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Cropping system influences on extractable water for mono- and double-cropped soybean

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Abstract

For rain-fed agriculture in the southeastern United States, efficient soil water use when double-cropping is essential. Water use by soybean [*Glycine max* (L.) Merr.] following winter wheat (*Triticum aestivum* L.) is, however, poorly documented. Winter wheat may deplete soil water, thus limiting subsequent soybean yield. Cropping system variables, such as soybean planting date and row spacing, may also affect water use. Therefore, a 4-year field experiment in northeastern Mississippi was conducted on Leeper (*Vertic Haplaquept*) and Catalpa (*Fluvaquentic Hapludoll*) silty clays. The objectives were to (1) determine the influence of soybean planting date, cropping system (monocropped versus double-cropped), and row spacing on extractable water (similar to available water) for soybean, and (2) identify a production system to improve the use of extractable water over a growing season. In mid- to late-May (the first soybean planting date), ''Centennial'' soybean in 38- or 76-cm rows was planted either between rows of standing wheat or in bare (monocropped) plots. After the wheat was harvested and the straw chopped, soybean was planted into bare soil or planted no-till into wheat stubble in mid-June for the second planting and in early July for the third. Soil water content was measured with a neutron probe from soybean emergence to maturity. Differences between each water content profile and a dry profile (constructed using the lowest recorded water content at each depth) were regarded as extractable water. Neither soybean planting date nor cropping system, as a main effect, exerted much influence on extractable water for soybean. As interacting factors later in the season, however, they were important. Plots with soybean in 38- rather than 76-cm rows contained more extractable water throughout the 1982 and 1983 seasons, and yielded over 9% more seed. Canopies closed about 20 days sooner with narrow rows than with wide rows. These full canopies protected and shaded the soil surface, probably reducing crusting and decreasing water losses by evaporation. We concluded that double-cropped soybean in 38-cm rows planted either into standing wheat in late May or into wheat stubble not later than mid-June utilized extractable water efficiently in silty clay soils in northeastern Mississippi.

Keywords: Available water; Row spacing; Relay planting; Planting date; Wheat

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1. Introduction

Double-cropping, especially winter wheat followed by soybean, is very common in the southeastern United States because of efficient land use and improved cash flow (Wesley and Cooke, 1988). In many non-irrigated double-cropping systems, the soil water available to the second crop (soybean) is critical. Numerous authors (Sanford and Hairston, 1984; Crabtree et al., 1987; Daniels and Scott, 1991) have warned that high-yielding wheat could leave a water-depleted profile for the subsequent soybean crop, severely reducing yields (Roder et al., 1989). Also, water in the soil at the seeding depth must be sufficient at soybean planting to assure adequate germination and a stand (Crabtree and Rupp, 1980; Wesley and Cooke, 1988). Other actively transpiring plants, such as weeds, growing in areas planted with soybean will compete for water (Whisler et al., 1982; Banks et al., 1985).

Numerous cropping system and management factors may affect the amount of water available to soybean planted after wheat. These include the soybean planting date, the presence of stubble and residue from preceding sorghum (*Sorghum bicolor* L. Moench) or wheat (Lehrsch et al., 1984, 1985; Roder et al., 1989), wheat and soybean row spacing, and tillage (Lehrsch et al., 1981, 1984). Tillage often initially increases infiltration rates, decreases bulk density, and thus increases soil water storage.

More available soil water, early in the growing season and at critical soybean reproductive growth stages, increases yields (Roder et al., 1989; Wesley et al., 1991). Soybean yields generally increase in the southeastern United States when soybean is (1) planted relatively early (Coale and Grove, 1990), and (2) grown in narrower rows (Crabtree and Rupp, 1980; Mason et al., 1982; Coale and Grove, 1990). Under severe drought stress, however, narrower row spacings may decrease yields (Alessi and Power, 1982). Heatherly (1988) concluded that the alleviation of drought stress from soybean growing on a clay soil should be a management goal. Infrequent and variable rainfall throughout the lower Mississippi valley during soybean reproductive growth often limits soybean yield without irrigation (Wesley and Cooke, 1988). Efficient use of precipitation, especially in multiple cropping systems, is thus essential (Denton and Wagger, 1992).

The amount of water available to a crop, termed plant extractable water (Ratliff et al., 1983; Ritchie, 1981), may be estimated by integrating the area between a measured soil water content profile and a hypothetical "dry" water content profile, sometimes termed the lower limit of available water profile (Ratliff et al., 1983). A dry profile is constructed using, for each depth, the minimum water content measured for that soil (or one very similar), that location, that crop, that tillage system, etc. The dry profile must be constructed carefully because it can be affected by poor early-season plant root development due to drought stress or low soil nutrient concentrations, restricted rooting caused by inadequate aeration or soil compaction, or management decisions such as late planting (Ritchie, 1981).

Thus, the objectives of this study were to (1) determine the influence of soybean planting date, cropping system (monocropped versus double-cropped), and row spacing on extractable water for soybean, and (2) identify a production system to improve the use of extractable water over a growing season and, thereby, crop production.

2. Materials and methods

The study was conducted at the North Mississippi Research and Extension Center at Verona, Mississippi, from 1981 to 1984. Experimental design was a split-split-split plot with treatments randomized in four complete blocks. Main plots were soybean planting dates, three each year. Subplots were wheat row spacings (no wheat, 18, 38, and 51 cm), sub-subplots were soybean varieties, and sub-sub-subplots were soybean row spacings (38, 51, and 76 cm). The wheat variety used was ''Southern Belle'', an early maturing soft red winter wheat. Soybean varieties (all determinant) were ''Centennial'' and ''Bedford'' in 1982, Centennial and ''Braxton'' in 1983, and Centennial only in 1984. Bedford is a Maturity Group V cultivar, Centennial VI, and Braxton VII.

From the fall of 1981 through the summer of 1983, the study was conducted on a Leeper silty clay (a fine, montmorillonitic, non-acid, thermic *Vertic Haplaquept*) on a 0.2% slope. Leeper is a shrinking and swelling soil, inherently fertile but difficult to manage, particularly when tilled at higher than optimum water contents. With the Leeper silty clay having a relatively limited capacity to store extractable water, efficient soil water management in it is crucial for profitable crop production. From the fall of 1983 through the summer of 1984, the study was conducted on a similar soil, a Catalpa silty clay (a fine, montmorillonitic, thermic *Fluvaquentic Hapludoll*) with slopes ranging from 1 to 2%. Each of these soils at field capacity can yield approximately 24 cm of extractable water (from a 168-cm profile) to the roots of growing soybean (G.A. Lehrsch, unpublished data).

Each fall, seedbeds were chisel plowed to a depth of 15 to 20 cm, then disked to incorporate 33 $kg \cdot ha^{-1}$ of P and 126 $kg \cdot ha^{-1}$ of K. Plots were then tilled to a depth of 6 to 8 cm twice with a row conditioner, a secondary tillage implement (locally termed a do-all) equipped with sweeps, a rolling cutter-bar, spike-tooth harrow sections, and followed by a leveling board. Wheat was subsequently seeded at 50.4 kg $seed \cdot ha^{-1}$ in all row spacings of all double-cropped plots on 21 October 1981, 23 October 1982, and 2 November 1983. The 18-cm rows were planted with a John Deere* Model 18-7B pull-type, end wheel grain drill with double disk openers but no press wheels. The 38- and 51-cm rows were planted with a John Deere Soybean Special* planter equipped with sorghum feed cups and rubber press wheels. Wheat was top-dressed with 28 and 84 kg $N \cdot ha^{-1}$ as ammonium nitrate in the fall and mid-February to mid-March of each year, respectively. Wheat was harvested with a John Deere* Model 55 combine equipped with a straw chopper.

The first of three soybean planting dates in each year was 5 May 1982, 30 May 1983, and 2 June 1984. A John Deere Soybean Special* planter equipped with heavy duty iron press wheels was used to plant soybean (at 432250 $seeds \cdot ha^{-1}$) into monocropped plots and to interseed it into plots with as-yet unharvested, standing wheat, in the milk growth stage in 1982 and medium-dough stage in 1983 and 1984. The planting of a second crop

*Trade names are included for the benefit of the reader and do not imply endorsement of the product by Mississippi State University or the USDA.

(e.g. soybean) into an earlier-planted crop (e.g. wheat) before the first crop is harvested is often termed a relay planting or relay intercropping system (Wallace et al., 1992). Monocropped plots were tilled the preceding fall in the same way as the double-cropped plots. All monocropped plots in the spring, however, were tilled with a do-all to control recently emerged weeds either two, three, or four times before the first, second, or third soybean planting date, respectively. At soybean planting, tractor wheels were positioned so that the wheel tracks were midway between the 51-cm wheat rows. The soybean planter units were mounted on the tool bar to position the 38- and 51-cm soybean rows midway between the 38- and 51-cm wheat rows, respectively. From the double-cropped plots of this first soybean planting date, wheat was harvested on 15 June 1982, 20 June 1983, and 18 June 1984.

From the double-cropped plots of the second soybean planting date, wheat was harvested on 11 June 1982, 13 June 1983, and 12 June 1984, prior to soybean planting. Soybean was subsequently planted no-till into either fallow or wheat stubble plots on 14 June in 1982, 1983, and 1984.

Wheat was harvested from the double-cropped plots of the third soybean planting date on 15 June 1982, 20 June 1983, and 18 June 1984. Thereafter, soybean was planted no-till on 21 June 1982, 8 July 1983, and 3 July 1984 into fallow or wheat stubble plots.

For weed control in soybean, glyphosate and metolachlor at 1.12 and 2.24 $kg \cdot ha^{-1}$ were applied preemergence to all plots of the second and third soybean planting dates. Acifluorfen and bentazon at 0.43 and 0.69 $kg \cdot ha^{-1}$ were also applied to all plots twice during each growing season to control cocklebur (*Xanthium strumarium* L.), morningglory (*Ipomea* spp.), and smartweed (*Polygonum* spp.). No cultivation was used for weed control. Soybean was harvested from all plots on 28 October 1982, 9 November 1983, and 14 November 1984.

Soil volumetric water content was measured about every 14 days. Logistically, it was impossible to monitor the water content in the nearly 300 plots of the study. Hence, we chose to monitor the water content in plots having only Centennial soybean planted in 38- and 76-cm row spacings. We measured the water content in both double-cropped plots that had wheat planted in 18-cm row spacings and in monocropped plots for all three soybean planting dates. Previous studies at Verona (F.D. Whisler, unpublished data) showed no difference in extractable water for Centennial, Bedford, and Braxton varieties planted on the same date in monocropped plots. Neutron thermalization (Gardner, 1986) was used to monitor soil water content from shortly after soybean emergence to physiological maturity. Counts were taken in 15-cm increments to a depth of 168 cm directly under an interior soybean row in each plot. Count ratios were converted to volumetric water contents using linear calibration equations developed for each soil.

Plant extractable water is illustrated in Fig. 1. Soil water content profiles were monitored to a depth of 168 cm so that the water content profiles converged, thus insuring an accurate measurement of extractable water. The dry profile was constructed, depth by depth, using the minimum water content reached by any replication of a particular treatment at any time during the four-year study. Most of the lowest water contents we measured occurred during the first two weeks of September, 1983. The wetter profile of Fig. 1 was measured on 12 June 1984 for the third replication of double-cropped soybean planted in 76-cm rows on planting date 1. Graphically, the extractable water for that treatment was simply the water represented by the shaded area between the two profiles shown in Fig. 1. Quantitatively, to

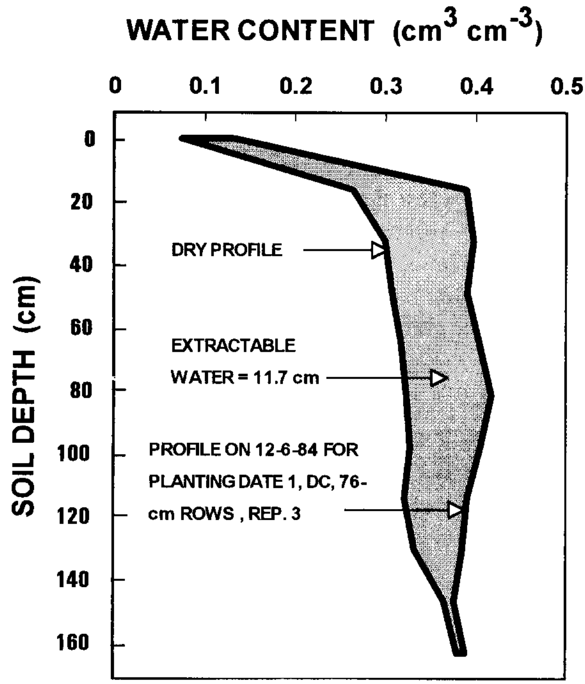

Fig. 1. Extractable water measured on 12 June 1984.

calculate extractable water, at each sampled depth, the difference in the volumetric water content between the two profiles was multiplied by the depth increment for which the water content difference was representative to obtain the amount of water that a plant could extract from that depth increment. By summing this quantity from all depths, we obtained the extractable water in the soil profile (Lehrsch et al., 1981).

Extractable water measured for Centennial soybean on each date was analyzed using an analysis of variance modeled for a split-split plot design with soybean planting dates as main plots, monocropping versus double-cropping as subplots, and soybean row spacings as sub-subplots. When an identified source of variation was found significant for a measurement date, means were separated using Fisher's protected LSD or Duncan's New Multiple Range Test with a significance probability of 5%.

3. Results and discussion

3.1. Main effects

Soybean planting date seldom significantly affected soybean extractable water (data not shown). However, later in the growing season (generally after mid-July), it occasionally interacted with soybean row spacing, cropping system, or both.

Cropping system, i.e. monocropping vs. double-cropping, as a main effect exerted little influence on soybean plant extractable water, and that, only in 1983 (data not shown). It did, however, frequently interact with row spacing in 1983 and 1984, discussed in more detail below.

Soybean row spacing was by far the most significant main effect influencing extractable water. Throughout all of 1982, a year in which precipitation during the soybean growing season (June–September) was 136% of normal, Fig. 2D, plots with soybean in 38-cm rows contained more extractable water than plots with soybean in 76-cm rows, Fig. 3. These differences were statistically significant through the first three fifths of the 1982 growing season. Throughout 1983, Fig. 3, and most of 1984 (data not shown), the trend was the same, with the difference in extractable water being statistically significant three times in 1983. Crop canopy above the narrower rows closed quicker, thus protecting the soil surface

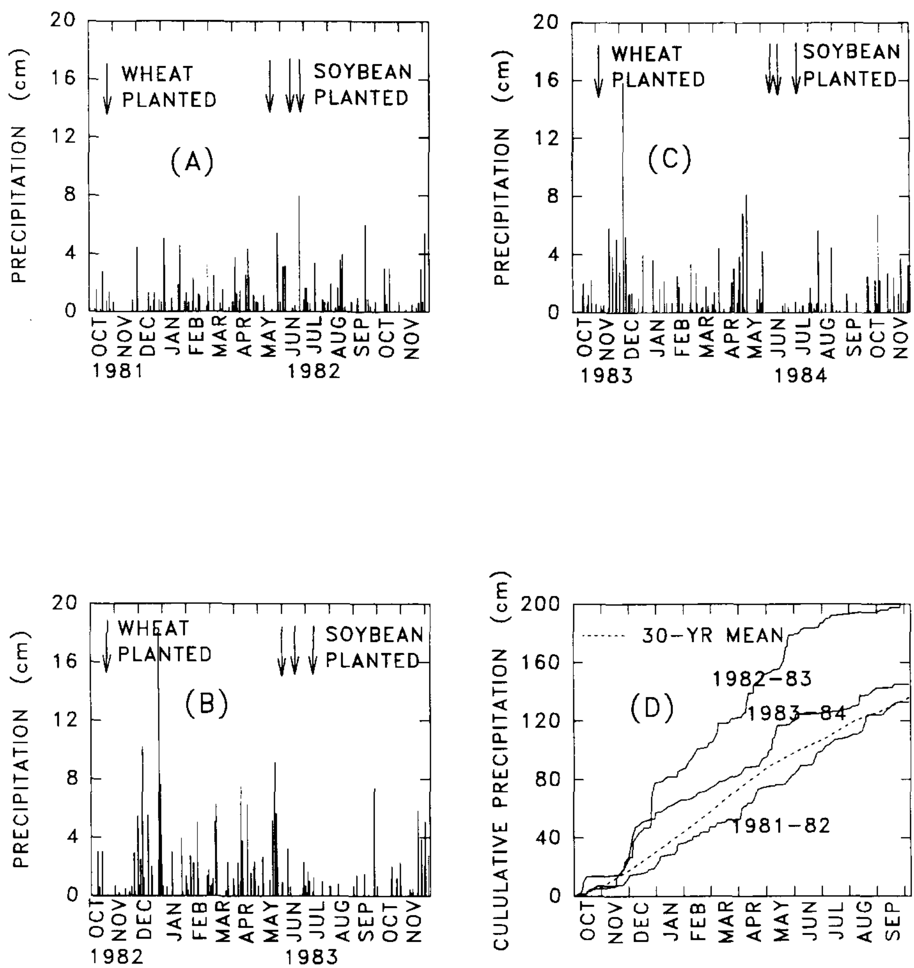

Fig. 2. Precipitation during the 1981–1982 (A), 1982–1983 (B), and 1983–1984 (C) double-cropping seasons, Verona, MS. Cumulative precipitation (D) is also shown.

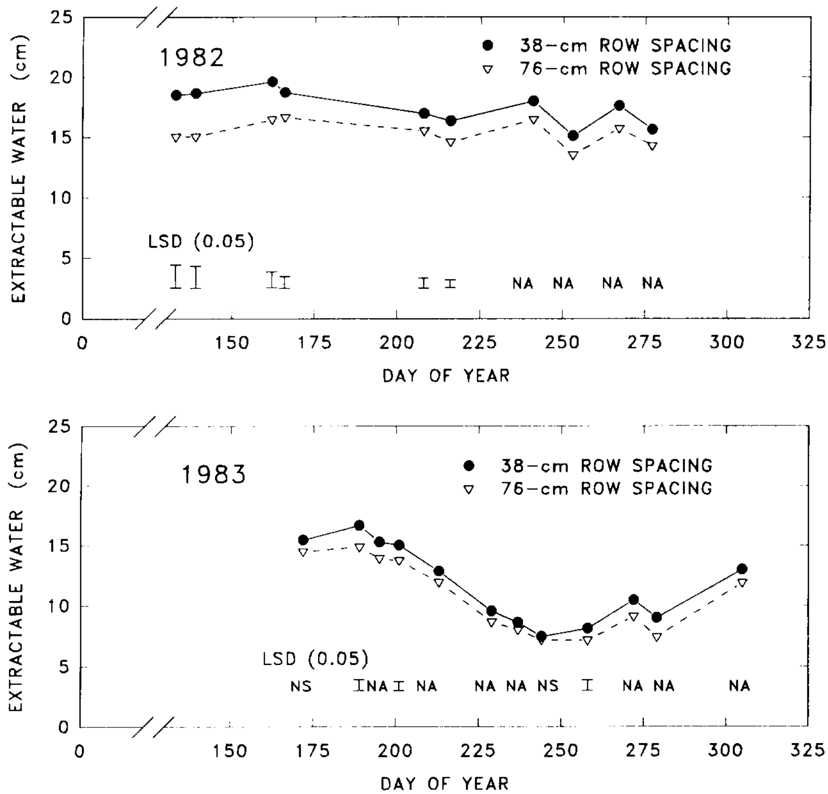

Fig. 3. Extractable water as a function of the day of the year for the 38- and 76-cm soybean row spacings for the 1982 and 1983 soybean growing seasons. Each error bar is the least significant difference, LSD ($p = 0.05$), between the treatments. NS indicates non-significance while NA indicates an LSD is not appropriate, i.e. a two or three way interaction involving row spacing was statistically significant.

from raindrop impact as well as shading it (Lehrsch et al., 1981; Denton and Wagger, 1992). An extensive soybean canopy lessens decreases in surface roughness due to rainfall and helps to maintain a less crusted surface, lower bulk density, higher porosity, and consequently, higher infiltration rates (Lehrsch et al., 1988). Moreover, soybean plants in narrow-row plots were distributed more uniformly over the soil surface than in wide-row plots. This more uniform distribution of plants shaded more of the soil surface, particularly early in the growing season. This shading likely slowed soil evaporation. Crabtree and Rupp (1980) found that an extensive crop canopy limited evaporative water loss. Crop canopy enlargement does, however, increase soil water loss due to plant transpiration (Taylor and Ashcroft, 1972). The drought in July, August, and September of 1983, Fig. 2B, was in part responsible for extractable water values measured late in 1983, about day of year (DOY) 278, being only about 55% of what they were one year earlier, Fig. 3. From late-July through September in all three soybean growing seasons, soybean row spacing often interacted with planting date, cropping system, or both to affect extractable water.

3.2. Interactions

Three types of statistically significant interactions were commonly seen. The first, between soybean planting date and row spacing, occurred after mid-July in both 1982 and 1984. A representative case, very similar to one seen on 29 August and 10 September in 1982 as well, is shown in Table 1. Soybean row spacing caused no differences in extractable water in the first or third planting; however, the narrow-row plots in the second planting contained 4.5 cm more than the wide-row plots. Increased infiltration and/or reduced evaporation due to quicker canopy closure (by about 20 days) with narrower soybean rows may explain, in part, this difference in extractable water.

Table 1 also illustrates delayed planting effects on extractable water. Soybean planted on 3 July 1984, probably had as much if not more water in the soil profile as did the others, but less of that water was extractable (alternatively, used) because the late-planted soybean simply did not have enough time to develop a root system deep in the profile. Management factors such as date of planting can affect extractable water (Ritchie, 1981). With less water available to late-planted soybean, yields decrease. Previous research (Hodges et al., 1983) revealed that, for every day planting was delayed after 15 June, soybean tended to yield 67 $kg \cdot ha^{-1}$ less than soybean planted from late-April to mid-June.

At a given soybean row spacing, planting dates had differing effects. At the 38-cm spacing (Table 1), plots of the first two plantings contained significantly more extractable water than plots of the third. In contrast, at the 76-cm spacing, planting date had no effect. Thus, for soybean in narrow rows, those planted by mid-June had more water available to them than to soybean planted later.

Relay planting did not reduce extractable water for soybean planted by mid-June. In 1984, regardless of spacing, soybean planted on 2 June had as much extractable water available to them as to soybean planted on 14 June, two days after wheat harvest (Table 1). This finding is important. It shows that the common reduction of double-cropped soybean yields compared to full-season yields may not be due to early season drought stress but largely the result of delayed planting (Hodges et al., 1983) until wheat has been harvested. Thus, relay planting uses soil water efficiently, lengthens the soybean growing season, and

Table 1
Soybean planting date and soybean row spacing effects on soybean extractable water measured on 19 July 1984

Soybean row spacing (cm)	Extractable water		
	Soybean planted on		
	2 June (cm)	14 June (cm)	3 July (cm)
38	16.5 a[a] x[b]	18.4 a x	12.9 a y
76	16.0 a x	13.9 b x	13.7 a x

[a] Means within a column not followed by a common letter (a or b) differ significantly ($LSD_{0.05}=2.43$ cm).
[b] Means within a row not followed by a common letter (x or y) differ significantly ($LSD_{0.05}=2.65$ cm).

as a consequence, may be a viable management option for double-cropping in northeastern Mississippi (Wallace et al., 1992).

A second common type of interaction, between cropping system and soybean row spacing, occurred six times, mid-season or later in 1982 and 1983 and early-season in 1984. In Table 2 appears data from 17 August 1983, representative of data from 1 November 1983 and 5 June 1984, also. Monocropped plots with 38-cm soybean row spacings had more extractable water than those with 76-cm spacings, the row spacing influence noted above. Lower soil evaporation rates and/or higher infiltration rates of these bare plots, due to less surface sealing with quicker canopy closure over narrower rows, could explain this finding. Extractable water in double-cropped plots, in contrast, was not affected by soybean row spacing. Wheat residue mulch protected plot surfaces and probably reduced evaporation and surface sealing equally for both soybean row spacings (NeSmith et al., 1987).

Double-cropped narrow-row soybean plots often contained less extractable water in the last half of the 1982 and 1983 seasons than monocropped narrow-row soybean plots, data in Table 2 being representative. Double-cropped soybean grew taller (N.W. Buehring, unpublished data) and likely extended its roots deeper in the soil profile because its roots had access to the established root channels of the wheat. Soybean roots in those channels might have grown at a faster rate than they might have in the absence of established root channels.

As the growing season progressed and upper soil horizons dried, double-cropped soybean did indeed extract water from deeper in the profile than monocropped soybean, as was also noted by Mason et al., 1982. Soybean extraction patterns on 17 August 1983 in the first planting indicated that monocropped soybean extracted most of its water down to the 34-cm depth while double-cropped soybean extracted most of its water down to the 46-cm depth. Reicosky and Deaton (1979) concluded that water held in deeper soil horizons was crucial for soybean growth and development during drought stress. Thus, double-cropped soybean evidently had a well-developed root system deeper in the soil profile than monocropped soybean. Other studies (F.D. Whisler, unpublished data) conducted at Verona and other locations in Mississippi showed that the higher-yielding soybean plots often had higher values of extractable water early in the growing season but lower values late in the season. In other words, soybean plants that yield most, use most of the profile's extractable water. Often, yield is positively correlated with water use (Whisler et al., 1986). Brun et al. (1985) also reported higher water use by higher-yielding soybean as the season pro-

Table 2
Cropping system and soybean row spacing effects on soybean extractable water measured on 17 August 1983

Soybean row spacing (cm)	Extractable water	
	Monocropped (cm)	Double-cropped (cm)
38	11.3 a[a] x[b]	7.8 a y
76	9.4 b x	8.0 a x

[a] Means within a column not followed by a common letter (a or b) differ significantly ($LSD_{0.05}$ = 0.93 cm).
[b] Means within a row not followed by a common letter (x or y) differ significantly ($LSD_{0.05}$ = 1.61 cm).

gressed. We would expect the best-yielding soybean plants to grow quickly and extend their root systems deep into the soil profile to access additional water to meet their transpiration needs (Hoogenboom et al., 1987). These soybean, then, efficiently utilized water deeper in the profile. Crabtree and Rupp (1980) also concluded that the double-cropping of wheat and soybean used water stored in a 120-cm profile more efficiently than the monocropping of either crop.

Cropping system had no significant effect upon extractable water in the 76-cm soybean plots (Table 2). Shallower root systems caused by either (1) roots growing horizontally toward inter-row soil containing water at higher potentials or (2) less extractable water under the wider rows (Fig. 3) may have minimized double-cropped soybean water loss via transpiration. An even more likely explanation for less water loss by transpiration is related to slow early season soybean growth (Caviness et al., 1986). In at least one of the three soybean growing seasons, double-cropped soybean initially grew more slowly than monocropped soybean (R. Johnson, 1992, personal communication). Thus, less water may have been transpired early in the season by the double-cropped soybean in relation to the monocropped soybean. If, on the other hand, transpiration rates were similar between monocropped and double-cropped soybean, wheat residue may provide an explanation. Some 60 days after planting, differences in extractable water under 76-cm rows were not significant (Table 2). This finding suggests that wheat residue increased infiltration and/or reduced evaporation from double-cropped plots in comparison to monocropped plots. NeSmith et al. (1987) found that winter wheat residue as a mulch on the soil surface increased soil water contents in the upper 10 cm of the profile by limiting evaporation, increasing infiltration, or reducing water use.

A third common type of interaction, between planting date, cropping system, and soybean row spacing occurred four times in 1983 and 1984, usually in mid-July or later. An interaction detected on 13 July 1983, typical for that year, is shown in Fig. 4. In 1983, the double-cropped 38-cm plots contained more extractable water than the double-cropped, 76-cm plots in Planting Dates 1 and 2. In Planting Date 3, however, the double-cropped 76-cm plots held more water than the double-cropped 38-cm plots. In 1984, Planting Date 2 responded as it did the year before, but the response of Planting Dates 1 and 3 in 1984 was similar to that of Planting Date 3 in 1983.

Fig. 4 reveals that, by 13 July, double-cropped soybean in 38-cm rows in the first planting had extracted nearly 2 cm more water from the profile than had the double-cropped soybean in 38-cm rows planted in the second planting, only 15 days after the first that season. These mid-season differences in extractable water between Dates 1 and 2 were due to more extraction from the soybean planted on the first relative to the second date. The earlier planted soybean had a deeper root system and had removed substantial quantities of water down to the 61-cm depth (data not shown). The later planted soybean had removed very little water, even from the uppermost portion of the profile.

In the double-cropped plots of the third planting, Fig. 4, the 76-rather than 38-cm row plots contained more extractable water. The disturbance of the wheat mulch on a greater portion of the soil surface with the no-till planter units likely led to more water being evaporated from the 38- than 76-cm plots in the 24 to 48 h after planting. This increased evaporation was likely because, on 13 July 1983, the uppermost 15 cm of the 38-cm plots contained 0.5 cm less extractable water than the 76-cm plots (data not shown). This 0.5-

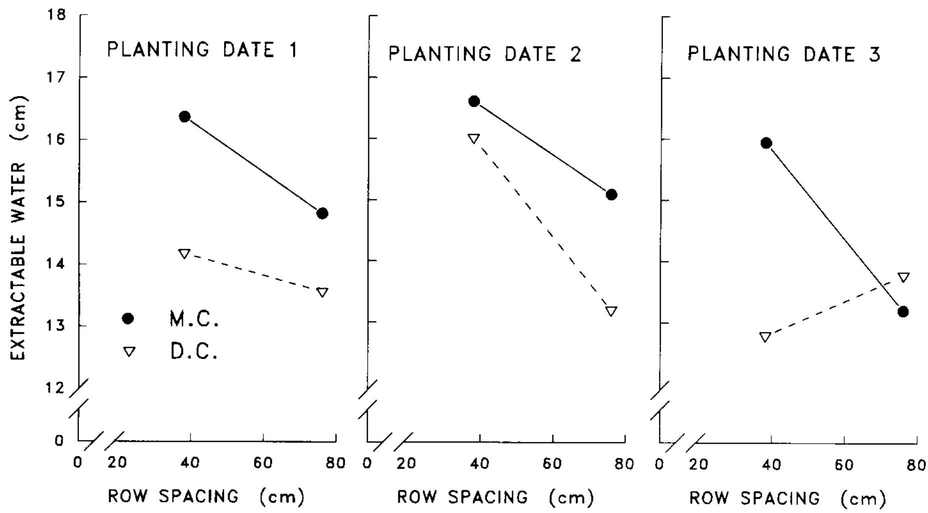

Fig. 4. Extractable water as a function of soybean row spacing for monocropped and double-cropped soybean for Planting Dates 1–3. Data illustrate a significant interaction detected on 13 July 1983.

Table 3
Soybean row spacing effects on soybean yield, 1982–1984. All yields are averaged over three planting dates and both monocropped and double-cropped production systems

Soybean row spacing (cm)	Soybean yield			
	1982 ($kg \cdot ha^{-1}$)	1983 ($kg \cdot ha^{-1}$)	1984 ($kg \cdot ha^{-1}$)	Average ($kg \cdot ha^{-1}$)
38	2610 a*	2230 a	2500 a	2450
76	2440 b	2000 b	2490 a	2310

* Means within a column not followed by a common letter differ significantly (using Duncan's New Multiple Range Test at $p = 0.05$ level).

cm water difference was nearly 52% of the difference in extractable water between the two entire 168-cm profiles (Fig. 4).

3.3. Soybean yield

Differences in extractable water were reflected in soybean yield (Table 3). Soybean row spacing, the most significant factor affecting extractable water throughout the study, influenced soybean yield in two of the three years studied. In 1982 and 1983, soybean plots with 38- rather than 76-cm rows had more extractable water (Fig. 3), and yielded 9% more (Table 3).

4. Conclusions

Three conclusions can be drawn from this study. First, soybean planting date or cropping system (monocropped vs. double-cropped), as a main effect, seldom influenced soybean extractable water. Later in the season, however, soybean planting date and cropping system interacted with row spacing and with each other to affect extractable water. Second, plots with 38- rather than 76-cm soybean rows nearly always contained significantly more extractable water, unless affected by planting date or cropping system. More extractable water under narrow rows was probably due to the maintenance of higher infiltration rates under the quicker-closing soybean canopies. Third, a soybean production system to efficiently use extractable water in 168-cm deep, silty clay soils in northeastern Mississippi is a wheat-soybean double-cropping system with soybean in 38-cm rows planted into standing wheat in late May or into wheat stubble on or before June 15.

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