EFFECT OF CROP RESIDUE ON SPRINKLER IRRIGATION MANAGEMENT

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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 amount of soil water evaporation occurs 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 reduce light 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 water movement to the surface. However, with high frequency of water application from sprinkler irrigation the soil may remain in the “energy” limited phase a large percentage of time. This produces the opportunity for crop residues to impact soil evaporation rates.

EVAPORATION-TRANSPIRATION PARTITION

Water applied by irrigation is consumed by two processes: soil water evaporation and plant transpiration. 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. Transpiration provides powerful transformation of this energy into forces for water flow through plants. It also 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 reaches a plateau at maturity. 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. Ideally, limited irrigation management reduces plant water stress in critical growth periods such as reproductive and grain fill and allows more stress during less critical growth period such as vegetative growth.

Evaporation from the soil surface has a limited effect on transpiration in the influence of humidity in the crop canopy. However, the mechanisms controlling evaporation from soil are generally 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 involve 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 productive transpiration.

EVAPORATION FROM BARE SOIL

Evaporation from bare soil surface after irrigation or rainfall is controlled by the atmospheric conditions and the shading of a crop canopy if applicable. Water near the soil surface readily evaporates and does so at a rate that is limited by the energy available at the surface. If water is readily available near the surface, bare soils can evaporate 0.4 in. during one energy-limited drying cycle (Klocke, 1983). The time it takes to complete an energy limited cycle depends on the energy in 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 energy limited evaporation has been completed, evaporation is controlled by how fast water and vapor can move to the surface. Rate of evaporation diminishes with time as the drying front moves deeper into the soil. The soil insulates itself from drying because it takes longer for water or vapor to move through the soil to the surface.

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EVAPORATION AND CROP RESIDUES

For more than 65 years, crop residues in dryland cropping systems have been credited for suppressing evaporation from soil surfaces. (Russel, 1939). Stubble mulch tillage and Ecofallow systems built on this early work with a progression of innovations in tillage and planting equipment and weed management systems 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 dry Central Plains. Water savings from soil evaporation suppression has been an essential element. In dryland management, accumulation of 2-4 inches of water during the over-winter/fallow period has been possible. The presence of standing wheat stubble has captured the precipitation, kept it where it has fallen, stored it, and reduced the evaporation.

Crop residues in dryland culture have reduced energy limited evaporation after rainfall events as long as the soil surface is wet. Crop residues tend to extend the energy limited evaporation phase with time when compared with bare soils. The evaporation rate is less under the crop residue. Given enough time between rainfall events, in dryland culture, accumulated evaporation under crop residue could catch up with evaporation for bare soil. This could take a time framework of weeks. The contribution of crop residues for soil water suppression is dependent on the frequency of wetting.

GARDEN CITY, KS STUDIES

Field Study

A field study was conducted in Garden City, Kansas during 2003-2005 to test the effectiveness of corn stover and wheat stubble for evaporation suppression in soybean and corn grown in 30-inch rows. Two twelve inch diameter PVC cylinders that held 6-inch deep soil cores were placed between adjacent soybean or corn rows. These “mini-lysimeters”, which were constructed from 21-inch PVC cylinders were pressed into undisturbed soil. The soil was bare or covered with no-till corn stover or standing wheat stubble to test the maximum effectiveness of various residues for evaporation suppression. Crop and mini-lysimeter treatments were replicated four times. Mini-lysimeters were irrigated once or twice weekly when rainfall did not satisfy crop needs. The mini-lysimeters were also watered to match rainfall events during 2004 since rains occurred during measurement periods that year. The mini-lysimeters were weighed daily. Weight differences were the evaporation amounts. Plant populations were reduced to match irrigation management in the once per week frequency treatment.

The results should be considered as preliminary. The statistical comparisons have not been completed. Only some of the large differences should be noted within each year. Year-to-year differences will be suggested, but should be considered speculative.

Soil water evaporation measurements began and ended within somewhat different time frameworks for the study years (table 1). Yearly variations in results due to duration of observations are reflected in the total evaporation, evaporation savings from bare soil, and the evaporation as a fraction of evapotranspiration. The latter factor is due to the growth stage during which the measurements were taken. During 2003 only the more frequent irrigation treatment for soybean was conducted. During observation period in 2003, only 8 irrigation events were measured. During 2004 ample rainfall added to 3 and 7 measured irrigation events for the two soybean treatments and 4 and 9 measured irrigation events for the two corn treatments. For 2005, only irrigation events were measured during the observation period.

Table 1. Soil Water Evaporation Summary—2003-2005.

Surface[1]	Total E (in.)	Daily Rate (in./day)	E Savings[2] (in.)	E/ET[3]	Watering Events[4]
2003 Soybean	July 18 to September 6 (51 days)				
Bare 1	3.1	0.06		25	8
Corn 1	1.8	0.03	1.3	14	8
Wheat 1	1.5	0.03	1.6	12	8
2004 Soybean	June 9 to September 20 (104 days)				
Bare 1	6.5	0.06		33	12
Bare 2	8.0	0.08		32	19
Corn 1	3.8	0.04	2.7	19	12
Corn 2	3.7	0.03	4.2	15	19
Wheat 1	3.4	0.03	3.1	17	12
Wheat 2	4.1	0.04	3.8	17	19
2004 Corn	June 2 to September 20 (111 days)				
Bare 1	5.8	0.05		32	14
Bare 2	6.6	0.06		35	22
Corn 1	3.1	0.03	2.7	17	14
Corn 2	3.8	0.03	2.8	19	22
Wheat 1	2.7	0.02	3.1	15	14
Wheat 2	3.8	0.03	2.9	19	22
2005 Corn	June 21 to August 11, 2005 (52 days)				
Bare 1	3.6	0.07		29	5
Bare 2	3.5	0.07		23	9
Corn 1	1.9	0.04	1.7	16	5
Corn 2	2.0	0.04	1.5	13	9
Wheat 1	2.4	0.05	1.1	20	5
Wheat 2	2.2	0.04	1.3	15	9

[1] Numbers indicate weekly watering frequency (1 = Once, 2 = Twice)

[2] Evaporation savings as the difference from bare soil evaporation

[3] Evaporation as a percent of calculated ET from water balance

[4] Includes rain events in 2004

Comparison of 2004 and 2005 is risky. One year was wet (2004), one year was dry in July (2005). One year had hail (2005) and the other did not (2004). One year has a longer record of observed days of data (2004).

The differences in soil water evaporation from covered and bare soil surfaces are consistent despite the variable years (table 1). The crop residues covered the entire surface and reduced evaporation nearly in half during the observation periods. Differences in evaporation between irrigation treatments with crop residues were not evident. If both irrigation treatments were predominately in energy limited evaporation, evaporation would be similar under the crop residue.

Control Study

A second set of replicated mini-lysimeters was established in a controlled outdoor, non-cropped setting. Irrigated clipped grass surrounded the control area. Measurements were taken between September 6 and October 7, 2005. The mini-lysimeters were buried in the ground but flush with the surface. The mini-lysimeters' position was rotated daily to avoid location bias in results. The 12 experimental treatments included:

> surface cover (bare soil, 25%, 50%, 75%, or 100% corn stover, or wheat stubble) X irrigation frequency (once per week or twice per week).

Partial cover corn stover treatments were established by evaluating the residue application with line-transect methods using mesh grids over the mini-lysimeters. The 100% corn stover and wheat stubble treatment lysimeters were similar to the field plot study treatments. The partial cover treatments were intended to simulate tillage practices equivalent to one pass chisel, one pass tandem disc, and two pass tandem disc for 75%, 50%, and 25% corn stover cover, respectively.

Figure 1 shows the resulting mass of residue cover on the mini-lysimeters for the control study. Percent cover and total cover mass did not always correlate well because the leaf and stem densities were not necessarily consistent among treatments. For example, average residue mass for the 50% corn stover actually exceeded the mass for the 75% corn stover treatment

Figure 2 combines the results of the cumulative soil water evaporation during September 6 to October 7. The patterns of evaporation results from bare soil, and the partially covered soil with corn stover are very similar. Statistical analysis will assist in interpretation of these data. Only the 100% corn stover and wheat stubble treatments appear to behave differently. The mass of these residue covers from Figure 1 was quite different. The reduced cover and mass of the partially covered treatments apparently allowed more radiant energy to reach the soil surface and increased evaporation.

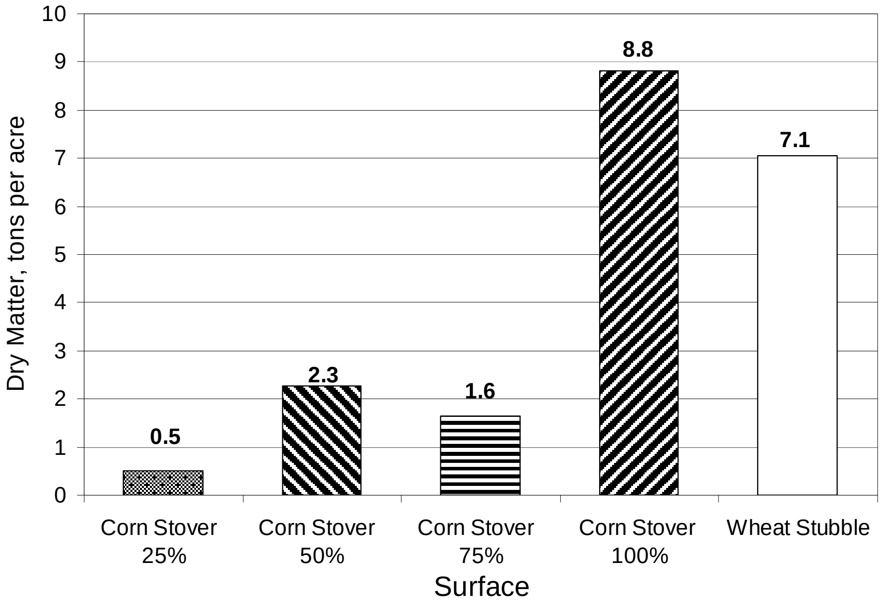

Fig. 1 Crop residue mass on mini-lysimeter surface for partial to full cover treatments.

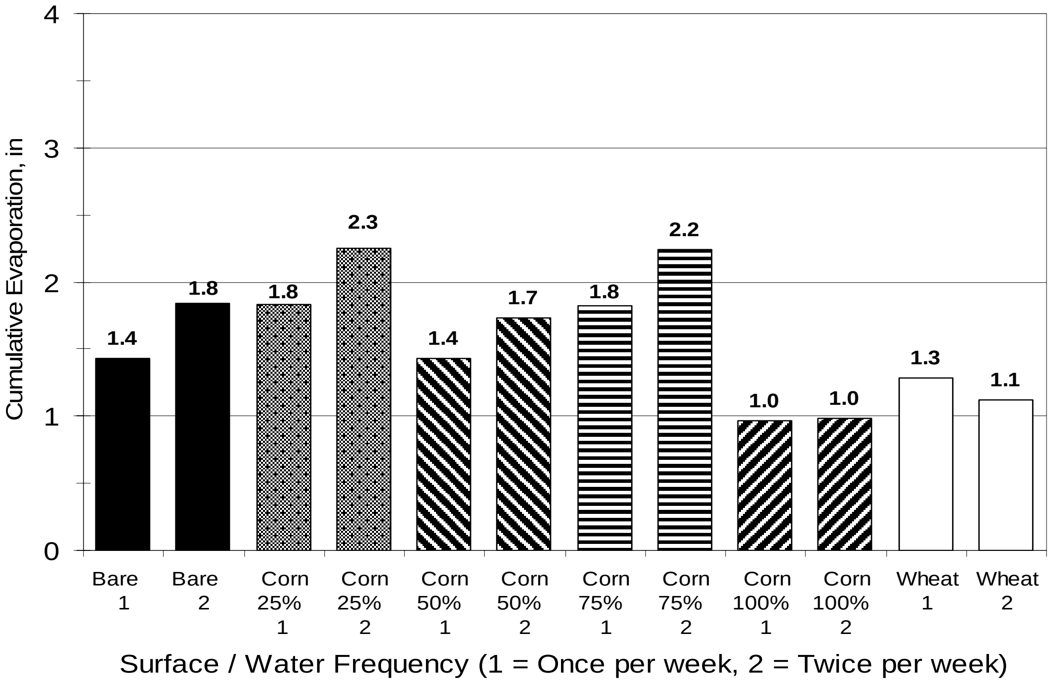

Fig. 2 Total soil water evaporation from September 6 to October 7, 2005 for bare, partially covered, and fully covered treatments.

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. This research demonstrated that evaporation from the soil surface is a substantial portion of total consumptive use (ET). We measured up to 30% of ET was E during the irrigation season for corn and soybean on silt loam soils. We also demonstrated under a variety of conditions that crop residues can reduce the evaporation from soil in half even beneath an irrigated crop canopy. This puts us closer to our goal to understand how reduce the energy reaching the evaporating surface.

We suggest the potential for a 2.5 to 3 inches water savings due to the wheat straw and no-till corn stover from early June to the end of the growing season. Dryland research suggests 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.

ACKNOWLEDGEMENTS

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