Effect of Corn or Soybean Row Position on Soil Water

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Abstract: Crop plants can funnel water to the soil and increase water content more in the row relative to the interrow. Because the row intercepts more soil water after rains and higher root density, the soil may also dry out more between rains than does soil in the interrow. The objectives of this study were to determine if there is a row position difference in soil wetting after rain and drying between rains, and to determine the seasonal nature of these differences. The first experiment examined soil water content 0 to 0.06 m in row, interrow, and quarter corn row positions for eight sites at specific times during a corn (*Zea mays* L.)-growing season. During the growing season, the second experiment examined automated soil water measurements at one site for two corn years and one soybean (*Glycine max* [L.] Merr.) year at row and interrow positions to 0.15-m depth. Soil water content changes were significantly greater in the row than the interrow for some mid-season dates. Temporal soil water changes showed that row wetting and drying dominated over interrow soil water changes for mid season. The mean ratio of row/(row + interrow) soil water changes for wetting was 0.76 and 0.77 for corn and 0.64 for soybean and for drying was 0.58 and 0.84 for corn and 0.60 for soybean. Soybean showed the row effect for a shorter time of the season (up to 71 days) compared with corn (up to 159 days).

Key words: Stemflow, infiltration, evapotranspiration.

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Clothier and Green (1997) identified stemflow as one of the key areas of promising soil water–root research. Corn plants funnel water down the stem (Parkin and Codling, 1990). Paltineanu and Starr (2000) observed increased soil wetting in the corn row compared with the interrow down to 50-cm depth. They had measured both stemflow down the plant as well as soil water infiltration effects. Hupet and Vanclooster (2005) measured and simulated stemflow effects on infiltration and root water uptake patterns for corn and showed that stemflow accounted for 44% to 86% of rainfall depending on time in the season. Timlin et al. (2001) examined the temporal dynamics of row and interrow soil water under soybean, both wetting and drying, and showed that soil water increased in the row more than the interrow because of rain, and dried more in the row because of transpiration. Van Wesenbeeck and Kachanoski (1988) examined soil water under corn at four row positions every few days and showed higher drying and recharge rates in the row compared with the interrow. Dolan et al. (2001) conducted a similar study examining row effects on rainfall distribution via stemflow or throughflow and showed less infiltration in the interrow as the canopy closed over the season.

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Consideration of stemflow in agricultural fields is considered critical to understand leaching and recommended placement of agricultural chemicals (Parkin and Codling, 1990; Dolan et al., 2001), generation of runoff (Parkin and Codling, 1990; Bui and Box, 1992), and appropriate placement of soil moisture sensors (Paltineanu and Starr, 2000; Hupet and Vanclooster, 2005). Canopy influences on stemflow were emphasized by Bui and Box (1992), Paltineanu and Starr (2000), Dolan et al. (2001), and Timlin et al. (2001), especially in relation to canopy closure and senescence. Proper simulation of soil water dynamics requires accurate assessment of stemflow (Bruckler et al., 2004; Hupet and Vanclooster, 2005).

Vervoort et al. (2001) observed greater ponded infiltration in the row compared with either trafficked or untrafficked interrows, which they attributed to greater macroporosity in the row. Prieksat et al. (1994) noticed a greater row effect if ponded measurements were made directly over where a corn plant had been than for locations between plants.

The objectives of this study under corn and soybean were to determine if there is a row position difference in soil wetting after rain and drying between rains at a rainfed site in Central Iowa and to determine the seasonal nature of these differences.

MATERIALS AND METHODS

Two experiments were conducted in a farmer's field (Fig. 1). The eight measurement sites in 2005 (Table 1, Fig. 1) were on fairly level ground. Sites 1 and 7 had considerable amounts of carbonates at the surface, which indicated Harps soil (fine-loamy, mesic Typic Calciaquoll). Sites 2 and 5 had shallow depths (<0.3 m) to carbonates, indicating Canisteo soil (fine-loamy, mixed [Calcareous], mesic Typic Endoaquoll). The soil at the rest of the sites was Webster (fine-loamy, mixed, mesic Typic Endoaquoll) that did not have carbonates above the 0.7-m depth. All three soils are poorly drained. The presence of carbonates at or near the soil surface indicates historical upward water flux, whereas the lack of carbonates at the soil surface indicates historical dominance of downward water flux.

The first experiment examined corn row position effect on surface soil water (0- to 6-cm depth) at eight sites within the field. This allowed statistical comparisons of row positions: row, quarter row, mid row, and three-quarter row at each site. Within the field, a weather station monitored rainfall (tipping bucket) and eddy covariance evapotranspiration (ET). The ET data were gap-filled for correction (Hernandez-Ramirez et al., 2010) using an iterative interpolation technique.

During the 2005 growing season, soil water was manually monitored at each of these eight sites. Surface water was monitored with a theta probe (Delta-T Devices, Cambridge, UK; marketed in the United States by Dynamax, Inc., Houston, TX) for each quarter-row position. On each measurement date, four replicate measurements were taken at each position and averaged. The corn had been planted on April 10, 2005. The theta probe was calibrated as described by Kaleita et al. (2005).

Changes in soil water content were compared among row positions for cumulative wetting and cumulative drying. In some cases, different start points were used for wetting and drying

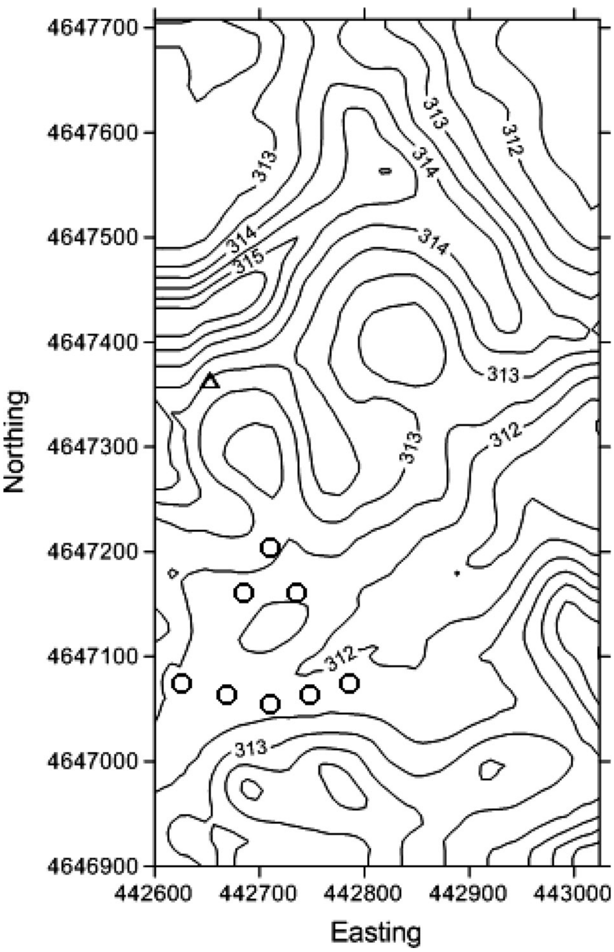

FIG. 1. Location of eight sites in 2005 (circles) and one site in 2007 to 2009 (triangle).

phases because of different maxima and minima in soil water across the samples. The eight sites were considered blocks and row position in the treatment analysis of variance and honest significant difference test (Tukey).

The second experiment examined corn row and interrow temporal effects on soil water to 15-cm depth, in response to rain and ET, but only at one site (Webster soil) for two corn years and one soybean year. One site in the same field with corn-soybean rotation was monitored over time for soil water content, soil temperature, and water table depth. Corn was planted on May 11, 2007, soybean was planted on May 16, 2008, and corn was planted on April 22, 2009.

Water content reflectometers (CS616; Campbell Scientific, Inc., Logan, UT) were used for monitoring soil water content, measured every hour. They were installed horizontally at 0.05- and 0.15-m depths in the row and mid-interrow positions, reinstalled each year. Additional probes were installed diagonally from row to interrow at 0.3-, 0.5-, 0.7-, 0.9-, and 1.1-m depths, kept in place throughout the study. Thermocouples were installed at the same depths for soil temperature measurements. Soil water monitoring was started on June 22, 2007, July 7, 2008, and May 12, 2009.

To calibrate the CS616 probes, sensor outputs were first converted from period to square root of apparent permittivity, $\varepsilon_a^{1/2}$ (Kelleners et al., 2005). The $\varepsilon_a^{1/2}$ was adjusted to minimize temperature influence of the 0.05- and 0.15-m depth probes. The converted or adjusted $\varepsilon_a^{1/2}$ values were then calibrated against gravimetric or neutron probe soil water content measurements for each depth.

Soil water content was converted to depth of soil water to 0.15 m using the trapezoid rule separately for row and interrow. Then we determined change in soil water content from before a key rain event to the time when water content was maximum in the row. We also determined the cumulative rain amount to each of these times as well as the cumulative amount of soil water lost from row and interrow positions between rain events. Likewise, we determined the change in soil water content from before the rain event to the (often later) time when the water content reached its maximum in the row or interrow.

Ratios of row to row plus interrow soil water change were calculated for each significant rain event and for each time between rains longer than 2 days. These ratios were followed over the season, and regressions as a function of day were determined for early season and for late season. The regressions were determined for ratios based on wetting to both maximum wetting in the row and to maximum wetting in the interrow. The regression equations were used to determine the early season day when more than half of the soil water change was in the row, which was indicated when the ratio rose more than 0.5. The regression equations were also used to determine the late season day when less than half of the soil water change was in the row, which was indicated by the ratio dropping to less than 0.5. The length of time between these early and late season dates indicated the seasonal time that row wetting was greater than interrow wetting. Correlation was sought for row minus interrow water increase after rain as a function of day after planting, rainfall amount, and mean soil water content before the rain (to 0.15-m depth). Allometric plant measurements included periodic determination of plant height, growth stage, and leaf area index.

RESULTS AND DISCUSSION

For some mid-season intervals in 2005, there was significantly more soil water increase in the row versus the interrow and also significantly more soil water drying in the row versus the interrow (Table 2). Trends were inconsistent in the early season as crops were growing, and differences were not significant late in the season as plant canopy underwent senescence.

TABLE 1. Site Characterization From Neutron Access Tube Sites at Brooks Field in 2005 as Well as the One Site in 2007–2009

Site	Mollic	Carbonates	Elevation, z
	M	m	m
1	0.64	0	312.62
1b	0.78	0	
2	0.41	0.24	312.54
3	0.45	>2.0	312.28
4	0.50	0.97	312.32
5	0.52	0.46	312.23
6	0.67	1.01	312.32
7	0.51	0	312.28
8	0.53	>2.0	312.47
2007–2009	0.79	1.8	313.5

Two samples were accidently taken at site 1.

Mollic is depth of mollic, other depths are depth to the characteristic.

TABLE 2. Row Position Comparisons of Change in Water ($m^3\ m^{-3}$) to 6-cm Depth Between Given Dates, With Eight Sites Considered Blocks, 2005

Date	Row	Quarter	Mid Row	Three Quarters	Rain, mm	ET, mm
137–154	−0.039a	−0.068b	−0.057ab	−0.060ab	—	—
154–158	0.004b	0.017ab	0.021ab	0.036a	8.64	7.84
194–199	0.100a	0.054b	0.051b	0.072ab	11.68	30.91
194–201	0.104a	0.061b	0.043b	0.058b	17.52	43.50
196–201	0.100a	0.072ab	0.058a	0.071ab	17.52	26.22
199–206	−0.076b	−0.039a	−0.032a	−0.051a	24.39	43.25
201–206	−0.080b	−0.046ab	−0.024a	−0.037a	18.55	30.66

Means within a row followed by the same letter were not significantly different at $P = 0.05$ by honest significant difference.

ET: evapotranspiration.

There was a less clear trend for absolute water content (rather than change in water content) (Fig. 2). On Day 158 (June 7), the mid row was significantly wetter than the quarter row. Similarly on Day 201 (July 20), there was greater soil water content in the row compared with the mid row. On the contrary, for days 234 and 237 (August 22 and 25), the row had significantly less soil water content than the mid row.

For 2007 to 2009 seasons, the ratio of row change in soil water to change in soil water for row plus interrow increased steadily during the season, leveled off, and then declined later in the season (Figs. 3–5). The trend was similar for both corn years and for both wetting and drying cycles (Figs. 3 and 5). There was even a small amount of row-interrow differential in the 2008 soybean year (Fig. 4). In other words, during mid season under full canopy, there was greater soil water increase beneath the row than the interrow in response to rain and greater soil water loss between rains. This would be expected to relate to canopy development (Figs. 3–5). As the canopy closes, more rain would be intercepted by the leaves rather than falling directly on the soil and much would then be funneled down the leaves to the soil in the row.

There was a broader plateau (seasonal time with ratio >0.5) in 2009 (134–159 total days) than 2007 (94–114 total days) with earlier increase in the ratio beyond 0.5, and later decrease in the ratio less than 0.5 (Table 3). A ratio greater than 0.5 indicated more wetting or drying in the row than in the interrow. The shortest duration for a row effect (Table 3) was for soybean in 2008 (67–total 71 days). Soybean leaves do not funnel water

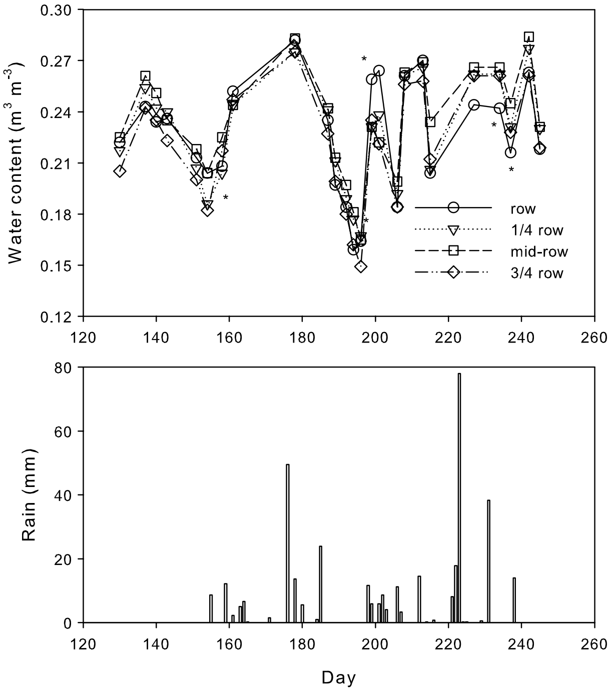

FIG. 2. Mean 2005 seasonal water content in the top 6 cm for various row positions and rain. *Significant positional differences.

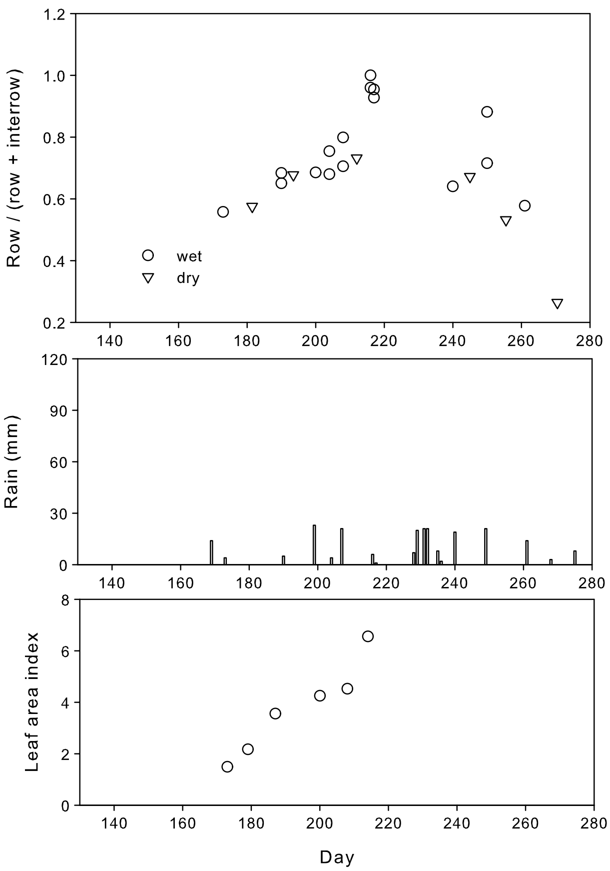

FIG. 3. Seasonal ratio (change in row soil water divided by change in row plus interrow soil water to 0.15-m depth) for wetting and mean drying days during the 2007 corn-growing season. Also shown are daily rainfall and plant height. Day indicates day of year.

down the plant to the same extent as corn, but roots concentrated in the row (Kaspar et al., 1991) could still dry the row more than the interrow.

Mean ratios during the plateau time for wetting were 0.76, 0.64, and 0.77 for 2007, 2008, and 2009. Mean ratios for drying were 0.58, 0.60, and 0.84 for the 3 years. The maximum ratios for wetting were 1.00, 0.89, and 1.13 for the 3 years; and for drying were 0.73, 0.80, and 1.01. Ratios larger than 1 for 2009 indicated that the interrow continued to dry even as rain had started to wet the row. Again, the row effect was greatest for corn in 2009, but a row effect was evident even for soybean in 2008, although the plateau time was shorter.

In corn years, the interrow position often took a longer time to reach maximum soil water content after rain than did the row position because of lateral soil water redistribution between positions when little rain water actually reached the interrow (Fig. 6). The mean interrow delay to maximum wetting was 5 h after the row maximum for corn in 2007 (59–130 days after planting) and 8 h in 2009 (63–156 days after planting). The mean delay for the early season 2009 was less than 1 h (21–52 days after planting). Similarly for soybean in 2008, the mean delay was less than 1 h (57–130 days after planting). In contrast, Dekker and Ritsema (1997) did not observe lateral redistribution in their water-repellent soils, although corn stemflow caused more wetting in the row than the interrow.

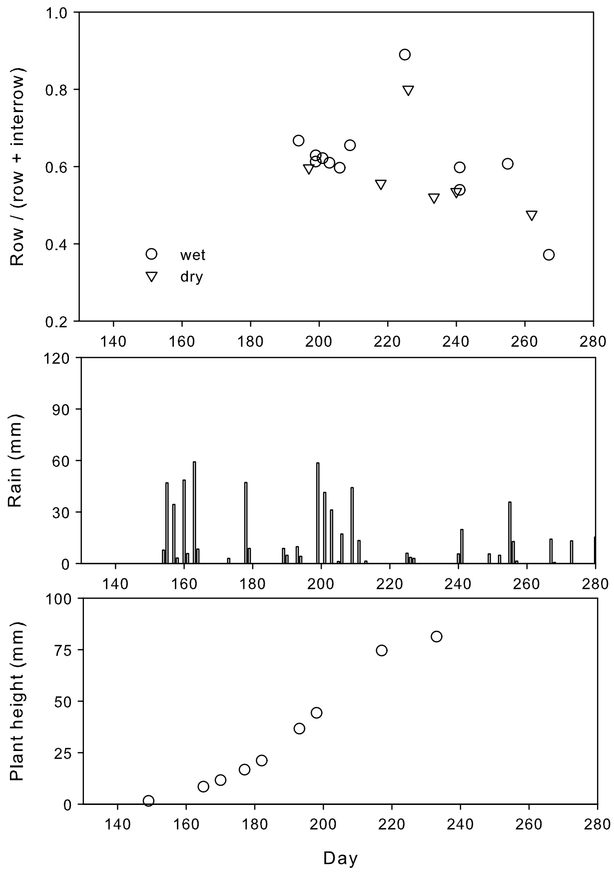

FIG. 4. Seasonal ratio (change in row soil water divided by change in row plus interrow soil water to 0.15-m depth) for wetting and mean drying days during the 2008 soybean-growing season. Also shown are daily rainfall and plant height. Day indicates day of year.

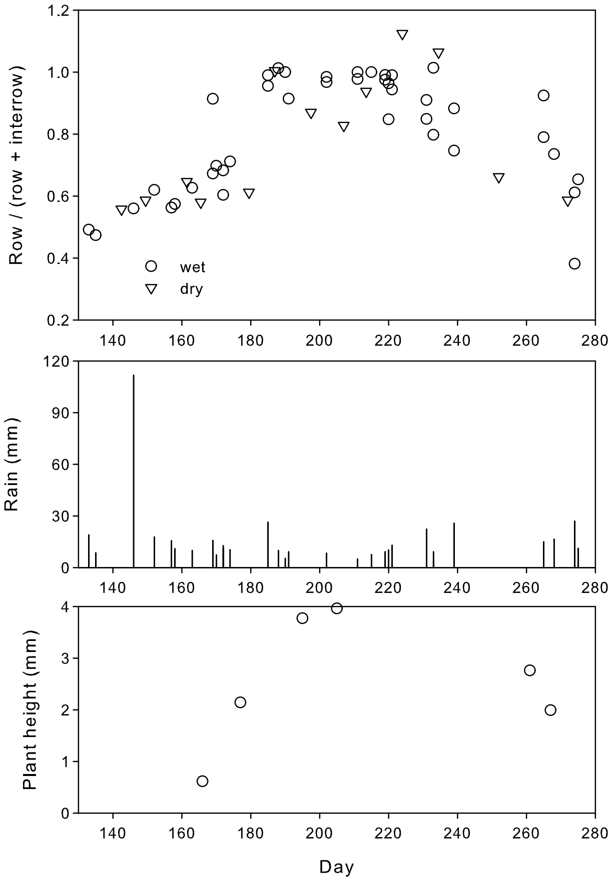

FIG. 5. Seasonal ratio (change in row soil water divided by change in row plus interrow soil water to 0.15-m depth) for wetting and mean drying days during the 2009 corn-growing season. Also shown are daily rainfall and plant height. Day indicates day of year.

We observed a larger corn row effect in 2009 (maximum ratio beyond 100%) than the stemflow observed by either Dolan et al. (2001) (maximum of 66%) or Hupet and Vanclooster

TABLE 3. Calculation of Day When Row Change Increased Beyond or Dropped Less Than 0.5 of Ratio, Row Increase/(Increase of Row + Irow), Based on Linear Regression for Early and Late Seasons

Period	Day Row >0.5	Day Row <0.5
2007 wetting, row maximum	170	284
2007 wetting, irow maximum	170	270
2007 drying	163	257
2008 wetting	185	256
2009 drying	185	252
2009 wetting, row maximum	141	300
2009 wetting, irow maximum	141	300
2009 drying	141	275

In 2007, Day 163 is V3, Day 170 is V4 to V5.

In 2008, Day 185 is V3. The row-interrow wetting differential time was rarely evident for soybean in 2008.

In 2009, Day 141 is V1 to V2.

Irow: interrow.

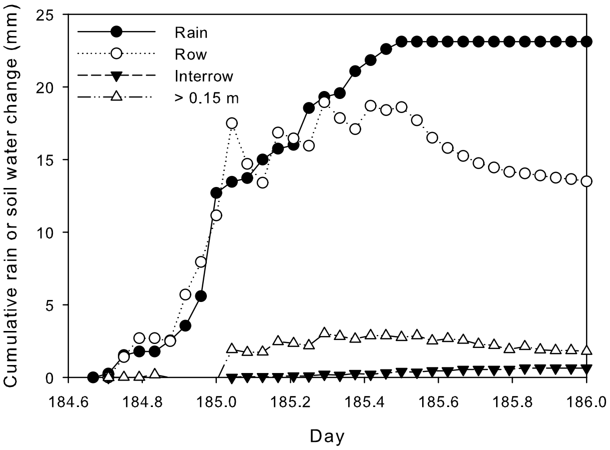

FIG. 6. Example 3–5 July 2009, for row and interrow wetting to 0.15-m depth and for subsoil wetting.

(2005) (maximum of 86%). Using regression equations for stemflow or throughflow as a function of rain (Paltineaunu and Starr, 2000) resulted in a mean ratio stemflow/(stemflow + throughflow) of 0.88, indicating a significant amount of stemflow in their study. Mean increases in soil water 0.05- to 0.55-m depth for row/(row + nontraffic interrow) was 0.87 for no-till corn when rain was less than 0.15 mm and 0.71 averaged across all rain events (Paltineaunu and Starr, 2000). Smaller ratios were shown for plow-till corn and for traffic interrows. Overall the row-interrow effect was somewhat less than the stemflow-throughflow effect.

Data from fig. 2 of Timlin et al. (2001) were interpolated to determine change in soil water content to 0.25 m for soybean row and interrow positions in response to rain and between rains. For site A, the calculated mean ratio row/(row + interrow) change in water content was 0.56 for increase caused by rain and 0.54 for decrease between rains. Soybean does show some row-interrow differences, but the differences are less pronounced than that shown for corn in other studies. Soybean leaves do not channel water to the stem as much as corn leaves. Both soybean and corn leaves could allow water to drip off the tips of the leaves (Dekker and Ritsema, 1997), wetting the interrow as well as the row. Corn leaves that are more upright would have less drip off the tips and more wetting in the row than the interrow.

Row minus interrow water increase after rain was most strongly correlated with mean water content (to 0.15-m depth) before the rain (not shown). At low water contents, the correlations were positive, but at high water contents, the correlations were negative. The crossover water content between dry and wet effects were 0.266, 0.261, and 0.220 $m^3 m^{-3}$ for 2007, 2008, and 2009. Other studies did not examine the relation between stemflow and water content before the rain. There was a positive correlation with rain amount for soybean in 2008, but rain amount was not significantly correlated for the corn years of 2007 and 2009. In contrast, Paltineaunu and Starr (2000) showed an inverse relation between stemflow and rainfall amount for corn.

CONCLUSIONS

These multiyear data support the influential role of plant canopy morphology and development of spatiotemporal variations on soil water content in row crops. A fully developed corn canopy induced the partitioning of incoming rainfall into stemflow rather than throughflow, which resulted in preferential wetting of the row position. Concomitantly, soil water at the row position tended to be depleted to a greater extent because of plant water uptake. This information regarding soil water patterns can be incorporated into mechanistic modeling efforts of crop production systems.

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