INFLUENCE OF TILLAGE SYSTEM, PLANTING DATE AND CULTIVAR SELECTION ON SOIL WATER AND SOYBEAN YIELD UNDER DRYLAND SOYBEAN PRODUCTION

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ABSTRACT

Experiments were conducted at the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, in 1995 and 1996 to determine the influence of tillage system, planting date and cultivar selection on soil water storage, soybean (*Glycine max*, L. Merr.) yield and economics. The soil series was Sharkey silty clay. 'Williams 82', 'Manokin' and 'RA 452' soybean cultivars were planted in mid-April, and RA 452, 'Pioneer 9592' and 'Pioneer 9641' were planted in mid-May, mid-June and mid-July. The cultivars were stripped in three production systems consisting of no-till, fallow and conventional. Soil water levels were monitored gravimetrically in each tillage system weekly to a depth of 60 cm. The Sharkey silty clay maintained high soil water storage of 8 to 10 cm in the 0- to 60-cm depth. Sharkey silty clay was able to maintain high soil water for April- and May-planted soybean. The adequate soil water resulted in high yields for April- and May-planted soybean with the early maturity-group cultivars, Williams 82 and RA 452. Delayed planting dates conserved soil water and resulted in the highest soybean yields in June- and July-planted soybean with Pioneer 9592 and Pioneer 9641. The June no-till production system had the highest costs because of high herbicide usage. The highest net returns corresponded to the highest soybean yields. Overall, under a conventional production system on a Sharkey silty clay, the most profit was obtained when an early maturity group soybean was planted in April or May.

INTRODUCTION

Dryland soybean production encompasses approximately 65% of soybean (*Glycine max*, L. Merr.) grown in Arkansas. The low profitability of soybean relative to some other enterprises has resulted in increased interest in minimum input production systems. The common occurrence of a drought in the mid-South from mid-July to mid-September has contributed to low and stagnant yields in dryland soybean (Bowers, 1995; Heatherly, 1996). Commonly planted Maturity Group V and VI cultivars are in the critical reproductive stages during the late-season drought, and their yield potential can be greatly reduced by these droughts (Miller, 1994). Dryland producers subjected to the possibility of drought during a growing season require a production system to avoid or tolerate the effect of a drought. Manipulation of practices such as tillage system, planting date and cultivar selection could potentially increase soybean yield under dryland conditions.

Tillage Practices

Typical soybean production in the mid-South includes some type of mechanical tillage for seedbed preparation (Bowers, 1995). The general purpose of conventional tillage is to control weeds and create a favorable environment for seed emergence and plant growth. Conventional tillage provides a tilled soil layer of 15 to 25 cm deep. No-till is a cropping system in which the soil is left undisturbed prior to planting, and weed control is accomplished by herbicides. No-till systems are associated with conservation tillage, which is defined as a tillage and planting system that maintains at least 30% of the soil surface covered by residue at the time of crop emergence (Dick et al., 1989; Parsch et al., 1993).

Costs

Different management practices result in varying costs of production. Webber et al. (1987) noted that no-till production systems reduce soil erosion, decrease overall fuel consumption and equipment costs and conserve soil moisture. Although no-till generally saves fuel, labor and machinery costs, total costs may be higher due to increased herbicide expenditures as compared to conventional systems (Letey, 1984).

Planting Date

Soybean production in the mid-South has been primarily limited to Maturity Group V and VI cultivars, which are planted in May and June. Yield reductions due to drought stress occur in these cultivars quite often, because they are blooming, setting pods and beginning seed fill during July and August when there is a high probability of soil moisture deficit. Changing the planting date to an earlier or later time would shift the time when soybean plants bloom, set seed and mature, thus creating the possibility that moisture stress could be avoided during these critical periods. In the mid-South, higher rainfall amounts occur in the spring and fall with the greatest spring rainfall occurring from April to early June. This corresponds with early bloom and pod set in April-planted, early maturity, indeterminate and determinate soybean cultivars (Bowers, 1995; Miller, 1994). The early maturity group culti-

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vars experience cooler temperatures and lower evaporative demand, which reduces overall water demand. The ability of early maturity group cultivars to bloom and set pods under milder temperatures with adequate moisture increases the chance of profitable yields (Board and Hall, 1984; Heatherly, 1996; Miller, 1994).

Planting early-maturing cultivars, however, has disadvantages. Cool temperatures can delay emergence and retard growth rate. Planting dates may also be delayed due to spring rains, and a reduction in seed quality can occur (Unger and Cassel, 1991). Weed control problems at leaf drop may be associated with early Maturity Group III and IV cultivars (Dombek et al., 1995; More, 1994, Parsch et al., 1993). This can create harvesting problems and necessitate the extra cost of a desiccant application.

Research that has been conducted on late plantings of soybean has provided lower yield results for July planting dates as compared to May and June planting dates (Hancock, 1994; Moore, 1994). Some research at many locations suggests that day length, not water stress, is responsible for the declining yield after mid-June, since the yield reduction could not be eliminated with irrigation (Beuerlein, 1988; Board and Hall, 1984; Reeves and Tyler, 1996). Board and Hall (1984) have shown that a major reason for yield losses at nonoptimal planting dates is inadequate vegetative growth due to premature flowering, but yield losses due to late planting dates vary by year.

Indeterminate growth characteristics are being utilized more in southern cultivar selection. The main difference in growth habit between the determinate and indeterminate types is that indeterminate cultivars continue main stem elongation several weeks after the plants begin to flower; whereas determinate cultivars halt elongation of the main stem at the onset of flowering (Beuerlein, 1988). Indeterminate cultivars can cease growth temporarily and then restart when stress is removed. These growth characteristics may be important factors for soybean grown in the mid-South due to prolonged drought conditions.

Soil Moisture

Tillage systems influence soil water content through infiltration and runoff, evaporation and precipitation storage. Evaporation from a soil is affected by the residues left on the soil surface and by the soil properties. Tillage alters infiltration and runoff through surface residue, bulk density and soil crusting.

Soil crusts may develop on no-till and conventionally tilled soils, reducing water infiltration and increasing runoff. Water infiltration and runoff are also influenced by surface residue and bulk density. Soils with high residue prevent the formation of soil crusts. If soil residue is adequate, surface infiltration will be enhanced. Soils with low residue levels require tillage for enhanced infiltration (Unger and Cassel, 1991).

Conventional tillage may promote degradation of the soil physical condition by reducing the soil pore volume and water storage area (Letey, 1984). Tillage increases the susceptibility of the soil to compaction by traffic or natural consolidation. Plants growing in soils with tillage pans may undergo severe moisture stress after 5 to 8 days without rainfall (Reeves and Tyler, 1996).

Conservation tillage results in greater compaction of the top 10 cm of soil as compared to conventional tillage. However, this compaction can prevent more severe compaction at greater depths (Reeves and Tyler, 1996). Soils with less-available moisture favor high yields in early-maturity group cultivars whereas deep soils favor high yields in late maturity group cultivars (Miller, 1994).

The objective of this research was to evaluate cultural practices, including tillage practice, planting date and cultivar selection, for potential to increase soybean yield and profitability under dryland conditions.

MATERIALS AND METHODS

Field experiments were conducted in 1995 and 1996 at the Northeast Research and Extension Center at Keiser, Arkansas, on a Sharkey silty clay soil series. The experimental design was a split-split strip plot with four replications. The individual plot size was 3 m wide by 7 m long with 9-m alleys. The main plot was four planting dates: mid-April, mid-May, mid-June and mid-July. Subplots were tillage levels: no-till, fallow and conventional. Three soybean cultivars were stripped within each tillage level. The tillage subplots had a 3-m fallow border between tillage systems. The plots were not irrigated. Weather data were collected at the location, and all production inputs were recorded by planting date and production practice.

Tillage levels were based on practices that potentially conserve soil moisture. No-till plots were not disturbed from the fall prior to experiment establishment until the conclusion of the experiment. The fallow treatments were tilled 3 to 5 cm deep with a roto-tiller following each rainfall event prior to planting. Conventionally tilled plots were tilled 10 to 15 cm deep in the fall and prior to soybean planting or when vegetation reached a height of 15 to 24 cm.

Herbicide programs were designed for complete weed control (Table 1). Two weeks prior to planting, the no-till system received a burndown application of glyphosate (Roundup Ultra®) to desiccate winter weeds and emerging summer annuals. The no-till and fallow systems then received applications of metolachlor (Dual II®)+ a premix of metribuzin and chlorimuron (Canopy®) applied preemergence. A preplant incorporated application of trifluralin (Treflan®) + metribuzin and chlorimuron (Canopy®) was applied to the conventional system. All tillage systems received fomesafen (Reflex®) as a post-emergence over-the-top application as needed for weed control during the growing season. Dates of post-emergence herbicide applications varied and are presented in Table 2.

Cultivars were selected from the Arkansas Variety Selection Program (Dombek et al., 1995) and varied with planting date (Table 3). Cultivars in Maturity Groups III and IV were selected for the mid-April planting date, and cultivars in Maturity Groups IV, V and VI were used in the mid-May, mid-June and mid-July planting dates. Both indeterminate and determinate cultivars were used in the cultivar selection.

Soybean seeds were planted flat in 18-cm row spacing with a 3-m-wide John Deere no-till drill. Seeding rate was 9 to 12 seeds/m of row. Plots were harvested with a plot combine at maturity.

Soil moisture in the tillage production systems was measured gravimetrically at planting and every week during the growing season, except after rainfall when soils were saturated. Soil samples were taken at random to a depth of 8 cm from each tillage method plot at planting and after planting in 1995. In 1996, soil samples were taken to a depth of 60 cm. Soil sampling was discontinued when the earliest maturing cultivar in the planting date reached the R6 growth stage.

Economic analysis of the experiment was conducted using the Mississippi State University Budget Generator computer program. All economic inputs were recorded and entered. Variable and total costs were generated along with net returns. The average price of soybean used in the economic analysis to calculate net returns was $5.92/bu.

All data were subjected to analysis of variance using the GLM (General Linear Model) procedure of SAS. Means were separated using Fisher's Protected LSD (0.05).

RESULTS AND DISCUSSION

Soybean yields, economic costs and net returns could be pooled over years. Environmental conditions varied little between years. Rainfall levels were higher in 1996 but did not significantly affect soil water storage or soybean yield.

Tillage level had few significant influences on soil water storage and soybean yield (data not shown). The tillage levels implemented were expected to alter soil water evaporation rates and soil water storage (Mwendera and Feyen, 1994). However, the shallow tillage operations could not be conducted immediately after rainfall due to travel and labor restrictions, and some evaporation occurred before the implementation of the fallow tillage system. Consequently, soil water samples were taken after evaporation losses in each production system.

Soil samples for soil water storage determination were taken randomly by planting date each year. As a result, years could not be combined by sampling date and will be discussed separately. Soil samples for soil water storage determination were taken from only a 0- to 8-cm depth in 1995, and there was no influence on soil water storage or soybean yields due to the shallow sampling depth. In 1996, the soil was sampled to a depth of 60 cm with a new sampling technique utilizing lubricants, and only these data will be discussed.

Planting date significantly affected soil water storage and soybean yield and will be discussed by specific planting date. Also, cultivar selection significantly affected soybean yields at the varying planting dates. Therefore, individual cultivar yields will be discussed within a planting date. Soil water sampling was taken at random across the three cultivar strips for each tillage level. Therefore, cultivars and their effects on soil water storage and economics could not be evaluated.

Soil Water Storage

In 1996, soil water storage was similar among the April, May and June planting dates (Fig. 1). Frequent rainfall replenished soil water levels until August. However, some variation in soil water levels was observed in June and in the duration of drought during each planting date.

The April planting date had the lowest soil water storage in mid-June to mid-July (Fig. 1). Since soil water utilization began in April, the April-planted soybean roots had removed soil water for the longest duration. Drought conditions did not occur until August, allowing the April-planted soybean to reach maturity before severe water stress. These results coincide with the findings of Bowers (1995) and Miller (1994).

The May and June planting dates maintained slightly higher soil water levels in June and July than the plots planted in April (Fig. 1). The May and June planting dates conserved soil water in April and May that could be used in June and July. In August, the May and June planting dates decreased dramatically in soil water. Drought conditions resulted in the use of all available soil water.

The July planting date maintained the highest soil water storage in August during the drought conditions (Fig. 1). The delayed planting date allowed soil water conservation in April, May, and June in the absence of vegetation. Previous research (Hancock, 1994) showed that weed-free areas have higher soil water storage.

Soybean Yields

The April- and May-planted soybean had the highest yields (Table 4). Soybean yields decreased when the planting date was delayed due to drought and decreasing photoperiod.

The Maturity Group III cultivar, Williams 82, yielded the highest of the April-planted cultivars. The early maturity cultivar matures during the highest soil water storage levels, and its indeterminate growth patterns can increase vegetative growth, which can increase soybean yield. Therefore, Maturity Group III cultivars can avoid water stress and produce high yields (Bowers 1995; Heatherly, 1996; Miller, 1994). The Maturity Group IV cultivars, RA 452 and Manokin, have a longer growing season, which extended the reproductive stage into drought conditions for a longer duration (Fig. 1) and affected yield.

RA 452, a Maturity Group IV cultivar with indeterminate growth, had the lowest yield of the cultivars planted in the delayed planting dates due to premature flowering (Table 4). Pioneer 9592, a Maturity Group V cultivar with determinate growth, had the highest yields and was the best-suited cultivar for the May and June planting dates. Pioneer 9641, a Maturity Group VI cultivar with determinate growth characteristics, had the longest growing season of the cultivars and the lowest yields when planted in May and June due to dry conditions during its reproductive period. However, when planted in July, Pioneer 9641 had the highest soybean yields.

Economics Costs

The conventional production system had the lowest costs (Table 5). Mechanical preplant tillage operations for weed control in conventional tillage resulted in lower production costs than equivalent herbicide programs in no-till.

The fallow production system costs were slightly higher than the conventional production system. The fallow-tillage system had shallow tillage after rainfall events of >2 cm to destroy soil crusts. Shallow tillage was often performed two or three times a month during frequent rainfall events. Thus, the high number of tillage operations increased costs in the fallow production system as compared to the conventional production system.

The no-till production system had the highest costs (Table 5), because no-till required the application of a preplant burndown herbicide for adequate weed control. The preplant burndown herbicide application was more costly than mechanical tillage, resulting in higher variable and total costs than the conventional tillage production system.

The June planting date, regardless of tillage system, had the highest variable and total costs and July the lowest of the planting dates under fallow and conventional production systems (Table 5). This was due to weed pressure, which necessitated post-emergence applications for June planting dates, while July planting dates required only preplant or preemergence herbicide applications (Table 2). The lowest production variable and total costs in the no-till production system were in April due to low herbicide costs (Table 5).

Net Returns

Production systems greatly influenced net returns (Table 6). The no-till system provided the lowest net returns due to higher herbicide costs. The slight increase in costs of the fallow production system did not affect net returns, since the fallow system had slightly higher net returns than the conventional system for all planting dates except June. The high cost of the no-till production system resulted in a decrease of approximately $80/ha and $62/ha in net returns as compared to the fallow and conventional production systems, respectively.

Average net returns were the highest in April and May planting dates (Table 6). After May, net returns decreased sharply, becoming the lowest in July. A relatively low range occurred in soybean yields between years, and the planting dates with the highest net returns should be used. To achieve the lowest risk in soybean production and highest average net returns, the planting dates for soybean should spread out among all the planting dates.

SUMMARY

Soil Water Storage

The Sharkey silty clay maintained approximately 8 to 10 cm of soil water to a 60-cm depth. Thus, April- and May-planted soybeans on the Sharkey silty clay potentially avoided drought stress by maturing before soil water was depleted in the root zone. Cumulative water removal of early-planted soybean resulted in low soil water levels during July and August under drought conditions. Maintaining a vegetation-free surface conserved soil water, which could subsequently be used by late-planted (June and July) soybean. This would be especially important during seasons with prolonged drought periods.

Soybean Yields

Soybean yields were influenced by planting date and cultivar selection. April- and May-planted soybean plots yielded the highest with the Maturity Group III indeterminate Williams 82 being the best for April planting. The Pioneer 9592 Maturity Group V determinate cultivar was best suited for May planting. RA 452, a Maturity Group IV indeterminate cultivar, also had high yields when planted in May. Soybean yields typically declined in June and July planting dates relative to April and May plantings. Pioneer 9592 should be planted in May. June and July planting dates should be avoided.

Economics

No-till production systems were always more expensive than the fallow or conventional production systems. Tillage operations cost less than herbicide applications for weed control. Planting dates influenced costs because of herbicide requirements with the June planting date having the highest cost. High weed pressure in June required repeated applications of postemergence herbicides and resulted in high herbicide costs. The lowest cost occurred in the July planting date, which did not have to rely on post-emergence herbicide applications.

A no-till production system resulted in approximately a $80/ha and $62/ha loss in net returns as compared to the fallow and conventional production systems, respectively.

The net returns at each planting date followed the same trend as soybean yields. April- and May-planted soybeans had the highest yields and highest net returns.

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Table 1. Herbicide programs.

Trade name	Common name	Method of application[1]	Rate
			kg/ha
Roundup Ultra[2]	glyphosate	PPBD	1.12
Dual II + Canopy[3]	metolachlor + chlorimuron/metribuzin	PRE	2.8
Treflan + Canopy[4]	trifluralin + chlorimuron/metribuzin	PPI	1.12
Ref lex [3]	fomesafen	POST	0.42

[1]Method of application: PPBD = preplant burndown, PPI = preplant incorporated, PRE = preemergence, POST = postemergence.
[2]Treatments used only in no-till tillage system.
[3]Treatments used only in no-till and fallow tillage systems.
[4]Treatments used only in conventional tillage systems.

Table 2. Postemergence herbicide applications.

Planting date	Herbicide	Application timing and soybean stage: 1995 Date	1995 Stage	1996 Date	1996 Stage
April	Reflex	6/21	V5	6/27	V5
May	Reflex	6/21	V3	6/27	V3
June	Reflex	7/08	V2	7/14+7/25	V2+V3
July	Reflex	7/25	V2	- - -	

Table 3. Planting date and cultivar selection.

Planting date	Cultivar	Maturity group	Growth characteristics[1]
Mid-April	Williams 82	III	ID
	Manokin	IV	D
	Ring Around 452	IV	ID
Mid-May,	Ring Around 452	IV	ID
Mid-June,	Pioneer 9592	V	D
Mid-July	Pioneer 9641	VI	D

[1]ID = indeterminate; D = determinate.

Table 4. Influence of planting date and cultivar on average soybean yield.

Cultivar	Planting date: April	May	June	July
	kg/ha			
Williams 82	3516	----	----	----
Manokin	3289	----	----	----
RA 452	3245	3301	2425	1193
Pioneer 9592	----	3559	2624	1565
Pioneer 9641	----	3173	2386	1753

$LSD_{0.05}$ for comparing among planting dates = 161
$LSD_{0.05}$ for comparing among cultivars = 134

Table 5. Influence of planting date and tillage system on average variable and total economic costs at Keiser (1995 and 1996).

Tillage	Variable costs				Total costs			
system	April	May	June	July	April	May	June	July
	($/ha)							
No-till	260.98	294.40	343.70	326.93	316.14	354.03	409.25	393.20
Fallow	216.67	225.19	245.05	204.22	257.67	272.86	299.54	260.81
Conv.	204.07	224.62	224.62	177.96	250.61	255.25	276.91	228.08

$LSD_{0.05}$ for comparing variable cost means among planting dates = 2.47
$LSD_{0.05}$ for comparing variable cost means among tillage systems = 2.47
$LSD_{0.05}$ for comparing total cost means among planting dates = 2.47
$LSD_{0.05}$ for comparing total cost means among tillage systems = 2.47

Table 6. Influence of planting date and tillage system on average net returns.

Tillage	Planting date			
system	April	May	June	July
	$/ha			
No-till	412.27	358.67	164.55	-25.34
Fallow	464.28	490.91	218.37	56.71
Conv.	453.93	449.52	240.31	13.81

$LSD_{0.05}$ for comparing among planting dates 11.65
$LSD_{0.05}$ for comparing among tillage systems 12.71

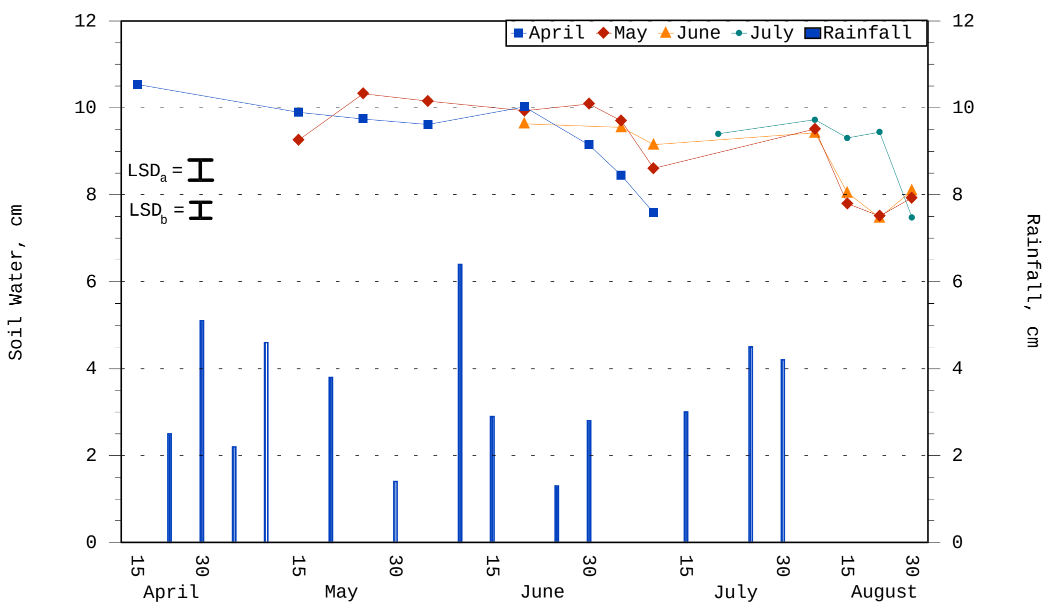

Fig 1. Influence of planting date and rainfall on soil water storage to a depth of 60 cm at Keiser in 1996. LSD (a) for comparing between planting dates. LSD (b) for comparing between sample dates.