CROP RESIDUE AND SOIL WATER EVAPORATION

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Introduction

Sprinkler irrigation can involve frequent wetting of the soil surface. Once to twice per week wetting is common. The largest rates of soil water evaporation occur when the soil surface is wet. At this time soil water evaporation rates are controlled by radiant energy. The more frequently the surface is wet, the more time that the evaporation rates are in the “energy” limited phase. Crop residues have the capacity to modify the radiant energy reaching the soil surface and reduce the soil water evaporation during the “energy” limited phase of evaporation. As the soil surface dries, the evaporation rate is controlled by soil properties. However, with high frequency sprinkler irrigation the soil may remain in the “energy” limited phase. This produces the opportunity for crop residues to impact soil evaporation rates.

Evaporation-Transpiration Partition

Evapotranspiration, consisting of two processes, consumes the water applied by irrigation. The two processes are transpiration soil water evaporation. Transpiration, the process of water evaporating near the leaf and stem surfaces, is a necessary function for plant life. Transpiration rates are related atmospheric conditions and by the crop’s growth stage. Daily weather demands cause fluctuations in transpiration as a result. It is literally the process that causes water to flow through plants. It provides evaporative cooling to the plant. Transpiration relates directly to grain yield. As a crop grows, it requires more water on a daily basis until it matures and generally reaches a plateau. Soil water begins to limit transpiration when the soil dries below a threshold which is generally half way between field capacity and wilting point. Irrigation management usually calls for scheduling to avoid water stress. Limited irrigation management requires management to limit plant water stress in critical growth periods and allow more stress during less critical growth periods.

Evaporation from the soil surface may have an effect on transpiration in the influence of humidity in the crop canopy. However, the mechanisms controlling evaporation from soil are independent of transpiration. The combined processes of evaporation from soil (E) and transpiration (T) are measured together as evapotranspiration (ET) for convenience. Independent measurements of E and T are difficult but independent measurements are becoming more important for better water management.

Field research in sprinkler irrigated corn has shown that as much as 30% of total evapotranspiration is consumed as evaporation from the soil surface (Klocke et. al., 1985). These results were from bare surface conditions for sandy soils. For a corn crop with total ET of 30 inches, 9 inches would be going to soil evaporation and 21 inches to transpiration. This indicates a window of opportunity if the unproductive soil evaporation component of ET can be reduced without reducing transpiration.

Evaporation from Soil Trends

Evaporation from the soil surface after irrigation or rainfall is controlled first by the atmospheric conditions and by the shading of a crop canopy if applicable. Water near the surface readily evaporates and does so at a rate that is only limited by the energy available. This so-called energy limited evaporation lasts as long as a certain amount of water that evaporates, 0.47 inches for sandy soils and 0.4 inches for silt loam soils. The time it takes to reach the energy limited evaporation depends on the energy available from the environment. Bare soil with no crop canopy on a sunny hot day with wind receives much more energy than a mulched soil under a crop canopy on a cloudy cool day with no wind.

After the threshold between energy limited and soil limited evaporation is reached, evaporation is controlled by how fast water and water vapor can move through the soil to the soil surface. There is a diminishing rate of evaporation with time as the soil surface dries. The soil surface insulates itself from drying as it takes longer for water or vapor to move through the soil to the surface.

The challenge for sprinkler irrigation is the high frequency that the soil surface is put into energy limited evaporation. With twice-weekly irrigation events it is likely that the soil surface will be in the higher rates of energy limited evaporation during the entire growing season. Only during the early growing season with infrequent irrigations and little canopy development would there be a possibility for lower rates of soil limited evaporation.

Evaporation and Crop Residues

For many years, crop residues in dryland cropping systems have been credited for suppressing evaporation from soil surfaces. Evaporation research dates back into the 1930’s when Russel reported on work with small canister type lysimeters (Russel, 1939). Stubble mulch tillage and Ecofallow have followed in the progression of innovations with tillage equipment, planting equipment, and herbicides to allow for crop residues to be left on the ground surface. These crop residue management practices along with crop rotations have increased grain production in the Central Plains. Water savings from soil evaporation suppression has been an essential element. In dryland management, saving 2 inches of water during the fallow period from wheat harvest until planting corn the next spring was important because in meant an increase of 20 to 25 bushels per acre in the corn crop. This difference came from the presence of standing wheat stubble during the fallow period versus bare ground.

North Platte, Ne Study

The question is to what extent water savings could be realized from crop residue management in sprinkler irrigation? A research project (Todd et al., 1991) was conducted near North Platte, NE during the mid 1980's to begin to address this question. Four canister type lysimeters were placed across the inter-row of sprinkler irrigated corn. The lysimeters were 6 inches in diameter and 8 inches deep and were filled by pressing the outer wall into the soil. The bottoms were sealed and the lysimeters were weighed daily to obtain daily evaporation from changes in daily weights.

Half of the lysimeter treatments were bare soil and half were covered with flat wheat straw mulch at the rate of 6000 pounds/acre or the equivalent to the straw produced from a 60 bu/acre wheat crop. The other variable was irrigation frequency: dryland, limited irrigation, and full irrigation. The sprinkler irrigation system was a solid set equipped with low angle impact heads on a grid spacing of 40 ft X 40 ft. The corn population varied with the irrigation variable and was appropriate with the expected water application and yield goal for that treatment. The resulting leaf area, shading, and biomass followed accordingly.

The results are summarized in Tables 1 and 2. Evaporation measurements with the mini-lysimeters were not taken during days of irrigation or rainfall. Data were collected from June 10 to September 13 in 1986 with 78, 75, and 75 days of collection from dryland, limited irrigation, and full irrigation, respectively. In 1987, data were collected from May 28 to August 20 with 65, 64, and 59 days of collection, for dryland, limited irrigation, and full irrigation, respectively.

To understand the possible full season implications of this study, the average daily evaporation rates were applied to the missing days of data during the respective time periods. These evaporation values may still be conservative since evaporation rates are highest immediately after wetting (Table 1).

Only six rainfall events were more than 0.4 inch of precipitation. After these significant rainfall events occurred, the bare soil in the dryland treatment showed brief periods of energy limited evaporation. When the straw covered and bare soil dry land treatments were paired together, they had nearly the same evaporation both with and without the crop canopy. This implied that the crop canopy had some effect on evaporation, but the wheat straw did not for dryland management. Soil limited evaporation was more of the controlling factor.

The limited irrigation added three irrigation events of, 2.0, 2.0, and 1.75 inch. The cumulative evaporation for bare soil unshaded treatment showed the classic patterns of energy limited-soil limited evaporation. These patterns were suppressed in the other treatments indicating that the canopy and residue prolonged the transition from energy limiting to soil limiting evaporation. During the last 40 days of the season, the mulched unshaded treatment and bare treatment under the canopy closely tracked one another and ended with similar cumulative evaporation. The singular contribution of the straw mulch and crop canopy, each acting alone, were the same. However, in limited irrigation straw mulch added a benefit to the canopy effect that was not evident in dryland management. The reduction in evaporation by the straw compared with the bare soil was more under the canopy than without the canopy. The straw mulch contributed to reducing energy limited evaporation more days under the canopy than in the unshaded treatment. The evaporation probably shifted from energy to soil limited sooner after wetting in the unshaded than the canopy treatment.

Full irrigation included nine irrigation events, seven of which were at weekly intervals and two that were at two-week intervals. The pattern of cumulative evaporation from the unshaded bare soil treatment indicated periods of both energy and soil limited evaporation. These patterns were more subtle early in the bare soil treatment under the crop canopy. The magnitude of unshaded bare soil evaporation was larger in the fully irrigated treatment, but the unshaded mulched and bare soil evaporation under the canopy was similar to the limited values. These latter two treatments also tracked each other closely as they did in they limited management. The reduction in evaporation from the wheat stubble was even more in the fully irrigated management than the limited and dryland management. This effect started early and carried on throughout the growing season.

Table 1. Projected growing season soil water evaporation including irrigation and rainfall days. (Klocke, 2004)

	---Unshaded----		Corn Canopy---	
Year	Bare	Straw	Bare	Straw
	-------------------in/season--------------			
	------------------Dryland-----------------			
1986	7.6	7.6	5.2	5.2
1987	8	7.1	6.1	5.7
	------------Limited Irrigation----------			
1986	10.4	8.5	7.6	5.2
1987	11.3	9.4	8.5	5.7
	------------Full Irrigation---------------			
1986	15.1	8.5	7.6	3.8
1987	14.6	9.4	8.5	4.7

*North Platte, NE

Table 2. Full season soil water evaporation savings from straw cover compared with bare soil. (Klocke, 2004).

Year	---Unshaded----	Corn Canopy--
	----------------in/season----------------	
	--------------------Dryland--------------	
1986	0	0
1987	0.9	0.4
	------------Limited Irrigation----------	
1986	1.9	2.4
1987	1.9	2.8
	---------------Full Irrigation------------	
1986	6.6	3.8
1987	5.2	3.8

***North Platte, NE**

Garden City, KS Study

A similar study was conducted in Garden City, Kansas during 2004 in soybean and corn canopies. Two twelve inch diameter PVC cylinders that held 6-inch deep soil cores were placed between adjacent soybean or corn rows. The crop rows were spaced 30 inches apart. These mini-lysimeters, which had been cored into natural field settings, were either bare or covered with corn stover or standing wheat stubble. The treatments were replicated four times in plots that were irrigated once or twice weekly.

Soil water evaporation measurements began on June 2 and June 9 for corn and soybean, respectively. The early season measurements were taken in an unshaded location out of the field setting and continued until June 30 and July 13 for corn and soybean, respectively. At these times, the lysimeters measurements were initiated in the field. Soil water evaporation measurements were recorded on 60 of 83 days between June 30 and September 20 for the corn canopy and 51 of 70 days between July 13 and September 20 for soybeans. The missing days were due to rainfall and irrigation. Average daily evaporation from measured data during vegetative and full canopy growth periods were used to fill the data gaps.

Growing season irrigation and rainfall event totals are in Table 3. The irrigation amounts for fully watered corn and soybean were approximately half of normal. Rainfall was above normal and timely and the soil profile was filled at the beginning of the season.

Table 3. Growing season irrigation and rainfall events and accumulation for Garden City site during 2004.

	----Soybean----		-----Corn---------	
	Events	Inches	Events	inches
Once/Week	3	3	4	4
Twice/Week	7	7	9	9
Rain	23	12.8	24	14.3

Results in Table 4 are the total evaporation amounts for the growing season and the percentages of evapotranspiration (ET). The development of the crop canopy affected evaporation rates as the season progressed. Evaporation rates and E as percentage of ET decreased as the canopy developed (data not shown).

The results in Table 5 give the same possibilities for reductions in evaporation as the results from the previous Nebraska corn study. Also, the roles of corn stover and standing wheat straw are shown. The corn stover in the lysimeters covered 87% of the soil surface, which is equivalent to very good no-till residue cover. These results reflect the maximum capability of the residue for evaporation suppression.

Table 4. Projected growing season (2004) soil water evaporation from soybean and corn crops with bare soil, corn stover, and wheat stubble surface treatments.

	-------Soybean-------		---------Corn-----------	
	----June 9-Sept. 20-		----June 2-Sept. 20-	
Cover*	Soil E --inches--	% of ET	Soil E --inches--	% of ET
Bare 1	6.50	33	5.78	32
Bare 2	7.90	32	6.59	35
Corn 1	3.80	19	3.10	17
Corn 2	3.66	15	3.77	19
Wheat1	3.37	17	2.72	15
Wheat2	4.07	17	3.74	19

*1=weekly and 2=twice weekly irrigation frequency

Table 5. Growing season (2004) soil water evaporation savings with corn stover and wheat stubble compared with bare soil.

	-------Soybean--------	---------Corn----------
	----June 9-Sept. 20--	----June 2-Sept. 20-
Cover*	Soil E	Soil E
	--inches--	--inches--
Corn 1	2.70	2.68
Corn 2	4.24	2.82
Wheat1	3.13	3.06
Wheat2	3.83	2.85

***1=weekly and 2=twice weekly irrigation frequency.

Summary

No matter how efficient sprinkler irrigation applications become, the soil is left wet and subject to evaporation. Frequent irrigations and shading by the crop leave the soil surface in the state of energy limited evaporation for a large part of the growing season. Research has demonstrated that evaporation from the soil surface is a substantial portion of total consumptive use (ET). These measurements have been 30% of ET for E during the irrigation season for corn on sandy and silt loam soils. It has also been demonstrated that crop residues can reduce the evaporation from soil in half even beneath an irrigated crop canopy. The goal is to reduce the energy reaching the evaporating surface.

We may be talking about seemingly small increments of water savings in the case of crop residues. The data presented here suggests the potential for a 2.5 to 3.5 inch water savings due to the wheat straw during the growing season. Dryland research would suggest that stubble is worth at least 2 inches of water savings in the non growing season. In water short areas or areas where water allocations are below full irrigation, 5 inches of water translates into possibly 20 and 60 bushels per acre of soybean and corn, respectively.

References

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