Evaluation of Collector Size for Low Pressure, Fixed-Plate Sprinklers for Center Pivots [1]

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Abstract

A lab study was conducted to evaluate the opening size of cylindrical collectors for use with measuring applications depths from low pressure, fixed-plate sprinklers used on center pivot irrigation systems. Four cylindrical collector sizes (52-mm, 101-mm, 148-mm and 198-mm in dia.) were evaluated for catch accuracy. Collectors were mounted on a moveable cart (trolley) in a randomized block design using six rows of the four collector sizes. The cart was pulled through various sprinkler patterns via a track and electric motor and winch system. Collected water depths were measured and compared using t-tests for paired comparisons of measured depths and F-tests for variance comparisons. Measured data were more variable for the sprinkler combinations that had low pattern breakup and distinct streams of water. While it would be convenient to use a reasonable size (<100 mm dia.) collector to measure application depths from center pivot systems with these types of sprinklers, the data from this study suggest that it is difficult to obtain consistent data even with collectors up to 198-mm in diameter.

Introduction

With a strong emphasis on irrigation scheduling, "just-in-time" applications, and as water supplies become more limited, irrigation systems need to apply water uniformly for optimal crop growth and development and proper utilization of applied cropping system inputs (seed, fertilizer, other crop chemicals). This requires an in-field assessment on the performance of the irrigation system. However, various sprinkler packages are used including fixed plate, rotating plate, and wobbling plate diffusers that can operate between 41 and 207 kPa (6 and 30 psi), be on 1.5 to 6 m (5 ft to 20 ft) spacings, and have vertical positions ranging from 0.3 to 2.4 m (1 ft to 8 ft) above the ground surface. The combinations of these diffuser plates, operating pressures, spacings and vertical positions result in a variety of application patterns and measurement conditions that do not conform to current measurement standards. This research will develop and test different techniques and procedures to measure and assess the uniformity of water application from center pivot irrigation systems.

Methods and Materials

Tests were conducted to evaluate different collector opening sizes for catch efficacy from low pressure, fixed plate sprinklers that are typically used on center pivot sprinkler systems. Four cylindrical collectors were tested that included inside diameters of 52, 101, 148, and 198 mm. All cylindrical collectors were made from PVC pipe, were 200 mm deep, and were constructed using

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the IrriGage design as reported by Clark et al. (2004). A wooden cart with dimensions of 1.2 m by 1.8 m (fig. 1) was constructed to hold the cylindrical collectors in a randomized block design. “Square” collectors (198 mm x 211 mm x 200 mm deep) were also used to characterize the sprinkler patterns (fig. 1).

Six different sprinkler combinations were evaluated (tab. 1) at 42 kPa (6 psi) of pressure. These combinations typically provided large streams or droplets with different patterns. Three sprinklers were located on drop tubes attached to an elevated PVC manifold and were spaced 1.5 m apart. The sprinklers were attached to 42 kPa (6 psi) pressure regulators and were positioned 1.1 m above the collector openings. The cart was pulled through the middle of the sprinkler pattern on a track made from aluminum channel attached to wooden blocks (fig. 1). The cart was moved by using a fixed speed electrical motor and cable system. The motor and cable drum were geared to pull the cart through the sprinkler pattern at a speed of 0.3 m/min. This speed is consistent with the mid-point tower speed on a 50 ha (125 acre; 1/4-section) center pivot system that is set to make 1 revolution in 60 hours.

At the beginning of each test, sprinkler collectors were set up as shown in fig. 1, the sprinklers were pressurized, and the cart pulley system was activated. All tests were conducted in the basement courtyard of Seaton Hall where wind effects were minimal. After the cart was pulled through the sprinkler pattern, collected water amounts were weighed and data were converted to depth units. Three test runs (reps) were conducted for each sprinkler combination (tab. 1) and collector arrangement (cylindrical or square). Data from the three test runs were summed for each unique collector size and location to simulate cumulative water collections from multiple runs in a field setting. This data averaging procedure helps to smooth out data spikes from single water streams.

Table 1. Sprinkler combinations used in the collector tests. All sprinklers were operated at 42 kPa (6 psi) of pressure.

Sprinkler Combination	Mfg.	Orifice Size (mm)	Plate Characteristics
S 16 1 Plate	Senninger	6.35	Single grooved disk plate; 33 grooves; concave pad
S 16 2 Plates	Senninger	6.35	Two grooved disk plates; 33 grooves each; concave pad and flat pad
S 20 3 Plates	Senninger	7.94	Three grooved disk plates; 33 grooves each; concave pad – flat pad – convex pad
N 32 Coarse	Nelson	6.35	Single grooved disk plate; 24 coarse grooves; flat pad
N 32 Medium	Nelson	6.35	Single grooved disk plate; 36 medium grooves; concave pad
N 32 Fine	Nelson	6.35	Single grooved disk plate; 30 fine grooves; flat pad

Results

The S_16_1 Plate, S_16_2 Plate, and N_32_Coarse Plate combinations resulted in larger droplets and distinct streams of water. The S_20_3 Plate, N_32_Medium Plate, and N_32_Fine Plate sprinklers resulted in smaller droplets and greater droplet breakup. These characteristics will be important in the analysis of the measured results.

Measured depths from the 52-mm, 101-mm and 198-mm collectors were generally lower than measured depths from the square collectors (tab. 2 and 3) while measured depths from the 148-mm collectors were typically greater than the square collector depths. Some of these differences were significant, but were also generally within ±6% of the square collector depths. It is not clear why some of these differences exist. The 101-mm collector has more statistically different depths and with greater differences than the 52-mm collectors; yet, they have nearly four times the surface area. Furthermore, the 148-mm collectors also have some relatively large differences in depths (tab. 3) but most of these differences are not significant.

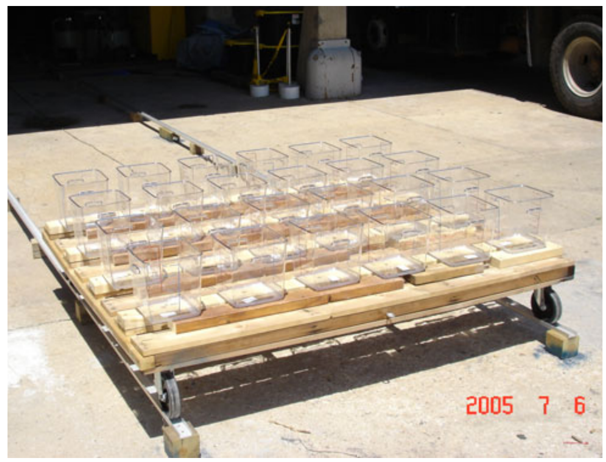


Figure 1. Collector cart system with cylindrical containers (left) and "square" collectors (right).

Table 2. Average collected depths (mm) from all three runs for each collector. Cylindrical collector (52, 101, 148, and 198 mm) results were compared to the square collector results using a paired t-test. Values were significantly different at the 0.1 (*), 0.05 (**), or 0.01 (***) level of significance, or not significant (NS).

Sprinkler Combination	Collector				
	Square	52 mm	101 mm	148 mm	198 mm
S_#16_1 plate	21.4	19.7 *	19.1 **	22.8 NS	20.8 NS
S_#16_2 plates	33.4	32.0 *	30.0 **	31.3 NS	32.4 NS
S_#20_3 plates	48.6	48.3 NS	46.5 *	51.4 *	46.9 *
N_#32_Coarse	20.0	19.5 NS	17.4 *	21.2 NS	19.6 NS
N_#32_Medium	19.8	20.4 **	18.9 NS	21.2 NS	18.7 *
N_#32_Fine	33.8	31.4 ***	32.2 **	34.2 NS	31.9 ***

The variances of the measured values (tab. 4) along with the charts in figure 2 help to explain some of these measured depth differences. Variances associated with only two of the collector/sprinkler combinations (tab. 3)were significantly greater than the variances from the "square" collectors. Yet the level of variability of some of the data was high. The most variable sprinkler combinations were the S_16_1 plate, S_16_2 plate, N_32_coarse, and N_32_medium (top four charts in fig. 2 and fig. 3). The S_20_3 plate and N_32_fine sprinkler combinations resulted in greater droplet breakup and a more visually uniform pattern (lower two charts in fig. 2 and fig. 3).

Table 3. Relative depth of collected water with respect to the depth of water collected in the square collectors.

Sprinkler Combination	Collector				
	Square	52 mm	101 mm	148 mm	198 mm
S_#16_1 plate	1.00	0.92	0.89	1.07	0.97
S_#16_2 plates	1.00	0.96	0.90	0.94	0.97
S_#20_3 plates	1.00	0.99	0.96	1.06	0.97
N_#32_Coarse	1.00	0.98	0.87	1.06	0.98
N_#32_Medium	1.00	1.03	0.95	1.07	0.94
N_#32_Fine	1.00	0.93	0.95	1.01	0.94

The relative coefficient of variation (fig. 4) was determined as the ratio of the CV for a particular cylindrical collector to the CV for the square collectors. One would think that larger collector sizes would result in less variable data; however, the relative CV data (fig. 4) for the S_16_1 plate, S_16_2 plate, N_32_coarse, and N_32_medium sprinkler combinations do not support this hypothesis. The S_20_3 plate sprinkler has greater pattern breakup and relative CV does decrease as collector size increases. Collector size does not seem to make any difference with the N_32_fine plate sprinkler that results in small droplets without distinct streams (as with the other sprinkler combinations).

Table 4. Variances (mm^2) of collected water depths. Variances of cylindrical collectors were significantly different from variances with the square collectors at the 0.1 (*), 0.05 (**), or 0.01 (***) level of significance, or not significant (NS).

Sprinkler Combination	Collector				
	Square	52 mm	101 mm	148 mm	198 mm
S_#16_1 plate	11.0	14.0 NS	18.9 NS	40.8 *	12.5 NS
S_#16_2 plates	19.1	19.1 NS	25.6 NS	39.7 NS	14.0 NS
S_#20_3 plates	7.2	25.0 *	18.4 NS	13.5 NS	9.0 NS
N_#32_Coarse	42.3	100.8 NS	34.4 NS	57.6 NS	76.5 NS
N_#32_Medium	9.7	10.1 NS	6.3 NS	25.0 NS	10.1 NS
N_#32_Fine	34.1	34.8 NS	40.3 NS	50.8 NS	31.4 NS

Summary and Conclusions

Four cylindrical collectors (52-mm, 101-mm, 148-mm and 198-mm in dia.) were evaluated for catch accuracy of water applied by low-pressure, fixed-plate sprinklers. Measured data were more variable for the sprinkler combinations that had low pattern breakup and distinct streams of water. While it would be convenient to use a reasonable size (<100 mm dia.) collector to measure application depths from center pivot systems with these types of sprinklers, the data from this study suggest that it is difficult to obtain consistent data even with collectors up to 198-mm in diameter.

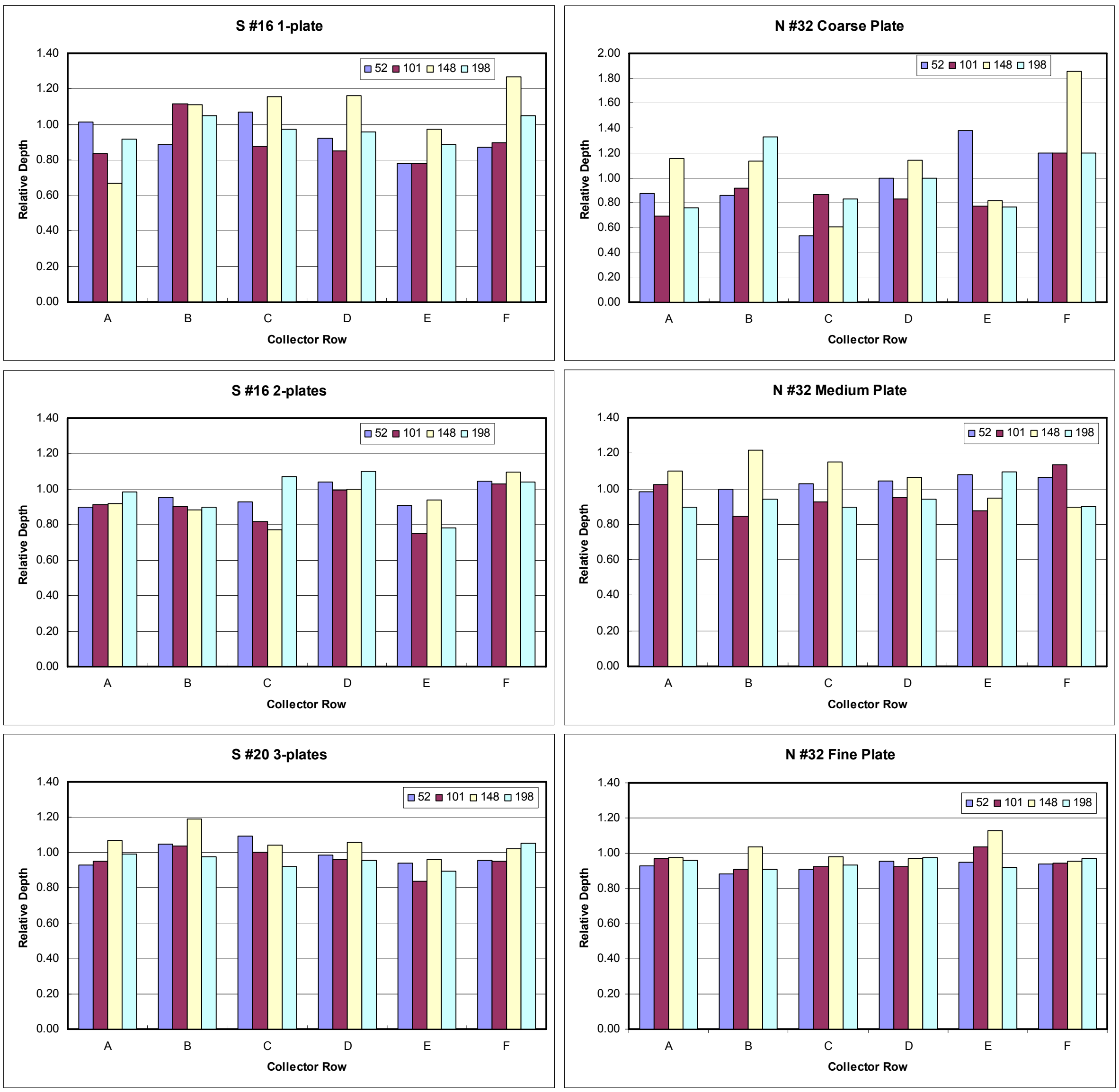


Figure 2. Relative depth distributions for the four cylindrical collectors (51-mm, 101-mm, 148-mm, and 198-mm) for each of the six collector rows on the cart for each of the six different sprinkler combinations.

Figure 3. Coefficient of variation (CV) of measured depths from the different sprinkler collectors for the six sprinkler combinations.

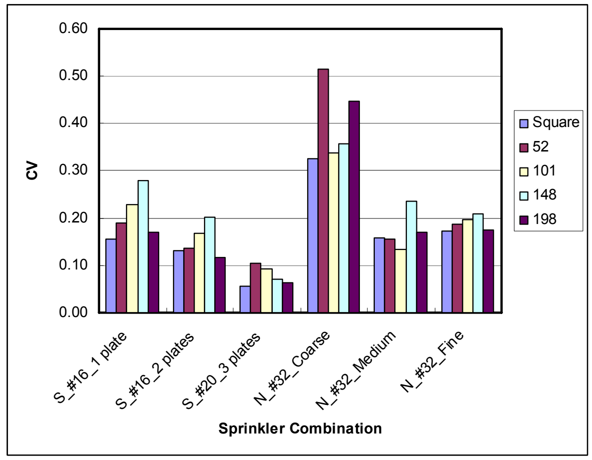
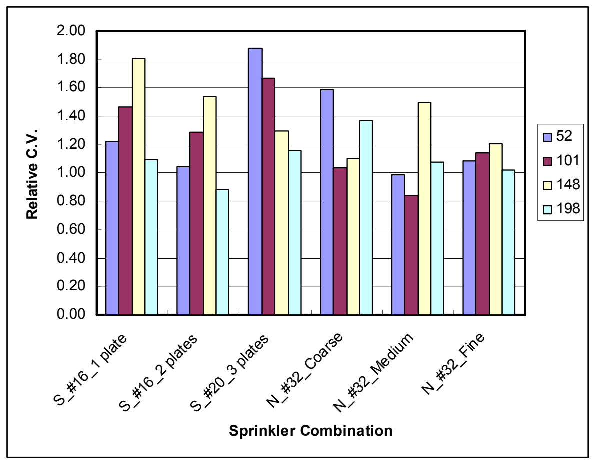


Figure 4. Relative coefficient of variation with respect to the "square" containers for the six sprinkler combinations.



Acknowledgements

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References

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