2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

***An ASABE Meeting Presentation***
***Paper Number: 084724***

# Effect of Crop Residue on Soil Water Content and Yield of Sprinkler-irrigated Corn

**Simon van Donk,** University of Nebraska, North Platte, Nebraska
**Derrel Martin,** University of Nebraska, Lincoln, Nebraska
**Suat Irmak,** University of Nebraska, Lincoln, Nebraska
**Steven Melvin,** University of Nebraska, Curtis, Nebraska
**James Petersen,** University of Nebraska, North Platte, Nebraska

**Written for presentation at the 2008 ASABE Annual International Meeting, Sponsored by ASABE**
**Rhode Island Convention Center, Providence, Rhode Island,**
**June 29 – July 2, 2008**

***Abstract.*** *Competition for water is becoming more intense in many parts of the USA, including west-central Nebraska. It is believed that reduced tillage with increased crop residue conserves water, but the magnitude of water savings is not clear. In 2007, a study was initiated on the effect of residue on soil water content and crop yield at North Platte, Nebraska. The experiment was conducted on a set of plots planted to field corn (Zea mays). There were two treatments: residue-covered soil and bare soil. Bare-soil plots were created by using a dethatcher and subsequent hand-raking, removing most of the residue. The residue plots were left untreated. The residue was mostly from previous no-till soybean crops. Residue mass and cover were measured twice: at the beginning (June) and at the end (October) of the growing season. The experiment consisted of eight plots (two treatments times four replications). Each plot was 12.2 m (40 ft) by 12.2 m. During the growing season, soil water content was measured seven times in each of the plots at six depths using a neutron probe (CPN Hydroprobe).*

*Winter and spring 2007 were very wet at North Platte and the corn was only irrigated three times with a total of 113 mm (4.5 inch) of water. The crop was purposely water-stressed, so that any water conservation in the residue-covered plots might translate into higher yields. Differences in soil water content between the residue-covered and the bare-soil plots were small. Corn yield was 12.4 Mg/ha (197 bu/ac) in the residue-covered plots and 10.8 Mg/ha (172 bu/ac) in the bare-soil plots, which was significantly ($p < 0.01$) greater. This yield difference may be interpreted as an additional amount of water of 50-100 mm (2-4 inch) available to the crop in the residue-covered plots. Water conservation of such a magnitude will help irrigators to significantly reduce pumping cost and more water would be available for competing needs including those of wildlife, endangered species, municipalities, hydroelectricity plants, and compacts with other states..*

**Keywords.** Water conservation, crop residue, soil water, irrigation, corn

## Introduction

In many parts of the USA, including west-central Nebraska, irrigation water is a precious commodity. Groundwater levels have been falling (McGuire, 2004; McGuire and Fischer, 1999), and stream flow has been decreasing, leading to some challenges. For example, it has been a challenge for Nebraska to supply the required amount of water to Kansas through the Republican River. Irrigated agriculture is a major water user and a reduction in use of irrigation water throughout the Republican Basin will be additional water that can help meet stream flow requirements in the Republican River. Also, by saving irrigation water, irrigators will be able to reduce pumping cost and more water would be available for competing needs including those of wildlife, endangered species, and hydroelectricity plants.

It is generally believed that reduced tillage and no-till, with increased crop residue levels, conserves water, but the magnitude of water savings is not clear. With more crop residue, soil water evaporation is tempered, because less solar energy reaches the soil surface, and wind speed (air movement) is reduced at the soil surface. Long-term reduced tillage or no-till leads to better soil structure, less soil crusting, greater infiltration, and less runoff. More residue, especially standing residue, means more snow trapping in the winter, thus storing more water in the soil, to be used by crops later on.

Van Donk et al. (2004) enhanced the process-based energy and water balance model (ENWATBAL) with the capability to simulate the effect of a mulch on evaporation and soil water content, and showed, in a simulation study, reduced evaporation from a mulched surface. Research at North Platte, Nebraska demonstrated that the equivalent of 6725 kg/ha (6000 lb/ac) of wheat stubble laying flat could reduce bare soil growing season evaporation by half under a fully irrigated corn crop (Todd et al., 1991; Klocke, 2006). Up to 30% of evapotranspiration (ET) can be evaporation (the E in ET) during the irrigation season for corn and soybean on silt loam soils and there is a potential for a 63 to 76-mm (2.5 to 3-inch) water savings due to wheat straw or no-till corn residue from early June to the end of the growing season (Klocke et al., 2006). Nielsen (2006) showed that soil water content increases with increasing amounts of residue in dryland cropping systems. Dryland research suggests that residue saves at least 50 mm (2 inches) of water in the non-growing season. In water-short areas or areas where water allocations are below full irrigation, 125 mm (5 inches) of water (75 mm from the growing season and 50 mm from the non-growing season) translates into possibly 1.3 and 3.8 Mg/ha (20 and 60 bu/ac) of soybean and corn, respectively (Klocke et al., 2006).

Jasa (2007) back-calculated the ‘water savings’ of reduced- and no-till compared to a clean-tilled moldboard plow system, based on three extra bushels of soybean per extra inch of available water. His analysis was based on dryland data, from the Rogers Memorial Farm near Lincoln, Nebraska, in low rainfall years (2000 and 2006). He calculated that, in 2000, more than 200 mm (8 inches) of additional water was available for crop use by the no-till system, compared to a moldboard plow system, and more than 100 mm (4 inches) of additional water was available for crop use compared to a double-disk tillage system. Much of the additional crop-available water can come from reduced runoff, so intensity of rainfall or irrigation makes a difference. The frequency of rainfall or irrigation affects evaporation. Jasa (2006) believes that an additional 125 to 300 mm (5 to 12 inches) of water is available over the entire season for continuous no-till compared

to a tilled system, depending on rainfall amount, intensity, and frequency. The more often rainfall occurs or the more intense a rainfall event, the more crop-available water with no-till. Likewise, the more often a crop is irrigated, the more crop-available water.

On the other hand, Lamm and Aiken (2007) found that strip-till and no-till generally had greater water use than conventional tillage (chisel/disk plowing). These small increases in total seasonal water use (less than 38 mm or 1.5 inch) for strip-till and no-till compared to conventional tillage could probably be explained by the higher grain yields (approximately 0.63 Mg/ha or 10 bu/ac) for these tillage systems.

Research, trying to quantify the effect of tillage system and crop residue on the water balance, has been limited and has resulted in a wide range of results. Some of the data and anecdotal evidence are based on rainfed crops and results may be different for irrigated systems. Thus, more research is needed to adequately quantify the effect of crop residue on ET and other components of the water balance, especially for irrigated agriculture. The objective of this study was to determine the effect of crop residue on soil water content and corn yield under conditions of deficit irrigation.

## Methods

The study was conducted at the University of Nebraska-Lincoln, West Central Research and Extension Center in North Platte, Nebraska (41$^o$ 10’ N, 100$^o$ 45’ W, 861 m elevation above sea level) on a Cozad silt loam with an average water content at field capacity of 0.29 $m^3/m^3$ and at wilting point of 0.11 $m^3/m^3$ (Klocke et al., 1999). The climate at North Platte is semi-arid, with an average annual precipitation of 508 mm (20.0 inch) and a reference evapotranspiration of 1403 mm (55.2 inch). On average, about 80% of the annual precipitation occurs during the growing season, which extends from late April to mid October (USDA, 1978).

The experiment was conducted on a set of plots planted to field corn. There were two treatments: residue-covered soil and bare soil. In April 2007, bare-soil plots were created by using a dethatcher (Figure 1) and subsequent hand-raking and shoveling (Figure 2), removing most of the residue. The residue-covered plots were left untreated. The residue came mostly from previous no-till soybean crops. The plots were in no-till corn in 2004 and in no-till soybean in 2005 and 2006.

The experiment consisted of eight plots (two treatments times four replications, Figure 3). Within each replication, the treatments (bare soil and residue-covered soil) were assigned randomly to the plots. Each of the eight plots was 24.4 m (80 ft) by 24.4 m. The actual experimental plots were 12.2 m (40 ft) by 12.2 m, centered in these larger plots. The areas outside the smaller experimental plots were border (buffer) zones. During the growing season, soil water content was measured seven times in each of the plots at six depths (0.15, 0.46, 0.76, 1.07, 1.37, and 1.68 m) using a neutron probe (CPN Hydroprobe). There were two neutron tubes per plot: one in the row and one between rows. The two tubes were located less than 1 m from each other.

Residue cover and mass were measured twice: at the beginning (June) and at the end (October) of the growing season. Residue cover was measured with the line-transect method (USDA-NRCS, 2002) using a 50-ft (15.2-m) measuring tape. Residue hits or misses were evaluated at each of the 50 footmarks. The tape was laid out over the two diagonals of each plot. This way, 100 points per plot were evaluated. The percent residue cover equals the total number of residue hits out of 100 point evaluations.

Residue mass was measured by collecting three samples per plot. In June, on the bare plots, only two samples per plot were taken, because there was very little residue. The area of a sample was 0.76 m (30 inch = row spacing) by 0.51 m (20 inch). Sample locations within a plot were selected randomly. A photo was taken of each sample area (Figure 4). Within a sample area, residue cover was measured using a ruler, evaluating residue hits or misses on the two diagonals, at every inch (2.54 cm) mark. Minimum, maximum, and average residue thickness was measured using a ruler. The average was area-weighted and was an estimate rather than a measurement.

Standing soybean stems were few and short, but were nonetheless collected separately. Standing residue was defined as stems anchored in the soil with an angle greater than 10 degrees from the soil surface (Steiner et al., 1999). Only the above-ground parts of the standing stems were collected; they were broken off at the soil surface. Non-standing (surface, flat) residue was cut on the boundaries of the sample area using a knife and collected by hand. If a piece of residue were partially buried, the entire piece was collected, unless it broke easily.

All collected residue was dried in an oven for 24 hours at 60 degrees C. Standing soybean stems were counted and their diameters and heights measured. Non-standing residue was separated into components: soybean material (mostly stems), corn stalks, corn cobs, and, for the residue collected in October, newly-senesced corn leaves. Each component was weighed and ground through a 1 mm sieve using a grinder (Udy Corporation Cyclone Mill, Model 3010-030). The resulting, fine, material was mixed well. Three subsamples were taken and weighed, ashed at 500 degrees C for six hours, and weighed again to determine the soil-free mass of each residue component.

Winter and spring 2007 were very wet at North Platte and the corn was only irrigated three times (Figure 5) with a total of 113 mm (4.5 inch) of water. The crop was purposely water-stressed, so that any water conservation in the residue-covered plots might translate into higher yields.

Corn was hand-harvested along 6.1-m (20-feet) rows in the center of each plot. Guess rows (outside rows of the four-row planter) were not used in the yield calculation. The rows closest to the sprinklers were harvested separately to study a potential skip-row effect (Klein et al., 2007). These rows were located next to a strip of land where no crop was growing, because the sprinklers were located here. Thus, the outside rows of corn had extra soil water available from these strips. This extra water might have translated into higher corn yield. The two-tailed, paired t-test was used to determine whether differences in yield between residue-covered plots and bare-soil plots were statistically significant.

## Results and discussion

In June, the bare-soil plots were almost totally void of residue (Figure 4, Table 1). For the residue-covered plots, the average residue cover was 63%. It would have been higher still if the planter had not moved residue away from the rows. In October, the bare-soil plots were no longer bare, because many newly-senesced corn leaves covered the soil surface (Figure 4d), explaining the average residue cover of greater than 80%. These leaves provided much cover at relatively low residue amounts in terms of mass: only 1322 kg/ha on average. In the residue-covered plots, average residue cover was also greater in October than it was in June, but residue mass was slightly less. Apparently, the mass increase due to newly-senesced leaves was more than offset by mass lost to residue decomposition.

Corn yield was significantly ($p < 0.01$) greater in the residue-covered plots compared to the bare-soil plots (Figure 6). The average yield of the four bare-soil plots was 10.8 Mg/ha (172 bu/ac) and the average yield of the four residue-covered plots was 12.4 Mg/ha (197 bu/ac). Based on data from Garden City, Kansas, Klocke et al. (2008) concluded that corn yields increase 10 bu/ac for each inch of irrigation water that is transferred from evaporation to transpiration. Our yield difference of 1.6 Mg/ha (25 bu/ac) would then translate into an additional 63 mm (2.5 inches) of crop-available water. Melvin and Payero (2007) reported amount of irrigation water and corn yield for five locations and four years in West-Central Nebraska. Based on their findings, our yield difference would translate into an additional 50-75 mm (2-3 inch) of crop-available water. An analysis with the Water Optimizer (Martin et al., 2007) indicates that it would take an additional 75-100 mm (3-4 inches) of irrigation water to raise corn yield from 10.8 to 12.4 Mg/ha at North Platte, Nebraska.

The outside corn rows in each plot were located next to a strip of land (1.52 m or 5 ft wide versus a regular row spacing of 0.76 m or 2.5 ft) where no crop was growing, because sprinklers were located here. Thus, these outside rows had extra soil water available from these strips. This extra water translated into higher corn yield: on average, the outside rows yielded 13.1 Mg/ha (209 bu/ac) and the rest of the plots yielded 11.5 Mg/ha (184 bu/ac). This effect is known as the ‘skip-row’ effect (Klein et al., 2007). The yield increase may not entirely be due to extra water. Extra light may also have boosted the yield. It should be noted that yield for the outside rows was calculated using the regular row spacing of 0.76 m. It may be more appropriate to use 1.14 m (half of the regular row spacing plus half of the land strip with the sprinklers). In that case the outside rows would have yielded 8.7 Mg/ha (139 bu/ac). It should also be noted that, unlike with intentionally skip-row-planted corn, the within-row distance between corn plants was the same for the outside rows as it was for the other rows.

The corn crop used water from all six depths, down to 1.68 m (5.5 ft, Figure 7). In July, soil water content decreased rapidly because of a corn crop transpiring at full canopy cover and only modest rainfall and no irrigation (Figure 5). In late July, irrigation was followed by a large rain, which greatly increased soil water content at shallower depths (Figure 7a, b). In August, soil water content again decreased rapidly because of high crop water use, little precipitation and no irrigation until late in August. As mentioned before, the crop was purposely water-stressed, so that any water conservation in the residue-covered plots might translate into higher yields. In September and October, irrigation and precipitation filled up the soil profile at the shallower depths. This water stayed in the soil, because of much reduced crop water needs.

Differences in soil water content between the residue-covered and the bare-soil plots were small (Figure 7). In July and August, the bare-soil plots were somewhat drier than the residue-covered plots at most depths. In September and October, the bare-soil plots were wetter at some depths (Figure 7b,c), which may be explained by the field observation that the corn in the bare-soil plots dried out more and matured earlier than the corn in the residue-covered plots, apparently induced by water stress. Thus, the corn in the residue-covered plots used more water later in the growing season and yielded more than corn in the bare-soil plots.

## Conclusions

Soil water content was not much different under residue-covered soil compared to bare soil. However, corn yield was 12.4 Mg/ha (197 bu/ac) in the residue-covered plots and

10.8 Mg/ha (172 bu/ac) in the bare-soil plots, which was significantly ($p < 0.01$) greater. Other researchers have shown that it takes 50-100 mm (2-4 inches) of water to grow this extra 1.6 Mg/ha. This amount may be considered the water 'savings' due to the residue. Water conservation of such a magnitude will help irrigators to significantly reduce pumping cost and more water would be available for competing needs including those of wildlife, endangered species, municipalities, hydroelectricity plants, and compacts with other states.

This study will continue, since the data presented here come from only one year. Also, additional research on water balance and crop yield is needed with real tillage systems. In this experiment, residue was artificially removed from the plots. Water conservation may be greater in the 'real world', where lower amounts of residue are associated with more tillage. A tillage pass will often result in loss of water by evaporation since, typically, it brings moist soil to the soil surface. In addition, long-term no-till would increase infiltration and decrease runoff and, in a real world scenario, reduced overwinter evaporation and increased snow trapping would also contribute to water conservation.

### *Acknowledgements*

The authors would like to acknowledge the financial support of the Anna H. Elliott Fund, administered by the University of Nebraska Foundation. We would also like to acknowledge the assistance provided by Don Davison during the field study.

## References

Jasa, P. 2006. Use no-till and residue to conserve soil moisture. Cropwatch, April 21, 2006. http://cropwatch.unl.edu/archives/2006/crop6/no-till.htm.

Jasa, P. 2007. Water savings with residue management and no-till. Cropwatch, April 27, 2007. http://cropwatch.unl.edu/archives/2007/crop9/water_savings.htm.

Klein R., D. Lyon, D. Baltensperger, A. Pavlista, C. Shapiro, S. Knezevic, S. Mason, L. Nelson, M. Bernards, R. Elmore, A. Schlegel, M. Vigil, N. Klocke, and S. Melvin. 2007. What is required to have success with rainfed skip row corn? Proceedings ASA-CSSA-SSSA Intenational Annual Meetings, New Orleans, Louisiana, November 4-8, 2007.

Klocke, N.L., D.G. Watts, J.P. Schneekloth, D.R. Davison, R.W. Todd, and A.M. Parkhurst. 1999. Nitrate leaching in irrigated corn and soybean in a semi-arid climate. Transactions of the American Society of Agricultural Engineers 42(6): 1621-1630.

Klocke, N.L. 2006. Residue reduces soil moisture evaporation. Cropwatch, April 21, 2006. http://cropwatch.unl.edu/archives/2006/crop6/evaposavings.htm.

Klocke, N.L., R.S. Currie, and T.J. Dumler. 2006. Effect of crop residue on sprinkler irrigation management. Proceedings Central Plains Irrigation Conference, Colby, Kansas, February 21-22, 2006. http://www.oznet.ksu.edu/irrigate/OOW/P06/Klocke06E.pdf.

Klocke, N.L., R.S. Currie, and T.J. Dumler. 2008. Water savings from crop residue management. Proceedings Central Plains Irrigation Conference, Greeley, Colorado, February 19-20, 2008. http://www.oznet.ksu.edu/irrigate/OOW/P08/Klocke08b.pdf.

Lamm, F.R. and R.M. Aiken. 2007. Conventional, strip, and no tillage corn production under different irrigation capacities. Proceedings Central Plains Irrigation Conference, Kearney, Nebraska, February 27-28, 2007. http://www.oznet.ksu.edu/irrigate/OOW/P07/Lamm07ICTRev.pdf.

Martin D., R. Supalla, B. McMullen, and S. Nedved. 2007. Water Optimizer, a Decision Support Tool For Producers With Limited Water. http://nebraskawater.unl.edu/cropswater/optimizer

McGuire, V.L. 2004. Water Level Changes in the High Plains Aquifer, Predevelopment to 2002, 1980-2002, and 2001-2002. Fact Sheet 2004-3026. U.S. Geological Survey, Lincoln, Nebraska.

McGuire, V.L. and B.C. Fischer. 1999. Water Level Changes, 1980-1997 and Saturated Thickness, 1996-97, in the High Plains Aquifer. Fact Sheet 124-99. U.S. Geological Survey, Lincoln, Nebraska.

Melvin, S. and J. Payero. 2007. Irrigation water conserving strategies for corn. Proceedings Central Plains Irrigation Conference, Kearney, Nebraska, February 27-28, 2007. http://www.oznet.ksu.edu/irrigate/OOW/P07/Melvin.pdf.

Nielsen, D.C. 2006. Crop residue and soil water. Proceedings Central Plains Irrigation Conference, Colby, Kansas, February 21-22, 2006. http://www.oznet.ksu.edu/irrigate/OOW/P06/Nielsen06.pdf

Steiner, J.L., H.H. Schomberg, P.W. Unger, and J. Cresap. 1999. Crop Residue Decomposition in No-Tillage Small-Grain Fields. Soil Science Society of America Journal 63:1817–1824.

Todd, R.W., N.L. Klocke, G.W. Hergert and A.M. Parkhurst. 1991. Evaporation from soil influenced by crop shading, crop residue and wetting regime. Transactions of the American Society of Agricultural Engineers 34 (2): 461-466.

USDA. 1978. Soil survey of Lincoln County, Nebraska. A publication of the U.S. Department of Agriculture Soil Conservation Service, in cooperation with University of Nebraska Conservation and Survey Division.

USDA, Natural Resources Conservation Service. 2002. National Agronomy Manual, 3rd ed. Washington D.C.

van Donk, S.J., E.W. Tollner, J.L. Steiner, and S.R. Evett. 2004. Soil temperature under a dormant bermudagrass mulch: Simulation and measurement. Transactions of the American Society of Agricultural Engineers 47: 91-98.

**Figure 1. Removing residue to create bare-soil plots using a dethatcher.**

**Figure 2. Removing more residue after the dethatcher.**

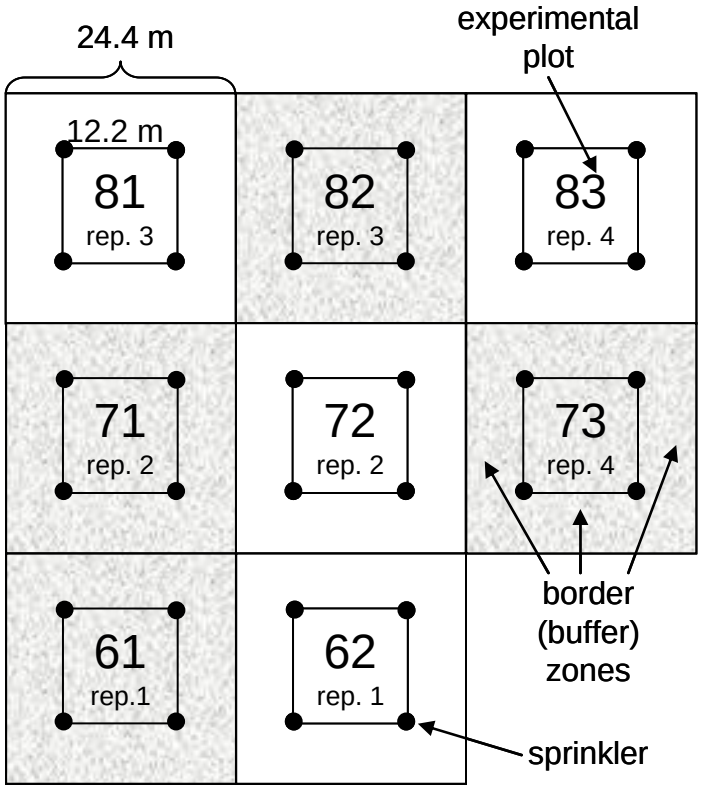
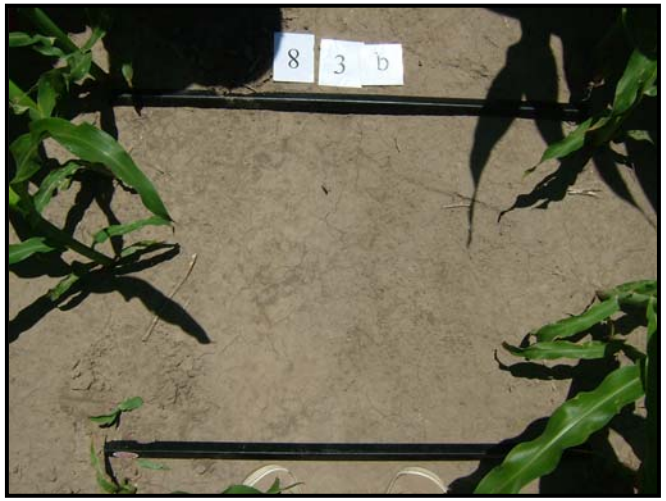



**Figure 3. Physical layout of the eight experimental plots in the study: two treatments and four replications. The shaded plots are the residue-covered plots, the others are the bare-soil plots. Plots 61 and 62 made up replication 1, plots 71 and 72 made up replication 2, plots 81 and 82 made up replication 3, and plots 73 and 83 made up replication 4. Within each replication, the treatments (bare soil and residue-covered soil) were assigned randomly to the plots. The areas outside the experimental plots are border (buffer) zones.**

a) sample area in a residue-covered plot in June

c) sample area in a residue-covered plot in October




b) sample area in a bare-soil plot in June

d) sample area in a bare-soil plot in October

**Figure 4. Sample areas in a residue-covered plots and a bare-soil plots. In each of the eight experimental plots, three random residue samples were collected from an area of 0.51 by 0.76 m, both in June and in October 2007.**

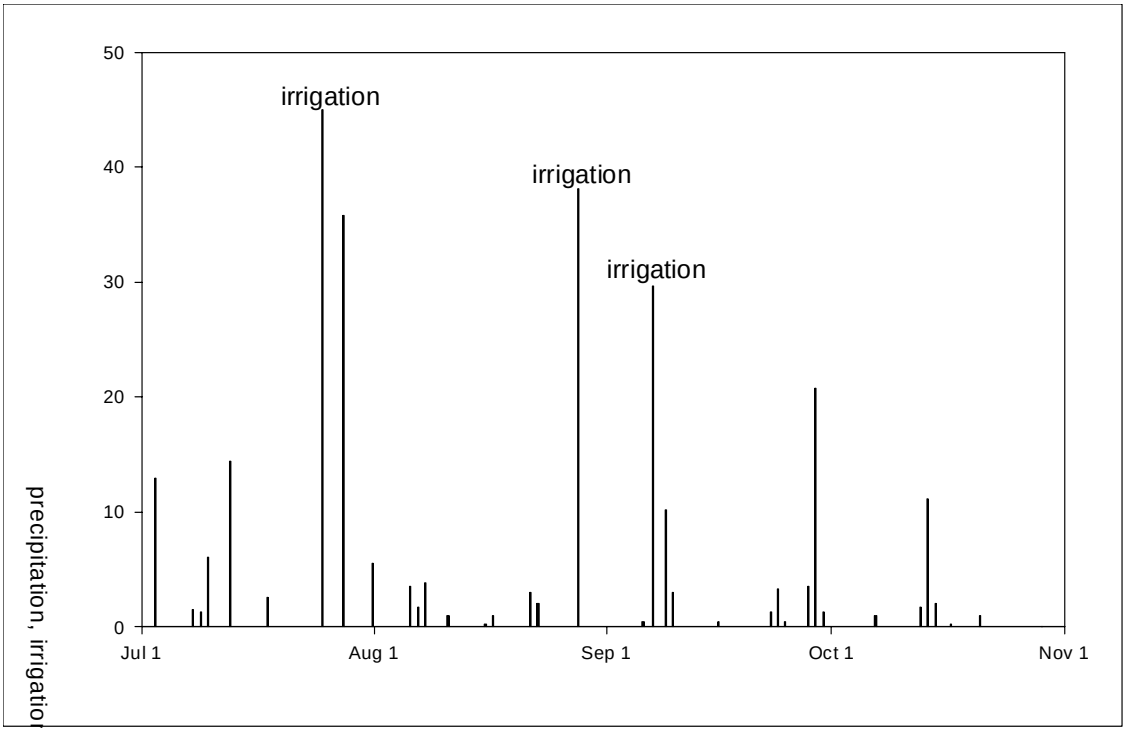



**Figure 5. Three irrigation events and precipitation at the experimental site.**

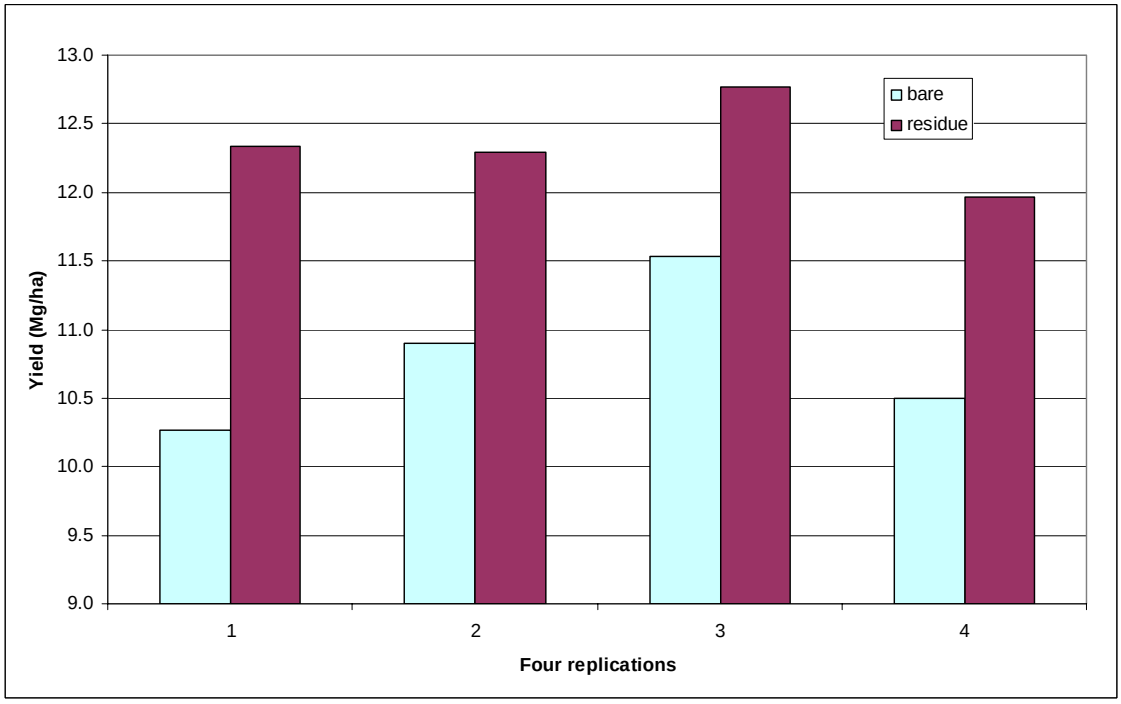



**Figure 6. Corn yield for eight experimental plots: two treatments (soil covered with soybean residue and bare soil) and four replications.**

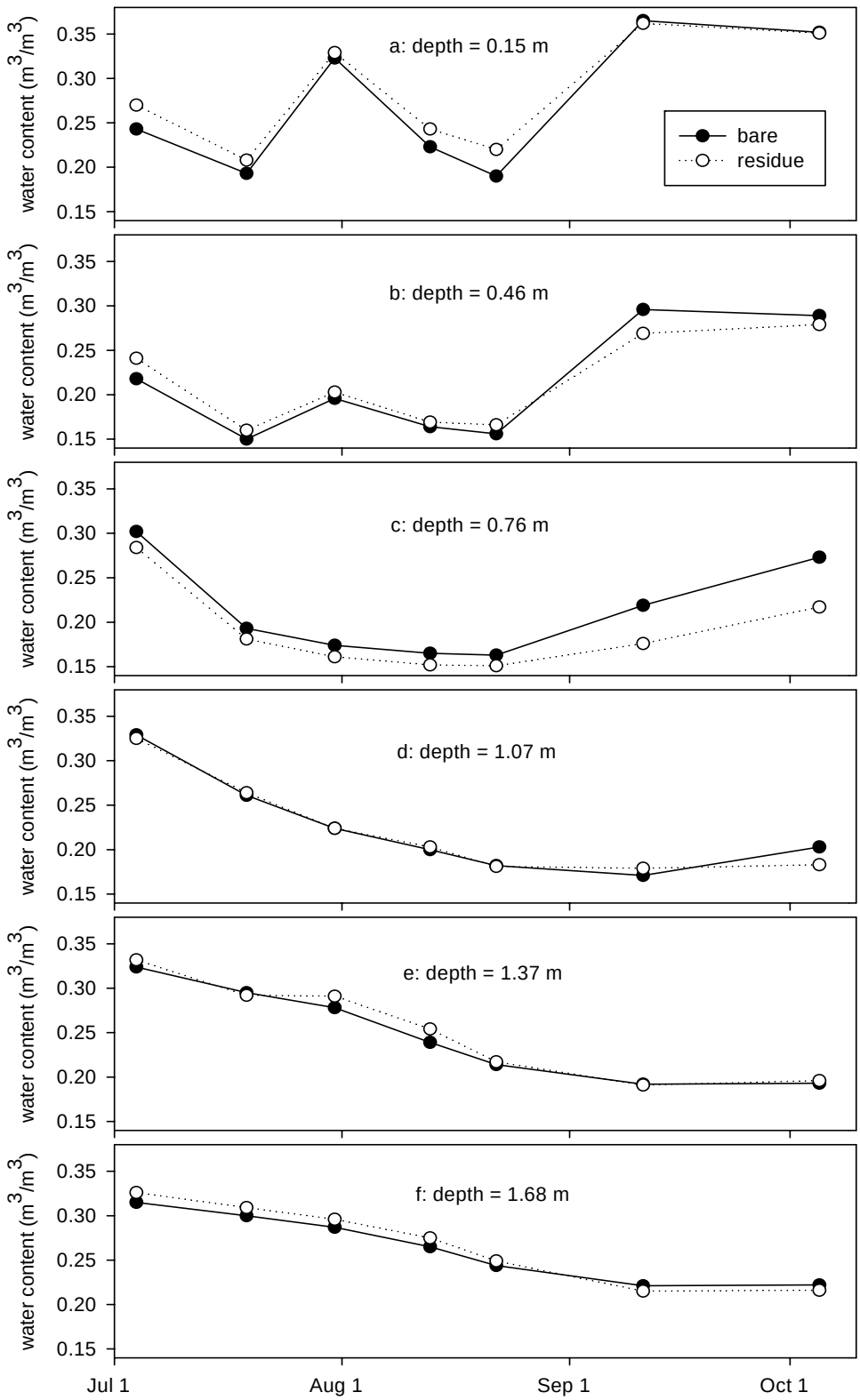



**Figure 7. Soil water content at six depths in bare-soil plots and in residue-covered plots. Each data point is the mean of eight neutron readings (four plots, two tubes per plot).**

Table 1. Residue cover and mass in June and October 2007 for bare-soil and residue-covered plots. See Figure 3 for the physical layout of the plots.

| **Bare-soil plots** | | | | | **Residue-covered plots** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **June** | | **October** | | | **June** | | **October** | |
| | **Cover** | **Mass** | **Cover** | **Mass** | | **Cover** | **Mass** | **Cover** | **Mass** |
| **plot #** | **%** | **kg/ha** | **%** | **kg/ha** | **plot #** | **%** | **kg/ha** | **%** | **kg/ha** |
| 62 | 2 | 127 | 82 | 1348 | 61 | 63 | 3306 | 91 | 2994 |
| 72 | 1 | 242 | 77 | 1718 | 71 | 60 | 3657 | 95 | 3215 |
| 81 | 1 | 102 | 79 | 1292 | 82 | 66 | 3278 | 95 | 3607 |
| 83 | 3 | 114 | 87 | 928 | 73 | 63 | 4341 | 94 | 3854 |
| **Mean** | **2** | **146** | **81** | **1322** | **Mean** | **63** | **3646** | **94** | **3418** |
| **St. dev.** | **1** | **56** | **4** | **280** | **St. dev.** | **2** | **428** | **2** | **334** |