EVALUATION OF LAND PREPARATION AND ROW SPACING FOR DOUBLE CROPPING SOYBEANS FOLLOWING WHEAT IN EASTERN OKLAHOMA

By

SATHIEN PHIMSARN

Bachelor of Science in Agriculture

Kasetsart University

Bangkok, Thailand

1968

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1975

Thesis
1975
P571e
Cop. 2

OKLAHOMA
STATE UNIVERSITY
LIBRARY

OCT 23 1975

EVALUATION OF LAND PREPARATION AND ROW SPACING FOR DOUBLE CROPPING SOYBEANS FOLLOWING WHEAT IN EASTERN OKLAHOMA

Thesis Approved:

L G Morrill
Thesis Adviser

Raymond C Ward

James S. Kirby

James H. Stiegler

N N Durham
Dean of the Graduate College

923583

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to his major adviser, Dr. Lawrence G. Morrill, for his time, guidance, and criticisms throughout the course of this study. Special recognition and appreciation is also due Dr. James H. Stiegler, an unofficial committee member, for his encouragement, help and advice during this study. Thanks are expressed to Dr. James S. Kirby and Dr. Raymond Ward for their time and criticisms as members of the graduate committee.

The author is deeply grateful to Dr. Robert D. Morrison for his assistance in conducting the statistical analysis.

Thanks are also extended to Mr. David Boyer, superintendent of the Eastern Oklahoma Pasture Research Station for his help in the field study.

The author is grateful to the Agronomy Department of the Oklahoma State University for the use of its facilities in conducting this research.

Deep appreciation is extended to the Agency for International Development and Royal Thai Government for the financial support received throughout the period of this study.

To the author's parents Mr. Maung and Mrs. Prom Phimsarn, relatives and friends, sincere gratitude is expressed for their encouragement during the course of this study.

The author is also grateful to Mrs. Carolyn Hackett who typed this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

There are certain principles that apply to soybean production in order to take full advantage of available resources for profitable yields. Soil, climate, management practices, competing crops and economics influence the distribution of soybean acreage. In evaluating possibilities for increasing or improving crop production, emphasis is traditionally placed on two dimensions: (1) expanding area, and (2) improving yield of individual crops. Peculiarly, little has been said about a third dimension, time. It is possible to make better use of time by multiple or double cropping, the practice of producing two successive crops on the same field during one year. Double cropping can achieve better utilization of land area, solar energy, and other resources.

Double cropping with winter wheat or barley followed by grain sorghum has been practiced in southern portions of the United States for 40 or 50 years. More recently, soybeans have joined sorghum as an important second crop. In some southern states, double cropping is almost a necessity because wheat alone is not sufficiently profitable (Dalrymple, 1971). An experiment conducted for three consecutive years, beginning in 1969, in Mississippi (51) showed that the wheat-soybean double cropping system produced significantly higher net returns than the wheat-grain sorghum system. In Virginia (11) soybeans have been widely grown after barley, since it was a more dependable crop than either corn or sorghum when planted after barley. Soybeans planted as late as July 16 produced low yields compared to earlier plantings in several studies, but the soybeans were of good quality in spite of early frosts. Double cropping systems are now widely accepted by farmers.

Recent improvement in herbicides, crop varieties, planting techniques and equipment have significantly aided farmers interested in double cropping.

Double cropping spreads out the farm workload and extends the time that farm labor and equipment can be used. Double cropping can offer both agronomic and economic advantages to Oklahoma farmers. With the longer growing season, and particularly, higher annual rainfall in the eastern part of Oklahoma, the potential of double cropping deserves exploration. This study was designed to explore the possibilities of double cropping with soybeans following wheat.

The objectives of this study were:

1. To evaluate the effects of four tillage methods and four row spacings on the yield of soybeans.

2. To determine if soybeans can be grown successfully in a double cropping system after wheat in Eastern Oklahoma.

CHAPTER II

LITERATURE REVIEW

Proper management with careful attention to every detail will enhance the successfulness of double cropping soybeans following wheat. Some variables of concern are: tillage systems, crop varieties, weed control, economics, and soil fertility.

Conventional vs. Minimum Tillage

Interest has been stimulated in reduced tillage and no-tillage because of recent developments in herbicides, planter modifications, and the rapidly increasing costs of crop production. The concern on the part of the general public for reduced pollution of lakes, streams and reservoirs from soil erosion and runoff has prompted researchers to develop and evaluate a system of farming that requires less tillage. Minimum tillage, generally refers to a system where fewer tillage operations are used to grow agricultural crops. Highly effective herbicides provide a practical alternative to pre-plant tillage and a possible alternative or supplement to post-plant tillage for weed control (67).

Timing is a key factor to be considered in selecting the best system used to plant the second crop in double cropping programs. The sequence of tillage used depends on the soil types, physical condition of the soil, and existing weed problems. Planting in a conventionally prepared seedbed has the advantage that no special equipment is necessary for planting the second crop and herbicide costs are reduced. The conventionally prepared seedbed is particularly well suited for producing a full season soybean crop but takes valuable time and decreases soil moisture in the plow layer as the soil preparation is made (18, 23). Conventional tillage also requires more trips across the field in land preparation, cultivation, and harvesting, while minimum tillage requires fewer. No-tillage requires only two or three trips for crop production, herbicide application and planting (46). 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 or no-tillage is a definite advantage. Excessive tillage affected silty soils or soil with excellent tilth less than plastic soils with poor tilth (8). Hayes (22) stated that double cropping with conventional tillage systems provides a greater opportunity for wind and water erosion than with reduced tillage. Since the moisture supply is often low after a small grain harvest, tillage methods that conserve soil moisture are especially desirable.

The advantages to the use of minimum tillage or no-tillage in double cropping systems have been enumerated by several workers (8, 22, 46): (1) reduced soil and water losses, (2) reduced costs and time requirements, (3) better protection of young seedlings from abrasion and desication, and (4) better soil structure by reducing compaction.

Crop Yield and Minimum Tillage

Extensive research has been conducted during recent years dealing with various means of reducing tillage for production of row crops, especially corn. Studies have demonstrated that crop yields with reduced tillage or no-tillage usually were equal to or higher than those obtained with conventional tillage (19, 34, 49, 66). In Virginia, limited tillage and no-tillage methods gave corn yields comparable to conventional methods. Wheel-track planting was found to be well adapted to coarse-textured soils and strip-till planting to heavier-textured soils (34).

Fink, et al. (17) reported that chisel plowing a week before planting provided for the highest corn yield on Clinton silt loam. In West Virginia (6) studies on no tillage practices in sod partially killed with herbicides, no-tillage or sod planting produced yields comparable or greater than conventional systems. Also, in Missouri (66) various plow-plant methods gave comparable corn yields to conventional tillage. Studies in Kansas (16) comparing the till-planter, plow and surface plant, and lister methods gave the same corn yields. Lister planted corn plots lodged less than plow and surface plant or till-plant treatments.

Studies with corn in Indiana (19) showed a four year average grain yield advantage of 1,000 kilograms per hectare for till-planting, but no significant differences among chisel, till, strip rotary, strip culture, and conventional systems of planting corn on sandy soils. The yield increases in the till-planting plots may have been due to the ridge made at cultivating time. On poorly drained, fine-textured soils, with poor weed control, mean yields of no-plow systems were lower than mean yields for plow systems. Germination and weed control tended to be more of a problem with no-plow systems than with the conventional system. Problems of germination and weed control were more severe on poorly drained fine soil than on well-drained, coarse-textured soils. Roger, et al. (49) stated that variations of "stubble mulch" farming have been used in experiments and by some innovative farmers for several years with differing degrees of success and that the nature of weed problems, type of soil, rainfall, available herbicides, and cropping sequences will determine the feasibility of minimum tillage.

Residue Management and Soybeans

Research in tillage and residue management for planting soybeans as a second crop after small grain was started only recently. From studies in Kansas with treatments of chisel plow, no-till, and in continuous crop, grain yields were 2325, 2540 and 2499 kilograms per hectare, respectively in 1972 (30). Studies in Mississippi (51), however, showed no-tillage plots produced 76 percent as many soybeans as conventional systems. Lack of nutsedge control by herbicides caused the lower yield, but where the crop was hand hoed, there was no yield difference.

In some states, results have been erratic. In Alabama, no-tillage soybeans produced yields as high as conventional systems in the first year of the experiment, but the yields were considerably lower in the following years in the same field (49). In oat-soybean rotation, burned and non-burned residue management treatments in combination with turn-plow, disk-harrow, lister planting produced the same soybean yield (3).

Ohio researchers (25) recommend that the seed should be planted at one to two inches deep and be well covered to have a good seed-soil contact for satisfactory crop establishment. Discing has produced yield equivalent to no-tillage methods. Planting with a no-tillage planter gave better yields than planting with the conventional drill in the disc and field cultivator plots. Failure to cover seed properly resulted in poor stands with the conventional drill. Disc plus drill, disc and no-till planter, cultivator and drill, cultivator plus no-till planter and no-till planter gave yields of 528, 1324, 591, 1149, and 1082 kilograms per hectare and percent stands of 40, 90, 50, 90, 90, respectively.

A study conducted in Kentucky (47) comparing no-tillage planted soybeans following the harvest of barley showed mid- to full-season varieties tended to be higher yielding with no-tillage and late planting in a double cropping system with small grains.

J. H. Palmer (41) stated that no-tillage for soybeans in South Carolina offered some advantages but required a working knowledge of all factors that influenced the result. No-tillage was no shortcut for profitable soybean production because it required more management than conventional systems. Further, weed control, choice of variety, cropping system, row width, chiseling, etc., were found to be interrelated. With conventional tillage some mistakes did not seriously affect yields, but with no-tillage, mistakes often caused low yields.

Although crop residue left on the surface of the soil is very effective in controlling erosion by wind and water, crop yields are occasionally reduced as compared with incorporation of the residues into the soil. As a result of the production of phytotoxic substances by microorganisms (20, 32). Wheat, oat, and sorghum residues collected at harvest time from each crop contained water soluble material that was toxic to growth of seedlings. The order of increasing percent of inhibition from the water extracts from stems from wheat, corn, oats and sorghum on root growth of wheat were 2, 11, 55, and 81 percent, respectively. All toxic components found in the water extract of wheat is disappeared after eight weeks of decomposition. The Penicillium urticae B. occurred in a greater number on the stubble mulch plots than on the plow-plant plots in the spring and fall of the year. This organism was found to produce a phytotoxic substance, Patulin, causing reduced growth of crops associated with stubble mulching. Patulin added to wheat in greenhouse experiments reduced seed germination and the wheat plants showed symptoms such as necrosis, narrow and shortened leaves, leaf-tip burning, reduced stem diameters and length, shortening the first internode and chlorosis.

Sommers (55) stated that generally plant residue toxins are absorbed or inactivated by soils or are distributed by tillage so that the effects are spotty within a field depending upon the probability of root contact with the residue microenvironment. The phytotoxic effects probably can be avoided by placing plant residues away from the seedlings and especially by avoiding fresh residue placement near the seed.

Tillage of soil generally increases bacteria, fungi and actinomycete activity but decreases the number of most species of yeast. Minimum tillage often increases plant diseases because surface residues are slowly decomposed and may contain elevated levels of inoculum. Minimum tillage increases microbial populations resulting in higher rates of mineralization, ammonification and nitrification (55).

Nitrate-nitrogen was found to be lower in the root zone under no-tillage (4). This difference is related to a reduction in evaporation loss which resulted in leaching nitrate to a greater depth following rain. Higher rates of nitrogen fertilizers may be needed for crops under minimum tillage management. Movement of P and K into soil profile following surface applications on untilled soil is slow (17).

Accumulation of phosphorus near the soil surface may be an advantage due to greater plant absorption during early growth. Studies showed higher uptake of phosphorus from the surface than from incoporated applications (53).

Deep Tillage Effect

Chisel-plow systems have been adopted by farmers in an effort to reduce the time and skill required for primary tillage and to reduce soil compaction, tillage costs, crop residues and to apply limestone, fertilizer or other soil amendments simultaneously. Crop yield from chisel plow and strip tillage systems compared favorably with those obtained with conventional methods on soils with good drainage if plant populations and weed control were comparable. Two planting difficulties may be encountered with chisel plow systems: (1) the seedbed may dry rapidly unless the chiseled soil is firmed with a light-fitting implement, such as spike tooth harrow, (2) the trash in the row area may interfere with planter operation (38). Experiments in South Carolina (58) showed that subsoiling to a depth of 13 inches to break the compact layer just below planting depth increased soybean yields significantly four years out of six without irrigation. The largest increases were 625 kilograms per hectare. It is thought that the principal benefit of the subsoiling is to enable the plant roots to penetrate deeper and make greater use of the subsoil moisture. Palmer (41) stated that a chisel mounted on a tool bar between the coulter and seedbed opener may give a significant yield advantage on sandy soils. On a soil with a higher clay content, chiseling may not be that beneficial. Chiseling lets soybean roots penetrate the hardpan and provide for better use of soil moisture and available nutrients below the plow layer. In a study in Texas (12) subsoiling has successfully increased yields in many soils, especially sandy and sandy loam soils. Precision tillage, subsoiling under the intended drill row, and bedding in the same operation, increased cotton yields in sandy soils and the increase in cotton yield was proportionate to the decrease in soil strength under the drill as modified by precision tillage.

Chiseling throughout the tillage pan every 12 inches reduced both soil and water losses more than cultivation with either sweeps or a one-way disc on deep, medium-textured soils. Chiseling eight inches deep and 12 inches apart was the most effective method for increasing water intake rate. If chiseling was performed when the soil was above one half of field capacity, new tillage pans were created and the stored moisture lost. The best time for chiseling appears to be after harvesting wheat when the soil water content is less than one half field capacity (58).

Soil Characteristics and Tillage

Minimum tillage tends to leave residue at or near the soil surface. The amount of residue remaining depends on the tillage implement used. The value of mulch in soil conservation has been recognized for a long time. Stubble mulch significantly improves moisture conditions in the seeding zone and markedly reduces surface crusting. Drying rate of the 0 to 0.5 inch portion of the soil profile is greatly reduced by surface plant residue (1). Mulching resulted in an increase of available moisture, compared to the unmulched soil and increased crop yields but decreased the surface soil temperature. The result was temporarily depressed early corn growth (35, 61). Crop residue plowed under slightly increased soil aggregates greater than 0.2 mm. and indicates a slight improvement in the physical condition and water intake rate. There was an average 15.02 inches of available water to a depth of six feet on plots where residue was plowed under as compared to 14.87 inches on plots that were plowed without surface residue (33). No-tillage, the method which left the most surface residues, had a higher volumetric moisture content to a depth of 60 inches during the corn growing season when compared to conventional tillage. The greatest difference occurred in the 0 to 8 centimeter layer. Beyond a depth of 60 cm. system of tillage had little influence on soil moisture (4). Other characters such as aggregate stability, organic matter, and bulk density were significantly better in the top 12 inches of the soil after 11 years of stubble mulching in wheat compared to soils conventionally plowed (59).

In Kansas a minimum tillage system consisting of plowing and planting in the wheel track, resulted in a higher rate of moisture infiltration, less soil resistance to penetration, lower bulk density, and less soil compaction than conventional methods. This work also showed higher rates of water intake for till-planting and listing methods than for conventional systems with till-planting having the highest rate (16). Another study in Indiana showed that infiltration rate was 24 percent greater and soil loss was reduced 34 percent by minimum tillage (31).

Row Spacing and Population

Row spacings of 10, 20, and 30 inches compared to the standard 40-inch rows have been investigated by a number of workers (60, 62, 63, 68).

Wiggans (68) stated that the soybean plant, like many others, has the ability to make wide adjustments to available space. Optimum seeding rate and spacing for soybeans should be determined not only for the various soybean producing areas, but also for the variety to be grown. Soybeans with large wide canopy, later maturity variety would hardly be expected to require the same seeding rate or spacing for optimum yield that small growing, early maturity varieties require.

Soybeans planted in narrow rows had higher yields than those planted in wider rows. Studies in Ohio (25) showed that soybeans planted in late June and early July produced small plants that flowered soon after emergence and the yields were increased six to ten bushels per acre when planted in 15-inch rows compared to 30-inch rows.

Plant population rather than row width or spacing in the row is a more important criterion for soybean yield, according to Thomson,et al. (60). When the row width was 18 to 27 inches, soybeans generally yielded best when spaced two to three inches apart in the row, but one to two inches apart was better for 36-inch rows.

In Kentucky, Shane et al. (52) tested three soybean varieties in three row spacings in 1966, 1967 and 1968. Amsoy, Clark 63, and Hood produced yields of 2654 kilograms per hectare in 20-inch rows; 2728 kilograms per hectare in 30-inch rows; and 2600 kilograms per hectare in 40-inch rows averaged over the three year period.

Judd (26) stated that a yield increase from narrow rows can be expected in any region under conditions of late planting and low soil fertility or with an early maturing variety and unfavorable growing conditions, but weed control must be maintained.

A study in Oklahoma (9), under weed-free conditions from 1969 to 1970, investigated the performance of selected soybean strains at two row spacings double cropping following wheat. The 40-inch row plots yielded more than 20-inch row plots both years. The plants in a narrow row spacing gave consistently higher shattering rates than plants in the wide rows. Spacing had no effect on seed weight, protein content or oil content. Weber (63) also stated that plant spacing and population had small effects on protein and oil content.

From a study in Iowa (64) it was concluded that oil and protein content and Iodine number were not affected by row spacing. In studies with five varieties at Purdue (65) it was shown that the following attributes are significantly correlated: (1) lateness of maturity with high oil content, (2) lateness of maturity with low protein content, and

(3) high protein content with low oil content. Howell (24) indicated that the temperature during the period of intensive oil synthesis was optimum at 85°F. He found protein level to be less affected by temperature than oil content.

Lodging and plant height were relatively unaffected by row width but they both tended to increase at the highest population density. The highest yield was obtained for a 10-inch row spacing treatment with 104,544 plants per acre. The plants at the highest population were taller, more sparsely branched, lodged more and set fewer pods and seeds than plants at lower densities (63).

Roger, et al. (49) found that lodging was reduced as the row width was narrowed and the height of the first pod on the stalk was higher as rows were narrower.

In a study of branch removal with plant population at equidistant spacings in Illinois (7) plant heights, lodging, stem weights, and leaf areas, were greater for plants with branches than in plants without branches. Seed weight, leaf efficiency, and leaf density were greater in plants without branches. Also, seed yield increased with narrower spacing of normal plants but decreased with wider spacing of plants without branches.

Probts (48) found that larger seed yield variations appeared among different varieties than among seeding rates. A seeding rate of 21 pounds per acre in 36-inch rows produced the highest yield. A study on a highly productive soil in Illinois (14) showed that seed yield was generally unaffected by seeding rate where no lodging differences occurred, but tended to be significantly lower where the higher seeding rate caused severe early lodging. These results indicate that early lodging is a major factor contributing to the yield decrease at higher seeding rates. Whether a lodging differential occurred between seeding rates was dependent on location, planting date, variety, and row spacing.

Planting Date

The soybeans are perhaps among the most responsive of plants to their environment. Their sensitivity to light is evidenced by the large number of maturity groups in the varieties grown within the United States. Within a given latitude, the planting date for soybeans is about the same (42). In Ohio (25) studies comparing soybean yields planted at different dates in wheat stubble, with and without irrigation, showed that decreases in yields with the later plantings were similar on both of them with an average decrease of five bushels of soybeans per week delay after June 15. This result emphasizes the importance of early planting of soybeans in wheat and soybean double cropping systems. Early maturing varieties gave the highest yields when planted about May 15, but late maturing varieties gave the highest yields when planted on May 1, and intermediate maturing varieties gave near maximum yields when planted on either date.

Early planting in dense populations, because of severe lodging, especially in narrow rows, caused reduction in yields (14).

Studies in Louisiana (49) showed the largest yield decrease was with the Group V varieties (medium maturity) approximately two bushels per acre for each week delayed in planting after May 1. Group VI varieties (medium maturity) decreased in yield almost one bushel per acre per week delay in planting. These results also showed that the later maturing varieties should be used only for early plantings to prevent damage by frost. The time for planting soybeans depends on at least three factors: (1) varieties, (2) moisture supply, and (3) temperature. Extremely hot temperature and lack of moisture will cause a reduction in seed vigor and germination. Cool temperatures will slow germination and allow microbial injury to the germinating seed.

When soil temperature two inches below the soil surface reaches 50°F at 7:00 a.m. or 55°F at 1:00 p.m. four inches deep, planting conditions are the most preferable according to Judd (26). At a soil temperature of 70°F soybeans will emerge in four or five days, but will require seven to ten days at 60°F. Soybeans need a rather high level of moisture for germination, about 50 percent moisture compared to about 30 percent moisture for corn (55).

The highest oil content of eight soybean varieties was attained in a May 1 planting and oil content decreased progressively with later plantings. However, the rate of decrease was not consistent for all varieties. Protein contents of soybean seed varied inversely to the general trend noted for oil content (39).

Weed Control and Cultural Practices

Historically, weed control was regulated by cultivation. Recommended weed control practices required several tillage operations, rotary hoeing one or more times as soybeans were emerging, and cultivation with a rotary hoe one to three times. Since 1960 chemical weed control has replaced some mechanical tillage (67).

Weed competition early in the growing season is very detrimental to soybean yields. Uncontrolled weeds during the first four weeks reduce yields, but if the soybeans are kept weed free for four weeks after emergence, maximum yields will be produced (67).

Outstanding weed control can be accomplished with systems that combine chemical and mechanical cultivation. The use of narrow row spacings have also been shown to reduce weed competition. Burnside and Collvile (10) 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 10-, 20-, 30- and 40-inch rows completely shaded the ground between the rows in 36, 47, 58, and 67 days, respectively. Weed populations increased as the row width increased. According to Burnside and Collvile (10) each 86 pounds of weeds per acre resulted in an average yield reduction of one bushel per acre. As soybean yields increased, weed yields decreased.

Peter, et al. (45) found that for 20- or 24-inch rows one or no cultivation, in addition to a herbicide treatment, was necessary, and one, or sometimes two, cultivations were needed for 32- or 40-inch rows. Combinations of cultivation and herbicides gave better yields, and sometimes increased yields even though weeds were not present. Cultivation destroyed surface crusts which are very beneficial in reducing runoff, soil erosion, and increasing water infiltration.

Rusell, et al. (50) found that cultivation at stage six (pods in lower half of plant well formed) at 114 mm deep and 152 mm from row caused a yield reduction of 325 kilograms per hectare compared to no cultivation. Cultivation at 114 mm deep and 305 mm from plants resulted in more lateral root pruning than the 64 mm deep and 152 or 305 mm from the rows but was, nevertheless, the most favorable cultivation for any stage of crop growth, and increased yields 80 to 200 kilograms per hectare over no cultivation treatments.

Today herbicides are available that will control cocklebur and johnson grass, the difficult weeds in soybeans. The use of Paraquat or Dinitro in combination with other residuals has proven most effective for weed control when planting directly in stubble (25, 28, 49). In a study in Mississippi (28) involving no tillage planting in stubble, weed control with Paraquat and Paraquat in combination with other residuals gave satisfactory results. Paraquat at the rate of 0.25 pounds per acre gave 100 percent control of cockleburs three inches tall, teaweed at 2.5 inches tall, little barley, peperweed, and coffeeweed. Combination of Paraquat and Lorox at 0.25 and 2.5 pounds per acre, respectively, gave the best residual weed control of the three treatments. Paraquat plus alachlor gave the poorest control. Kirby (29) stated that Paraquat has proven to be much less selective and less dependent upon environmental and biological factors when compared to other post emergence herbicides. Paraquat as a post emergence herbicide must be sprayed below the top of the crop so that the spray contacts the crop stems one to three inches above the soil surface if injury to the crop is to be avoided.

The combination of Paraquat at .25 pound per acre plus Lorox and Lasso at .75 and 1.50 pounds per acre, respectively, also gave satisfactory weed control and resulted in good soybean yields. Higher rates of Linuron than 0.75 pounds per acre resulted in seed injury and poor yields (25).

Another study with Paraquat plus Lasso or Lorox by Roger, et al. (49) controlled weeds and the yields of soybeans produced in the no-till plots were equal to those in conventional plow plant plots with preplant herbicides and cultivation in 1969. The same herbicides were not effective in controlling weeds in the following years, however, and the yields obtained were considerably lower. Linuron at 2.0 pounds per acre on a fine sandy soil severely injured the soybeans and was apparently leached out of the soil by a heavy rain soon after the soybeans emerged.

Wax and Pendleton (62) found that Trifluralin failed to control picklysida and velvetleaf but controlled grassey weeds well. Trifluralin-treated plots (at the rate of one pound per acre, applied as a broadcast spray prior to planting and thoroughly incorporated by two discings) and cultivated plots produced yields about the same with 30-, 20-, and 10-inch rows. However, at the 40-inch row spacing, the cultivated plots significantly outyielded the plots treated with herbicide.

Studies in Missouri and Nebraska (10, 45) showed that Amiben controlled weeds considerably better than PCP (sodium pentachlorophenale). Amiden was more effective as row spacing was reduced. The 10-inch rows required less Amiben than the 40-inch rows.

Hoeff, et al. (23) stated that Lorox or Moloran are best adapted to soils with less than three percent organic matter for control of grasses and weeds. Lasso or Surflan, pre-emergence herbicides, control annual grasses.

Reduced plant stands and increased weed problems are more likely to occur in minimum tillage systems than in conventional systems. Most researchers believe that where comparable stands and weed control exist, very little yield differences may be expected for the various tillage systems. However, they do agree that greater managerial ability is necessary for most reduced tillage systems than for the normal or conventional systems utilizing the mold-board plow and disc (44).

There is a consistent decrease in height of soybeans at the number of weeds increase, and the number of pods per plant decrease (36).

Fertility and Water Requirement

There seems to be agreement that a pH of 6.0 to 6.5 is desirable for soybean production. Liming soils that are too acid is essential for high soybean production. The soil pH affects nodulation and when soil pH is adjusted with lime, a considerable yield increase can be expected (40, 60). Under soil conditions when pH was 4.2, the nitrogen-fixing bacteria could not function and yield response was obtained from added nitrogen (37). Studies in Louisiana (43) showed that for the soils of pH 5.1 the best possible yields were 20 to 24 bushels per acre. When the soil pH was raised up to 5.6, the yields increased. The highest yields (34.0 bu/acre) were produced at pH 7.0. Studies in South Carolina (58) also showed that soybean yields were not significantly affected by the addition of dolomitic limestone to a soil with a pH of 6.4

Kamprath (27) stated that response to lime is due to the following factors: (1) neutralization of exchangeable aluminum, (2) decrease in water soluble manganese, (3) increased availability of soil molybdenum, (4) promotion of nodulation and rhizobiumactivity, and (5) supplying calcium and magnesium. The supply of calcium is very important for nodulation of legumes. A much higher concentration of calcium was required for nodulation of soybeans than for growth according to Kamprath (27). Soil acidity is probably the main factor limiting the nubmer of rhizobia in soils. Species of rhizobia, however, differ in their sensitivity to acidity. Liming mineral soils to a neutral pH will eliminate Al and Mn toxicity and will provide an environment favorable for nodulation and rhizobia activity (27).

Soybean plants are not highly responsive to direct applications of phosphorus. In double cropping systems, enough phosphorus and potassium should be applied to the preceding crop in the sequence to maintain levels sufficient for soybeans. Soils testing "low" in phosphorus and potassium gave satisfactory increases from additions of these elements (49). Application of high rates of P_2O_5 or K_2O (500 pounds per acre) reduced yields significantly two years out of three when compared to a moderate rate (250 pounds per acre) (58). Generally, the response of soybeans to nitrogen has been inconsistent. Nitrogen produced vegetative growth but did not increase yields (49).

Inoculation with rhizobium species is more economical than nitrogen fertilization. It has been shown that inoculation of soybeans increased yields on soils where soybeans had not been grown previously. Improving soil conditions for rhizobium bacteria activity and soybean plants is required. Fertilizing with nitrogen at the present time does not appear to offer an economically feasible means for increasing soybean yields. It was agreed that inoculation is not necessary as a regular practice where well nodulated crops of soybeans have been grown within the past three to five years, but soybeans should be inoculated in fields where soybeans have not previously been grown (37).

Water is often the primary limiting factor in soybean production and is an important management concern. Early season droughts are likely to affect stands. Early reductions in vegetative growth can often be made up for in later stages of growth. Peak water requirement extends through most of the pod filling period even though actual leaf area is decreasing by the end of the period (54). Harpich (21) stated that adequate soil moisture is essential to the production of optimum yields and that total water use by soybeans ranges from 18 to 26 inches according to location. Early moisture stress (pre-bloom) caused less yield reduction than stress later in the reproductive stage of development. An adequate moisture supply for germination, seedling establishment, early bloom, and later bloom stages is required for top yields (21).

CHAPTER III

MATERIALS AND METHODS

This study was conducted under dry land conditions on the Eastern Pasture Research Station, Muskogee, Oklahoma, from June 25, two weeks after wheat harvesting, to December 23, 1974.

The soil is a Taloka silt loam, classified as Mollic Paleudalfs (seventh approximation) with a zero to one percent slope. It is a grayish brown to dark brown, deep, well-developed soil, somewhat poorly drained, and has a perched water table during wet seasons. Abruptly below the A_2 horizon is a compact, mottled clay B_{2t} horizon (28 to 64 inches depth). The A_p horizon, zero to eight inches, contains 27.1 percent sand, 64.4 percent silt, and 8.5 percent clay. It is 63 percent base saturation and is described as a weak, fine granular structure, friable, and permeable, slightly hard soil, according to Stiegler and Gray (57).

The soil had a pH of 5.0, available phosphorus of 20 pounds (P) per acre, and exchangeable potassium of 60 pounds (K) per acre. The climatic conditions at planting were unfavorable for the growth and development of seedlings due to rapid drying conditions. Few weeds were present and were killed with Paraquat except for the check plots.

Prior to planting wheat in the fall of 1973, the land received good seedbed preparation with conventional tillage. Treatments were established after the wheat was harvested prior to any other tillage.

The experiment was arranged in four by four factorial treatment (four tillage methods and four row spacings). The four row spacings studied were 10-, 20-, 30-, and 40-inch rows. No-tillage without herbicide, chemical tillage (no tillage plus Paraquat), disc plus Lasso and Lorox, and chisel plus disc with Lasso plus Lorox comprised the tillage methods studied.

Paraquat (1', 1'-dimethyl-4, 4'bipyridinium salt), Lasso [2-Chloro-2', b'-dimethyl-n-(methoxy-methyl) acetanilide], and Lorox [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] were applied to specified seedbeds at the rate of 0.28, 3.36, and 1.12 kilograms per hectare, respectively.

A randomized complete block design was used with four replications of the sixteen treatment combinations. Plots were 7.16 meters by 4.57 meters and had 6.09 meters border.

Plots were "tilled" and seeded on June 25, 1974. The tillage systems are described in detail as follows:

1. <u>No-Tillage</u>. There was no weed control or cultivation of this plot. Soybeans were seeded directly into standing wheat stubble.

2. Chemical Tillage. Weeds were killed by a pre-plant application of Paraquat. A three-gallon hand sprayer was used to spray Paraquat. Soybeans were seeded direclty into standing wheat stubble after herbicide application.
3. Disc and Chemical. Plots were disced once with a conventional tandem disc. A 28-feet boom sprayer was used to spray Lasso and Lorox after seedbed preparations.
4. Chisel, Disc and Chemical. Plots were chiseled 20 to 50 centimeters deep once with chisel plows equipped with two-inch chisel points spaced 30 centimeters apart. Plots were then disced and treated with herbicides as per treatment number three above.

All plots were seeded with a 10-inch row International 150 hoe drill equipped with a fertilizer attachment. Forrest, medium maturity soybean variety (maturity group V), was used with a seeding rate of three bushels per acre. Nitrogen (N) and phosphorus (P_2O_5) fertilizers at the rate of 22.40 and 44.8 kilograms per hectare, respectively, were placed five cm below the seed. One hundred and sixty-eight kilograms per hectare of K_2O were broadcasted before planting. All plots were thinned to the same plant population (approximately 250,000 to 300,000 plants per hectare) three weeks after planting. Seedling emergences of plots were not uniform and some seeds were left exposed on the surface.

Plots were hand harvested on December 23, 1974. Two, three, four, and eight rows, 4.42 meters long in the center of the plots of 40-, 30-, 20- and 10-inch row plots, respectively, were harvested. Plants were threshed in the field, cleaned and weighed. Soybeans are reported in bushels per acre and kilograms per hectare.

Approximately 500 gram soil samples zero to ten centimeters and 20 to 30 centimeters deep were collected from no-tillage, disc, and disc plus chisel plots to determine the percent of soil moisture by weight three weeks after planting. Net weight of each soil sample was recorded before drying. After drying for two days at 110°C, soil samples were weighed and the percent moisture of the soil samples calculated. Soil samples were collected from two blocks and two locations each.

The wheat stubble was left on the soil surface (eight to 12 inches height). Estimated wheat residues on the no-tilled plots were 4480 kilograms per hectare.

Yields of plots and percent of moisture of soil samples for each depth were analyzed by using Statistical Analysis System (Barr and Goodnight). Differences among treatments were determined by method of fitting constants (Steel and Torrie).

CHAPTER IV

RESULTS AND DISCUSSION

All growing weeds were killed by the chemical tillage by the application of Paraquat, including pigweeds (about one foot tall) and grassy weeds just emerging, as observed three weeks after treatment. Weeds were found later in the chemical tillage plots that came up after the application of Paraquat.

No-tilled plots had a severe weed infestation. Mechanically tilled plots plus herbicide treatments (disced plus Lasso and Lorox and chiseled plus disced plus Lasso and Lorox) killed weeds initially present and gave satisfactory weed control subsequently. However, there were "spotty" weeds found in these plots but should not have caused yield reduction.

The precipitation during the early stage of seedling development was far below the long-range average as recorded and shown in Figure 1. The surface soil at planting time was quite dry and crusted and there was no significant rainfall for three weeks after the soybeans were planted.

The soil moisture (percent by weight) of surface and subsurface layers are shown in Table I. Analysis of

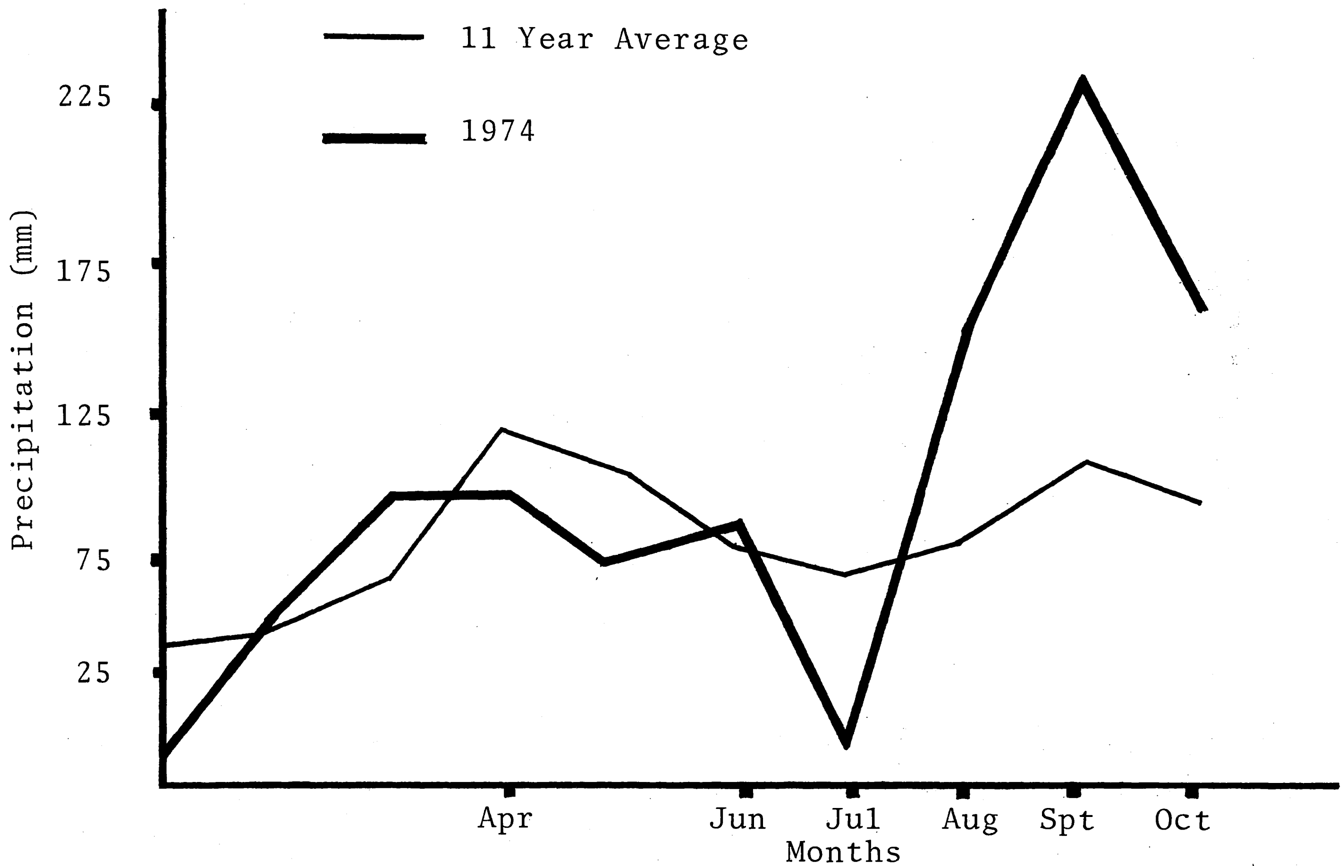

Figure 1. 1974 Precipitation in Eastern Oklahoma, with 11-Year Average

TABLE I

AVERAGE SOIL MOISTURES (PERCENT BY WEIGHT) OF TOPSOIL AND SUBSOIL WITH DIFFERENT TILLAGE METHODS

Tillage Methods	No-Till	Disc	Chisel plus Disc
Topsoil	12.1	8.35	9.45
Subsoil	17.8	16.60	17.40

variances of surface and subsurface soil moisture is shown in Table II. No significant differences in soil moisture were found three weeks after planting as a result of tillage treatments, though topsoil for no-tillage (and chemical tillage) plots seemed somewhat higher (see Table II). This should be compared with work done by Belvins, et al. (3) who found that no-tillage treatments had higher volumetric moisture contents to a depth of 60 centimeters during most of the growing season with the greatest difference occurring in the surface soil. Researchers in Nebraska (69) noted that discing dried out the surface soil more than other tillage treatments.

It seems likely that soil should not be disced prior to planting soybeans after wheat in Oklahoma unless late spring rains provide a moist soil of the upper 60 cm.

Wheat residue was reduced by the treatments with mechanical tillage. The plots received both chiseling

TABLE II

MEAN SQUARE FOR PERCENT MOISTURE BY WEIGHT OF TOPSOIL AND SUBSOIL

Sources	df	Top Soil MS	Subsoil MS
Total	5	0.438	5.651
Block	1	0.060	0.060
Treatment	2	0.747[NS]	7.432[NS]
Treatment by Block	2	0.320	6.665
C. V. Percent	-	3.27	25.87

NS = Nonsignificant

and discing which presented an uneven surface that caused some difficulties in planting.

Because of dry surface and unloosed soil in the no-tillage and chemical tillage plots at planting time, the 10-inch row International 150 hoe drill did not work well. It did not penetrate deep enough to place and cover the seed in the soil. In the mechanically tilled plots, it worked satisfactorily except the residue mulched and left on the surface of the chiseled and disced plots interfered with the operation of the hoe drill.

Many workers (13, 25, 41, 47) have noted that minimum tillage or no-tillage crop productions require special planters. A planter selected should be properly equipped and set open a very narrow slot and loosen soil enough to ensure seed-soil contact. Extra weight may be needed for good coulter penetration when plantings are made in dry, fine-textured soils. The packer wheel should firm the soil over the seed row but avoid pressing a deep trench. No-tillage planters require: (1) a rolling or fluted coulter mounted ahead of the row opener that will cut through the existing vegetation or crop residues and penetrate the soil to a uniform depth; (2) a seed opener with positive planting depth control. The double disc seed opener has the advantage of cutting through vegetation or crop residue that may have been missed by the coulter in front of the unit; and (3) a narrow row press wheel that will firm the soil over the seed in the planted row.

Seedling emergence of soybeans in the no-tilled and chemical tilled plots was somewhat lower than in the mechanically tilled plots, because of drill difficulties as stated previously. As much as 30 percent of the soybean seed was left on the surface for these two treatments. Seedling emergences in the disced plots were higher than the chiseled and disced plots because of the uneven surface mentioned earlier, since more seeds were left exposed than for the disced plots.

Soybean yields are shown inTables III, IV, and V (see also Figures 2, 3, and 4). The average yield for this experiment was 783 kilograms per hectare. The analysis of variance for yield is shown in Table VI. Tillage treatments

TABLE III

AVERAGE YIELD OF SOYBEANS WITH DIFFERENT TILLAGE METHODS

Tillage Methods	No Tillage	Chemical Tillage	Disc Lasso + Lorox	Chisel + Disc Lasso + Lorox
Yield (Kg/ha)	374.2	661.2	1138.3	1056.0
Yield (bu/acre)	5.6	9.8	16.9	15.7

TABLE IV

AVERAGE YIELD OF SOYBEANS WITH DIFFERENT SPACINGS

Row Spacings (Inches)	10	20	30	40
Yield (Kg/ha)	906.7	820.4	856.2	647.4
Yield (bu/acre)	13.5	12.2	12.7	9.6

TABLE V

MEAN YIELDS WITH DIFFERENT ROW SPACINGS AND TILLAGE METHODS

Tillage Methods	Row Spacings (Inches) 10	20	30	40
No-Tillage	706.9 10.5	898.3 13.4	694.5 10.3	969.6[a] 14.4[b]
Chemical Tillage	776.1 11.5	898.5 13.3	829.1 12.3	796.8 11.9
Disc + Lasso + Lorox	999.3 14.9	766.2 11.4	821.2 12.2	693.9 10.3
Chisel + Disc + Lasso + Lorox	773.8 11.5	737.92 10.9	911.3 13.6	764.7 11.4

a = Kg/ha

b = bu/acre

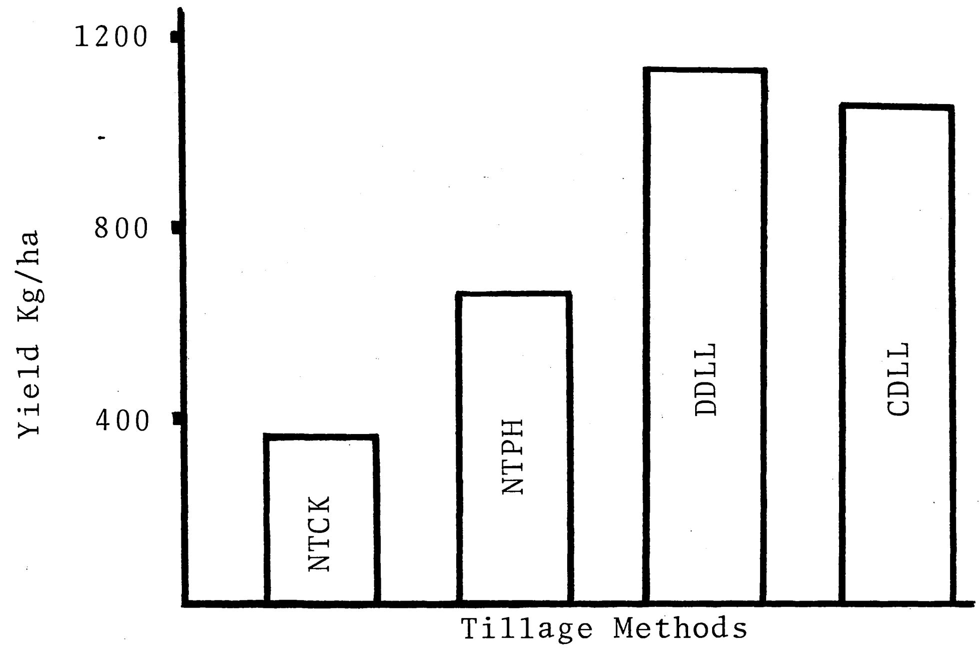

Figure 2. Mean Yields of Soybeans With Different Tillage Methods

NTCK = No-Tillage
NTPH = Chemical Tillage
DDLL = Disc + Lasso + Lorox
CDLL = Chisel + Disc + Lasso + Lorox

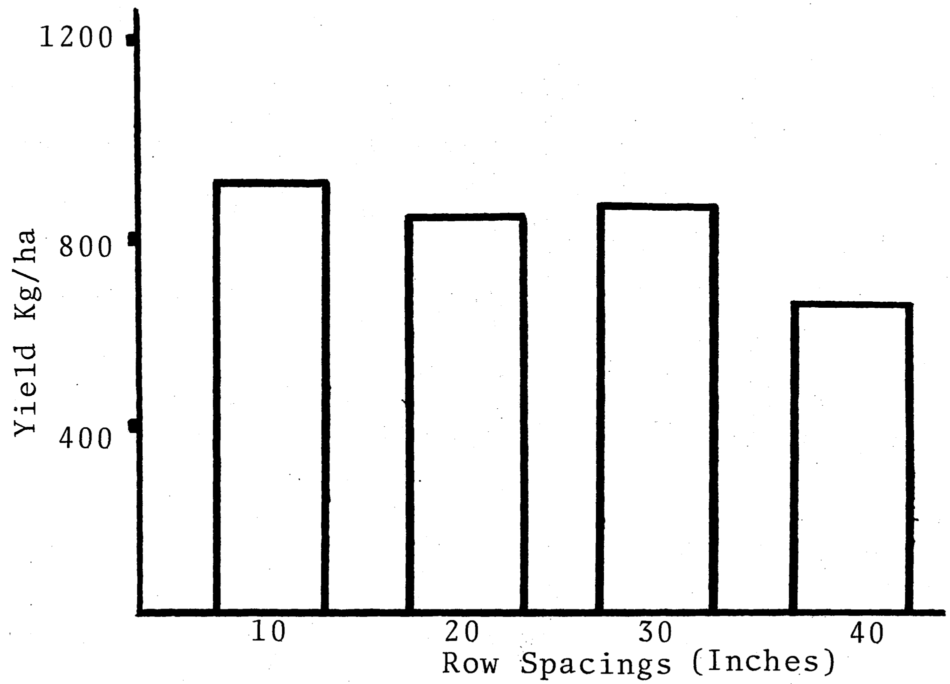

Figure 3. Mean Yields of Soybeans With Different Row Spacings

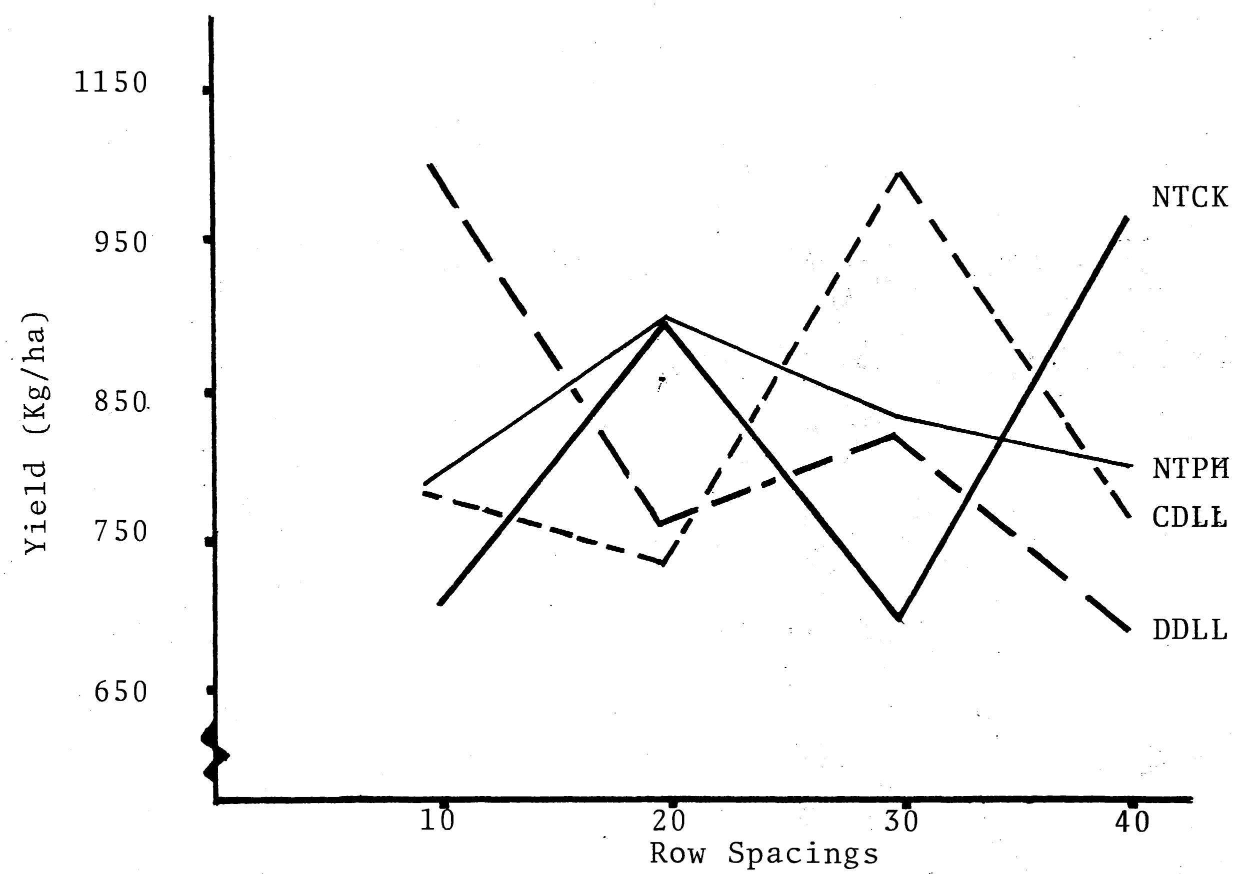

Figure 4. Mean Yields of Soybeans With Different Row Spacings and Tillage Methods

NTCK = No-Tillage
NTPH = Chemical Tillage

DDLL = Disc + Lasso + Lorox
CDLL = Chisel + Disc + Lasso + Lorox

TABLE VI

MEAN SQUARES FOR SOYBEAN YIELDS WITH DIFFERENT TILLAGE METHODS AND ROW SPACINGS

Sources	df	MS	OSL
Total	39		
Block	2	95,334.4	0.59
Tillage	3	1,254,846.9**	0.002
(NTCK + NTPH) VS (DDLL + CDLL)	1	3,345,831.5**	0.0003
NTCK VS NTPH	1	12,191.4	0.79
CDLL VS DDLL	1	406,517.8	0.15
Spacing	3	129,099.9	0.55
Linear	1	276,964.3	0.22
Quadratic	1	276,964.4	0.72
Cubic	1	22,712.4	0.55
Tillage + Spacing	9	34,281.3	0.99
Error	22	178,164.3	

C. V. 53.899 percent

**Significant at the .01 level of probability.

DDLL = Disc + Lasso + Lorox

CDLL = Chisel + Disc + Lasso + Lorox

NTCK = No-Tillage

NTPH = Chemical Tillage

produced yields that were significantly different at the 1.0 percent level of probability. The average yields of tillage methods are shown in Table III and Figure 2. The average yields of the no-tillage and chemical tillage treatments were significantly lower than the average of disc and chisel plus disc with Lasso and Lorox. The lower yields on the no-tillage and chemical tillage plots may be due to poorer soybean seedling establishment and larger weed infestation. However, Paraquat application in the chemical tillage plots increased the average yields of soybeans over no-tillage treatment two-fold. This is explained by the removal of the weed competition for moisture early in the season by using Paraquat. Although the average yields of chemical tillage plots were higher than no-tillage plots, there was no significant difference statistically between the two treatments. This is due to much variation between plots as evidenced by coefficients of variation in Table VI (53 percent). Plots receiving Paraquat produced yields lower than the mechanical tillage treatments receiving Lasso and Lorox. The chiseled and disced plots with Lasso and Lorox produced yields slightly lower than the disced plots with Lasso and Lorox. The lower yield may be due to lower seedling emergence.

Row spacings showed no significant effect on yields and there was no significant interaction between row spacing and tillage methods. The 10-, 20-, 30-, and 40-inch rows gave average yields of 906.7, 820.4, 856.2, and 647.4

kilograms per hectare, respectively (Table IV and Figure 3). Narrow row yields tended to be higher than the wider row yields. The highest yield in the individual plots was 10-inch row plots. This agreed with the results supported by other investigators (23, 49).

In this experiment, the variation between treatments was relatively high. The coefficient of variation was 53.9 percent. Generally, the coefficient of variation of 25 percent is considered maximum for experiments with agronomic crops.

Yields of soybeans reported here are quite low. The most drastic reduction in yield from these experiments was caused by rabbits. Data from one replication were discarded because of rabbit damage, and data from eight plots in the other three replications were also discarded because of rabbit damage.

In addition, the soil pH of 5.0 is too low for good growth and development of soybean plants because of poor and ineffective nodulation. E. J. Kamprath (27) noted that poor or ineffective nodulation is likely a result of low molybdenum. He noted also that yield reduction may also be due to aluminum or manganese toxicities or a micronutrient deficiency. Soybeans yield best in a slightly acid to nearly neutral soil pH (6.2 to 6.8) (40). Liming acid soils to pH 6.2 or above is essential if high soybean yields are to be produced. Researchers in Louisiana and Alabama (43, 49) have shown that soybean yields on soils with pH values lower than 6.2 are very low. Good yield response was achieved only by the addition of lime.

In double cropping soybeans after small grains, acid soil reaction should be corrected before the small grain is planted. There is little value to applied lime at soybean planting time for that crop. Furthermore, enough phosphorus and potassium should also be applied to the preceding crop to maintain levels sufficient for soybeans (13, 41, 49).

The no-tillage treatment produced negative profits as shown in Table VII. The application of Paraquat resulted in negative profits also (Table VIII). Chisel plus disc with Lasso and Lorox treatment showed a net profit (see Table IX) but the disc plus Lasso and Lorox showed the best profit (Table X).

TABLE VII

PRODUCTION COSTS AND RETURNS FOR SOYBEANS FOLLOWING WHEAT: BUDGET FOR NO-TILLAGE

Variable Costs	Cost Per Acre
Land Preparation	None
Herbicide Application	None
Herbicide	None
Fertilizers:	
Nitrogen 20 pounds at 25¢/lb	5.00
Phosphorus 40 pounds at 30¢/lb	12.00
Potassium 150 pounds at 10¢/lb	15.00
Seed and Inoculation	10.00
Planting	2.50
Harvesting and Hauling	10.00
Total Cost	54.50
Yield 5.5 Bushels Per Acre	
Price at Harvest	
At $7.00/bushel Gross Income	38.50
At $5.00/bushel Gross Income	27.50
Net Income Above Variable Costs	
At $7.00/bushel	-16.00
At $5.00/bushel	-27.00

TABLE VIII

PRODUCTION COSTS AND RETURNS FOR SOYBEANS FOLLOWING WHEAT: BUDGET FOR CHEMICAL TILLAGE

Variable Costs	Cost Per Acre
Land Preparation	None
Herbicide Application	1.75
Herbicide	5.50
Fertilizers:	
Nitrogen 20 pounds at 25¢/lb	5.00
Phosphorus 40 pounds at 30¢/lb	12.00
Potassium 150 pounds at 10¢/lb	15.00
Seed and Inoculation	10.00
Planting	2.50
Harvesting and Hauling	10.00
Total Cost	61.75
Yield 9.8 Bushels Per Acre	
Price at Harvest	
At $7.00/bushel Gross Income	68.60
At $5.00/bushel Gross Income	49.50
Net Income Above Variable Costs	
At $7.00/bushel	+6.85
At $5.00/bushel	-12.25

TABLE IX

PRODUCTION COSTS AND RETURNS FOR SOYBEANS FOLLOWING WHEAT: BUDGET FOR CHISEL PLUS DISC PLUS LASSO AND LOROX

Variable Costs	Cost Per Acre
Land Preparation - Disc	2.50
- Chisel	4.00
Herbicide Application	1.75
Herbicides	10.00
Fertilizers:	
Nitrogen 20 pounds at 25¢/lb	5.00
Phosphorus 40 pounds at 30¢/lb	12.00
Potassium 150 pounds at 10¢/lb	15.00
Seed and Inoculation	10.00
Planting	2.50
Harvesting and Hauling	10.00
Total Cost	72.75
Yield 15.72 Bushels Per Acre	
Price at Harvest	
At $7.00/bushel Gross Income	110.04
At $5.00/bushel Gross Income	78.68
Net Income Above Variable Cost	
At $7.00/bushel	+37.29
At $5.00/bushel	+ 5.85

TABLE X

PRODUCTION COSTS AND RETURNS FOR SOYBEANS FOLLOWING WHEAT: BUDGET FOR DISC PLUS LASSO AND LOROX

Variable Costs	Cost Per Acre
Land Preparation - Disc	2.50
Herbicide Application	1.75
Herbicides	10.00
Fertilizers:	
Nitrogen 20 pounds at 25¢/lb	5.00
Phosphorus 40 pounds at 30¢/lb	12.00
Potassium 150 pounds at 10¢/lb	15.00
Seed and Inoculation	10.00
Planting	2.50
Harvesting and Hauling	10.00
Total Cost	68.75
Yield 16.94 Bushels Per Acre	
Price at Harvest	
At $7.00/bushel Gross Income	118.58
At $5.00/bushel Gross Income	84.70
Net Income Above Variable Costs	
At $7.00/bushel	+49.83
At $5.00/bushel	+15.95

CHAPTER V

SUMMARY AND CONCLUSIONS

The object of this study was to evaluate tillage methods and row spacing effects and to determine the feasibility of producing soybeans in a double cropping system after wheat in Eastern Oklahoma.

Soybean mean yields varied from 374 to 1138 kilograms per hectare. Minimum tilled plots (disc plus Lasso and Lorox) produced higher yield than no-tilled plots. Chiseling plus discing plus Lasso and Lorox plots tended to produce lower soybean yields than disc plus Lasso and Lorox plots.

Row spacings of 10, 20, 30, and 40 inches produced no significant differences in soybean yields. However, the narrow rows tended to give higher yields than the wide rows.

Paraquat (chemical tillage) substituted for mechanical tillage doubled average soybean yields of the no-tillage treatment. Lasso and Lorox added to mechanically tilled plots gave satisfactory control of weed throughout the growing season.

Seedling emergence was the most significant problem in this study. The hoe drill used in planting soybeans did not work satisfactorily in the no-tillage or chemical tillage plots. It did not place seed deep enough or provide good seed-soil cover and contact to ensure good seedling emergence. Special planting equipment that provides for uniform placement of seed and which can cut through crop residues is needed for successful planting of soybeans in wheat residue.

Inadequate soil moisture at planting time caused poor stands and low yields in this study.

Low soil pH likely reduced yields of soybeans in this study. Correcting soil pH and making a proper application of phosphate and potash before planting the preceding small grain crop is essential for a successful double cropping system with soybeans.

With proper tillage and associated management practices, double cropping soybeans after small grains in Eastern Oklahoma can be profitable. In this experiment, discing plus spraying Lasso and Lorox provided the highest net profit.

Suggestions for further study must emphasize the need for appropriate planting equipment. Soybeans should be sowed as soon as possible after harvesting wheat to avoid further soil moisture reduction.

BIBLIOGRAPHY

(1) Army, T. J., T. J. Weise, and R. J. Hanks. 1961. Effect of Tillage and Chemical Control Practices on Moisture Loss During the Fallow Period. SSSA 25:410-413.

(2) Barr, A. J., and J. H. Goodnight. 1972. A User's Guide to Statistical Analysis System. Department of Statistics. Raleigh, North Carolina: North Carolina State University.

(3) Beal, O. W., and G. W. Langdal. 1966. Tillage and Residue Management Practice for Production in Soybean and Small Grain Rotation. Agron. J. 59:31-33.

(4) Belvins, R. L., R. E. Pillips, and G. W. Thomas. 1972. Moisture Relationships and Nitrogen Movement on No-Tillage and Conventional Corn Production. Proceedings No-Tillage Systems Symposium. OARDC. Columbus, Ohio, 140-145.

(5) __________, __________, D. Cook, and S. H. Pillips. 1971. Influence of No-Tillage on Soil Moisture. Agron. J. 63:593-596.

(6) Bennett, O. L., E. L. Mathias, and P. E. Lundberg. 1973. Crop Response on No-Till Management Practice on Hilly Terrain. Agron. J. 66:488-491.

(7) Beuerlein, J. E., J. W. Pendleton, M. E. Beuer, and S. R. Ghorashy. 1971. Effect of Branch Removal and Plant Populations at Equidistant Spacings on Yield and Light Use Efficiency of Soybean. Agron. J. 62:317-319.

(8) Bowers, W., and H. P. Bateman. 1960. Research Study on Minimum Tillage. Trans. ASAE 3(2):1-3.

(9) Bratcher, B. G. 1971. The Performance of Selected Soybean Strains Following Small Grain in Oklahoma. Unpublished Master Thesis, Oklahoma State University, 51 p.

(10) Burnside, O. C., W. L. Collvile. 1964. Soybean and Weed Yield as Affected by Irrigation, Row Spacing, Tillage, and Ambiden. Weed Science 12: 109-112.

(11) Camper, H. M., C. F. Genter, and K. E. Loope. 1972. Double Cropping Following Winter Barley Harvest in Eastern Virginia. Agron. J. 63:490-493.

(12) Carter, L. M., and J. R. Tavernetti. 1968. Influence of Precision Tillage and Soil Compaction on Cotton Yield. Trans. ASAE 11(1):65-67, 73.

(13) Clapp, J. G. 1972. No-Tillage Soybean Production. Soybean Digest 32:6-9.

(14) Cooper, R. L. 1971. Influence of Production Practice on Lodging and Seed Yield on High Production Environment. Agron. J. 63:490-493.

(15) Dalrymple, D. G. 1971. Survey of Multiple Cropping in Less Developed Nation. USDA, FEDR-12, 108 p.

(16) Fairbanks, G. E., R. F. Sloan, H. L. Manges, and R. E. Marin. 1963. Minimum Tillage for Corn and Sorghum Crops in Kansas. Kansas Agr. Exp. Sta. Bull. 465.

(17) Fink, R. J., and D. Wesley. 1973. Corn Yield as Affected by Fertilization and Tillage System. Agron. J. 65:70-72.

(18) Gill, W. R. 1974. Tillage and Soybean Root Growth. Soybean Production, Marketing and Uses. TVA. Bull-y-69, 66-71.

(19) Griffith, D. R., J. W. Mannering, S. D. Golloway, and C. B. Rishey. 1973. Effect of Eight Tillage-Planting Systems on Soil Temperation, Percent Stand, Plant Growth and Yield of Corn on Five Indiana Soils. Agron. J. 65:321-326.

(20) Guenzi, W. P., T. M. McCalla, and F. A. Norstadt. 1967. Present and Persistence of Phytotoxic Substances in Wheat, Oat, Corn and Sorghum Residues. Agron. J. 59:163-164.

(21) Harpich, R. 1973. Illigation. Soybean Handbook, Kansas State University Cir. 449.

(22) Hayes, W. A. 1973. Double Cropping. Conservation Tillage. Soil Conserv. Soc. of Am., 202-212.

(23) Hoeff, R. G., M. C. Shurtleff, and J. Wedberg. 1974. Double Cropping in Illinois. University of Illinois. Extension Service. Cir. 1106.

(24) Howell, R. W. 1960. Physiology of the Soybean. Advances in Agronomy, 14:265-302.

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

(26) Judd, R. W. 1970. 1970 Soybean Management Guide. Soybean News, 21:3,4.

(27) Kamprath, E. J. 1974. Nutrition in Relation to Soybean Fertilization. Soybean Production Marketing and Use. TVA Bull-y-69, 28-33.

(28) Kincade, R. T. 1972. The Role of Paraquat in Soybean Stubble Plant System in Mississippi Delta. Proceedings No-Tillage Systems Symposium. OARDC. Columbus, Ohio, 113-125.

(29) Kirby, B. W. 1972. Postemergence Directed Spray. Proceedings No-Tillage System Symposium. OARDC. Columbus, Ohio, 125.

(30) Knight, C. 1973. Effect of Tillage, Rotation and Fertilization on Soybeans. Pro. Rep. of East Central Kansas Agr. Exp. Field, Ottawa.

(31) Mannering, J. W., L. D. Meyer, and C. B. Johnson. 1966. Infiltration and Erosion as Affected by Minimum Tillage for Corn. SSSA 30:101-105.

(32) McCalla, T. M. 1967. Effect of Tillage on Plant Growth as Influenced by Soil Organism. Tillage for Greater Crop Production. ASAE. Michigan, 19-26.

(33) __________. 1968. Crop Residues Agricultural Waste. Nebraska Agr. Exp. Sta. Quarterly. Spring 15(1): 20.

(34) Moody, J. E., J. N. Jones, J. H. Lillard, G. M. Shear, and W. W. Moshler. 1964. Reduced and No-Tillage Practices for Growing Corn in Virginia. Virginia Agr. Exp. Sta. Bull. 553.

(35) __________, __________, __________. 1963. Influence of Straw Mulch on Soil Moisture, Soil Temperature, and Growth of Corn. SSSA 27:700-703.

(36) Moolani, M. R., E. L. Knake, and F. W. Slef. Competition of Smooth Pigweed with Corn and Soybean. Weed Sci. 12:126-128.

(37) Ohrogge, A. J. 1960. Mineral Nutrition of Soybean. Advances in Agronomy 12:230-261.

(38) Oschwald, W. R. 1973. Chisel Plow and Strip Tillage Systems. Conservation Tillage. Soil Conser. Soc. of Am., 194-202.

(39) Osler, R. D., and J. L. Cattes. 1954. Effect of Planting Date and Chemical Composition and Growth Characteristics of Soybeans. Agron J. 62:267-270.

(40) Owens, H. L., and B. F. Lampler. 1974. Double Cropping with Soybean . . . "Will It Pay on Your Farm." USDA Extension Service. Program AID. No. 1080.

(41) Palmer, J. H. 1973. Guide for Producing No-Tillage Soybean in South Carolina. Clemson University Cir. 539.

(42) Park, W. L., and J. Overton. 1974. Effect of Water and Light on Soybean Yield. Soybean, Production, Marketing and Use. TVA Bull-y-69, 33-38.

(43) Peevy, W. J., B. E. Newman, J. E. Sedberry, and R. H. Brupbacher. 1969. The Influence of Soil Reaction, Residual Soil Phosphorus, and Fertilizer Phosphorus on Yield of Soybean Grown on Olive Silt Loam. Louisiana Agr. Exp. Sta. Bul. 669.

(44) Pendleton, J. W., and E. E. Hartwig. 1973. Management. Soybean, Improvement Production. Amer. Soc. of Agron. Madison, 211-231.

(45) Peter, E. J., M. R. Gebhardt, and J. F. Stritzke. 1965. Interrelation of Row Spacings, Cultivation and Herbicides for Weed Control in Soybeans. Weed Sci. 13:285-289.

(46) Pillips, S. H., and H. M. Young. 1973. No-Till Farming. Perman Associates, Wisconsin, 244 p.

(47) ___________. 1969. No-Tillage Crop Production. Kentucky Univ. Ext. Misc. 377:15-16.

(48) Probts, A. H. 1945. Influence of Spacing on Yield and Other Characteristics in Soybean. Agron. J. 37(5):49-54.

(49) Roger, H. T., D. L. Turlow, R. Adams, C. E. Evan, and J. E. Wear. 1971. Soybean Production. "Recent Research Finding." Louisiana Agr. Exp. Sta. Bull. 670.

(50) Rusell, W. J., W. R. Fehr, and R. L. Michel. 1971. Effect of Row Cultivation on Growth and Yield. Agron. J. 63:772-776.

(51) Sanford, J. O., D. L. Myhre, and N. C. Merwine. 1973. Double Cropping System Involving No-Tillage and Conventional Tillage. Agron. J. 65:978-982.

(52) Shane, W. D., T. Charles, and B. Stuart. 1969. Soybean and Row Spacing. Kentucky Univ. Ext. Misc. 377:25-26.

(53) Singh, T. A., G. W. Thomas, W. W. Moseher, and D. C. Mertens. 1966. Phosphorus Uptake by Corn Under No-Tillage and Conventional Practices. Agron. J. 58:147-148.

(54) Sommers, L. E. 1971. New Soybean Growing Tips. Successful Farming 66(7):23-27.

(55) Sommers, L. E., and V. O. Biederebeck. 1973. Tillage Management Principle: Soil Microorganism. Conservation Tillage. Soil Conserv. Soc. of Am., 87-108.

(56) Steel, G. D., and J. H. Torrie. 1960. Principles and Procedures of Statistics. New York: McGraw-Hill Book Company, Inc., 481.

(57) Stiegler, J. H., and F. Gray. 1967. Detailed Soil Survey, Eastern Oklahoma Pasture Research Station, Muskogee, Oklahoma. Okla. Agr. Exp. Sta. Processed Series, P-567.

(58) Suman, R. F., and T. L. Peile. 1974. Limiting Agronomic Factors in Soybean Production. South Carolina Agr. Expt. Sta. Tech. Bull. 1051.

(59) Tandrandraphong, S., and J. M. Davidson. 1970. Bulk Density, Aggregate Stability and Organic Matter Content as Influenced by Two Wheatland Soil Management Practices. Agron. J. 63:302-305.

(60) Thomson, L. G., and W. R. Robertson. 1969. Effect of Residual Fertilizer, Row Width and Spacing Within the Row on Soybean and Soil Fertility. Soil and Crop Sci. Soc. of Flo. 29:49-57.

(61) Verma, A. B. S., and H. Kolruke. 1951. Effect of Organic Mulchs on Soil Conditions and Row Spacing and Soybean Yields. Soil Sci. 72:149-156.

(62) Wax, L. M., and J. W. Pendleton. 1968. Effect of Row Spacing on Weed Control in Soybeans. Weed Sci. 16:462-464.

(63) Weber, L. 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.

(64) __________, __________. 1966. Let's Push up Soybean Yield. Iowa Farm Sci. 2:10-12.

(65) Weiss, M. C., C. R. Weber, L. F. Williams, and A. A. Probts. 1950. Variability of Agronomic and Seed Compositional Characteristics in Soybean as Influenced by Variety and Time of Planting. USDA Tech Bull. 1017.

(66) Whitaker, F. D., J. S. McKibben, and M. M. Jones. 1966. Reduced Tillage in Corn Production. Missouri Agr. Exp. Sta. Bull. 852.

(67) Wiese, A. F. 1972. Weed Control in Conservation Tillage. Conservation Tillage. Soil Conserv. Soc. of Am., 108-116.

(68) Wiggans, R. G. 1939. Influence of Space and Arrangement on Production of Soybean Plants. Agron. J. 31:314-321.

(69) Williams, J. H., J. L. Hughes and H. O. Wittmuss. 1972. Double Cropping Soybean After Wheat. Nebraska Agr. Exp. Sta. Quarterly, Spring, 1972., 21-25.

VITA

Sathien Phimsarn

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF LAND PREPARATION AND ROW SPACING FOR DOUBLE CROPPING SOYBEANS FOLLOWING WHEAT IN EASTERN OKLAHOMA

Major Field: Agronomy

Biographical:

Personal Data: Born at Phrae Province, Thailand, August 11, 1944, the son of Mr. Maung and Mrs. Phrom Phimsarn.

Education: Attended elementary school at Phrae, Thailand, graduated from The Prince Royal's College, Chieng Mai in March, 1963; received the Bachelor of Science in Agriculture with a major field in Agronomy from Kasetsart University, Bangkok, Thailand, in April, 1968.

Professional: Employed by the Thai Government as research assistant, Division of Agricultural Chemistry, Agriculture Department, Ministry of Agriculture, Bangkok, Thailand, February to present.