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Tillage Effect on Soil Water Content and Soybean (*Glycine max*) Yield in a Strip Intercropping System

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Soybean [*Glycine max* (L.) Merr.] response to strip-intercropping with corn (*Zea mays* L.) and oat (*Avena sativa* L.) interseeded with nondormant alfalfa (*Medicago sativa* L.) may be affected by soil moisture. A three-crop strip-intercropping system of corn, soybean and oat interseeded with nondormant alfalfa was established to determine the effect of tillage system and row position on soil water content and grain yield in the soybean strip. The experiment was a split-plot design with three tillage treatments (conventional, CT; reduced, RT; and minimum tillage, MT) as main plot effects and three row positions (both edge rows and the center row) as subplot effects. In 1989 (a dry year), MT resulted in greater soil water content and soybean yield than other tillage treatments. The row bordering the oat-alfalfa strip had a lower soil water content and soybean yield than did the other two positions. Tillage did not have a significant effect in 1990 (a wet year) on soil water content or soybean yield. The 1990 soybean yield was lower in the soybean row bordering corn, but water availability did not differ significantly between row positions. MT was the most suitable tillage system for soybean production with the three-crop strip intercropping on this soil for both the wet and dry year in which this study was conducted.

INDEX DESCRIPTORS: soybean [*Glycine max* (L.) Merr.], corn (*Zea mays* L.) oat (*Avena sativa* L.), alfalfa (*Medicago sativa* L.) strip intercropping, tillage, soil moisture.

The temporal (rotational) and spatial variations in crops associated with strip intercropping are intended to reduce resource competition between species and thereby increase yield potential. The grain yield of corn that is strip-intercropped with soybean can increase from 10 to 40% over sole-cropped corn (Pendleton et al. 1963, Francis et al. 1986). This is especially true at the border with soybeans, where the intercropped corn plant intercepts more sunlight than corn which is sole-cropped. Yield advantages up to 35% for intercropped corn over sole-cropped corn were reported for the corn component of the following experiment by Ghaffarzadeh et al. (1997).

More efficient use of one resource, however, can be offset by significant interspecies competition for other resources (Francis et al. 1986). The corn yield advantage at the border with soybean has often been offset by a proportionally equivalent yield decrease in the border rows of soybean (Pendleton et al. 1963, Francis et al. 1986). This yield reduction has been attributed to the shading effect and water competition from the adjacent corn. The result was little or no increase in land use efficiency (Crookston and Hill 1979).

Other research, however, suggests that the interaction effect of corn on soybean is not limited to the interface between the crops, but affects the entire soybean strip. Radke and Hagstrom (1976), investigating 14-row soybean strips, found that only the two soybean rows immediately adjacent to corn suffered yield loss as compared with sole crops. The remainder of the strip produced significantly greater yields than the sole crops, leading to a 13% yield increase for the strip-cropped soybeans over sole-crops across the seven year experiment. This interaction is not only because of shading, but includes a windshield effect of the taller corn. Rosenberg et al. (1983) concluded that shelters consistently: 1) alter the microclimate, 2) reduce potential and actual evapo-transpiration, 3) improve water relations of the sheltered crop, 4) provide improved opportunity for net photosynthesis, and 5) generally increase yields.

Inclusion in the strip-cropping system of a third strip of either small grain or legume, such as oat or clover, benefits soybean by reducing the portion of that strip which is directly shaded (Fortin et al. 1994, Ghaffarzadeh et al. 1997). Small grain also may compete with soybean if soil moisture is limited. Water availability is a seemingly important aspect in soybean response to strip cropping and it is known that tillage systems alter soil water availability (Allmaras and Nelson 1971, Blevins et al. 1971, Van Doren Jr. and Allmaras 1978, Phillips et al. 1980, Ghaffarzadeh et al., 1994) and root growth patterns for all crops. It is hypothesized that tillage also has an important effect on a crop's response to row position within a strip.

Francis et al. (1986) indicated that definitive research was needed to quantify the importance of light, water, and nutrient competition in the competitive interface between corn and soybean rows. Whigham (1985) reported similar observations for underground growing factors. This paper describes the response of soybean in strips grown immediately adjacent to the corn strips described by Ghaffarzadeh et al. (1997). The objective of this study was to improve the productivity of strip-cropped soybean through better understanding of the effect of tillage and strip position on soil water content and soybean yield within a strip intercropping system of corn, soybean, oat and alfalfa.

METHODS

The experiment was conducted within a corn-soybean-oat/alfalfa strip intercropping system at the Iowa State University McNay Re-

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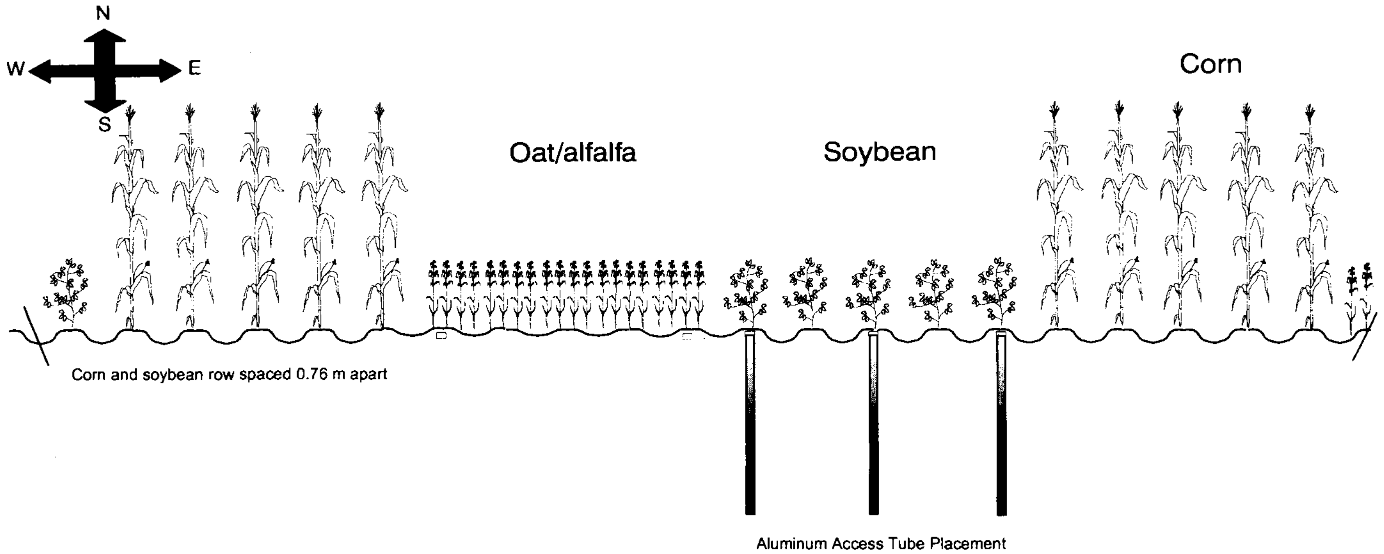

Fig. 1. Schematic diagram of strip intercropping, including strip direction, crop orientation, row spacing and position and placement of access tubes in the oat and soybean strips.

Table 1. Monthly growing-season precipitation (mm) for the McNay Research Center in Lucas County, Iowa.

		Year		
Month	Normal[a]	1988	1989	1990
March	62	4	8	75
April	92	9	20	82
May	101	66	147	161
June	123	22	74	155
July	98	34	70	198
August	102	143	120[b]	91
September	113	80	132	62
Total	691	357	450	824

[a]Chariton, Iowa (NOAA 1990)
[b]96.52 mm after August 23.

search Center in Lucas County, Iowa. All plots were located on a Haig soil that was poorly drained and had less than 1% slope. The field was fall chisel-plowed in 1987 and the crop rotation was begun in 1988. Crop and soil data were collected during the 1989 and 1990 growing seasons.

The experiment was a split-plot design with three tillage treatments as main-plot treatments and three row positions as the subplot treatment. The experiment was replicated four times. Tillage treatments were: conventional tillage (CT), fall moldboard plowing and two secondary tillage operations in the spring; reduced tillage (RT), fall chisel plowing and one secondary tillage operation in the spring; and minimum tillage (MT). All tillage treatments included row cultivation for weed control; thus, the latter treatment is best described as minimum tillage rather than as a no-till system. The strip positions were the two outside rows and the single middle row. Each plot was 12.2 m long and 3.8 m wide, and crops were rotated annually within each plot in a corn-soybean-oat/alfalfa sequence (Fig. 1). Strips and rows were oriented from north to south (Fig 1). The soybean strips were consistently laid out from north to south with the adjacent corn strip to the east and oat/alfalfa strip to the west.

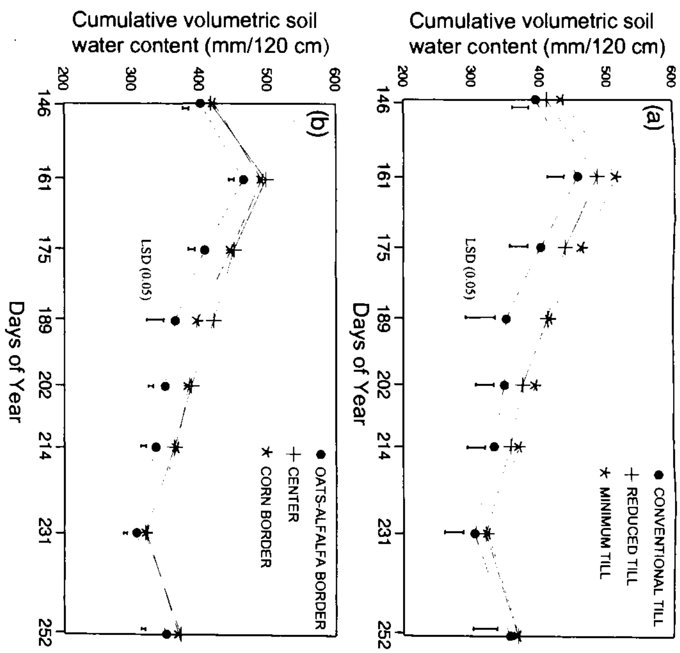

Fig. 2. Soil water content 1.0 m deep under soybean during the 1989 season by tillage (a) and row position (b).

Soybean was planted in five 76-cm-spaced rows on 10 May 1989 and 4 June 1990. Late planting in 1990 resulted from above-normal rainfall. Soybean plant populations were 26.7 plants m^{-1} in 1989, and 22.5 plants m^{-1} in 1990. A five-row planter and cultivator and 3.8-m wide field equipment were used. Crops were harvested from the center 9.14 m of each row using a single-row plot combine. Grain moisture was measured with an electronic sensor in the weighing hopper of the combine and grain yields were adjusted to 130g kg^{-1} (13%) grain moisture.

Weeds in the soybean strip were managed with herbicides and cultivation. Alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxy-

Table 2. 1989 and 1990 grain yield by tillage system and row position for soybean grown in strip intercrop with corn and oat-alfalfa.

	Mg ha-1 Year							
	1989				1990			
	Tillage Method				Tillage Method			
Row Position	MTa	RT	CT	Mean	MT	RT	CT	Mean
1 (corn border)	2.24	1.60	1.15	1.66	2.64	2.50	2.32	2.49
2	2.03	1.77	1.28	1.69	3.14	3.09	3.17	3.13
3 (center)	2.03	1.72	1.24	1.67	3.35	3.34	3.29	3.33
4	1.18	1.62	1.19	1.54	3.25	3.65	3.04	3.31
5 (oat/alfalfa border)	1.50	1.16	0.96	1.20	3.15	3.64	3.46	3.42
Mean	1.92	1.57	1.16	3.24	3.11	3.06		
1989 SE[b]:	Tillage means:	0.31						
	Position means:	0.05						
	Interaction means:	0.15						
1990 SE:	Tillage means:	0.30						
	Position means:	0.07						
	Interaction means:	0.16						

[a]MT, minimum tillage; RT, reduced tillage; CT, conventional tillage
[b]SE = standard error of the mean for treatment effects

methyl)acetanilide], and Metribuzin (4-amino-6-(1,1-dimethylethyl)-3-(methyltio)-1,2,4-triazin-5(4H)-one) were applied at planting on a 0.25-m wide band centered over each row. One or two interrow cultivations were performed each year with a Buffalo cultivator with 17 cm–sweeps. No P or K fertilizers were used because of high soil test values and no N fertilization was used with soybean.

Soil water content distribution was measured approximately every 15 d by using neutron attenuation in five 20 cm increments to a depth of 1.0 m. Aluminum access tubes were installed in the edge and center soybean rows of each soybean strip (Fig. 1). Neutron probe calibration was based on simultaneous probe readings and gravimetric measurements for widely contrasting soil water contents on three dates in 1989. Soil water depletion at each depth was calculated as the difference with soil depth in soil water content between dates with the highest and lowest soil water contents. Depletion was measured between 9 June and 18 August in 1989 and 22 August and 8 September in 1990.

Analysis of variance was used to determine the significance of tillage and row position effects on total soil water content, soil water depletion (by depth) and soybean yield. Treatment means with significant effects were compared using the protected least significant difference (LSD) test. Mean effects were compared only within individual dates, so as to reduce the potential for non-independence of observations. The significance of interactions between tillage and row position effects was tested using single-degree-of-freedom contrasts. Differences identified in the paper were declared significant only when they occurred at the $P \leq 0.05$ level of probability.

RESULTS AND DISCUSSION

Soil Water Content

Precipitation in 1989 was below normal during most of the summer (Table 1) and soil water content decreased with the intensity of the tillage systems; MT had the highest soil moisture content and CT the lowest. Differences in soil moisture content between the three systems were significant for most of the season (Fig. 2). Soil moisture differed with row position so that the oat-alfalfa border had a significantly lower soil moisture content than did the center and corn border positions.

The tendency of minimum tillage systems to conserve soil moisture may explain significant interactions observed during this season. Soil moisture content was greater at the corn border relative to the other two strip positions (observed under MT but not under the RT and CT systems). There was also a smaller difference in moisture content between the oat-alfalfa and center row under MT than under the RT and CT systems (data not shown).

In 1990, rainfall was above normal for much of the season (Table 1). Soil water content remained high throughout the season, and no significant tillage effects were observed (data not shown). Only on August 22 did the border with oat-alfalfa have significantly more soil water than did the average of the other positions (data not shown). The interaction contrasts were not significant.

Soil Water Depletion

Total soil water depletion in 1989 was significantly greater in MT than that in the average of the other two tillage treatments, while RT and CT were not significantly different (Fig. 3). The soybean border with oats/alfalfa had significantly lower soil water depletion than did the average of the other two positions under RT and CT, which may have resulted from the lower seasonal water content (and hence availability) at that position. This trend was reversed in MT, where the border with oat-alfalfa had greater soil water depletion than did the average of the other two positions.

Soil water depletion by depth showed significant effects between 0.6 and 1.0 m (Fig. 3). Contrasts revealed that significantly greater soil water depletion occurred 1) under MT than under the average of the other tillage treatments; 2) under RT than CT; and 3) in the average of the center and corn border positions than at the oat-alfalfa border. For MT at this depth, the oat-alfalfa border had depletion equal to or greater than other positions. The average RT and CT depletion at this depth in the oats/alfalfa border, however, was lower than that observed at the other positions and comparable depths. Also, at the three lower depth increments the corn border under MT

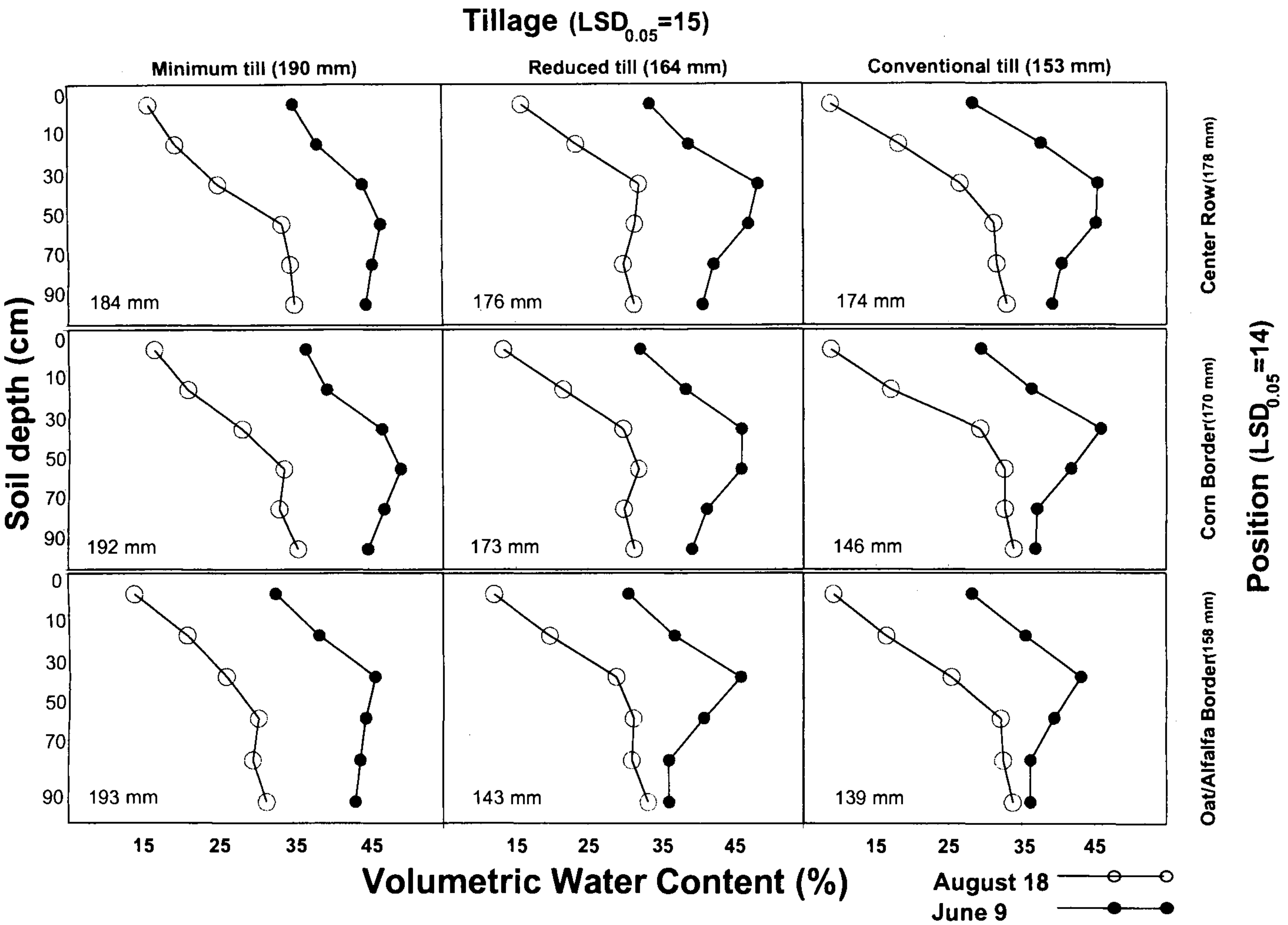

Fig. 3. Volumetric soil water content profiles under wettest (June) and driest (August) conditions under soybean in 1989 by tillage and positions. The values of each graph, position, and tillage correspond to total (1.0 m deep) soil water depletion between both dates.

had significantly higher depletion than the center row, but was lower with RT and CT.

MT had more soil water than did the other tillage treatments at the upper two depth increments early in the 1990 season, but total soil water depletion in 1990 was affected by neither tillage nor row position (data not shown).

Grain Yield

Both tillage system and row position affected soybean grain yield in 1989. MT soybean yield was significantly greater than the average of RT and CT (Table 2). The soybean row bordering corn yielded more than the average of the other two rows, and the row bordering oat-alfalfa yielded less than the center row. The yield advantage of MT and yield disadvantage at the oat-alfalfa border are likely associated with the differences in water content that occurred with these treatments.

Tillage and row position effects also interacted significantly. Soybean yield advantage at the border with corn was significant under MT but not under RT or CT. Soybean at the border with corn under MT enjoyed greater soil moisture and suffered less water stress during the dry year than did soybeans in the other positions.

Soybean grain yield in 1990 was not significantly affected by tillage (Table 2). Row position did affect soybean yield. Yield at the corn border was significantly lower than the average of the other two positions. Because the soil water content was not limited, a possible cause of the lower soybean yield next to the corn border was shading by the taller corn plants.

Minimum tillage was found to be the most suitable tillage system for soybean production in a three-crop strip intercropping system. Under dry conditions, minimum tillage results in higher water content and soybean yields compared with other tillage systems. This is important at the border of soybean and oat, where water content is lower and soybean plant stress may be higher during dry years. In wet years, soil water content and crop yields are not affected by tillage treatments.

Position in the strip also affects soil water content and soybean yield. Soybean yields were lower at the oat border than in the center of the strip during the dry year. During the wet year, however, soybean yields were lower at the corn border than in the center of the strip, possibly because of the effects of shading.

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