INFLUENCE OF NOZZLE PLACEMENT ON CORN GRAIN YIELD, SOIL MOISTURE AND RUNOFF UNDER CENTER PIVOT IRRIGATION

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Maximizing irrigation efficiency is of enormous importance for irrigators in the Central Great Plains to conserve water and reduce pumping costs. High temperatures, frequently strong winds and low humidity increase the evaporation potential of water applied through sprinkler irrigation. Thus, many newer sprinkler packages have been developed to minimize water losses by evaporation and drift. These systems have the potential to reduce evaporation losses as found by Schneider and Howell (1995). Schneider and Howell found that evaporation losses could be reduced by 2-3% as compared to above canopy irrigation. Many producers and irrigation companies have promoted placing sprinklers within the canopy to conserve water by reducing the exposure of the irrigation water to wind. However, runoff losses can increase due to the reduced wetted diameter which increases the application rate greater than soil infiltrate capacity. Schneider and Howell (2000) found that furrow dikes were necessary to prevent runoff with in-canopy irrigation.

In 2003 and 2004, a study was conducted comparing sprinkler nozzle placement near Burlington, Colorado in cooperation with a local producer. The objective of this study was to determine the impact of placing the sprinkler devices within the canopy upon soil moisture, runoff and crop yield. A secondary objective was to determine the usefulness of in-season tillage on water intake and preventing runoff.

METHODS

For this study, the current configuration of a center pivot irrigation system owned by our cooperating farmer was utilized. This configuration included drops with spray heads at approximately 1.5 feet (in-canopy) above the ground surface. The sprinkler heads on the seventh and outside span of the center pivot were raised to approximately 7 feet above ground level (above canopy). This nozzle height allowed for an undisturbed spray pattern for a majority of the growing season. The sprinkler heads on the sixth span of the center pivot remained at the original height (in-canopy). In 2003, the nozzles were raised by attaching the flexible drop hose using truss rod slings. Because the farmer decided not to irrigate this field in 2004, the study was moved to an adjacent pivot in 2004. The pivot nozzles were raised by replacing the drop hoses and ‘j-tubes’ on this system. In 2004 the nozzle heights in the outside span were left at 1.5 feet above ground level and the next span into the field were raised to 7 feet. Spacing was 5-feet between nozzles for both site-years.

For the 2003 growing season, three in-season tillage treatments were replicated three times under each of the sprinkler heights. The three tillage treatments were cultivation, inter-row rip and basin tillage. The cooperating farmer implemented the tillage treatments when the corn was at the V6 growth stage. The tillage treatments were implemented in strips running the length of the field. The field was planting perpendicular to the sprinkler direction. In 2004, the cooperating farmer chose to use grow the corn crop using no-till and planted in a circular pattern. In-season tillage was was to be implemented, inter-row rip and basin tillage operations, it was prevented by wet weather in June.. Thus, the only tillage in 2004 was no-till. The cooperating farmer conducted all field operations (planting, fertilization, pest control, irrigation, etc.) during 2003 and 2004.

Runoff was measured on cultivation and basin tillage for 2 replications and both sprinkler heights in 2003. Four-inch, V-notch furrow weirs installed at the bottom of the 8-row plots. The runoff for two 30-inch rows for the entire length of the pivot span (plot) was directed into the weir by the tillage treatment and soil berms where needed. The water level height in the stilling-wells of the weirs was recorded using auto-logging pressure transducers. Because the cooperating farmer chose no-till for the 2004 season, two 10-foot by 38-foot runoff plots using landscape edging were installed. Furrow weirs were installed on the lower end of the plots to measure runoff.

The soil type at both sites was Kuma Silt Loam. The slope was approximately 1 to 1.5 percent and was fairly uniform across treatments. We measured soil moisture from mid-June through early September using a Troxler neutron probe at one-foot increments to five feet of soil depth. A neutron access tube was installed in each tillage and nozzle height treatment in 2003 and six access tubes were installed in each nozzle height treatment in 2004. The study was repeated in 2005 but the results are not published. Problems associated with the bowls created surging and resulted in sections of sprinklers not outputting water. These sprinklers were generally the above canopy sprinklers.

RESULTS

Grain Yield

Grain yields in 2003 were not significantly different for in-canopy and above canopy irrigation (Tables 1 and 2). Statistically significant difference between tillage treatments were not found. However the yields for above canopy irrigation were consistently 4 bushels per acre greater than in-canopy irrigation within each tillage treatment. This would indicate that moisture stress did not occur under either above canopy or in-canopy irrigation. Grain yields for above canopy sprinkler placement were not statistically greater than in-canopy placement in 2003 as well. However, grain yields averaged across tillage treatments over the two-year period suggest that a potential trend where above canopy placement of sprinklers has greater yields than that of in-canopy placement. We plan to continue measuring grain yield and soil moisture at this site in 2005 to determine if this potential yield trend continues.

Soil Moisture

Soil moisture was measured for both above canopy and in-canopy sprinklers during the 2003 growing season. When comparing above canopy to in-canopy irrigation, changes in soil moisture were greater for in-canopy irrigation than above canopy (Figure 1). The depletion of soil moisture was significantly higher for the in-canopy sprinkler placement than with above canopy sprinklers. With similar yields, this would indicate that greater runoff losses occurred with in-canopy irrigation since soil moisture usage offset reduced infiltration. The greatest difference in change in soil moisture between above and in canopy irrigation occurred during early August when the difference was greater than 3 inches of soil moisture between the two sprinkler placements. Differences in soil moisture usage at physiological maturity were 1.7 inches greater for in-canopy irrigation than above canopy irrigation.

Changes in soil moisture between tillage treatments in 2003 were not significantly different from each other within a sprinkler height during the growing season. This would indicate that sprinkler height was the dominant factor in soil moisture content.

Contrary to 2003, soil moisture initially increased early in the 2004 growing season, declining after drier weather and higher ET rates began in July. Soil moisture content initially showed a greater increase for in-canopy placement as compared to above canopy placement (Figure 2). Much of this was due to the in-canopy placement being drier at the beginning of the season and above canopy placement reaching field capacity in mid-July. Most likely, deep percolation occurred in the above canopy placement while stored soil moisture increased for the in-canopy placement. Changes in soil moisture for both in-canopy and above canopy placement were similar after July 27. This was after the above canopy and in-canopy placement reached maximum stored soil moisture during the growing season.

Runoff

Due to inconsistent and unreliable readings from one replication of the data loggers installed on the weirs recording runoff, only one replication of the 2003 measurements was used for this paper. Runoff was greater with in-canopy irrigation than above canopy for the conventional cultivation and basin tillage treatments (Table 3). Changes in soil moisture between sprinkler placement treatments agree with runoff results collected for each placement. Greater amounts of runoff between sprinkler packages were offset by greater soil moisture loss. Runoff amounts were less for basin tillage as compared to cultivation. The reduction in runoff was due to the increase in surface storage created by the implanted basins. Although not measured, no or little runoff or signs of runoff was observed in the inter-row ripping tillage plots.

Only two significant runoff events due to irrigation, 1.1 and 0.89 inches of runoff, were recorded in 2004. This was due to management changes made by the producer. Irrigation depths in 2003 were 1.5 to 2 inches per application. In 2004, application amounts were reduced to 0.7 inches per application. This reduction in application depth reduced runoff in all but two irrigations where the producer applied higher amounts (at least 2 inches) per application.

Conclusions

Results from this study suggest that above canopy irrigation was more efficient at increasing stored soil moisture and reducing runoff as compared to in-canopy irrigation. Less runoff from above canopy irrigation in 2003 resulted in more stored soil moisture and similar to slightly more grain yield than in-canopy irrigation. In-season tillage such as basin tillage decreased runoff as compared to conventional cultivation. Yields between tillage treatments were not significantly different, but a trend of yield increases was observed when soil intake rates were modified by tillage.

No statistically significant yield differences were observed when irrigation sprinkler nozzles were placed above the canopy and soil moisture differences between above canopy and in-canopy placement reflected the differences in runoff. The results of this project suggest that sprinkler placement above a corn canopy would be preferable to placing sprinklers in-canopy unless significant changes in irrigation management practices occur.

References:

1995. Schneider, A. D. and Howell, T. A. Reducing sprinkler water losses. In Proc. 1995 Central Plains Irrigation Short Course & Equipment Exposition. Kansas Cooperative Extension Service, Manhattan, KS. pp. 60-63.

2000. Schneider, A. D. and Howell, T. A. Surface runoff due to LEPA and spray irrigation of a slowly permeable soil. Trans. ASAE 43(5):1089-1095.

Table 1. Average grain yields for sprinkler placement and tillage treatment (2003).

	Above Canopy		In-Canopy	
	Yield*	Moisture	Yield	Moisture
Tillage Treatment	(bu/acre)	(%)	(bu/acre)	(%)
Cultivation	187	15.2	182	17.5
Basin Tillage	188	14.5	184	18.1
Inter-row Rip	193	14.9	189	18.7
Average	189	14.9	185	18.1

*Grain yields adjusted to 15.5% grain moisture.

Table 2. Grain yields for sprinkler placement averaged across tillage treatments for 2003 and 2004.

	Grain Yield*		
	Above Canopy	In-Canopy	
Year	--------- bu/acre ---------		P>F
2003	189	185	0.33
2004	253	246	0.3
Average	221	216	0.17

*Grain yields adjusted to 15.5% grain moisture.

Table 3. Estimated runoff from July 4 to August 30 for sprinkler nozzle placement and tillage treatment in 2003. Runoff represents 15 irrigation events.

	--- Nozzle Placement ---	
	Above Canopy	In-Canopy
Tillage Treatment	--------- Inches Runoff ---------	
Cultivation	5.8	9.3
Basin Tillage	0.0	2.0

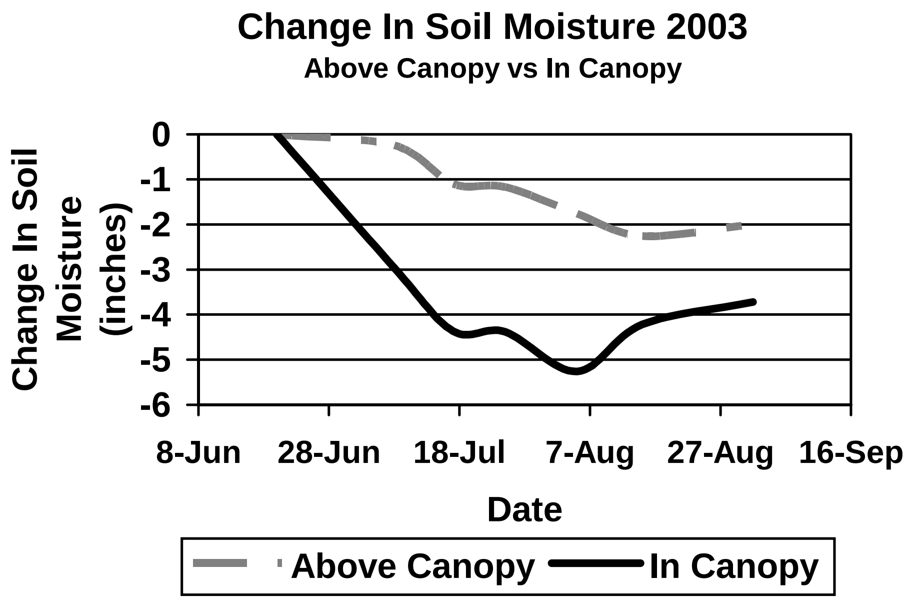

Figure 1. Change in soil moisture (from initial values) during the 2003 growing season for above canopy and in-canopy placement of sprinklers.

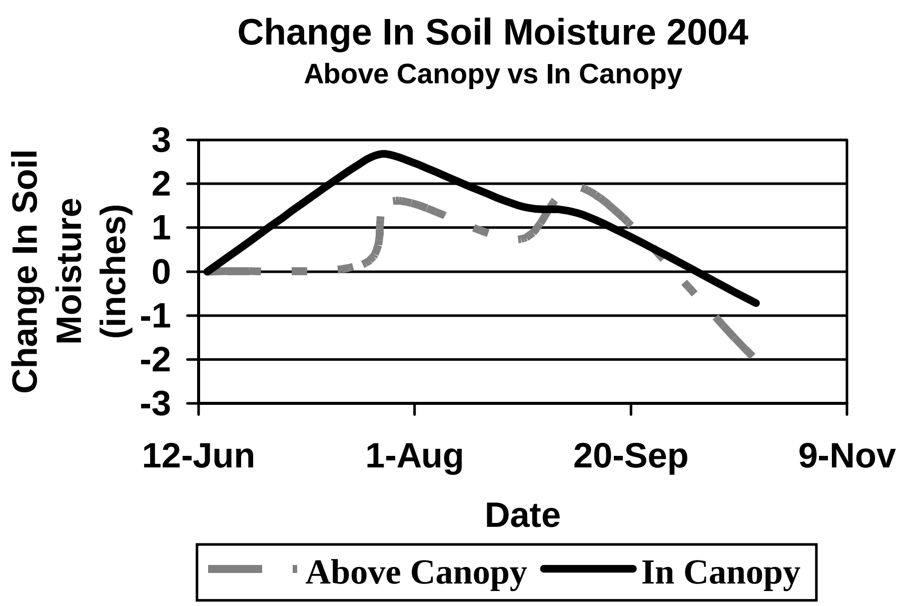

Figure 2. Change in soil moisture (from initial values) during the 2004 growing season for above canopy and in-canopy placement of sprinklers.