TILLAGE, PLANTING EQUIPMENT, ROW SPACING, AND PLANT POPULATION EFFECTS ON YIELDS IN A WHEAT-SOYBEAN DOUBLE CROPPING SYSTEM

By

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CHAPTER I

INTRODUCTION

As the food requirements for the world continue to increase, the necessity of finding ways to produce more food from the land available becomes more important. Complicating this problem is the fact that energy needed to produce food is becoming more expensive and less available. However, the use of no-tillage production practices and double cropping management systems is one potential solution.

The practice of omitting tillage and planting directly into stubble lends itself to a double cropping farming scheme. The second crop must be planted quickly after harvest of the first. Planting directly into stubble saves time and, in many instances, may facilitate emergence of seedlings by lessening compaction, surface crusts, moisture loss, and the need for different types of tillage equipment. Fuel consumption and labor costs may also be reduced.

As new and improved herbicides and equipment become available, double cropping with no-tillage becomes even more profitable and practical. Soybeans (*Glycine max* L. Merrill) and small grains are two crops that perform well when grown on the same land in the same year.

In eastern Oklahoma there is adequate rainfall for two crops; however, periods of drought during the summer make soils with good water storage capacities a requirement for double cropping. The objective of this study was to evaluate minimum and no-tillage practices, type of planting equipment, row spacing, and plant population of soybeans when grown after winter wheat (Triticum aestivum L. em Thell) in a double cropping system near Bixby, Oklahoma.

CHAPTER II

REVIEW OF LITERATURE

"Double cropping" is defined by Owens and Lanpher (1974) as producing two successive crops on the same field during one year. They also state that this practice can be profitable even when yields of the individual crops are reduced. In particular, they point out that when soybeans are grown after small grains, the added income from the soybean crop should offset the cost of production. By providing a vegetative cover for a greater part of the year, double cropping can result in a greater utilization of climatic resources (Sanford et al., 1973).

No-tillage, zero-tillage and non-tillage are terms that refer to the practice of planting without plowing the seedbed and often these practices increase the success of double cropping by eliminating many problems associated with seedbed preparation (McKibben and Oldham, 1973). Time is an important factor during the harvest of one crop and the planting of the second, and no-tillage provides the least delay of planting time (Sanford et al., 1973).

Research by Gard and McKibben (1973) showed that soybeans were successful following wheat in a no-till, double cropped system. Sanford et al. (1973) state

> when unsatisfactory results were obtained from reduced tillage methods, they were usually related to poor weed control, poor management, or a lack of knowledge of the complete technology of production (p. 978).

Tillage

Tillage practices have a great impact on soil properties and crop yields. Plowing has disadvantages which must be considered. It reduces soil strength (Soane and Pidgeon, 1975) and sacrifices the protection from erosion and surface runoff that minimum tillage affords (Graffis et al., 1973).

No-tillage

Amemiya (1970) defines slot or "zero" tillage as that which uses a fluted coulter to cut through crop residues and till a 5 to 7.5 cm strip per row. Spatcher (1971) states that four primary advantages of no-tillage are erosion control, excessive rain shock absorbance by crop residues, improved soil structure and reduced evaporation. Gard and McKibben (1973, p. 148) state that the no-tillage system "exhibits the potential for becoming the most significant single conservation measure yet developed to control erosion and sedimentation." Blevins and Cook (1970) found that no-tillage uses soil and water more efficiently in spite of increased percolation losses. This is due primarily to increasing infiltration, reducing runoff and reducing evaporation, which is high in conventionally tilled soil during the early part of the season. The greater moisture storage of no-tilled soil can carry a crop through periods of drought without stress. In fact, in the early part of the growing season, corn (Zea mays L.) was found to withstand one to two weeks of drought (Shanholtz and Lillard, 1969).

Studies by Cannell and Finney (1973) show that drilling directly, without plowing, leads to greater mechanical strength, more continuous pores (although the proportion of large pores is less), more earthworms, greater moisture content, more organic matter content, and greater structural stability at the surface. The old root channels, earthworm channels and planes of weakness that are left undisturbed facilitate root growth (Cannell and Finney, 1973) and serve as avenues for infiltration (Blevins and Cook, 1970). Blevins and Cook (1970) showed a higher moisture content in no-tilled soils up to a 61 cm depth. Soane and Pidgeon (1975) also found that no-tillage resulted in increased compaction of the top 12 cm of the soil, resulting in higher bulk density, lower air-filled pore space and fewer larger pores. However, Stranak (1968) found that cereals had highest yields when grown in soils of higher bulk densities. For winter wheat, the optimum bulk density was established at 1.45 to 1.54 g/cm^3.

Increased yields were attributed to closer soil-seed contact, more nutrients per unit volume of soil, higher moisture, and better root development.

Another benefit of no-tillage is better seedling emergence. Sanford et al. (1973) found with 5 cm of rain after planting, conventionally planted plots emerged first. However, with 8 cm of intense rain followed by hot winds which caused the formation of a crust, no-tillage plots emerged first. Stucky (1976), using a no-till planter, obtained best emergence at a 7.5 cm depth for soybeans as compared to 5 and 10 cm depths. In a similar experiment in which planting followed winter wheat, a 7.5 cm depth with only 5 cm of soil cover emerged better than 5 or 10 cm depths.

Cannell and Finney (1973) found no evidence of reduced uptake of phosphorus and potassium in no-tilled systems, in spite of accumulation of phosphorus at the surface. They also found that although slower seminal root growth occurred in winter wheat that had been direct drilled, the effect on later roots was small. In some cases this root effect decreased with time in continually direct drilled plots.

Shanholtz and Lillard (1969) found yields to be higher in no-tilled corn as opposed to conventionally tilled corn. In Ohio, at the Wooster and Western Branch experiment stations, the best yield for soybeans and small grains in double cropped systems were obtained with no-till treatments (Owens and Lanpher, 1974).

Minimum Tillage

Soane and Pidgeon (1975) maintain that poorly drained soils, soils with low structural stability and traffic damaged soils will still require tillage. However, Hardcastle (1973) and Blevins and Cook (1970) feel that there may be an advantage in decreasing the amount of tillage from conventional standards because of reduced costs. This cost reduction is accomplished primarily by lower fuel consumption and decreased labor requirements. Graffis et al. (1973) list minimum tillage advantages as lower cost, rapid water absorption, more water absorption, protection from crusting, slower runoff, and protection from wind erosion. They also list disadvantages as loose, trashy seedbeds resulting in low emergence, residue interference with herbicides or cultivation and possible accumulation of lime and fertilizers at the soil surface.

Planting Equipment

McKibben (1968) states that the key to establishing good crop stands in no-tillage systems is the use of proper equipment. It is necessary to have enough pressure on the drill to force a runner or double disk opener through crop residues and into the soil. An adjustable depth gauge is also needed to avoid placing the seed too deep. In no-tillage studies, Jeffers et al. (1973) showed that one or two diskings did not prepare heavily straw-covered soil well enough for conventional drills or planters to function properly. Graffis et al. (1973) state that minimum tillage has one disadvantage in that it requires planters to be designed and equipped to plant through crop residues.

According to Hofman (1977), no-tillage grain drills were used as early as 1905 and over the years improved models with standard press drills and coulter attachments have been manufactured and sold. Hofman (1977) also states that the newer drills on the market are either equipped with a rolling coulter or apply considerable pressure on the double disks of conventional drills for planting through mulch. The diameter of the coulter must increase as the amount of allowed residue increases. In some instances a notched coulter may be necessary to prevent heavy residues from bunching up in front of the coulter. Fenster et al. (1977) point out that drills designed for minimum tillage must cut through dry soil or crop residue and place the seed in moist soil. For wheat, they define three types of planting equipment. Surface drills consist of single or double disk drill units spaced 15 to 20 cm apart. Semideep furrow drills are single disk or small hoe drill units spaced 20 to 25 cm apart. Mulch hoe drills have hoes or shoes every 30 to 35 cm. The latter two types are needed when the crop must be planted through dry soil in the furrows, when furrows are used to provide a rough soil surface to reduce wind erosion or when a mulch is present.

In tests on sorghum (Sorghum bicolor Moeuch) following wheat, Allen et al. (1975) used flex type planters equipped with fluted coulters, single disk drills and the flex planter units alone. The flex type unit alone and the single disk drills worked well in mellow soil between stubble rows and where only moderate residue was present, while the flex type planter equipped with fluted coulters performed much better in heavy residues.

Wittmuss et al. (1971) developed a till-plant unit that contained a 38.1 cm sweep followed by a runner and planting unit, a four rod trash guard, a 2.5 by 25 cm press wheel, and covering disks. The planter required no tillage prior to planting. Yields obtained from crops planted with this unit were not significantly different from conventionally planted crops.

Row Spacing

It has been established that equidistant spacing of plants gives the highest yields and best erosion control (Lyles and Allison, 1975). Weber et al. (1966) conducted experiments in which they varied row spacing and population density within the row. They found that maturity date, plant height, and lodging were unaffected by row spacing. However, Reiss and Sherwood (1965) found some variance in plant height due to row width.

Yield has often proven to be higher for soybeans grown in narrow row spacings. Wax and Pendleton (1968) tested soybeans for yield in 102, 76 , 51, and 25 cm rows and obtained the highest results from 25 cm rows. Soybean row widths of 18, 36, 71, and 107 cms were evaluated by Kust and Smith (1969) one year and 18, 36, 71, and 89 cm rows were studied the second year. Their highest yield came from 18 and 36 cm rows with no significant difference between the two. Soybean seed yield was maximized in 25 cm rows when compared with 13, 51 and 102 cm rows by Weber et al. (1966). Timmons et al. (1967) found 20 cm rows to be better than 61 or 102 cm rows for soybean production. Cooper (1971) observed soybean yield improvements in 17 cm rows over 50 cm rows. Reiss and Sherwood (1965) obtained best results for soybeans in 61 cm row spacings rather than 20, 41, 81, or 102 cm rows. Fifty-one cm rows out yielded 76 cm rows in experiments by Stucky (1976). Fehr and Rodriguez (1974) found a 10% yield increase in 71 cm rows compared to 100 cm rows. There is one exception in a study by Hicks et al. (1969) in which yields were not significantly greater for narrower rows.

Peters et al. (1965) stated that when chloramben (3-amino-2, 5-dichlorobenzoic acid) was used to suppress early weeds the closer row spacings controlled weeds to a greater extent than wider row spacings. Wax and Pendleton (1968) found broadleaf weeds that were unaffected by trifluralin (a,a,a-trifloro-2,6-dinitro-N,N-dipropyl-ptoluidine) to impair yields less in narrow rows. They also noted narrow rows reduced tillage requirements and the amount of herbicide needed. Kust and Smith (1969) showed that yellow fox tail (Setaria lutescens) and barnyardgrass (Echinochloa crusgalli) were suppressed by narrow rows. Wax (1972) found that closely drilled soybeans shade the soil sooner, aiding control of late germinating weeds.

In double cropping, with no-tillage procedures employed, the weed control obtained from the plant leaf canopy is increased in importance. Gard and McKibben (1973) said close row spacing was advantageous in double cropping soybeans and wheat.

Plant Population

Several studies have been done on planting rates for soybeans. It is generally accepted that high seeding rates increase lodging as shown by Hicks et al. (1969) and Cooper (1971). Tontes and Ohlrogge (1972) found that not only did lodging increase with high populations, but the number of barren plants also increased. When yield is considered, the studies on high seeding rates for soybeans are less consistent. In experiments by Reiss and Sherwood (1965) yields were not significantly affected by seeding rates. Hicks et al. (1969) found that plant population did not produce a consistent effect on yield. However, Timmons et al. (1967) reported that yields increased as population and row spacing decreased. Cooper (1971) planted soybeans in 50 and 17 cm rows with three planting rates and found that the yield advantage of the 17 cm rows decreased as the seeding rate increased. Johnson and Harris (1967) noted that 26.2 plants per meter of 92.4 cm rows or approximately 345,940 plants per ha produced the highest soybean yields while Weber et al. (1966) obtained best results with 129,164 plants per ha.

Weed Control

Erbach and Lovely (1974) note that with continuous use of any tillage system, weed control remains a concern. This is due, they further state, to the fact that weed species can adapt, making rotation of crops, tillage systems or weed control methods necessary. Erbach et al. (1969) pointed out that soybeans are planted in late spring when one to two months of weed growth may have already occurred. According to Burnside (1973), the greatest yield losses are due to weed competition rather than difficulties during harvest caused by the presence of weed populations. Losses to competition can be great as shown by Nave and Wax (1971). They found 25 to 30% yield reduction due to one smooth pigweed (Amaranthus hibridus) plant every 30 cm in a 76 cm row. One giant foxtail (Setaria faberii) plant every 30 cm reduced yields 13%.

It has been shown that closely drilled soybeans shade the soil sooner and thus aid in the control of late germinating weeds (Wax, 1972). Gard and McKibben (1973) and Peters et al. (1965) also gave evidence that closely spaced rows suppress weed growth.

Cultivation has long been used as a means of weed control during the growing season. Peters et al. (1965) reported that with 51 and 61 cm rows of soybeans, only one cultivation was needed in addition to a herbicide to control weeds. In 81 and 102 cm rows one and sometimes two cultivations were necessary. Parochetti (1973) studied several herbicide treatments for soybeans and found that cultivation increased weed control with each treatment. Dowler and Parker (1975) obtained 75% weed control in beans with three cultivations, and 87 to 90% with a herbicide-cultivation combination. These findings suggest that because cultivation reduces weed competition it should increase yield; however, cultivation at later growth stages can reduce yields by destroying plant roots (Russell et al., 1971).

Some of the more recent advances in weed control have come in the area of herbicides. Hauser et al. (1972) obtained as high as 99 to 100% control of common cocklebur (Xanthium pensylvanicum) and Florida beggarweed (Desmodium tortuosum) in soybeans with the use of herbicides. Similarly, they obtained 93 to 95% control with herbicides alone in other tests. For double cropped, no-tilled soybean production, herbicides used must have a high degree of contact activity, have favorable residual characteristics and be safe for the soybean plant (Spatcher, 1971). Penner and Meggitt (1970) tested 27 herbicide treatments using 13 herbicides. None of the treatments significantly altered the percentage oil content of the seed. No correlation of fatty acid composition with yield or injury was found. Worsham (1974) studied linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea) effects on soybeans and reported that rates four times as great as the recommended amounts were tolerated. Worsham's (1974) work indicates that herbicides like linuron used properly will have no ill effect on a soybean crop.

Trifluralin is a common preplant herbicide that can be used for soybeans. It has been used both preplant, incorporated and pre-emergence, but in studying its effect on johnsongrass (Sorghum halepense), Standifer and Thomas (1965) discovered that when it is surface applied, it is effective when dry but not when wet. Along with the possibility of erosion, this favors incorporation into the soil. McWhorter (1974) applied trifluralin and nitralin (4-(methylsulfonyl)-2-6-dinitro-N,N-dipropylaniline) to freshly disked soil and disked it in twice. After two years of fall application, he obtained a good control of johnsongrass in soybeans with trifluralin. After the first year, good control came from a combination of nitralin and trifluralin treatments in both fall and spring. Dalapon

(2,2-dichloropropionic acid) applied preplant increased control the first two years only. Parochetti (1973) got the best control with dalapon and nitralin applied preplant.

Linuron has also been used as a pre-emergence herbicide in soybean production. Sanford et al. (1973) found it controlled weeds, except for nutsedge (Cyperus sp.), in no-tillage soybeans. Kust and Smith (1969) varied row spacing and linuron rates and obtained evidence that weed control increased as the rate of linuron applied was increased within a given row spacing from 0.56 to 1.12 to 2.24 kg/ha. In another study, linuron showed superior weed control (Wax, 1972). Spatcher (1971) used linuron in combination with paraquat (1,1l-dimethyl-4,4'-bipyridinium ion) plus a surfactant and obtained good control.

Paraquat, a contact herbicide applied pre-emergence has also been used to advantage in double cropped soybeans (Spatcher, 1971). However, glyphosate (N-(phosphonomethyl) glycine) applied pre-emergence was shown to give better initial knockdown of weeds in soybeans planted in wheat stubble than paraquat did (Hardcastle, 1973). Control was also maintained longer with glyphosate plus alachlor (2-chloro-2',6'-diethyl-N-(methoxy-methyl) acetanilide) than with paraquat plus alachlor or linuron.

In the area of post emergence herbicides, 2,4-DB (4-(2,4-dichlorophenoxy) butyric acid) was tested for control of cocklebur in soybeans by McWhorter and Hartwig (1966).

Although some crop injury occurred, yields were usually higher than those of cocklebur infested plots. From most effect to least effect, Silvex (2-(2,4,5-trichlorophenoxy) propionic acid), 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid), 2,4-D((2,4-dichlorophenoxy) acetic acid) and 2,4-DB injured soybeans when applied at 0.01 to 0.28 kg/ha (Smith, 1965). Another post emergence chemical that has found use in soybean production is bentazon (3-isopropyl-1H-2,1,3-benzothiadiazin-4-(3H)-one 2,2-dioxide). Andersen et al. (1974) controlled common cocklebur, common ragweed (Ambrosia artemesiifolia), velvetleaf (Abutilon theophrasti), and Pennsylvania smartweed (Polygonum pensylvanicum) with 0.84 kg/ha bentazon with only 0.7% crop injury. Common lambsqyarter (Chenopodium album) and wild mustard (Brassica kaber) were controlled at early growth stages while no grass control was obtained. Wax et al. (1971) used bentazon (BAS 3512-4) and got the best results with 1.68 kg/ha following pre-emergence application of triflurain, alachlor or chloramben.

Abernathy and Wax (1971) made an extensive study on herbicide control of cocklebur in soybeans. The following were effective in order of least effective to most effective: BAY 94337 (4-amino-6-t-butyl-3-(methyl-thio)-as-triazin-5-(4H)-one) and prometryne (2,4-bis (isopropylamino) (methylthio)-s-triazine), preplant, incorporated; BAY 94337 linuron, prometryne, naptalam (N-1-naphthylphthalamic acid), and chloropropham (isopropyl m-chlorocarbinilate), pre-emergence; BAY 94337, 2,4-DB, chloroxuron (3-(p-(p-chlorophenoxy) phenyl)-1,1-dimethylurea), bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), and BAS 3512 H (bentazon), post-emergence.

Time of herbicide application is just as important as the type used. Wilson and Burnside (1973) found the best control of cocklebur when the plants were 8 to 15 cm tall, of green foxtail (*Setaria viridis*) at 3 to 8 cm, and of velvetleaf under 15 cm. Weishar et al. (1971) have shown that weed control with BAS 3512-H decreased when weeds were beyond the 4 to 6 leaf stage.

CHAPTER III

MATERIALS AND METHODS

A wheat followed by soybean double cropping experiment was conducted at the Oklahoma Vegetable Research Station, Bixby, Oklahoma, from 22 November 1977 to 5 November 1979.

The soil of the experimental area is Wynona silty clay loam, which is classified as a fine, silty, mixed, thermic, Cumulic Haplaquoll. The series consists of deep, slowly permeable nearly level soils on flood plains. A typical profile consists of 25 cm of very dark brown silty clay loam with moderate fine granular structure and a mildly alkaline pH; this is underlain by 32 cm of black silty clay loam with moderate fine granular structure and a slightly acid pH. The subsoil consists of 48 cm of very dark gray silty clay loam with moderate fine subangular blocky structure and a slightly acid pH, followed by 56 cm of very dark gray silty clay loam with weak fine subangular blocky structure.

Winter wheat cultivar TAM-W-101 was planted with no tillage into soybean stubble on 22 November 1977, and after moldboard plowing on 19 October 1978 at a rate of 100 kg/ha in 25 cm rows using a hoe drill. The wheat was top dressed by broadcasting NH_4NO_3 at a rate of 100 kg N/ha on 18 March 1978 and 2 March 1979. This fertilizer addition provided 100% nutrient sufficiency levels as determined by the Oklahoma State University soil testing laboratory procedures and recommendations. Wheat grain yields were obtained by harvesting a 3 m strip down the center of each plot on 28 June 1978 and 1979 using an Allis Chalmers Gleaner A mechanical harvester. Wheat grain yields were analyzed as a randomized complete block design with four replications.

Two experiments were carried out on the soybean double crop phase of the experiment. The first was arranged in a 2^3 factorial using two types of tillage, two kinds of planting equipment and two seeding rates. The second included two types of tillage, two row spacings and two seeding rates. All experimental plots were 45.7 m long and 6.1 m wide. A randomized complete block design with four replications was used for all double cropped soybean treatments (Table I).

Minimum tillage treatment plots were tandem disked once, then planted. No-tillage treatment plots were planted into standing wheat stubble with a John Deere hoe drill equipped with rolling coulters and modified narrow planting shoes, and an Allis Chalmers no-tillage planter equipped with fluted coulters 5 cm wide, double disk openers with 3.8 cm depth bands and press wheels.

TABLE I

EXPERIMENTAL TREATMENTS FOR SOYBEAN PHASE OF DOUBLE CROPPING SYSTEM

Treatment Number	Tillage	Equipment	Row Spacing (cm)	Population (plants/ ha)
		Experiment I		
1	no-tillage	John Deere	50	395,360
2	no-tillage	John Deere	50	494,200
3	no-tillage	Allis Chalmers	50	395,360
4	no-tillage	Allis Chalmers	50	494,200
5	minimum tillage	John Deere	50	395,360
6	minimum tillage	John Deere	50	494,200
7	minimum tillage	Allis Chalmers	50	395,360
8	minimum tillage	Allis Chalmers	50	494,200
		Experiment II		
1	no-tillage	John Deere	50	395,360
2	no-tillage	John Deere	50	494,200
3	no-tillage	John Deere	25	395,360
4	no-tillage	John Deere	25	494,200
5	minimum tillage	John Deere	50	395,360
6	minimum tillage	John Deere	50	494,200
7	minimum tillage	John Deere	25	395,360
8	minimum tillage	John Deere	25	494,200

'Forrest' (Maturity group V) soybeans were planted 30 June 1978 and 2 July 1979. Immediately after planting, paraquat, oryzalin (3,5 dinitro-N^4,N^4-dipropylsulfanilimide) and metribuzin (4-amino-6-(1,1-dimethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one) were broadcast on the soybean plots as a tank mixture, with application rates of 0.56, 1.12 and 0.37 kg/ha active ingredient, respectively, in 234 l/ha water. No other weed control was initiated. A 3 m strip was cut down the center and extending the full length of each plot with an Allis Chalmers Gleaner A mechanical harvester on 5 November 1979.

CHAPTER IV

RESULTS AND DISCUSSION

1978 Experiment

The experimental area was seeded to wheat following a wheat-soybean double cropping production system for both 1976 and 1977. Precipitation in December, 1977, and January, 1978 was considerably lower than for the 25-year average (Table II). During this period, the lack of moisture coupled with cold temperatures resulted in little vegetative growth and led to lower wheat grain yields in 1978 as compared to 1979 (Table III). Wheat grain yields in 1978 showed no significant differences at the 0.10 level of significance (Table IV).

Although rainfall in June was above average (Table II), no precipitation occurred during the seven days prior to the planting of soybeans on June 30 (Table V). Soybeans were planted into dry surface soil with the anticipation of receiving rainfall shortly after planting. However, the dry period continued through July with no rainfall ocurring for a total of 29 days (Table V). This resulted in an approximate crop stand of only 15-20%. Rainfall in the latter part of July and in August was only minimal and most

TABLE II

MONTHLY AND YEARLY PRECIPITATION TOTALS FOR 1977, 1978, 1979, AND THE 25-YEAR AVERAGE (1950-1975) AT THE VEGETABLE RESEARCH STATION NEAR BIXBY, OKLAHOMA

	Rainfall (cm)			
Month	1977	1978	1979	25-Year Average
January	2.16	1.77	3.18	3.91
February	4.01	9.32	0.76	4.14
March	8.74	8.13	7.86	6.60
April	5.26	7.36	8.45	9.96
May	12.75	18.79	18.07	11.84
June	9.47	12.33	10.53	11.56
July	8.43	1.66	6.52	9.40
August	7.65	2.80	9.79	7.11
September	21.74	0.00	1.27	11.10
October	5.08	1.52	7.38	8.15
November	6.83	12.63	13.96	6.55
December	1.78	0.76	2.59	4.83
Totals	93.90	77.06	90.32	95.05

TABLE III

TREATMENT MEAN YIELDS FOR WHEAT IN 1978 AND 1979 AND SOYBEANS IN 1979 (KG/HA)

Treat-ment Number	Wheat 1978	Wheat 1979	Soybeans 1979
		Experiment I	
1	1480	3450	1330
2	1340	3260	1480
3	1420	2720	1450
4	1600	3220	1430
5	1450	3340	1550
6	1500	3290	1460
7	1540	2930	1550
8	1450	3390	1620
		Experiment II	
1	1450	3450	1330
2	1340	3260	1480
3	1390	3250	1470
4	1390	3050	1330
5	1450	3340	1550
6	1500	3290	1460
7	1300	3100	1450
8	1520	2720	1530

of this was lost to surface evaporation. No precipitation was received in September (Table V). Consequently, the soybean crop for 1978 was lost.

TABLE IV

MEAN SQUARES FOR WHEAT YIELDS (KG/HA) IN 1978 AND 1979

Source	df	1978 Mean Square	1979 Mean Square
		Experiment I	
Rep	3	78986	106442
Treatment	7	25121	108213
Error	21	96398	218768
		Experiment II	
Rep	3	46531	240727
Treatment	7	25099	204170
Error	21	68647	181060

1979 Experiment

After unsuccessfully completing the wheat-soybean double cropping sequence during the summer of 1978, the

TABLE V

PRECIPITATION DISTRIBUTION FOR 1978 AT THE VEGETABLE RESEARCH STATION NEAR BIXBY, OKLAHOMA

Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)
Jan. 11	0.25	Mar. 7	1.40	May 7	1.14	Aug. 4	0.64
Jan. 16	1.02	Mar. 14	0.64	May 18	1.90	Aug. 6	0.64
Jan. 25	0.25	Mar. 20	2.08	May 21	5.97	Aug. 10	1.52
Jan. 26	0.25	Mar. 22	1.90	May 28	2.16	Oct. 7	0.76
Feb. 1	0.25	Mar. 24	2.11	June 5	2.16	Oct. 30	0.76
Feb. 6	0.76	Apr. 4	0.38	June 6	1.27	Nov. 6	0.81
Feb. 8	0.51	Apr. 6	0.51	June 19	2.54	Nov. 15	3.81
Feb. 9	0.51	Apr. 10	3.81	June 21	0.64	Nov. 16	3.56
Feb. 12	5.51	Apr. 17	1.14	June 22	5.08	Nov. 25	3.81
Feb. 15	0.51	Apr. 28	1.52	July 22	0.51	Nov. 26	0.64
Feb. 17	1.27	May 1	4.06	July 27	0.51	Dec. 31	0.76
		May 5	3.56	July 28	0.64		

experimental area was moldboard plowed. Little precipitation fell prior to seeding on 19 October (Table V). However, good rainfall in November resulted in an excellent stand of wheat. Average moisture was received during the first six months of 1979 (Table II) which enabled the wheat crop to progress through the vegetative, flowering and grain filling physiological stages of growth without water stress, and resulted in good grain yields (Table III). The experimental treatments showed no differences at the 0.10 level of significance (Table IV).

Average precipitation during June (Table II) provided good surface moisture at the time of planting soybeans, and in addition, a significant rain occurred four days later (Table VI). This helped to establish a good stand of soybeans. Normal rains during August continued to support good crop growth. Moisture was still available during the blooming stage around 1 September and two mm pods developed by 5 September. However, the month of September was far below average in precipitation and a total of 42 consecutive days without rain elapsed during September and October (Table VI). This stress came during the critical pod filling stage and led to the production of beans that were notably smaller than would be expected. The result was a reduced overall yield of soybeans (Table III).

<u>Experiment I</u>

The analysis of variance showed no differences in

TABLE VI

PRECIPITATION DISTRIBUTION FOR 1979 AT
THE VEGETABLE RESEARCH STATION
NEAR BIXBY, OKLAHOMA

Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)
Jan. *	3.18	Apr. 1	1.60	June 1	3.38	Aug. 10	5.72
Feb. 6	0.76	Apr. 7	0.25	June 6	1.14	Aug. 19	0.51
Mar. 3	1.91	Apr. 10	2.79	June 11	1.32	Sep. 1	1.27
Mar. 16	0.25	Apr. 24	3.81	June 21	0.25	Oct. 15	1.02
Mar. 18	2.67	May 3	5.71	June 25	4.44	Oct. 22	3.18
Mar. 20	1.91	May 4	8.13	July 6	4.44	Oct. 30	3.18
Mar. 22	0.66	May 10	1.14	July 17	2.68	Nov. 8	1.90
Mar. 30	0.46	May 23	1.32			Nov. 21	12.06
		May 26	1.77			Dec. 22	2.54

*Daily distribution is unavailable.

soybean yields at the 0.10 level of significance for Experiment I (Table VII).

TABLE VII

MEAN SQUARES FOR SOYBEAN YIELDS (KG/HA) OBTAINED IN EXPERIMENT I

Source	df	Mean Square
Reps	3	155782
Tillage (T)	1	117035
Equipment (E)	1	24278
Population (P)	1	6025
T X E	1	4073
T X P	1	12829
E X P	1	95
T X E X P	1	59539
Error	21	81683

Tillage methods used prior to planting did not significantly affect yields (Table VII). This may be a reflection of different advantages expressed by both treatments. Although no weed evaluations were carried out, it appeared that plots that were disked had somewhat fewer weeds. This stands to reason as tillage would eliminate some weeds that might not be killed by herbicides. On the other hand, plots that were not tilled probably retained more moisture near the soil surface and in this way provided an advantage over tilled plots when trying to establish a stand of soybeans.

The type of planting equipment used did not significantly affect yields (Table VII). This is important as it implies that either type of planter, a modified hoe drill or other no-tillage type planters, may be used in planting soybeans in a double cropped, reduced tillage production system. In shifting to this type of system it may not be necessary to purchase specialized equipment if equipment already on hand can be modified for use in double cropping. This modification would primarily involve the addition of rolling coulters. It might also be necessary to add weight to the planter in order to supply increased pressure needed to plant through crop residues.

Plant population did not significantly affect soybean yields (Table VII). This seems to indicate that soybeans can compensate to a certain degree for high or low populations. This is generally in agreement with the literature reviewed. Neither planting rate was high enough to cause lodging during the 1979 crop year.

Tillage X equipment, tillage X population, equipment X population, and tillage X equipment X population interactions were not significant (Table VII).

Experiment II

The analysis of variance showed no differences in soybean yields at the 0.10 level of significance for Experilent II (Table VIII). Tillage and plant population showed no differences as in Experiment I.

TABLE VIII

MEAN SQUARES FOR SOYBEAN YIELDS (KG/HA) OBTAINED IN EXPERIMENT II

Source	df	Mean Square
Reps	3	81126
Tillage (T)	1	71214
Row Spacing (RS)	1	889
Population (P)	1	1
T X RS	1	130
T X P	1	481
RS X P	1	7450
T X RS X P	1	99950
Error	21	80935

Row spacing had no significant effect on yield (Table VIII). Although narrow rows have been shown to produce higher yields than wide rows, this effect was not manifested in the 25 and 50 cm rows tested during the 1979 crop year. The advantage of narrow rows is attributed in part to less competition between crop plants, more sunlight reaching the lower leaves of the canopy, increased moisture conservation, and less weed competition. All these variables may not have been fully evaluated in 1979 due to the drought period when pods were trying to fill, and they merit further evaluation.

Tillage X row spacing, tillage X population, row spacing X population, and tillage X row spacing X population interactions were not significant (Table VIII).

CHAPTER V

CONCLUSIONS AND SUMMARY

The objective of this study was to evaluate tillage practices, type of planting equipment, plant population, and row spacing of soybeans when grown after winter wheat in a double cropping system in Eastern Oklahoma.

During 1979, tillage practices did not affect yields, possibly because no-tillage resulted in higher water content and more weed competition, while minimum tillage resulted in lower water content but fewer weeds.

In the 1979 growing seasons, planting equipment did not affect yields. Either type, modified hoe drills or other no-tillage planters, may be used in double cropping, reduced tillage management systems.

Row spacing did not affect yields in 1979. Either 25 or 50 cm spacings are suitable for soybeans grown after wheat.

Plant population did not affect soybean yields in 1979. Either population may be suitable, however, further evaluations should be made.

The most significant problem encountered in this study was weed control. Further study should emphasize the evaluation of crop rotation or other management practices to reduce weed populations, and the development of more effective herbicides and better methods of applying herbicides.

LITERATURE CITED

Abernathy, J. R. and L. M. Wax. 1971. Control of common cocklebur in soybeans. Proc. N. Cent. Weed Contr. Conf. 26:82.

Allen, R. R., J. T. Musick, F. O. Wood, and D. A. Dusek. 1975. No-till seeding of irrigated sorghum double cropped after wheat. Am. Soc. Agr. Engr. Trans. 18: 1109-1113.

Amemiya, Minoru. 1970. Tillage alternatives for Iowa. Iowa State Univ. of Sci. and Tech. Coop. Ext. Ser. PM-488. P. 7.

Andersen, Robert N., William E. Lueschen, Dennis D. Warnes, and Wallace W. Nelson. 1974. Controlling broadleaf weeds in soybeans with bentazon in Minnesota. Weed Sci. 22:136-142.

Blevins, R. L. and Doyle Cook. 1970. No-tillage--its influence on soil moisture and soil temperature. Kentucky Agr. Exp. Sta. Progr. Rep. 187. 15 pp.

Burnside, O. C. 1973. Influence of weeds on harvesting losses with a combine. Weed Sci. 21:520-523.

Cannell, R. Q. and J. R. Finney. 1973. Effects of direct drilling and reduced cultivation on soil conditions for root growth. Outlook Agr. 7:184-189.

Cooper, Richard L. 1971. Influence of soybean production practices on lodging and seed yield in highly productive environments. Agron. J. 63:490-493.

Dowler, Clyde C. and M. B. Parker. 1975. Soybean weed control systems in two southern coastal plain soils. Weed Sci. 23:198-202.

Erbach, D. C., D. E. Wilkins and W. G. Lovely. 1969. An evaluation of chemical and mechanical weed control for soybeans grown with no-plow tillage systems. Proc. N. Cent. Weed Contr. Conf. 24:74-75.

Erbach, Donald C. and Walter G. Lovely. 1974. Weed control with conservation tillage production of corn and soybeans. J. of Soil and Water Cons. 29:44-45.

Fehr, W. R. and S. R. Rodriguez. 1974. Effect of row spacing and genotypic frequency on the yield of soybean blends. Crop. Sci. 14:521-525.

Fenster, C. R., H. I. Owens and R. H. Tollett. 1977. Conservation tillage for wheat in the Great Plains. United States Dept. of Agric. Ext. Ser. PA-1190. Pp. 20-21.

Gard, L. E. and G. E. McKibben. 1973. "No-till" crop production proving a most promising conservation measure. Outlook Agri. 7:149-154.

Graffis, D. W., E. L. Knake, W. O. Scott, and W. R. Oschwald. 1973. Soil management and tillage systems. Illinois Agronomy Handbook. Circular 1069. Pp. 49-53.

Hardcastle, W. S. 1973. Weed control in conventional, non-tilled, and stale bed plantings of soybeans. Proc. South. Weed Sci. Soc. 26:88.

Hauser, Ellis W., M. D. Jellum, Clyde C. Dowler, and W. H. Marchant. 1972. Systems of weed control for soybeans in the coastal plain. Weed Sci. 20:592-598.

Hicks, D. R., J. W. Pendleton, R. L. Bernard, and T. J. Johnston. 1969. Response of soybean plant types to planting patterns. Agron. J. 61:290-293.

Hofman, Vernon. 1977. Tillage machinery. Tillage Seminar Proc. Pp. 3-9.

Jeffers, D. L., G. B. Triplett and J. E. Beuerlein. 1973. Double-cropped soybeans. Ohio Report. 58(4):67-69.

Johnson, B. J. 1969. Influence of herbicides on plant growth and agronomic characteristics of soybean varieties. Agron. J. 61:791-793.

Johnson, B. J. and H. B. Harris. 1967. Influence of plant population on yield and other characteristics of soybeans. Agron. J. 59:447-449.

Kust, Cyril A. and R. R. Smith. 1969. Interaction of linuron and row spacing for control of yellow foxtail and barnyardgrass in soybeans. Weed Sci. 17:489-491.

Lyles, Leon and Bruce E. Allison. 1975. Wind erosion: uniformly spacing nonerodeable elements eliminates effects of wind direction variability. J. of Soil and Water Cons. 30:225-226.

McKibben, George E. 1968. No-tillage planting is here. Crop Soils. 20(7):19-21.

McKibben, G. E. and M. G. Oldham. 1973. Double cropping soybeans in small grain stubble. Illinois Res. 15: 10-11.

McWhorter, C. G. 1974. Johnsongrass control in soybeans with trifluralin and nitralin. Weed Sci. 22:111-115.

McWhorter, C. G. and E. E. Hartwig. 1966. Cocklebur control in soybeans with 2,4-DB. Weed Sci. 14:187-190.

Nave, W. R. and L. M. Wax. 1971. Effects of weeds on soybean yield and harvesting efficiency. Weed Sci. 19:533-535.

Owens, Harold L. and Buel F. Lanpher. 1974. Double cropping with soybeans--will it pay on your farm? United States Dept. of Agri. Ext. Ser., Program Aid 1080. 21 pp.

Parochetti, J. V. 1973. Johnsongrass control in soybeans with dalapon and preemergence herbicides. Weed Sci. 21:426-428.

Penner, Donald and William F. Meggitt. 1970. Herbicide effects on soybean (Glycine max L. Merrill) seed lipids. Crop Sci. 10:553-555.

Peters, Elroy J., Maurice R. Gebhardt and J. F. Stritzke. 1965. Interrelations of row spacings, cultivations, and herbicides for weed control in soybeans. Weed Sci. 13:285-289.

Reiss, W. D. and L. V. Sherwood. 1965. Effect of row spacing, seeding rate, and potassium and calcium hydroxide additions on soybean yields on soils of southern Illinois. Agron. J. 57:431-433.

Russell, W. J., W. R. Fehr and R. L. Mitchell. 1971. Effects of row cultivation on growth and yield of soybeans. Agron. J. 63:772-774.

Sanford, J. O., D. L. Myhre and Norman C. Merwine. 1973. Double cropping systems involving no-tillage and conventional tillage. Agron. J. 65:978-982.

Shanholtz, V. O. and J. H. Lillard. 1969. Tillage systems effects on water use efficiency. J. of Soil and Water Cons. 24:186-189.

Smith, Ray J. 1965. Effects of chlorophenoxy herbicides on soybeans. Weed Sci. 13:168-169.

Soane, B. D. and J. D. Pidgeon. 1975. Tillage requirement in relation to soil physical properties. Soil Sci. 119:376-384.

Spatcher, David L. 1971. Influence of linuron on minimum tillage of soybeans. Proc. South. Weed Conf. 24:172-177.

Standifer, Leon C., Jr. and Carl H. Thomas. 1965. Response of johnsongrass to soil-incorporated trifluralin. Weed Sci. 13:302-306.

Stranak, A. 1968. Soil compaction and direct drilling of cereals. Outlook Agri. 5:241-246.

Stucky, Donald J. 1976. Effect of planting depth, temperature, and cultivars on emergence and yield of double cropped soybeans. Agron. J. 68:291-294.

Timmons, D. R., R. F. Holt and R. L. Thompson. 1967. Effect of plant population and row spacing on evapotranspiration and water-use efficiency by soybeans. Agron. J. 59:262-265.

Tontes, L. A. N. and A. J. Ohlrogge. 1972. Influence of seed size and population on yield and other characteristics of soybeans (Glycine max L. Merr.). Agron. J. 64:833-836.

Wax, L. M. 1972. Weed control for close-drilled soybeans. Weed Sci. 20:16-19.

Wax, L. M., J. R. Abernathy and R. M. Hayes. 1971. Evaluation of BAS 3512-H for control of weeds in soybeans. Proc. N. Cent. Weed Contr. Conf. 26:50.

Wax, L. M. and J. W. Pendleton. 1968. Effect of row spacing on weed control in soybeans. Weed Sci. 16:462-465.

Weber, C. R., R. M. Shibles and D. E. Byth. 1966. Effect of plant population and row spacing on soybean development and production. Agron. J. 58:99-102.

Weishar, A. L., C. W. Carter and M. A. Veenstra. 1971. BAS 3512-H, a new postemergent broadleaf herbicide for soybeans. Proc. N. Cent. Weed Contr. Conf. 26:50.

Wilson, R. G., Jr. and O. C. Burnside. 1973. Weed control in soybeans with postemergence-directed herbicides. Weed Sci. 21:81-85.

Wittmuss, H. D., Delbert E. Lane and Bertrand R. Somerhalder. 1971. Strip till-planting of row crops through surface residue. Am. Soc. Agr. Engr. Trans. 14:60-63.

Worsham, A. D. 1974. Influence of no-tillage planters on tolerance of soybeans to linuron. Weed Sci. 22:340-344.

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