TILLAGE AND ROW SPACING EFFECTS ON YIELD AND SOIL WATER CONTENT IN A WHEAT-SOYBEAN DOUBLE CROPPING SYSTEM

By

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CHAPTER I

INTRODUCTION

The ever increasing world population results in the need for continuous increases in production of food crops. Double cropping is one method by which the increased needs can be produced. Double cropping, producing two successive crops from the same acreage during one year, offers an opportunity to increase yields with maximum utilization of land area, time, energy, and other valuable resources.

New herbicides and equipment, reduced tillage practices, better crop varieties, and planting techniques make double cropping possible and profitable for many producers.

As a result of these developments, interest has increased in the possibility of using soybeans (*Glycine max* L. Merril) in a double cropping system following small grains, particularly wheat (*Triticum aestivum* L. em Thell). With the relatively long growing season, and particularly, higher annual rainfall in the eastern part of Oklahoma, there exists a high potential of double cropping soybeans and wheat in this area. However, in view of the typically dry conditions encountered during the summer months in Oklahoma, tillage methods that conserve soil moisture would seem to enhance the success of double cropping soybeans and wheat.

The objectives of this study were to evaluate the effects of tillage methods, row spacings, and varieties on the yields of soybeans and wheat in a double cropping system with special emphasis on the effects of tillage methods and row spacings on the volumetric soil water content in the double cropping system.

CHAPTER II

REVIEW OF LITERATURE

Double cropping increases use of land, increases income, and helps lower production costs (Hinkle, 1975). McKibben and Oldham (1973) describe double cropping in the Midwest as harvesting two crops a year on the same acreage: a small grain that was planted the previous fall, and a second crop planted after small grain harvest. Double cropping achieves greater utilization of solar energy and other climatic resources (Sanford et al., 1973).

According to Jeffers et al. (1973) and Phillips (1969), the most widely used double cropping program in the United States is small grains and soybeans. In Virginia, soybeans have been widely grown after barley, since it was a more dependable crop than either corn or sorghum when planted after barley (Camper et al., 1972).

A series of cropping systems involving two small grains (barley and wheat) and two soybean varieties (Calland and Essex) of different maturities were investigated by Tutt and Egli (1973). Double cropping was compared with conventional systems of planting and growing only small grains or soybeans. Soybeans planted after barley yielded 3427 kg/ha averaged across both years compared with 3454 kg/ha for conventional planted soybeans. In comparison with conventional planting, yields of the earlier maturing Calland were decreased 25% when planted after wheat, whereas yields of the later maturing Essex decreased only 15% when planted after wheat.

Sanford et al. (1973) found that the yield of wheat when double cropped was not affected by the method of tillage used for the previous crop. However, differences in wheat yields occurred due to the effects of the previous crop. Wheat following soybeans produced more grain than wheat following grain sorghum. This difference in yield is attributed to the influence of the soybean crop on increasing the soil nitrogen by fixation.

Conventional Tillage

Larson (1962) describes conventional tillage as a system of soil preparation for planting which includes plowing, disking, harrowing, and in many cases, subsequent cultivation.

Some of the advantages of conventional tillage are: (1) a fine seedbed for easy planting, (2) flexible and adaptable to a wide range of soil, crop, and weather conditions, (3) necessary equipment is readily available on most farms, and (4) results in yields as high or higher than other systems over a wider range of soil and climatic conditions (Graffis et al., 1973 and Hoeft et al., 1975).

Disadvantages of conventional tillage include: (1) higher cost because of the large number of tillage operations, (2) excessive tillage resulting in soil crusting and compaction, (3) small soil aggregates leading to reduced water intake, (4) subjects fine and compact soil to wind and water erosion, and (5) takes valuable time and decreases soil moisture in the plow layer, making it less suitable for double cropping (Graffis et al., 1973 and Hoeft et al., 1975).

Larson (1962) reports that if a layer of soil 7 inches thick with a bulk density of 1.4 gm/cm^3 is loosened by plowing to a bulk density of 1.0 gm/cm^3, the total porosity is increased from 47 to 62 percent. The total amount of water that could be stored temporarily in the initial 7-inch soil layer was 3.3 inches, but with the increased porosity resulting from plowing can be increased to 6.7 inches.

Cultivation is the best method of weed control, regardless of the tillage method, where weeds that are difficult to control such as Johnsongrass, cocklebur, and nutsedge are present. Tolerant weed species prosper under reduced tillage where a high reliance on chemical control forces a shift in weed populations. Plowing every three to four years is beneficial in reducing problem weeds when reduced tillage is used (Reichenberger, 1976 and Sanford et al., 1973).

Slow decaying organic matter from crop residues in no-tillage fields provides an ideal environment for crop pests. Several workers indicate that soil-inhabiting insects may be the most serious threat to no-till crop production, while conventional tillage not only exposes grubs to environmental stresses but also enables insecticides to be incorporated into the soil (Musick and Petty, 1973).

Fall plowing decreases tillage problems on poorly drained silty clay or silty clay loam soils with high organic matter content. These soils are usually wet in the spring and develop poor physical conditions if tilled when too wet. Fall plowing also allows these cool and wet soils to warm up more rapidly in the spring, thus insuring earlier planting than when reduced tillage systems are used (Graffis et al., 1973 and Peterson, 1973).

Yield differences caused by tillage or mulch cover are reduced or eliminated in growing seasons with excellent rainfall. With adequate well distributed rainfall, there may be sufficient water to satisfy the needs of the crop and yields will be nearly equal for all tillage systems (Bone et al., 1977).

Minimum Tillage

Minimum tillage is a group of soil preparation methods for planting in which the number of operations and trips over the field is less than in conventional tillage (Larson, 1962 and Wiese, 1972).

Within the last 15 years, two major technological advances have greatly increased the possible successful alternatives to plow based tillage systems. One is the development of both selective and non-selective herbicides that can control unwanted vegetation without tillage. The other is development of planting equipment that can properly place seeds in a wide range of tilled and non-tilled soils, regardless of soil roughness or residue cover (Bone et al., 1977 and Sanford et al., 1973).

Graffis et al. (1973) lists some of the advantages of minimum tillage as (1) lower cost than conventional tillage because there are fewer tillage operations and (2) mulch from the previous crop results in higher water intake and less wind and water erosion. Disadvantages include (1) planters must be equipped to plant in crop residues, (2) crop residues may interfere with herbicides or cultivation, resulting in a more severe weed problem and (3) crop residues may harbor insect and disease pests.

In minumum tillage systems, plant residues are managed on a year round basis whereby harvesting, tillage, planting, and cultivating operations are performed in view of keeping protective amounts of residue on the soil surface. Instead of being removed, destroyed, or plowed under, residues are left on the soil surface for protection against wind and water erosion (Roberts et al., 1963).

Crop residues affect soil water storage capacity and soil water content. Residues increase soil moisture available for plant use by reducing evaporation and increasing infiltration of water into the soil. Evaporation is reduced by lowering the soil temperature and the vapor pressure gradient between the soil water and the atmosphere. Crop residues on the surface are also effective in maintaining good soil structure (Larson, 1962, and Meyer and Mannering, 1961).

The extra field traffic required for conventional farming systems may destroy the initial suitable soil physical condition by compaction and thereby limit plant growth. The effects of compaction are most pronounced on clay soils where less compaction from minimum tillage is a definite advantage. Excessive tillage affects silty soils or soils with excellent tilth less than plastic soils with poor tilth (Bowers and Bateman, 1960).

Double cropping with conventional tillage systems provides a greater opportunity for wind and water erosion than with minimum tillage. Since the moisture supply is often low after a small grain harvest, tillage methods that conserve soil moisture are especially desirable (Hayes, 1973).

Bone et al. (1977) found that corn yields and, to a lesser extent, soybean yields on well-to-moderately-well drained soils respond favorably to minimum tillage and mulch cover provided by the previous crop.

Jeffers et al. (1973) found that disking resulted in higher yields of double cropped soybeans than no-tillage at several locations in Ohio. However, at other locations, disking or field cultivation followed by a conventional planter resulted in lower yields than no-tillage due to poor stands. The disking or field cultivation did not prepare the soil adequately for the conventional planter to cover the seeds properly.

Erbach and Lovely (1974) suggested that weed control methods for minimum tillage must be altered from those used for conventional tillage. Consideration should be given to modify the weed control equipment, chemicals and techniques used for conventional tillage, selecting those most adapted to minimum tillage conditions.

No-Tillage

A method of double cropping soybeans after small grains is no-tillage. In this method, the second crop is planted in the small grain stubble without any seedbed preparation; a no-till planter opens a narrow slit in the soil, places the seed in this slit and presses the soil around the seed. Weeds are controlled by use of herbicides and either no cultivation or a minimum number of cultivations (Hinkel, 1975).

Advantages of no-tillage production include (1) lower tillage costs, (2) maximum control of wind and water erosion, (3) earlier planting, (4) reduced soil compaction, (5) yields equal to or higher than those from conventional tillage, and (6) reduced double cropping risks (Blevins and Cook, 1970; Graffis et al., 1973; Gregory et al., 1971; and Phillips, 1969).

Disadvantages of no-tillage production consist of (1) special planting equipment required, (2) weed control problems due to interference of crop residues with herbicides, (3) poor stands which limit yields, and (4) insect and disease development due to crop residues (Graffis et al., 1973 and Gregory et al., 1971).

Studies conducted in Arkansas by Hinkle (1975) showed that yields of a second crop planted by the no-tillage method and grown without tillage during the growing season resulted in comparable yields to conventional tillage when conditions were favorable for good weed control by herbicides. However, when little or no weed control was obtained with the no-tillage method by herbicides, yields were reduced with the no-tillage system.

A study was conducted in Mississippi by Sanford et al. (1973) where no-tillage and conventional tillage methods were compared using double cropped soybeans. The two year average yield of soybeans was 1,708 kg/ha for no-tillage and 2,250 kg/ha for conventional tillage. This difference was due mainly to lack of weed control by herbicides in the no-tillage plots. In the third year, when the crop was hand hoed, no yield differences occurred due to tillage methods. Weed control was the greatest problem encountered with no-tillage.

Studies conducted in Kansas by Knight (1973) with tillage treatments of chisel plow and no-tillage, resulted in soybean yields of 2,325 and 2,450 kg/ha, respectively.

Jeffers et al. (1973) in Ohio found that yields for double cropped soybeans planted no-tillage, have been equal to or better than any other tillage system at several locations and years. The yield differences were attributed to the conservation of soil moisture in the no-tillage treatments.

Soil measurements by Jones et al. (1968) indicated that the mulch provided by no-tillage reduced evaporation and runoff from the soil surface. Results from the studies in Virginia show that the average soil moisture in the top 15 cm was higher under no-tillage than with conventional tillage.

A Kentucky study was conducted by Blevins et al. (1971) to compare the effect of no-tillage versus conventional tillage corn production on soil moisture. No-tillage treatments had higher volumetric moisture contents to a depth of 60 cm during most of the growing season. The greatest differences occurred in the upper 0 - 8 cm depth. Beyond a depth of 60 cm, systems of tillage had little influence on soil moisture during the growing season. The conservation of soil moisture under no-tillage is associated with soil conditions that maintain good surface infiltration, reduction in evaporation due to the surface mulch, and the absorptive properties of the decaying roots and surface mulch.

Bennet et al. (1973) reported that lower soil temperatures under mulch reduced evaporation rates considerably in the no-till plots, and coupled with reduced runoff, resulted in a significantly greater amount of available soil moisture for plant growth.

Jones et al. (1969) showed results that emphasize the importance of surface mulch in conserving water and reducing runoff. Results indicated that soil water in the major root zone area was the primary factor causing plant growth and yield differences among tillage treatments. The value of the sod mulch in the no-tillage system was evident throughout the study.

Row Spacing

Hinkel (1975) reports the use of narrow rows (48 cm) as opposed to standard width rows (96.5 cm) with no-tillage had variable effects on the yields of soybeans and grain sorghum. However, there was a tendency for increased soybean yields when narrow rows were used.

The importance of narrow row width was illustrated by studies conducted in Ohio by Jeffers et al. (1973). The authors state that narrow rows are necessary to achieve maximum sunlight interception and yield, since small plants, which are generally the case when double cropping, do not produce a canopy that covers the soil completely when wide rows are used. Yields were increased 400 to 670 kg/ha when planted in 38 cm rather than 75 cm rows.

Tutt and Egli (1973) report that two soybean varieties, representing early and full season maturities were double cropped no-till in wheat stubble at three row spacings (25, 50, and 75 cm). The yield of both varieties increased as row spacing was narrowed. The yield of the early variety, Calland, was increased 15% as the rows were narrowed from 75 to 50 cm and increased another 10% as rows were narrowed from 50 to 25 cm. Yield of the full season variety, York, increased 19% as rows were narrowed from 75 to 50 cm and increased another 11% as rows were narrowed from 50 to 25 cm.

In Kentucky, Shane et al. (1969) tested three soybean varieties with three row spacings in a three year study. Amsoy, Clark 63, and Hood produced average yields of 2,654 kg/ha in 50 cm rows, 2,728 kg/ha in 75 cm rows, and 2,600 kg/ha in 101 cm rows for the three year period.

Carter and Hartwig (1962) noted maximum grain yields from soybeans grown in a short season will be obtained from narrow rows, and that the row width which will result in maximum yields also depends on the growth type of the soybeans, soil fertility, and location.

The highest yields of double cropped soybeans in Illinois were achieved with varieties from maturity groups III and IV when planted in 51 cm rows. Yields obtained for 50 and 75 cm row spacings were 2,041 kg/ha and 1,672 kg/ha, respectively (Stuckey, 1976).

Oswalt et al. (1969) conducted a row spacing study using Ford, Clark 63, and Hill soybean varieties spaced 36, 53, and 71 cm between rows. Results indicated that the varieties produced highest yields at the 53 cm row spacing.

Research in Arkansas by Frans (1959) indicated that soybeans grown in rows narrower than the conventional 91 to 107 cm rows would on occasion produce higher yields than those in conventional rows. It appeared from this data that the major advantage from close spacing in cases where an increased yield was obtained was better control of weeds.

The use of narrow row spacings have been shown to reduce weed competition. Burnside and Collville (1964) have shown that if weeds are suppressed early in the season, the narrow row soybean canopy effectively suppresses weeds later. The use of narrow rows increased yields and reduced the need for tillage and the amount of herbicide required. Soybeans in the 25, 50, 75, and 100 cm rows completely shaded the ground between the rows in 36, 47, 58, and 67 days, respectively. Weed populations increased as the row width increased and as soybean yields increased, weed yields decreased. Similar results were observed by Burnside (1977).

Soil Water and Yield

Many factors are important in soybean production but water stress at critical growth periods appears to be one of the most frequent limiting factors. Rogers and Thurlow (1970) state that the true "yield barrier" for soybean production generally is lack of water. In a maximum yield test at eight Alabama locations, Rogers and Thurlow found that soybean yields averaged 44% higher the year of highest rainfall during pod fill (90% more rain) than the average for a six year period.

Herpich (1973) found that adequate soil moisture is essential to the production of optimum yields and that total water use by soybeans ranges from 46 to 66 cm, depending on location. Early moisture stresses (pre-bloom) caused less yield reduction than stress later in the reproductive stage of development. It was found that 65 to 75 percent of the soybeans' total water needs is used during the period of 40 to 100 days after emergence.

Hiler et al. (1974) determined that the most susceptible stage to damage due to water stress for soybeans is late flowering and early pod formation. Nickell (1973) found that the photosynthetic rate of the soybean plant during the growing season is highest during pod filling. Water stress during this period caused the greatest yield reduction.

Doss et al. (1974) found that maintaining available soil water below 10% for 10 days during flowering, early pod fill, and late pod fill reduced soybean yields. Yields were reduced more as the water stress period was delayed from flowering to late pod fill. Maintaining water below the 10% level for 10 days during late pod fill reduced yields by 450 to 990 kg/ha. Yields were higher when water was applied after full-bloom than earlier.

Somerhalder and Schleusener (1960) reported that one 10 cm irrigation at late-bloom resulted in higher soybean yields than did 10 cm of irrigation water divided between applications at early- and late-bloom. Soybeans irrigated only at late-bloom also outyielded those irrigated with 20 cm of water distributed throughout the season.

In a two year study of irrigating soybeans, Brady et al. (1974) found that (a) irrigation increased soybean yields about 20 percent; (b) one-third to one-half the water necessary for full-season irrigation produced equal yields if applied during the podding stage of growth; and, (c) most efficient use of water occurred when irrigation was initiated in the podding stage or at 60 to 65 percent soil moisture depletion level in the vegetative or flowering stages.

Doss and Thurlow (1974) found that daily water use rates differed little between row widths except that for a period early in the season when plants were 25 to 60 cm high more water was used on 90 cm than on 60 cm rows. The lower water use rate on 60 cm rows probably resulted from less evaporation from the soil surface due to more shading effect by the narrower rows during the early season before complete ground cover was obtained in the 90 cm rows. The authors concluded from this data that water use rates were influenced more by soil water regime than by row width.

CHAPTER III

MATERIALS AND METHODS

Field studies were conducted on double cropping soybeans after wheat under dryland conditions on the Oklahoma Vegetable Research Station, Bixby, Oklahoma, from December, 1975, to November, 1977.

The soil of the experimental area was Wynona silty clay loam. The Wynona series is classified as fine silty, mixed, thermic Cumulic Haplaquolls. This series consists of deep, slowly permeable, nearly level soils on broad flood plains. In a typical profile the surface layer is very dark brown, mildly alkaline silty clay loam 25 cm thick. The remaining 35 cm of the surface layer is black, slightly acid silty clay loam. The upper part of the subsoil is 50 cm of very dark gray, slightly acid silty clay loam. The lower part of the subsoil, to a depth of 160 cm is very dark gray, neutral silty clay loam (Cole et al., 1977).

1976 Experiment

Conventional tillage was used to prepare a seedbed prior to planting wheat in the fall of 1975. Soybeans had been grown on the experimental area the previous summer. The wheat variety, Tam W - 101, was planted on December 11, 1975, at a seeding rate of 100 kg/ha. The relatively high seeding rate was used due to the late planting date. Nitrogen (N) and potassium (K_2O) were applied on February 20, 1976, at the rate of 44.8 and 112 kg/ha, respectively. The fertilizer was broadcast as a bulk blend of ammonium nitrate (NH_4NO_3) and muriate of potash (KCl).

The experiment was arranged in a 4 x 2 x 2 factorial (4 tillage-management systems, 2 row spacings, and 2 soybean varieties). Conventional tillage, minimum tillage, no-tillage, and single crop conventional tillage comprised the tillage-management systems. The two row spacings studied were 50 and 75 cm. The two soybean varieties studied were Forrest (Group V) and Calland (Group III). A single crop conventional tillage wheat treatment was also established.

A randomized complete block design was used with four replications of the 17 treatment combinations. Plots were 45.7 meters by 6.09 meters.

The wheat was harvested on July 6, 1976, using an Allis Chalmers Gleaner A mechanical harvester. The late harvesting date was due to wet conditions. The entire experimental area (1.23 hectares) was bulk harvested and the yield per plot was calculated to be 2,486 kg/ha.

Immediately after the wheat harvest, the plots were laid out and treatments were established. The tillage-management systems are described in detail as follows:

1. Conventional Tillage (CT). Plots were moldboard plowed once and tandem disked twice.
2. Minimum Tillage (MT). Plots were tandem disked twice.
3. No-Tillage (NT). Soybeans were seeded directly into standing wheat stubble.
4. Single Crop Conventional Tillage (SCS and SCW). The tillage for the single crop soybean treatment (SCS)

consisted of moldboard plowing plus two tandem diskings. The single crop wheat treatment (SCW) remained in stubble mulch until wheat planting. Prior to wheat planting these plots were tandem disked twice to establish a seed bed.

After tillage was completed, soybeans were planted on July 10, 1976, at the rate of 56 kg/ha using a four row Allis Chalmers no-till planter. The planter was equipped with a fluted coulter 5 cm wide, double disk openers, and 3.8 cm depth bands. All seed was inoculated and no fertilizer was applied at the time of planting.

Herbicides were applied immediately after planting. Roundup [N - (phosphonomethyl) glycine], Surflan [3,5 - dinitro - N^4, N^4 - dipropylsulfanilamide] and Sencore [4 - amino - 6 - tert - butyl - 3 - (methythio) - as - triazine - 5 (4H) one-] were applied to a specified one-half of each plot at the rates of 0.84, 1.12, and 0.40 kg/ha, respectively. Roundup, Lasso [2 - chloro - 2', 6' diethyl - N - (methoxymethly) acetamide], and Lorox [3 - (3,4 - dichlorophenyl) - 1 methoxy - 1 - methylurea] were applied to the remaining one-half of each plot at the rates of 0.84, 2.24, and 0.84 kg/ha, respectively. No weed control other than herbicides was initiated.

The Calland and Forrest soybean plots were harvested on November 5 and November 10, 1976, respectively. A 3.05 meter wide strip was mechanically harvested from the center of each plot.

1977 Experiment

All materials and methods in the 1977 experiment were the same as those in the 1976 experiment, unless specified as follows.

The entire experimental area received two tandem diskings following the 1976 soybean harvest. Wheat was planted at the rate of 100 kg/ha on November 19, 1976. Nitrogen (N), at the rate of 50.4 kg/ha, was broadcast in the form of ammonium nitrate (NH_4NO_3) on March 16, 1977. Wheat yields were obtained by mechanically harvesting a 3.05 meter wide strip from the center of each plot on June 14, 1977. All plots received the same tillage-management systems in 1977 as in 1976. Soybeans were planted at the rate of 72.8 kg/ha on June 18, 1977.

Due to sprayer equipment failure, the herbicide combination of Roundup, Lasso, and Lorox was not applied until June 20, 1977. The seed had already germinated and young seedlings were emerging. Herbicide damage was noted on some plots. Damage was most severe on the Calland variety planted in the conventional tillage plots.

The soybeans were mechanically harvested on November 12, 1977. A 3.55 meter and 3.81 meter wide strip was harvested from each 50 and 75 cm row spacing plot, respectively.

Soil Water Measurements

The neutron scatter method was used to measure the volumetric soil-water content. One access tube per plot was installed between the rows. Treatments monitored included conventional tillage (50 and 75 cm rows), no-tillage (50 and 75 cm rows), single crop conventional tillage soybeans (50 and 75 cm rows), and single crop conventional tillage wheat. Measurements were made on three of the four replications and only for the Forrest variety. The water content measuring device was a Nuclear-Chicago P - 19 probe. Measurements were made on several dates during the 1976 and 1977 growing seasons. The sampling dates correspond with certain growth stages of the wheat and soybean plant as described by Large (1954) and Fehr et al. (1971), respectively (Table I). Measurements were made at depths of 15, 30, 45, 60, 75, 90, 105, and 120 cm. The 15 cm reading utilized a calibration curve developed for this depth. All other depths were from a curve developed for deep readings.

TABLE I

SAMPLING DATES FOR SOIL WATER CONTENT AND RESPECTIVE CROPS AND GROWTH STAGES

Dates	Crop	Stage and Description	
May 11, 1976 May 16, 1977	Wheat	10.5	Flowering ended, kernel "watery ripe"
June 19, 1976 June 11, 1977	Wheat	11.	Fully ripe; kernel hard and difficult to divide with the nail
July 29, 1976 July 18, 1977	Soybeans	V4.	Four nodes on the main stem beginning with the unfoliate node
August 25, 1976 August 22, 1977	Soybeans	R2.	Full bloom; flower at node immediately below the uppermost node with a completely unrolled leaf
September 25, 1976	Soybeans	R6.	Pod containing full size green beans at one of the four uppermost nodes with a completely unrolled leaf

CHAPTER IV

RESULTS AND DISCUSSION

Precipitation

Precipitation during 1976, particularly during the soybean growing season, was considerably below the 25-year average (Table II). The 1977 total precipitation was near normal and well distributed, with the exception of September being above normal and October being considerably below normal. The soybean yields obtained reflect the precipitation patterns with overall yields lower in 1976 than in 1977.

Soybean Yields

The analyses of variance for soybean yields showed varieties to be highly significant in both 1976 and 1977 (Table III). Forrest variety had significantly higher yields than the Calland variety both years (Table IV). This may be partially due to the Forrest variety being more drought tolerant than the Calland variety, making the Forrest variety more suitable for double cropping. The low yields of the Calland variety in 1977 were due in part to herbicide damage explained in the materials and methods. Damage was most severe on the conventional tillage plots and yields were reduced (Tables V and VI). Damage was also noted on the Forrest variety, but yields did not seem to be affected.

TABLE II

DISTRIBUTION AND TOTAL RAINFALL FOR 1976 AND AND 1977 AND THE 25-YEAR AVERAGE (1950-1975) AT THE VEGETABLE RESEARCH STATION NEAR BIXBY, OKLAHOMA

Month	Rainfall (cm)		
	1976	1977	25-Year Average
January	0.00	2.16	3.91
February	1.78	4.01	4.14
March	7.19	8.74	6.60
April	14.12	5.26	9.96
May	6.20	12.75	11.84
June	4.27	9.47	11.56
July	6.93	8.43	9.40
August	8.51	7.65	7.11
September	7.98	21.74	11.10
October	4.98	5.08	8.15
November	1.63	6.83	6.55
December	2.79	1.78	4.83
Totals	66.37	93.90	95.05

TABLE III

MEAN SQUARES FOR SOYBEAN YIELDS (kg/ha) IN 1976 AND 1977

Source	df	Mean Squares 1976	Mean Squares 1977
Reps	3	935515**	102030
Variety (V)	1	2066267**	7677220**
Tillage-Management (TM)	3	58275	4523298**
TM x V	3	238222*	120185
Row Spacing (RS)	1	67593	40644
RS x V	1	420079*	1884
TM x RS	3	151168	54333
TM x RS x V	3	25896	24451
Error	45	57486	54296

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

TABLE IV

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY VARIETY IN 1976 AND 1977

Variety	Yield (kg/ha)	
	1976	1977
Calland	1164	1054
Forrest	1523	1746
$LSD_{.05}$	121	117

In 1976, tillage-management effects were not significant (Table III). However, the single crop soybeans had lower yield than conventional tillage and no-tillage (Table VII). Disking was initiated for weed control prior to planting in the single crop soybeans. Loss of top soil moisture by evaporation in these plots resulted in poor stands and subsequently lower yields. All other treatments were shaded by standing wheat with top soil moisture losses minimized and good stands were established. This suggests that if single crop planting is delayed into July, yields of the single crop soybeans may be reduced due to the loss of top soil moisture by evaporation and subsequently poor stands.

The analysis of variance of soybean yields showed tillage-management to be highly significant in 1977 (Table III). Soybeans were planted on June 18, 1977, and the single crop soybeans had higher yields than in 1976 when they were planted late. Single crop soybeans

TABLE V

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY VARIETY, ROW SPACING, AND TILLAGE-MANAGEMENT SYSTEM IN 1977

	Tillage-Management System							
	CT		MT		NT		SCS	
Row Spacing (cm)	50	75	50	75	50	75	50	75
Variety								
Forrest	1174	1022	1741	1780	1745	1668	2429	2413
Calland	435	400	779	974	1353	1128	1747	1614
LSD (.05 level) = 341 kg/ha								
Averaged Over Varieties	805	711	1260	1377	1549	1398	2088	2014
LSD (.05 level) = 242 kg/ha								

TABLE VI

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY VARIETY, ROW SPACING, AND TILLAGE-MANAGEMENT SYSTEM IN 1976

	Tillage-Management System							
	CT		MT		NT		SCS	
Row Spacing (cm)	50	75	50	75	50	75	50	75
Variety								
Forrest	1760	1778	1633	1365	1649	1183	1504	1311
Calland	1007	1166	1040	1140	1374	1174	1039	1368
LSD (.05 level) = 332 kg/ha								
Averaged Over Varieties	1384	1472	1337	1253	1512	1179	1272	1340
LSD (.05 level) = 235 kg/ha								

had a significantly higher yield than all other tillage treatments. Minimum tillage and no-tillage were not significantly different from each other but both were significantly different from conventional tillage (Table VII).

TABLE VII

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1976 AND 1977

Tillage-Management	Yield (kg/ha) 1976	1977
Conventional Tillage	1428	758
Minimum Tillage	1295	1319
No-Tillage	1345	1474
Single Crop Soybeans	1305	2051
$LSD_{.05}$	171	166

In 1977, no-tillage had the highest yields of the double crop treatments (Table VII). However, poor weed control was noted in the no-tillage treatment. Higher yields for no-tillage possibly could have been achieved with better weed control.

Row spacing was not significant in 1976 or 1977 (Table III). However, the 50 cm row spacing average yields were higher both years (Table VIII). The effect of row spacing was most evident in no-tillage plots where the narrow row spacing generally had higher yields both years (Tables V and VI). Better weed control in the narrow rows may have contributed to the higher yields. For all other treatments, row spacing effects were variable and generally yield differences due to row spacing were small.

TABLE VIII

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY ROW SPACING IN 1976 AND 1977

Row Spacing (cm)	Yield (kg/ha) 1976	1977
50	1376	1426
75	1311	1375
$LSD_{.05}$	121	117

A significant row spacing x variety interaction occurred in 1976 (Table III). Due to this interaction, row spacings were compared within varieties (Table IX). The Forrest variety had significantly higher yields in the 50 cm row spacing. The difference in yield between row spacings was not significant for the Calland variety; however, the 75 cm row spacing had higher average yields. This interaction was not significant in 1977 (Table III) and both varieties produced higher average yields at the 50 cm row spacing (Table IX).

A significant tillage-management x variety interaction occurred in 1976 (Table III). Due to this interaction, tillage-management systems were compared within varieties (Table X). Forrest yielded higher when conventionally tilled as compared to Calland, which had the highest average yields when no-tilled. This interaction was not significant in 1977 (Table III) and both varieties had significantly higher yields when single cropped.

TABLE IX

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY VARIETY AND ROW SPACING IN 1976 AND 1977

Variety	Row Spacing (cm)	Yields (kg/ha) 1976	Yields (kg/ha) 1977
Forrest	50	1636	1772
Calland	50	1115	1079
Forrest	75	1409	1720
Calland	75	1212	1030
$LSD_{.05}$		171	166

Wheat Yields

The analysis of variance of 1977 wheat yields (excluding the single crop wheat treatment) showed the residual effects of soybean varieties to be highly significant (Table XI). Plots that had grown Calland soybeans the previous summer (1976) produced significantly

TABLE X

MEAN SOYBEAN YIELDS (kg/ha) AS AFFECTED BY VARIETY AND TILLAGE-MANAGEMENT SYSTEM IN 1976 AND 1977

Year	Variety	Tillage-Management			
		CT	MT	NT	SCS
1976	Forrest	1769	1499	1415	1407
	Calland	1086	1089	1274	1203
	$LSD_{.05}$	242			
1977	Forrest	1098	1761	1707	2421
	Calland	418	877	1241	1681
	$LSD_{.05}$	235			

TABLE XI

MEAN SQUARES FOR WHEAT YIELDS (kg/ha) IN 1977 EXCLUDING SINGLE CROP WHEAT TREATMENT

Source	df	Mean Squares
Rep	3	291326**
Variety (V)	1	207246**
Tillage (T)	2	96670**
T x V	2	59138**
Row Spacing (RS)	1	23027
RS x V	1	5302
T x RS	2	2423
T x RS x V	2	1821
Error	33	6973

**Significant at the 0.01 probability level.

higher wheat yields the following spring (1977) than plots that had grown Forrest soybeans (Table XII). This effect is probably due to the lower soybean yields of the Calland variety and an accumulation of soil water not used in producing the soybean crop (Table IV).

TABLE XII

RESIDUAL EFFECTS OF SOYBEAN VARIETY ON WHEAT YIELDS (kg/ha) IN 1977

Soybean Variety	Wheat Yield (kg/ha)
Forrest	2303
Calland	2434
$LSD_{.05}$	49

Residual effects of tillage of the soybean crop on wheat yields were determined to be highly significant based on the analysis of variance (Table XI). Conventional tillage versus no-tillage were not significantly different but both were significantly different from minimum tillage (Table XIII).

The analysis of variance shows a highly significant tillage x variety interaction (Table XI). As a result of this interaction, tillage systems were compared within varieties (Table XIV). The Calland plots had a significantly higher yield than the Forrest plots when conventionally tilled. The difference in wheat yields between

Calland and Forrest plots was not significant in minimum and no-tillage; however, Calland plot wheat yields tended to be higher than Forrest. Once again, this is possibly due to the lower yields of the Calland soybeans and the relatively higher yields of the Forrest soybeans, particularly in conventional tillage (Table V).

TABLE XIII

RESIDUAL EFFECTS OF SOYBEAN TILLAGE ON WHEAT YIELDS (kg/ha) IN 1977

Tillage of Soybeans	Wheat Yield (kg/ha)
Conventional Tillage	2411
Minimum Tillage	2279
No-Tillage	2416
$LSD_{.05}$	61

Soybean row spacing effects on wheat yields were not significant in the analysis of variance (Table XI). However, the 50 cm row spacing plots generally had higher wheat yields than the 75 cm row spacing plots (Table XV).

The single crop wheat treatment was excluded from the previous analysis of variance due to unequal sample size. The single crop treatment mean was comprised of only four observations in contrast with the tillage means which were comprised of 16 observations. Therefore, comparisons could not be made between the single crop treatment mean and the tillage means. A separate analysis of variance was made, including the single crop treatment (Table XVI).

TABLE XIV

RESIDUAL EFFECTS OF SOYBEAN VARIETY AND TILLAGE ON WHEAT YIELDS (kg/ha) IN 1977

	Soybean Tillage		
Soybean Variety	CT	MT	NT
Forrest	2275	2250	2384
Calland	2547	2308	2448
$LSD_{.05}$	85		

The analysis of variance of wheat yields (including the single crop wheat treatment) showed that treatments were highly significant. The single crop wheat yield was significantly higher than the yield of all other treatments (Table XVII). The lower wheat yield of the double crop treatments when compared to the wheat yield of the single crop treatment illustrates the effect of double cropping on the following years' wheat yields. This effect is probably due to higher soil moisture content in the single crop wheat.

TABLE XV

MEAN WHEAT YIELDS (kg/ha) IN RELATION TO RESIDUAL EFFECTS OF TILLAGE, ROW SPACING, AND VARIETY OF SOYBEANS IN 1977

	Tillage					
	CT		MT		NT	
Row Spacing (cm)	50	75	50	75	50	75
Soybean Variety						
Forrest	2298*	2252	2235	2265	2410	2357
Calland	2580	2514	2339	2278	2481	2414
Averaged Over Varieties	2439**	2383	2287	2271	2446	2386

*LSD (.05 level) = 120 kg/ha.

**LSD (.05 level) = 85 kg/ha.

TABLE XVI

MEAN SQUARES FOR WHEAT YIELDS (kg/ha) IN 1977 INCLUDING SINGLE CROP WHEAT TREATMENT

Source	df	Mean Squares
Rep	3	332022**
Treatment	12	117289**
Error	36	7372

**Significant at the 0.01 probability level.

Soybean Yields of Treatments Monitored for Soil Water Content

The analysis of variance of the soybean yields for the treatments monitored for soil water content (conventional tillage, no-tillage, and single crop soybeans) show that tillage-management was highly significant in 1976 (Table XVIII). Conventional tillage had significantly higher yields than both no-tillage and single crop soybeans (Table XIX). Topsoil moisture was very limited when soybeans were planted in 1976. Poor stands occurred in no-tillage and the single crop soybeans due to the dry conditions. The moldboard plowing of the conventional tillage treatment brought some moisture to the surface, resulting in better stands and higher yields than the other treatments.

Tillage-management was significant in 1977 (Table XVII). Single crop soybeans had significantly higher yields than conventional tillage

TABLE XVII

MEAN WHEAT YIELDS (kg/ha) IN RELATION TO MANAGEMENT SYSTEMS AND RESIDUAL EFFECTS OF TILLAGE, ROW SPACING, AND VARIETY OF SOYBEANS IN 1977

	Tillage						
	CT		MT		NT		SCW
	50	75	50	75	50	75	
Soybean Variety							
Forrest	2298*	2252	2235	2265	2410	2357	2849
Calland	2580	2514	2339	2278	2481	2414	2849

*LSD (.05 level) = 120 kg/ha.

TABLE XVIII

MEAN SQUARES FOR SOYBEAN YIELDS (kg/ha) OF TREATMENTS MONITORED FOR SOIL WATER CONTENT IN 1976 AND 1977

Source	df	Mean Squares 1976	Mean Squares 1977
Reps	2	35176	92231
Tillage-Management (TM)	2	2184745**	355805*
Row Spacing (RS)	1	42782	344453*
TM x RS	2	15769	70119
Error	10	71093	68897

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

TABLE XIX

MEAN SOYBEAN YIELDS (kg/ha) OF TREATMENTS MONITORED FOR SOIL WATER CONTENT AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM AND ROW SPACING IN 1976

Tillage-Management	Row Spacing (cm) 50	Row Spacing (cm) 75	Mean
Conventional Tillage	1958	1861	1910
No-Tillage	1728	1212	1470
Single Crop Soybeans	1618	1401	1509
$LSD_{.05}$	478	478	338
Mean	1768	1491	
$LSD_{.05}$	278		

and no-tillage (Table XIX). In 1977, the soybeans were planted at an earlier date and when moisture conditions were more favorable and the single crop soybeans produced significantly higher yields. No-tillage had significantly higher yields than conventional tillage (Table XX).

TABLE XX

MEAN SOYBEAN YIELDS (kg/ha) OF TREATMENTS MONITORED FOR SOIL WATER CONTENT AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM AND ROW SPACING IN 1977

	Row Spacing (cm)		
Tillage-Management	50	75	Mean
Conventional Tillage	1272	1056	1164
No-Tillage	1727	1688	1708
Single Crop Soybeans	2388	2350	2369
$LSD_{.05}$	477	477	338
Mean	1796	1698	
$LSD_{.05}$	278		

Row spacing effects were significant in 1977 (Table XVII). The 50 cm row spacing had significantly higher yield than the 75 cm row spacing (Table XIX). The higher yield of the narrow rows was attributed to better weed control. Row spacing effects were most noticeable in no-tillage, indicating the advantage of narrow rows, particularly when no-tillage is used. Row spacing effects were not significant in 1976 (Table XVIII). However, the narrow rows had higher average yields than the wide rows (Table XX).

Soil Water

The sampling dates for soil water content were treated as individual experiments and an analysis of variance was made for each sampling date. Comparison tests involving treatment means were made only within each sampling date. Error mean squares from each sampling date were used in calculating least significant differences (LSD) for each sampling date.

Tables XXI and XXII are the analyses of variance for total soil water content. The line entries listed below Error (a) in the analyses of variance are not discussed. The statistically significant interactions did not seem to be of practical importance and therefore were not included in the discussion. Tables XXIII and XXIV show soil water means for each treatment and sampling date. The values are the mean of three replications and eight depths. Figures 1 and 2 are graphical representations of the means of total soil water content. Values are totals of soil water from eight depths in 120 cm of soil profile and are the mean of three replications.

Soil water contents were generally higher in 1976 than 1977 (Tables XXIII and XXIV). With more precipitation in 1977, the lower soil water contents in 1977 were possibly due to the effects of the previous years double cropping rather than lack of precipitation.

From the analyses of variance of soil water in 1976 and 1977, treatments were significant on all sampling dates except for July 29,

TABLE XXI

MEAN SQUARES FOR SOIL WATER CONTENT (cm) ON FIVE SAMPLING DATES IN 1976

Source	df	DATES May 11	June 19	July 29	Aug. 25	Sept. 25
Total	167					
Reps	2	2.339**	4.215**	2.863*	0.113	0.266
Treatments (Trts.)	6	1.289**	4.645**	1.353	1.316*	6.651**
Tam vs. Others	1	0.148	1.155	0.315	1.744	19.419**
Others	5	1.518**	5.343**	1.561	1.230	4.097**
Management (Mgmt.)	2	2.667**	12.823**	3.821**	2.846*	6.386**
Row Spacing (R.S.)	1	1.077*	0.076	0.040	0.024	4.880*
Mgmt. x R.S.	2	0.588*	0.497	0.061	0.218	1.417
Error (a)	12	0.140	0.471	0.506	0.434	0.710
Depth	7	2.671**	4.061**	4.620**	8.928**	5.570**
Linear	1	6.438**	15.657**	16.791**	55.623**	7.480**
Quadratic	1	2.936**	2.486**	2.955**	2.016**	24.182**
Residual	5	1.865**	2.056**	2.519**	0.971**	1.466**
Trts. x Depth	42	0.468**	0.184*	0.089	0.126	0.324**
(Tam vs. Others) x Depth	7	0.133**	0.060	0.042	0.449**	1.053**
Others x Depth	35	0.535**	0.208**	0.099	0.061	0.178**
Mgmt. x Depth	14	1.189**	0.444**	0.185**	0.094	0.277**
R.S. x Depth	7	0.169**	0.083	0.054	0.087	0.107
Mgmt. x R.S. x Depth	14	0.064*	0.035	0.035	0.016	0.114
Error (b)	98	0.029	0.105	0.075	0.099	0.078

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

TABLE XXII

MEAN SQUARES FOR SOIL WATER CONTENT (cm)
ON FOUR SAMPLING DATES IN 1977

Source	df	DATES May 16	June 11	July 18	Aug. 22
Total	167				
Reps	2	0.386	2.282*	0.394	1.443
Treatments (Trts.)	6	4.502**	9.266**	2.553**	5.427*
Tam vs Others	1	2.145	5.365**	0.007	17.773**
Others	5	4.974**	10.046**	3.063**	2.957
Management (Mgmt.)	2	10.334**	22.457**	6.474**	5.124*
Row Spacing (R.S.)	1	1.741	0.514	0.263	1.996
Mgmt. x R.S.	2	1.229	2.400*	1.051	1.272
Error (a)	12	0.481	0.550	0.523	1.216
Depth	7	14.597**	5.930**	3.859**	8.685**
Linear	1	85.434**	7.824**	4.656**	46.064**
Quadratic	1	7.061**	27.509**	20.272**	8.100**
Residual	5	1.936**	1.235**	0.417**	1.327**
Trts. x Depth	42	0.220**	0.597**	0.301**	0.463**
(Tam vs Others) x Depth	7	0.023	0.095	0.381**	2.128**
Others x Depth	35	0.259**	0.698**	0.285**	0.130**
Mgmt. x Depth	14	0.516**	1.620**	0.545**	0.156**
R.S. x Depth	7	0.041	0.068	0.070	0.154**
Mgmt. x R.S. x Depth	14	0.112	0.091	0.131	0.091
Error (b)	98	0.071	0.142	0.103	0.053

*,** Signifcant at the 0.05 and 0.01 probability levels, respectively.

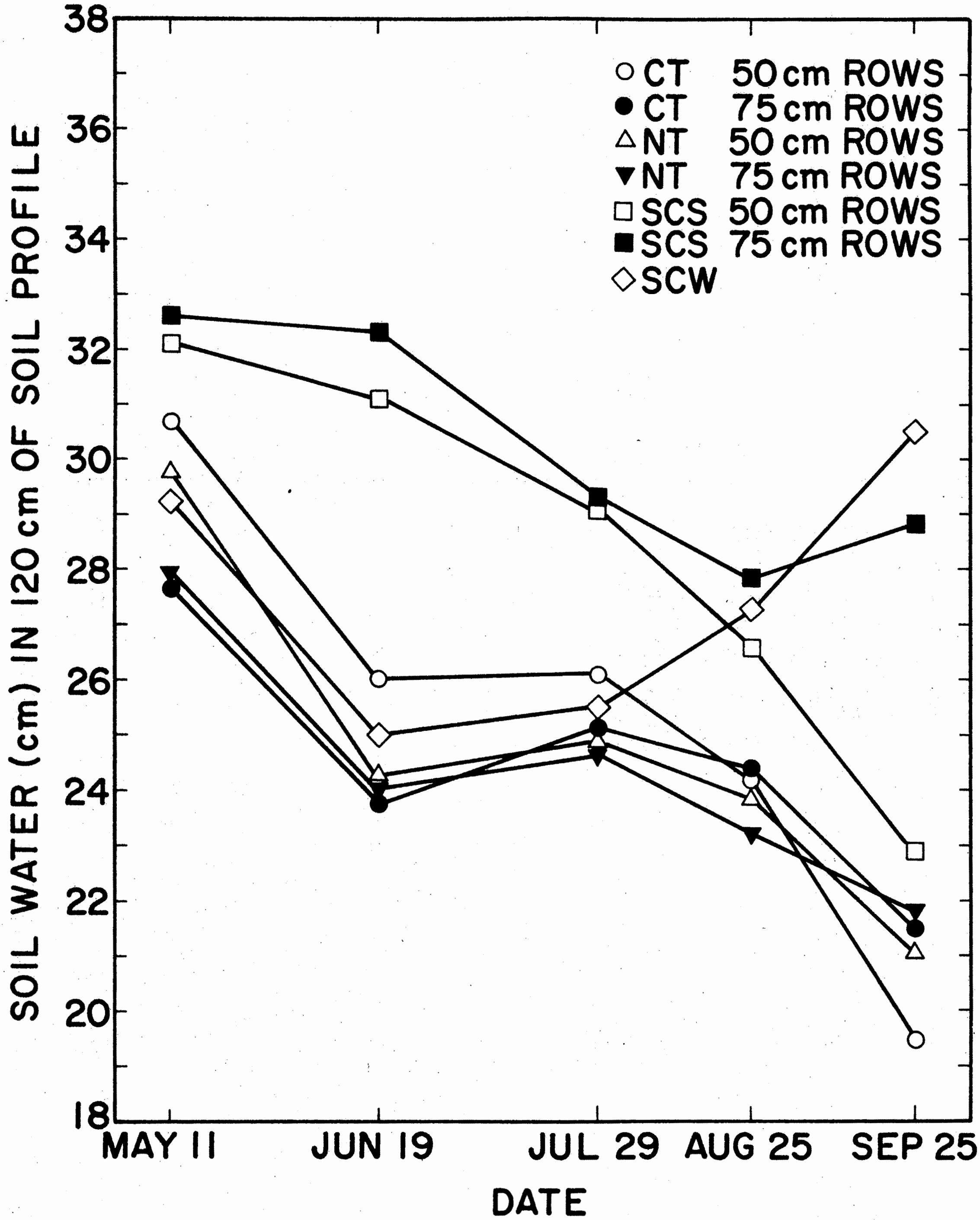

Figure 1. Total Soil Water Content (cm) in 120 cm of Soil Profile as Affected by Tillage-Management System in 1976

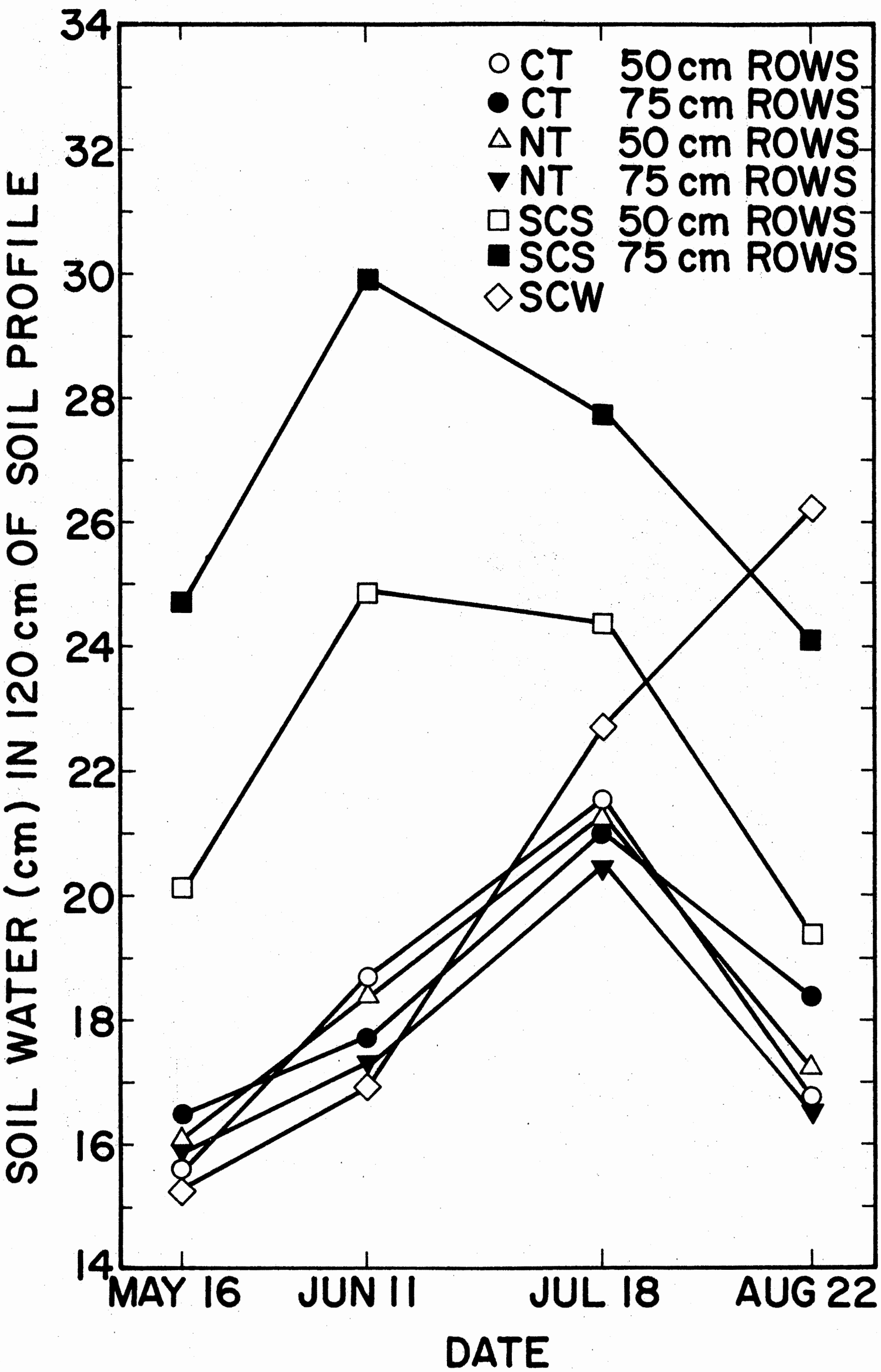

Figure 2. Total Soil Water Content (cm) in 120 cm of Soil Profile as Affected by Tillage-Management System in 1977

TABLE XXIII

TOTAL SOIL WATER CONTENT (cm) IN 120 cm OF SOIL PROFILE AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM in 1976

Tillage-Management	Row Spacing (cm)	Dates May 11	June 19	July 29	Aug. 25	Sept. 25
CT	50	3.839	3.246	3.251	3.023	2.437
CT	75	3.480	2.990	3.138	3.029	2.689
NT	50	3.724	3.032	3.124	2.995	2.628
NT	75	3.493	3.001	3.113	2.897	2.726
SCS	50	4.004	3.883	3.629	3.317	2.866
SCS	75	4.076	4.033	3.653	3.487	3.621
SCW		3.675	3.127	3.194	3.416	3.799
LSD (.05 level)		0.236	0.432	0.448	0.414	0.530

TABLE XXIV

TOTAL SOIL WATER CONTENT (cm) IN 120 cm OF SOIL PROFILE AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1977

Tillage-Management	Row Spacing (cm)	Dates			
		May 16	June 11	July 18	Aug. 22
CT	50	1.956	2.329	2.692	2.099
CT	75	2.043	2.218	2.625	2.294
NT	50	2.004	2.306	2.649	2.149
NT	75	1.992	2.133	2.545	2.081
SCS	50	2.510	3.112	3.048	2.428
SCS	75	3.095	3.746	3.475	3.007
SCW		1.944	2.129	2.858	3.273
LSD (.05 level)		0.436	0.466	0.455	0.694

1976, and highly significant on all but the August 25, 1976, and August 22, 1977, sampling dates (Tables XXI and XXII). The significant treatment differences on the May, June, and July sampling dates are due to the significantly higher total soil water content of the single crop soybeans (Figures 1 and 2, Tables XXIII and XXIV). The single crop soybean plots were fallow on the May and June dates and the other treatment plots were supporting growing wheat. The wheat plants were extracting water from the soil, accounting for the lower total soil water content. Wheat harvest and soybean planting had been completed prior to the July sampling dates. However, the soybean plants were small and did not seem to affect the total soil water content. This accounts for the single crop soybeans still having higher total soil water content on the July dates.

The single crop wheat generally had significantly higher total soil water content than the other treatments on the August and September (1976) sampling dates (Tables XXIII and XXIV). After wheat harvest, the single crop wheat remained in stubble mulch and accumulated soil water with each subsequent rainfall. The soybean treatments had actively growing plants extracting soil water resulting in a loss of total soil water (Figures 1 and 2).

The analyses of variance showed Tam vs. Others to be highly significant on September 25, 1976, and June 11 and August 22, 1977 (Tables XXI and XXII). The F-test for this entry compared the mean of the single crop wheat treatment (Tam) with the mean of all other treatments (Others). On the September, 1976, and August, 1977, dates, the single crop wheat had significantly higher total soil water content than all other treatments (Tables XXIII and XXIV). On the June 11, 1977, date, the very high total soil water content of the single crop soybeans and the very low content of the single crop wheat accounts for the significant difference.

From the analyses of variance, Others was determined to be highly significant on the May, June, and September sampling dates in 1976 and the May, June, and July dates in 1977 (Tables XXI and XXII). The F-test for this entry compared the means of all the treatments, excluding the single crop wheat treatment. On the May and June dates during both years, and the July date in 1977, the single crop soybeans were generally significantly higher in total soil water content than conventional tillage and no-tillage (Tables XXIII and XXIV). On the September, 1976, sampling date, single crop wheat and single crop soybeans (75 cm rows) were significantly higher in total soil water content than the other treatments (Tables XXIII and XXIV).

Management (conventional tillage, no-tillage, single crop soybeans) was significant on all sampling dates and highly significant on all but the August 25, 1976, and August 22, 1977, sampling dates (Tables XXI and XXII). Single crop soybeans were significantly higher in total soil water content than conventional tillage and no-tillage on all dates (Tables XXIII and XXIV). There were no significant differences in total soil water content due to tillage (conventional vs. no-tillage) on all dates except May 11, 1976 (Tables XXIII and XXIV). This is different from most of the literature cited concerning tillage effects on soil water content. However, the research investigating tillage effects on soil water has been conducted only with monocropping systems in regions with different soil moisture regimes and climatic conditions than Oklahoma. High temperatures and low rainfall during the summer months in Oklahoma may overshadow any effects of tillage on soil water in double cropping systems. Also, a more severe weed problem was encountered in no-tillage which may have resulted in soil water losses due to weeds.

Row spacing effects were significant only on the May 11 and September 25, 1976, sampling dates (Table XXI). On the May 11 sampling date, the 50 cm row spacing for conventional and no-tillage were higher in total soil water content than the 75 cm row spacing (Table XXIII). However, on this sampling date, tillage and row spacing treatments had not been established and these differences were due to variations within the experimental area. On all other sampling dates there were no significant differences in total soil water content due to row spacing for conventional and no-tillage (Tables XXIII and XXIV). However, the 50 cm row spacing generally had higher total soil water content than the 75 cm row spacing.

The significant row spacing effects on the September 25 sampling date were due to the high total soil water content of the 75 cm row spacing single crop soybeans. The single crop soybeans (75 cm row spacing) were also significantly higher in total soil water content on the May 16 and June 11, 1977 sampling dates. Although not significantly higher, the single crop soybeans (75 cm rows) were higher in total soil water content on all other dates (Table XXIII and XXIV). These results are generally contrary to those reported in the literature. The wide rows having higher total soil water content in the single crop soybeans could possibly be attributed to differences in rooting patterns between row spacings. This difference in rooting patterns may not exist in double-cropped soybeans.

The management x row spacing interaction was significant only on the May 11, 1976, and the June 11, 1977, sampling dates (Tables XXI and XXII) and did not seem to be of great importance.

The difference in total soil water content between the single crop wheat and the double crop treatments (conventional and no-tillage) on the September 25, 1976, and the August 22, 1977, sampling dates was approximately eight cm of total soil (Figures 1 and 2). This suggests that most of the recharge of soil water for single crop wheat occurs after the soybean growing season and during the winter months. The eight cm of total soil water may be better utilized in a double cropping system rather than in a single crop wheat system.

The distribution of soil water in 15 cm increments of soil profile at each sampling date are shown in Tables XXV-XXVIII. A graphical representation of the soil water at each depth and sampling date are shown in Figures 3-6.

There was very little difference in soil water content between conventional tillage (50 and 75 cm row spacings) and no-tillage (50 and 75 cm row spacings) at all depths and sampling dates in both 1976 and 1977 except May 11, 1976 (Tables XXV-XXVIII). On the May 11 sampling date, treatments had not been established and the differences between conventional tillage and no-tillage were due to variation within the experimental area. Excess water losses due to a more severe weed problem in no-tillage possibly caused the no-tillage to not have higher soil water content than the conventional tillage. Soil water content may have been higher if better weed control has been obtained.

TABLE XXV

SOIL WATER CONTENT (cm) AT 15, 30, 45, AND 60 cm DEPTHS AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1976

15 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	3.724	3.459	3.513	2.304	3.172
CT-75	3.351	2.996	3.565	2.297	3.424
NT-50	3.322	2.937	3.042	2.113	2.866
NT-75	3.176	2.889	3.332	2.009	3.125
SCS-50	5.202	4.128	3.464	2.356	3.592
SCS-75	5.709	4.385	3.595	2.467	4.000
SCW	3.505	3.037	3.341	2.720	3.965
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

30 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	2.946	2.526	2.654	2.084	2.238
CT-75	2.787	2.281	2.505	2.276	2.500
NT-50	2.786	1.989	2.393	2.029	2.428
NT-75	2.811	2.317	2.576	1.972	2.700
SCS-50	3.333	3.367	2.686	2.042	2.551
SCS-75	3.797	3.589	2.601	2.381	2.952
SCW	2.924	2.316	2.703	3.099	3.752
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

45 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	3.385	2.459	2.531	2.413	1.364
CT-75	3.135	2.281	2.311	2.484	1.634
NT-50	3.217	2.071	2.228	2.200	1.523
NT-75	3.333	2.404	2.524	2.435	2.025
SCS-50	3.764	3.588	3.095	2.539	2.041
SCS-75	4.087	3.968	3.080	3.096	3.089
SCW	3.208	2.401	2.527	3.280	3.731
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

60 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	4.011	3.090	3.156	3.146	1.639
CT-75	3.529	2.752	2.749	3.091	1.732
NT-50	3.869	2.894	3.065	3.039	1.876
NT-75	3.276	2.780	2.805	3.060	1.865
SCS-50	3.806	4.003	3.867	3.608	2.311
SCS-75	4.075	4.231	3.829	3.866	3.623
SCW	3.787	3.025	2.999	3.622	3.985
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

* The F-test for treatments was not significant on the July 29 sampling date, therefore an LSD test was not performed.

TABLE XXVI

SOIL WATER CONTENT (cm) AT 75, 90, 105, AND 120 cm DEPTHS AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1976

75 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	4.002	3.381	3.427	3.415	2.198
CT-75	3.621	3.172	3.274	3.425	2.361
NT-50	3.931	3.401	3.359	3.465	2.423
NT-75	3.448	3.136	3.196	3.217	2.445
SCS-50	3.788	4.043	3.911	3.900	2.541
SCS-75	3.725	4.225	4.021	4.033	3.728
SCW	3.752	3.403	3.374	3.761	3.921
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

105 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	4.221	3.721	3.550	3.531	2.959
CT-75	3.801	3.474	3.557	3.519	3.361
NT-50	4.202	3.654	3.623	3.690	3.357
NT-75	3.996	3.494	3.473	3.477	3.236
SCS-50	4.044	3.966	3.939	4.072	3.303
SCS-75	3.684	3.901	3.985	4.013	3.881
SCW	4.085	3.605	3.510	3.571	3.666
$LSD_{.05}$	0.350	NS	NS	NS	0.563

90 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	4.015	3.355	3.403	3.488	2.515
CT-75	3.628	3.319	3.417	3.343	2.875
NT-50	4.074	3.420	3.446	3.487	2.840
NT-75	3.769	3.325	3.278	3.298	2.882
SCS-50	3.866	3.880	4.006	3.970	2.959
SCS-75	3.664	4.029	4.109	4.012	3.815
SCW	3.872	3.364	3.327	3.452	3.560
$LSD_{.05}$	0.350	0.653	NS	0.632	0.563

120 cm Depth	DATES				
Trts.	May 11	June 19	July 29*	Aug. 25	Sept. 25
CT-50	4.409	3.979	3.775	3.805	3.409
CT-75	3.983	3.644	3.728	3.793	3.624
NT-50	4.390	3.890	3.838	3.933	3.713
NT-75	4.134	3.661	3.722	3.710	3.527
SCS-50	4.229	4.090	4.065	4.050	3.634
SCS-75	3.864	3.936	4.003	4.027	3.882
SCW	4.271	3.868	3.774	3.821	3.824
$LSD_{.05}$	0.350	NS	NS	NS	NS

* The F-test for treatments was not significant on the July 29 sampling date, therefore an LSD test was not performed.

TABLE XXVII

SOIL WATER CONTENT (cm) AT 15, 30, 45, AND 60 cm DEPTHS AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1977

15 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22
CT-50	1.499	3.396	3.153	1.974
CT-75	1.483	2.619	3.412	2.040
NT-50	1.286	2.530	2.790	1.693
NT-75	1.316	2.232	2.913	1.900
SCS-50	2.761	3.882	3.006	2.275
SCS-75	2.780	4.531	3.716	2.642
SCW	1.476	2.683	3.736	3.567
$LSD_{.05}$	0.594	0.736	0.711	0.776

45 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22
CT-50	1.011	1.141	2.385	1.197
CT-75	1.034	1.079	1.813	1.490
NT-50	0.919	1.198	2.197	1.136
NT-75	1.091	1.300	2.107	1.272
SCS-50	1.830	3.331	3.020	1.494
SCS-75	2.571	4.085	3.687	2.383
SCW	0.996	1.108	2.827	3.326
$LSD_{.05}$	0.594	0.736	0.711	0.776

30 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22
CT-50	0.872	1.786	2.469	1.123
CT-75	0.874	1.525	2.193	1.494
NT-50	0.811	1.704	2.283	1.010
NT-75	0.861	1.542	2.191	1.204
SCS-50	1.366	3.167	2.344	1.337
SCS-75	1.893	3.716	3.064	1.885
SCW	0.910	1.749	2.958	3.207
$LSD_{.05}$	0.594	0.736	0.711	0.776

60 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22
CT-50	1.761	1.703	2.287	1.730
CT-75	1.503	1.514	1.863	2.029
NT-50	1.475	1.593	1.878	1.614
NT-75	1.485	1.549	2.006	1.539
SCS-50	2.418	3.040	3.289	2.174
SCS-75	3.372	3.863	3.615	3.152
SCW	1.583	1.575	2.369	3.737
$LSD_{.05}$	0.594	0.736	0.711	0.776

TABLE XXVIII

SOIL WATER CONTENT (cm) AT 75, 90, 105, AND 120 cm DEPTHS AS AFFECTED BY TILLAGE-MANAGEMENT SYSTEM IN 1977

75 cm Depth	DATES				105 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22	Trts.	May 16	June 11	July 18	Aug. 22
CT-50	2.140	2.171	2.322	2.179	CT-50	2.806	2.761	2.963	2.803
CT-75	2.134	2.048	2.217	2.244	CT-75	3.126	3.031	3.203	3.029
NT-50	2.072	2.072	2.165	2.087	NT-50	3.208	3.168	3.382	3.269
NT-75	1.925	1.911	2.072	2.049	NT-75	3.090	2.807	3.047	2.900
SCS-50	2.389	2.493	2.775	2.362	SCS-50	3.089	3.039	3.296	3.227
SCS-75	3.450	3.329	3.264	3.349	SCS-75	3.550	3.516	3.472	3.539
SCW	1.958	1.972	2.196	3.234	SCW	2.902	2.644	2.950	2.950
$LSD_{.05}$	0.594	0.736	0.711	0.776	$LSD_{.05}$	0.594	0.736	NS	NS

90 cm Depth	DATES				120 cm Depth	DATES			
Trts.	May 16	June 11	July 18	Aug. 22	Trts.	May 16	June 11	July 18	Aug. 22
CT-50	2.413	2.458	2.590	2.455	CT-50	3.151	3.155	3.364	3.333
CT-75	2.647	2.513	2.692	2.519	CT-75	3.546	3.415	3.603	3.510
NT-50	2.668	2.649	2.731	2.701	NT-50	3.592	3.535	3.761	3.691
NT-75	2.628	2.358	2.486	2.374	NT-75	3.538	3.369	3.543	3.411
SCS-50	2.823	2.707	2.984	2.820	SCS-50	3.404	3.234	3.673	3.733
SCS-75	3.498	3.381	3.434	3.513	SCS-75	3.626	3.545	3.547	3.593
SCW	2.445	2.219	2.453	2.781	SCW	3.280	3.079	3.374	3.377
$LSD_{.05}$	0.594	0.736	0.711	0.776	$LSD_{.05}$	NS	NS	NS	NS

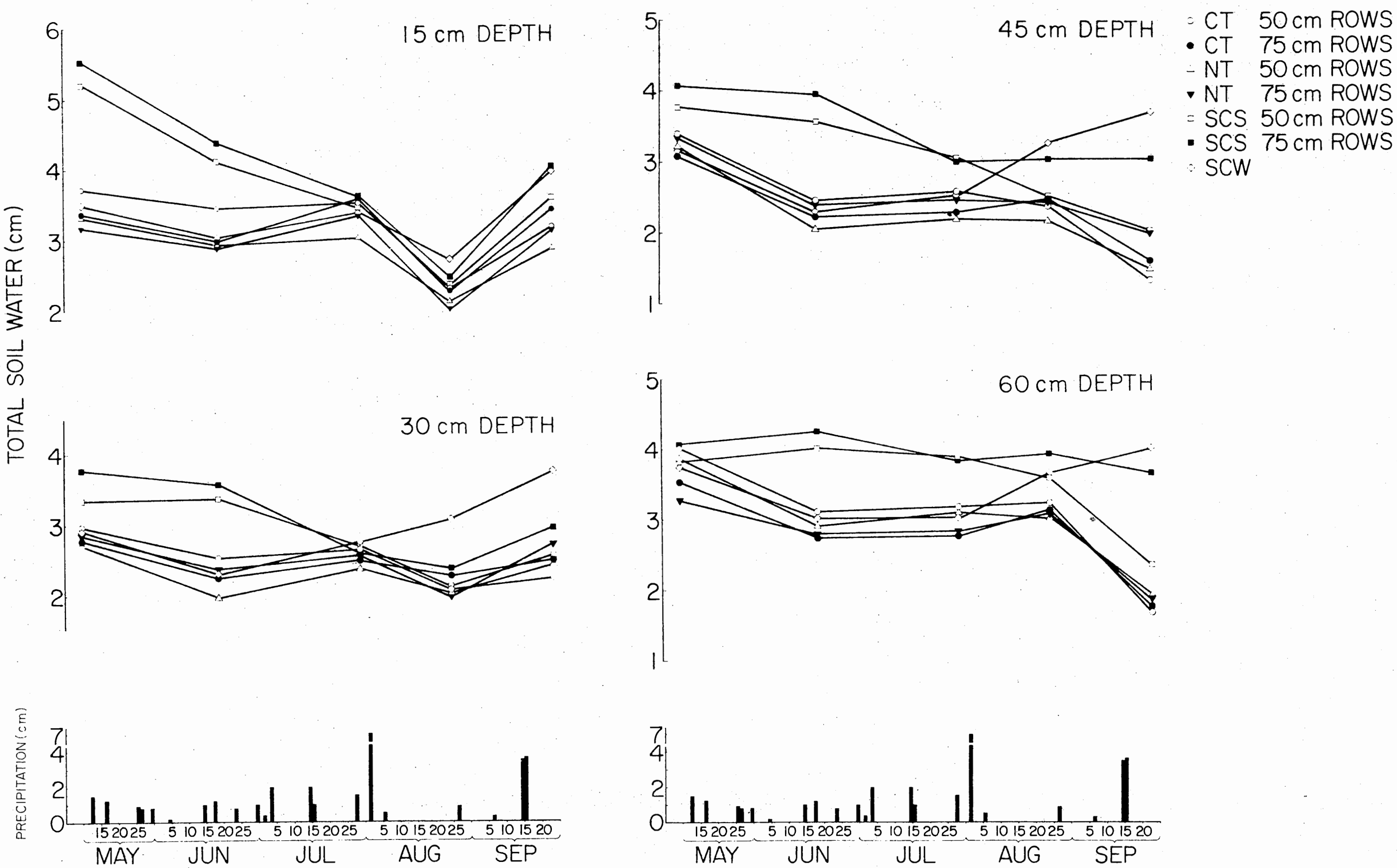

Figure 3. Soil Water Content (cm) at 15, 30, 45, and 60 cm Depths as Affected by Tillage-Management System in 1976

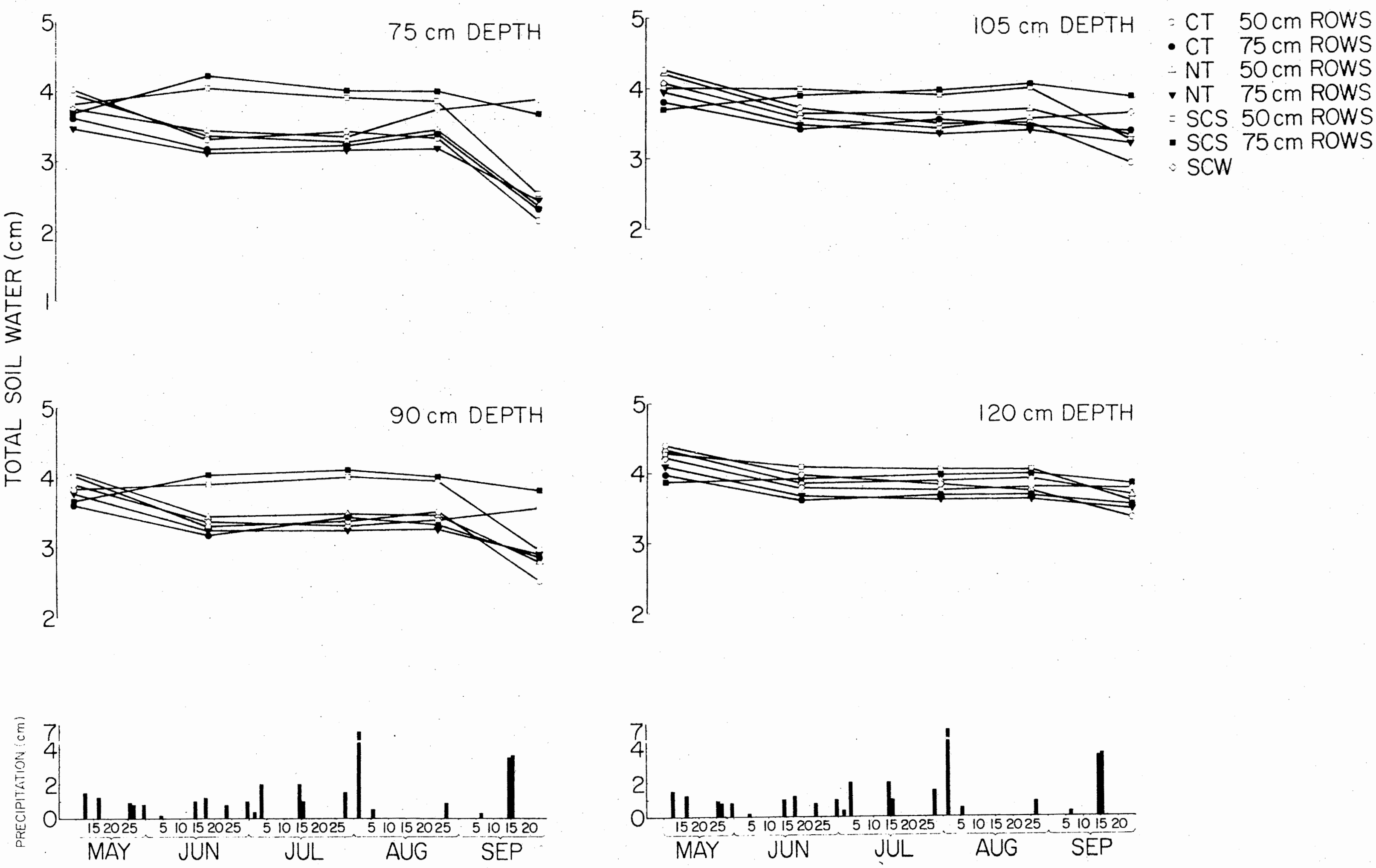

Figure 4. Soil Water Content (cm) at 75, 90, 105, and 120 cm Depths as Affected by Tillage-Management System in 1976

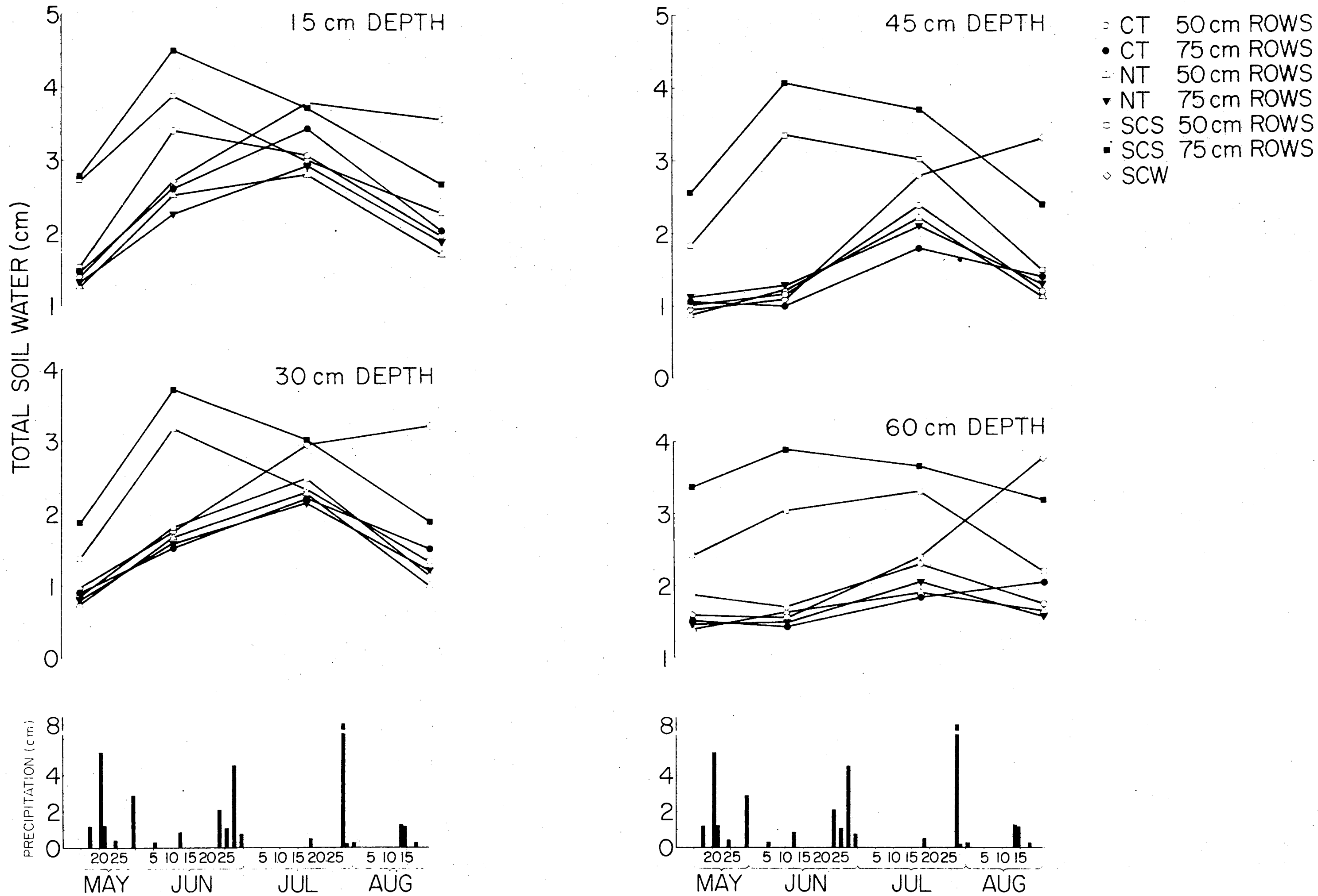

Figure 5. Soil Water Content (cm) at 15, 30, 45, and 60 cm Depths as Affected by Tillage-Management System in 1977

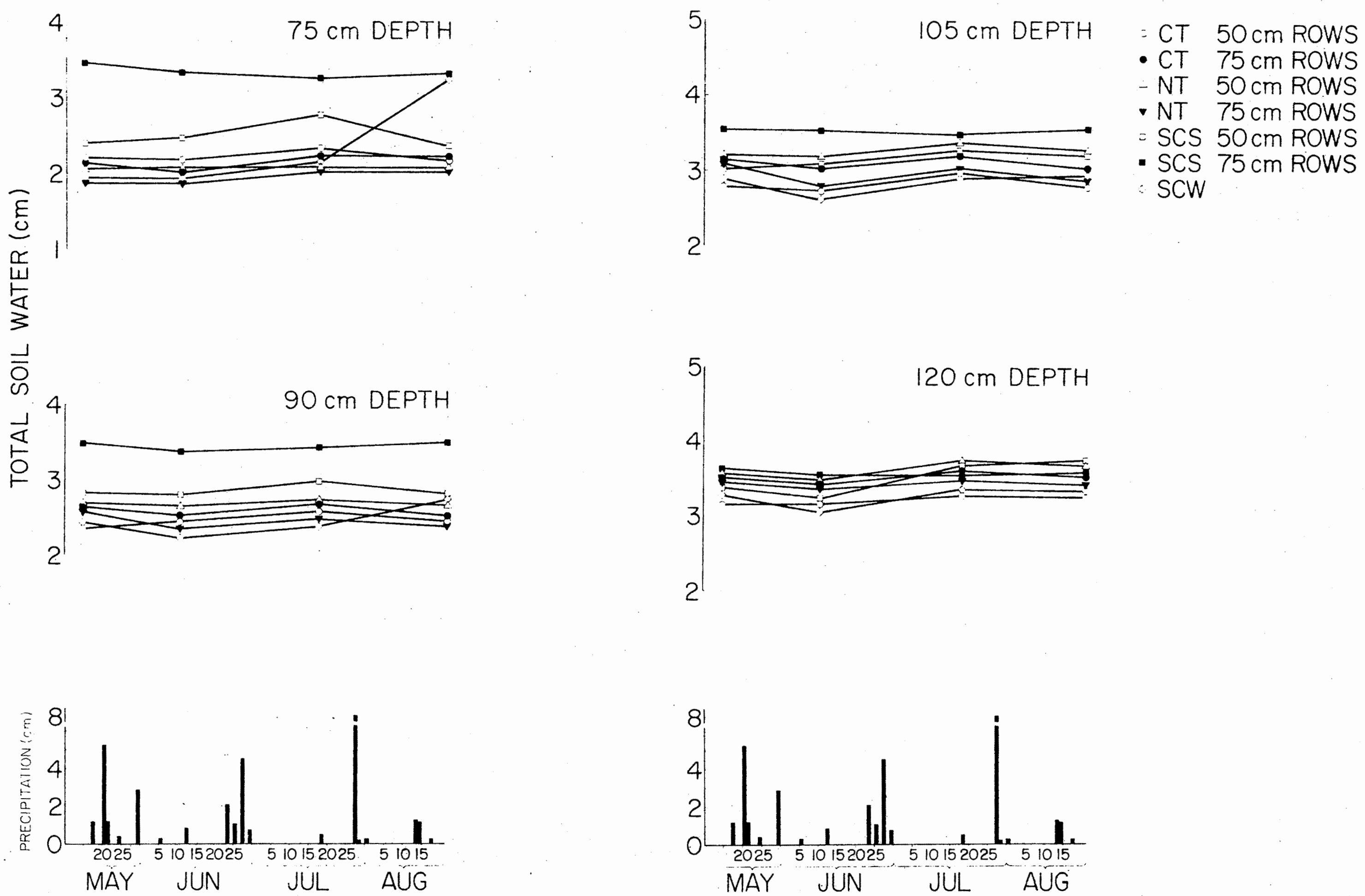

Figure 6. Soil Water Content (cm) at 75, 90, 105, and 120 cm Depths as Affected by Tillage-Management System in 1977

The effect of precipitation and evaporation losses on soil water content can be seen in Figures 3 and 5. Rainfall was considerably below normal in May, June, and July in 1976. Soil water contents generally decreased or remained the same for all treatments at the 15, 30, and 45 cm depths. Evaporation losses were very evident at the 15, 30, and 45 cm depths in the single crop soybeans, which were fallow during May and June. In 1977, rainfall was above or near normal during May, June, and July. Soil water content at the 15, 30, 45, and 60 cm depths increased during this period for conventional tillage, no-tillage, and single crop wheat. Soil water content in the single crop soybeans at the 15, 30, 45, and 60 cm depth increased during May and early June but steadily decreased during the remainder of the growing season. The high rainfall during May increased soil water content, but evaporation and increased plant use during June, July, and August decreased soil water content.

The single crop wheat generally increased in soil water content at the 15, 30, 45, and 60 cm depths following wheat harvest in both 1976 and 1977. The single crop wheat had generally exceeded the other treatments in soil water content by the August or September sampling date. With each rainfall the single crop wheat increased in soil water content and the other treatments decreased in soil water content due to water use by the growing soybeans (Figures 3 and 5).

Below a depth of 75 cm and particularly below a depth of 105 cm, management and tillage had very little effect on soil water content in 1976 (Figure 4). The only differences that did occur were between the single crop soybeans and all other treatments. The limited amount of rainfall from August 5 to September 15 generally decreased the soil water content for all treatments at the 90 and 105 cm depth and particularly at the 75 cm depth (Figure 4). Soil water content remained fairly constant below a depth of 105 cm, with only minor fluctuations due to the dry period during August and early September (Figure 4).

In 1977, below a depth of 75 cm, management and tillage had only minor effects on soil water content (Figure 6). At the 75 and 90 cm depth, the single crop soybeans (75 cm rows) had higher soil water content than all other treatments which were generally all equal. This may be due to differences in rooting patterns between row spacings. At the 75 cm depth, the single crop wheat sharply increased in soil water content during August just as it did at all depths above 75 cm. Soil water content differences among treatments were generally small at the 105 and 120 cm depth.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to evaluate tillage and row spacing effects on yields and soil water content in a wheat-soybean double cropping system in Eastern Oklahoma. Yields and soil water content of the double cropping systems were compared with those of conventional single cropping systems. Soybean variety effects on yield were also evaluated.

Two year average soybean yields of 1,541 and 1,143 kg/ha were obtained for varieties Forrest and Calland, respectively, when double-cropped after wheat which had an average yield of 2,369 kg/ha. In comparison, single crop soybean yields averaged 1,941 and 1,442 kg/ha for Forrest and Calland, respectively, and the single crop wheat yield was 2,849 kg/ha.

Forrest soybeans produced significantly higher yields than Calland soybeans in both 1976 and 1977. Forrest produced 359 kg/ha more in 1976 and 692 kg/ha more in 1977 than Calland.

No-tillage produced double crop soybean yields nearly equal to or higher than conventional and minimum tillage. Single crop soybeans produced significantly higher yields than the double crop soybeans in 1977. In 1976, the single crop soybean yields were reduced due to poor stands and late planting date.

Row spacings of 50 and 70 cm produced no significant differences in soybean yields. However, the narrow rows tended to give higher average yields than the wide rows. The yield advantage of narrow rows was most evident in no-tillage.

The residual effects of soybean tillage and variety on wheat yields was determined to be significant. Conventional tillage and no-tillage produced higher wheat yields than minimum tillage. Plots that had grown Calland soybeans produced higher wheat yields than plots that had grown Forrest soybeans.

Soybean row spacing did not significantly affect wheat yields. However, the 50 cm row spacing plots tended to have higher wheat yields than the 75 cm row spacing plots.

The effects of double cropping on wheat yields were shown by the single crop wheat having significantly higher yields than all double crop treatments. This difference in yield was attributed to higher soil water content of the single crop wheat.

No statistically significant differences in soil water content due to tillage were observed. Extreme temperatures and generally dry conditions encountered during the summer months in Oklahoma may offset any beneficial effects of no-tillage in regards to soil water content.

Row spacing effects on soil water content were significant only for the single crop soybeans where soil water content was generally higher for the 75 cm row spacing. This effect is possibly due to differences in rooting patterns between row spacings.

Management systems were found to have significant effects on soil water content. Single crop soybeans and wheat had higher total soil water content than the double crop soybeans during the early and late portions, respectively, of the growing season.

No significant differences in soil water content among tillage methods or management systems were observed below a soil depth of 90 cm.

Results of this study indicate that the use of narrow rows and no-tillage appears to be the best choice of management practices when double cropping soybeans after wheat in Eastern Oklahoma. Weed control in no-tillage was the most significant problem encountered in this study. Suggestions for further study must emphasize the development of herbicide combinations and application methods to obtain better weed control in a soybean-wheat double cropping system utilizing no-tillage.

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VITA 2

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