 ± 1.0 cm).

Table 2. Dry weights of three plants collected at from the plots with the two irrigation regimes at harvest.

Irrigation system	Dry wt (g)			
	Total	Pod	Leaf	Stem
Seepage	41.8 ± 6.7	11.8 ± 2.1	17.5 ± 2.4	12.5 ± 2.5
Center pivot	32.8 ± 5.7	16.3 ± 5.9	9.5 ± 2.4	7 ± 2.8

Table 3. The length, diameter, and length/diameter ratio of the harvested green beans.

Irrigation system	Length (cm)	Diameter (mm)	Length/diameter
Seepage	12.3 ± 1.0	7.8 ± 0.7	16.0 ± 1.5
Center pivot	11.8 ± 1.1	8.0 ± 0.1	14.9 ± 1.5

This trial showed the water-saving potential of the center pivot irrigation system in snap bean production, even though the beans yield and quality were relatively worse than for seepage irrigation system. Further study should be focused on the combination of center pivot irrigation with more a suitable fertilization program (such as fertigation), to improve fertilizer use efficiency, yield, and reduce losses of nutrients to the environment.

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