HERBICIDE USE IN DOUBLE CROPPING

SOYBEAN TILLAGE SYSTEMS

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CHAPTER I

INTRODUCTION

Economic pressures have forced farmers into more efficient means of crop production and increased utilization of land. Utilization may be enhanced if crops are grown during the normal fallow period. In some areas, soybeans [Glycine max (L.) Merr.] or grain sorghum [Sorghum bicolor (L.) Moench] may fit into a double cropping situation where they are planted just after wheat harvest. Following the harvest of soybeans or sorghum, the area may again be planted to wheat (Triticum aestivum L.). Double cropping of soybeans and wheat has been attempted in many locations. Limited success at some locations has been partly due to the loss of soil moisture during tillage of the wheat stubble before soybean planting. One means to conserve soil moisture after wheat harvest is to plant the soybeans directly into the wheat stubble without disturbing the soil. This lack of tillage in double cropping systems is referred to as no-tillage double cropping. Since the stubble is not turned under cultivation is very difficult. This reduces fuel, equipment and labor costs due to the reduction in the number of times the grower works the field. Weed control is essential in a no-tillage double cropping system. Herbicides must be selected to control weeds present at wheat harvest as well as weeds emerging throughout the soybean growing season. Several herbicides were selected to evaluate their phytotoxicity to soybeans and to weeds present throughout the season.

The objectives were:

(1) Compare no-tillage and conventional-tillage herbicide application systems and their influence on weed control and soybean yields.

(2) Develop herbicide systems to control the shift of weed species occurring in the no-tillage system.

(3) Evaluate the effects of water carrier volume and straw on the phytotoxicity of herbicides to soybeans and weeds.

CHAPTER II

LITERATURE REVIEW

Successful farming today requires a person knowledgeable about many related areas. A farmer must be able to make decisions concerning the production of his crops or livestock. He also must be an economist to strengthen his ability to get maximum gains for his product. He must be a scientist to test new products on his own farm in finding whether they are suited to his own production needs. Finally, farmers must be excellent managers. Each individual farmer must decide how to increase his profit by deciding what crops best fit his farm, whether to take a loss on one crop to increase his gain on another, whether to devote all his inputs toward one crop or several and can he produce two crops where one has been normally produced.

Double cropping (production of two crops in one year) has sparked the interest of scientists and farmers for many years. However, many things have hindered its success. Insufficient length of growing season and soil moisture loss after harvest of one crop have been major drawbacks in some areas. One of the most interesting areas for double cropping has been production of various crops behind small grains or corn (*Zea mays* L.). The loss of soil moisture during the tillage of the stubble in conventional production systems has made double cropping success dependent upon timely rainfall. This has led to attempts to produce grain sorghum, soybeans and other crops planted directly into the small grain stubble without prior tillage or very little tillage (to be called no-tillage or minimum-tillage throughout this text).

Ross et al. (22) defines zero-tillage and double cropping. Zero-tillage refers to the soybean crop spring-planted directly into the previous year's crop of soybean, corn, sorghum, or various other crops. Double cropping refers to the soybean crop summer-planted into standing stubble of recently harvested small grain. However, the standing stubble has presented planting and cultivation problems. Since cultivation can not be utilized, herbicides must be used to control the weeds both prior to planting and those emerging during the growing season. This usually involves use of a contact and one or more residual herbicides.

Contact Herbicides

Ilnicki et al. (13) studied several combinations of residual herbicides with paraquat or glyphosate (chemical names of all herbicides are in Table I) in no-till double cropped soybeans following wheat harvest. Hedge bindweed (*Convolvulus sepium* L.) appeared more frequently where combinations of alachlor and linuron were used with paraquat than when the two residual herbicides were combined with glyphosate. Metribuzin plus glyphosate gave slightly better fall panicum (*Panicum dichlotomiflorum* Michx.) control than metribuzin plus paraquat. Michieka et al. (18) found that paraquat and glyphosate gave good weed control in no-till soybeans following wheat harvest but control was not long-lived. Herron et al. (11) found residual herbicides gave better control of grasses when paraquat was used in the combinations applied to wheat stubble before soybean emergence. Glyphosate and paraquat

TABLE I

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common Name	Chemical Name
alachlor	2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
chloramben	3-amino-2,5-dichlorobenzoic acid
dinoseb (DNBP)	2-sec-butyl-4,6-dinitrophenol
glyphosate	N-(phosphonomethyl)glycine
H22234	N-chloroacetyl-N-(2,6-diethylphenyl)-glycine ethyl ester
H26910	N-chloroacetyl-N-(2-methyl-6-ethylphenyl)-glycine isopropyl ester
linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methyl urea
MCPA	[(4-chloro-o-tolyl)oxy]acetic acid
metolachlor	2-chloro-N-(2-ethyl)-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide
metribuzin	4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5 (4H -one)
oryzalin	3,5-dinitro-N^4,N^4-dipropylsulfanilamide
oxyfluorfen	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoro-methyl)benzene
paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
prodiamine	N^3,N^3-dipropyl-2,4-dinitro-6-trifluoro-methyl-N-phenylenediamine
profluralin	N-(cyclopropylmethyl)-α,α,α-trifluoro-2,6-dinitro-N-propyl-p-toluidine
propazine	2-chloro-4,6-bis(isopropylamino)-s-triazine
2,4-D	(2,4-dichlorophenoxy)acetic acid

were compared for vegetation control in no-tillage crop production (30). Glyphosate plus atrazine and glyphosate plus linuron gave a higher yield than the same residual herbicides with paraquat for corn and soybeans, respectively.

Volunteer sorghum may compete with soybeans planted in wheat stubble if grain sorghum had been cropped the previous year. Hardcastle (9) applied combinations of paraquat or glyphosate with various residual herbicides to volunteer sorghum 15 to 25 cm high. All glyphosate rates equalled or exceeded comparable paraquat treatments for sorghum control. He indicated possible antagonism between glyphosate and some of the residual compounds used in combination. Hardcastle (8) found glyphosate gave better initial knockdown of weeds in wheat stubble than paraquat. Combinations of glyphosate and alachlor gave longer lasting weed control than paraquat plus alachlor or linuron on the same weed species in non-tilled plantings following wheat harvested for grain.

Perennial Weeds

Chappell (5) compared paraquat and glyphosate for killing a rye (Secale cereale L.) cover crop on an area which was to be planted to soybeans. Perennial type weeds such as horseweed [Conyza canadensis (L.) Cronq.] and horsenettle (Solanum carolinense L.) were killed by the glyphosate but were not controlled by paraquat. The cover crop of rye was completely killed by both herbicides. Johnsongrass [Sorghum halepense (L.) Pers.] can present quite a problem in double cropping of soybeans in grain stubble. Connell and Jeffery (7) desiccated johnsongrass present in grain stubble with glyphosate, planted soybeans, and applied various herbicides as preemergence treatments. Ratings showed superior seedling johnsongrass control by metolachlor followed by H-26910, oxyfluorfen, H-22234, alachlor, and oryzalin. Connell and Derting (6) attributed reduced seedling weed reinfestation after the control of the initial infestation to no-tillage and stale seedbed systems. This was verified for several species except johnsongrass which germinated at 2 to 3 weeks and established highly competitive populations. Preplant glyphosate applications without additional treatments was judged unacceptable. However, a preplant glyphosate application plus a post directed glyphosate application gave good results.

Residual Weed Control

Several preemergence herbicides have been used for residual weed control in no-till soybean production. Residual weed control has been the most difficult to obtain. Until recently, herbicides were not adequate for this task. However, now some herbicides may give control throughout the season without residual effects on the succeeding crop. Rogers et al. (21) found weed control to be roughly equivalent for combinations of oryzalin + linuron + paraquat, oryzalin + metribuzin + paraquat, and alachlor + linuron + paraquat. All combinations gave better weed control than paraquat used alone. Hicks et al. (12) found that acceptable weed control was obtained with oryzalin in combination with linuron or metribuzin plus paraquat as a tank-mix preemergence no-till treatment. Soybeans were tolerant to these tank-mixed combinations. Martin and Rieck (17) compared double cropping systems of soybeans following wheat. Poor stands resulted in yield reduction for aerial seeded soybeans treated with oryzalin and prodiamine. The aerial seeding did not provide adequate protection from chemicals harmful to the germination of soybeans. Conventional and other no-till systems produced greater yields with no crop injury from preemergence applied chemicals. Henard et al. (10) used several herbicide treatments for weed control in soybeans and sorghum planted in small grain stubble. Dinoseb, linuron, and chloramben with or without paraquat gave excellent weed control 3 weeks after treatment. However, 6 weeks after treatment, weed control and soybean vigor had begun to decrease. Propazine and atrazine gave similar results in grain sorghum. The need for season-long weed control was apparent. Combinations of herbicides or postemergence herbicides might have provided this control.

Double cropping of soybeans and grain sorghum can follow other small grains such as barley (*Hordeum vulgare* L.) and oats (*Avena sativa* L.). Parochetti (20) applied many herbicide treatments to soybeans planted in barley stubble for weed control evaluation. Best control of weeds present after barley harvest occurred with herbicide combinations containing the foliar active herbicides paraquat or glyphosate.

Pre-Harvest Wheat Weed Control

Weed control in soybeans planted in wheat stubble requires reducing or eliminating those weeds emerged at the time of wheat harvest. Generally, a contact herbicide is used around harvest time to alleviate this problem. However, by this time much soil moisture may be lost to the weeds. Many of these weeds may be treated at earlier stages with a phenoxy herbicide, but most grasses are not controlled by such a treatment. Addison et al. (1) applied oryzalin over the top of small grains at various stages to reduce the early germinating grasses. Oryzalin caused no adverse effects to wheat or rye when applied at the fully tillered, jointing, or boot stages of growth. Lynn et al. (15) also found no adverse effects of oryzalin applied to wheat at the jointing stage of development but did note slight root injury when the wheat had been sprayed at the fully tillered stage of wheat development. Contact herbicides might be used at earlier weed stages but their effects on wheat when treated at different growth stages must be determined.

Planting Systems

Finding a planter that can cut through small grain stubble has presented another serious problem to no-till double cropping. Adaptation of conventional planters, if possible, with a coulter and disk openers may provide an answer. The planter must be able to cut the stubble, place the seed at the proper depth, and cover the seed. The influence of different planters under no-tillage planting methods on tolerance of soybeans to linuron was studied by Worsham (29). He found that a standard International Harvester Planter modified for no-tillage planting allowed less injury to soybeans than did the Allis-Chalmers "No-Till" planter with fluted coulter or Cole no-tillage planter with a chisel opener. He speculated that these caused more injury due to a slight depression left over the seed which probably allowed more herbicide to be leached into the seed germination zone by rainfall.

Following a small grain crop may delay seeding of the soybeans or grain sorghum. If this is the case, the soybeans may not reach the size normally expected in single cropping. Row width of 102 cm may not allow maximum utilization of the land. Narrow rows should increase the soybean yield by better land utilization and shading of weeds. Jeffers et al. (14) discussed the results of research on planting date, tillage, and row widths on double cropping of soybeans behind wheat. Yield of soybeans decreased 4.4 hectoliter per hectare (hl/ha) per week of planting delay after June 15. Yields were increased by 5.2 to 8.7 hl/ha when planted in 38 cm rather than 76 cm rows. They found yields with no-tillage to be equal to or better than any other tillage system at all locations. Burnside and Colville (4) found that narrow soybean rows increased yield, reduced tillage, and reduced the rate of chloramben required for weed control. These results were attributed primarily to earlier shading by the soybeans in the narrower rows.

Straw Cover and Carrier Volume

The influence of the stubble on planting of crops has caused interest as to how much of the stubble is needed for water conservation and what affect the straw has on weed control and on persistence of the herbicide in the soil. Royster and Kerr (23) conducted studies to determine effects of mowed versus unmowed straw, amounts of straw, and burning of straw on the emergence of soybeans planted after wheat harvest. Mowing the straw increased the soybean stand over the unmowed treatments. The soybean stand was greater in burned straw plots than in incorporated straw plots in a silt loam soil but not in a clay. Normal and double rates of straw did not affect the stand in either soil type. Worsham (28) applied several herbicide treatments to plots having wheat mowed during the soft dough stage and the straw removed. These same herbicide treatments were made to harvested small grain stubble. All herbicide treated plots gave significantly higher soybean yields than the untreated plots. Yields were higher in the mowed areas but this was probably due to the earlier planting date. The effects of stubble height, row spacing, and spray volume were compared by Mullins et al. (19). The duration of crabgrass (Digitaria spp.) control by herbicide combinations to small grain stubble was longer in 51 cm than in 102 cm soybean rows. Weed control was better when wheat stubble was cut to 10 cm than when it was 46 cm. Spray volumes of 47 to 374 l/ha had no influence on effectiveness of linuron and paraquat. Slack et al. (25) found 3 chloro-s-triazines to be less persistent under no-tillage conditions than when the soil is tilled. This would prove advantageous in that residues remaining would be less toxic to succeeding crops. However, season long weed control might not be obtained in this no-tillage system.

Long Term Tillage Effects

Studies have been conducted comparing conventional-tillage with no-tillage on several factors. Comparisons of yield, water use and infiltration, pH and other soil factors, and energy consumption have been made. Soybeans and grain sorghum were double cropped following wheat on a Blackbelt soil comparing no-tillage and conventional-tillage methods (24). Conventional-tillage produced greater yields of both soybeans and grain sorghum when averaged over 2 years, this difference being attributed to the lack of nutsedge (Cyperus sp.)

control in the no-tillage plots. In the third year, the crop was hand-hoed resulting in no soybean yield differences between the tillage systems and greater sorghum grain production in the no-tillage system. Wheat following soybeans produced more grain than wheat following grain sorghum. Allen et al. (2) showed an increase in sorghum grain yield for no-till versus a till system during a 5 year study. No-till seedlings generally emerged faster, grew taller and matured up to 5 days earlier. Water use efficiency under irrigation was greater with no-till because of slower soil surface drying under the small grain residues. No-till seeding required fewer operations and less time between crops and reduced fuel requirements about 55%. Field time to prepare and plant a seedbed averaged only one-fifth that of the till system. Double cropping no-tillage production may increase water infiltration and reduce erosion. Mannering et al. (16) found that 82% of the 13 cm of applied rainfall infiltrated the minimum-tilled-mulched corn crop as compared with 42%, 27%, and 55% on conventional-cultivated, minimum-tilled-noncultivated, and minimum-tilled-cultivated plots, respectively. Soil loss on the mulched plot was only 2% of that on the conventional treatment. Blevins et al. (3) studied the effects of long term continuous no-till corn on various soil factors. After 5 years of no-tillage, organic carbon and nitrogen increased, soil pH decreased, and bulk density was unchanged in the top 5 cm of soil when compared to conventionally-tilled cropping. They concluded that no-tillage with moderate rates of N most nearly preserved the soil chemical characteristics found under the original bluegrass (*Poa pratensis* L.) sod.

Other double cropping systems have utilized sod or poor pastures. Planting legumes or grasses into poor pastures may be justifiable if herbicides are applied to the existing vegetation. Much research has been conducted in no-tillage corn production in chemically killed sod. Worsham (27) investigated the possibility of growing corn in fescue (*Festuca arundinacea* Schreb.) sod treated chemically to retard the growth but not kill it. He applied atrazine plus paraquat in various band widths to see the effect on corn silage growth and recovery of the fescue the following year. His results indicated that no band treatment allowed both maximum corn production and good sod recovery.

This research was conducted to determine if there is a niche for double cropping of soybeans and wheat in Oklahoma. Emphasis was placed on comparisons of conventional and no-tillage systems. Various herbicide combinations were compared for weed control in the no-tillage system. Triplett and Lytle (26) reported a shift in predominant weeds when a herbicide treatment was used in continuous no-till corn. Observations were made throughout this study to determine if a weed shift did occur. Effects of straw cover and water carrier volume were studied to determine their influence on weed control and crop tolerance.

CHAPTER III

METHODS AND MATERIALS

Tillage System

A study was established in the summer of 1976 to evaluate the effects of two long term tillage systems on weed control, soybean, and wheat production. The study was conducted at the Eastern Research Station, near Haskell, Oklahoma on a Taloka silt loam soil. The entire area was plowed using a two-bottom turning plow, disked twice with a tandem disc, and harrowed.

Treatments were designated as conventional-tillage or no-tillage systems. Conventional-tillage treatments consisted of a pre-plant incorporated (PPI) application of profluralin at 0.8 and 1.7 kg/ha. Forrest soybeans were planted June 10 at the rate of 0.9 hl/ha on flat bedded 102 cm row centers. Preemergence (Pre) applications of metribuzin at 0.4 or 0.8 kg/ha were made within 1 day after planting. Check plots were present in all replications.

No-tillage treatments consisted of a tank-mixed combination application of metribuzin and glyphosate at rates of 0.4 + 1.1 and 0.8 + 1.1 kg/ha active ingredient (a.i.) applied before soybean emergence. No-tillage check plots were used for comparisons.

Water carrier volume used for all herbicidal treatments was 234 l/ha. Plots were 9.2 x 19.8 m in size arranged in a randomized complete block design with 4 replications. Visual ratings (based on a scale of 0-10 where 0 equals no injury and 10 means complete plant elimination) of soybean vigor and crabgrass, pigweed, and carpetweed (*Mollugo verticillata* L.) control were made throughout the season. During the season, a heavy infestation of silverleaf nightshade (*Solanum elaeagnifolium* Cav.) and horsenettle emerged and were hoed out of all plots. The fourth replicate was treated with glyphosate late in the season to kill these perennials.

Soybean yield was taken at the earliest time of maturity possible (November 24). The area was then lightly disked, harrowed and planted to Triumph 64 wheat using a 25 cm spaced hoe drill at the rate of 0.9 hl/ha. Replication 4 was not seeded to wheat. The wheat did not germinate until late January of 1977 and was harvested for grain on June 14.

Within 5 days, the plots designated for conventional-tillage were plowed, tandem disked twice, harrowed, and treated with the same PPI and Pre applications used the previous year. Forrest soybeans were planted on 51 cm centers at the rate of 0.9 hl/ha.

The no-tillage treatments were planted directly into the wheat stubble with a four-row Allis Chalmers no-till planter. The planter was equipped with a 5 cm-wide fluted coulter, double disk openers and 3.8 cm depth bands. Preemergence combinations of metribuzin and glyphosate were applied as in 1976.

After soybean harvest wheat was planted (1.3 hl/ha) without previous tillage to the area but with an adapted standard 25 cm spaced hoe drill. The hoe drill was equipped with fluted coulters to cut through the soybean and wheat stubble. Ammonium nitrate (34-0-0) was applied to the wheat at the rate of 135 kg/ha in the spring of 1977 and 168 kg/ha in 1978.

No-Tillage Continuous Double Cropping

An experiment was initiated on July 10, 1976, on the Oklahoma Vegetable Research Station, Bixby, Oklahoma on a Wynona silty clay loam soil. It was designed to evaluate herbicides for their performance in a no-till soybean-wheat double cropping system. Forrest soybeans were seeded directly into wheat stubble using the four-row Allis Chalmers no-till planter previously described. Soybeans were seeded on 102 cm row centers at the rate of 0.7 hl/ha. Wheat was planted after soybean harvest and a light disking at a seeding rate of 1.3 hl/ha. Nitrogen, at the rate of 50 kg/ha, was broadcast in the form of ammonium nitrate on March 16, 1977. In the summer of 1977 soybeans were again planted at the rate of 0.9 hl/ha directly into the wheat stubble after wheat harvest. In 1977 the soybeans were planted in 51 cm rows.

Several herbicide combinations were applied as preemergence treatments to soybeans in both 1976 and 1977. Treatments consisted of either glyphosate or paraquat for quick kill of weeds present at wheat harvest. One or two other herbicides were used in the combinations for residual grass and broadleaf weed control (Table II contains herbicide combinations and rates used). All treatments were made to the same plots each year.

Water carrier volumes used for all treatments were 281 and 374 l/ha for 1976 and 1977, respectively. Herbicide treatments were applied with an experimental plot tractor sprayer. Plot size was 4.1 m wide x 15.3 m long replicated four times in a randomized complete block design.

TABLE II

TREATMENTS USED IN NO-TILL CONTINUOUS DOUBLE CROPPING

Treatment	Rate (kg/ha)
Glyphosate + Oryzalin + Metribuzin	0.8 + 1.1 + 0.4
Glyphosate + Oryzalin + Linuron	0.8 + 1.1 + 0.8
Glyphosate + Alachlor + Metribuzin	0.8 + 2.2 + 0.4
Glyphosate + Alachlor + Linuron	0.8 + 2.2 + 0.8
Paraquat + Oryzalin + Metribuzin	0.6 + 1.1 + 0.4
Paraquat + Oryzalin + Linuron	0.6 + 1.1 + 0.8
Paraquat + Alachlor + Metribuzin	0.6 + 2.2 + 0.4
Paraquat + Alachlor + Linuron	0.6 + 2.2 + 0.8
Paraquat + Oryzalin	0.6 + 1.1
Paraquat + Alachlor	0.6 + 2.2
Glyphosate + Oryzalin	0.8 + 1.1
Glyphosate + Alachlor	0.8 + 2.2
No-Till Check	---

Wheat was planted (1.3 hl/ha) to the area after soybean harvest in the fall of 1977. An adapted coulter-equipped 25 cm spaced hoe drill was used without any previous tillage. Ammonium nitrate was applied at 168 kg/ha on March 18, 1978. Soybeans and weeds were visually rated and plant counts and height measurements were made throughout the study. Soybean and wheat yields were collected throughout the study.

Milk Stage Pre-Harvest Wheat Treatments

An experiment was conducted at Lake Carl Blackwell near Stillwater on a Port loam soil to evaluate two herbicides for their potential for injury to wheat when applied over the top of the crop in the milk stage of growth. Centurk wheat was grown on the loam flood plain soil. Paraquat at 0.6 and 1.1 kg/ha and glyphosate at 1.1 and 2.2 kg/ha were applied on May 11, 1977 to wheat in the milk stage when plants were approximately 110 cm tall. A randomized complete block design with three replications was used for evaluations. Plot size was 3.1 m wide x 9.2 m long. Treatments were applied with an experimental plot tractor sprayer in 374 l/ha of water. Yield was taken by harvesting a 1.5 m x 9.2 m strip through the center of each plot with an experimental plot combine. Wheat seed test weights were taken with a standard 1 quart (0.946 l) test weight apparatus.

Effects of Straw Cover and Carrier Volume on Herbicide Phytotoxicity

The effects of straw cover and water carrier volume on the crop injury and weed control by several herbicide combinations were evaluated. Forrest soybeans were planted in a Teller sandy loam soil at the rate of

0.9 hl/ha on 102 cm rows. Half of the plots were then covered with straw. Wheat straw, cut only once by a combine, was used at a rate of 4.5 ton/ha which allowed a cover of 5.1 to 10.2 cm deep over the designated plots. Five herbicide combinations were applied prior to soybean emergence to both the bare and straw covered plots. Each combination was applied at both 140 and 374 l/ha with an experimental plot tractor sprayer. Plot size was 2 m x 9.2 m, replicated four times, in a randomized complete block design. Visual ratings based on a scale of 0-10 for crop injury and weed control were taken. A hoe timing evaluation was taken 35 days after herbicide application. Soybeans were harvested at maturity for yield determinations.

Effects of Removing Wheat Stubble After Mowing

An experiment was conducted to determine if mowing and removing the excess wheat stubble affected herbicide phytotoxicity to soybeans and weeds. A Teller sandy loam soil from which wheat had been harvested was selected for this study. The entire area was mowed with a rotary blade mower. The straw was then baled and removed from half the area. The straw was left on the other half of the area. Forrest soybeans were planted to the entire area in dry soil using an Allis Chalmers no-till planter set for 51 cm rows. Preemergence herbicide combinations were applied in 140, 280 and 374 l/ha water carrier to plots 2 m x 8.2 m. Treatments were applied with an experimental plot tractor sprayer and replicated 4 times. Five days after planting and herbicide treatment, 0.25 cm rain moistened the top 4 cm of soil. Crop and weed phytotoxicity ratings were made. A plant count and two height measurements were taken to determine the effects of straw cover and water carrier volume on herbicide phytotoxicity. Soybeans were counted in 4.9 meters of row. Six plants at randomly selected points were measured.

CHAPTER IV

RESULTS AND DISCUSSION

Tillage System

Visual ratings were taken to evaluate weed control by the herbicides used in the conventional versus no-tillage systems study (Table III). All treatments of profluralin and metribuzin provided adequate crabgrass, pigweed and carpetweed control throughout the soybean growing season of 1976. The preemergence combination of metribuzin and glyphosate at 0.4 + 1.1 kg/ha did not give satisfactory control of crabgrass and carpetweed throughout the season. The same combination at the higher rate did give adequate control of all weeds. Soybeans were visually rated throughout the season (Table IV). The treatments of profluralin and metribuzin in which metribuzin was present at a rate two times the recommended rate (0.8, 0.8 and 1.7, 0.8) caused slight leaf burn which lasted up to 4 weeks after treatment. A rating 8 weeks after treatment showed no leaf burn but very slight stunting caused by treatments containing profluralin at two times its recommended rate. However, a rating taken later in the season showed no visual damage to the soybeans from these treatments. The metribuzin + glyphosate combinations also caused slight leaf burn early in the season but the injury was not noticeable 8 weeks after treatment. Since all treatments were applied to bare soil in 1976, there are no differ-

TABLE III

WEED CONTROL FOR TILLAGE SYSTEMS IN 1976

Treatment	Rate (kg/ha)	Treatment Stage	Visual Evaluations* Crabgrass 8**	Crabgrass 11	Pigweed 8	Carpetweed 8	Carpetweed 11
Conventional-Tillage							
Profluralin, Metribuzin	0.8,0.4	PPI,Pre	10	8	9	10	7
Profluralin, Metribuzin	0.8,0.8	"	9	10	10	10	9
Profluralin, Metribuzin	1.7,0.4	"	10	10	10	10	10
Profluralin, Metribuzin	1.7,0.8	"	9	10	10	10	10
Conventional-Till Check	---	---	6	6	5	0	2
No-Tillage							
Metribuzin + Glyphosate	0.4+1.1	Pre	7	6	8	8	6
Metribuzin + Glyphosate	0.8+1.1	"	6	9	9	10	9
No-Till Check	---	---	2	2	3	0	1

*Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.

**Weeks after treatment that visual ratings were made.

TABLE IV

SOYBEAN HERBICIDE EVALUATIONS FOR TILLAGE SYSTEMS IN 1976

Treatment	Rate (kg/ha)	Treatment Stage	Soybean Rating (0-10)			Soybean Yield (hl/ha)
			4*	8	11	
Conventional-Tillage						
Profluralin, Metribuzin	0.8,0.4	PPI,Pre	0	0	0	9.1 bc**
Profluralin, Metribuzin	0.8,0.8	"	2	0	0	9.1 bc
Profluralin, Metribuzin	1.7,0.4	"	0	1	0	7.6 c
Profluralin, Metribuzin	1.7,0.8	"	2	1	0	10.1 bc
Conventional-Till Check	---	---	0	0	0	6.9 c
No-Tillage						
Metribuzin + Glyphosate	0.4+1.1	Pre	1	0	0	8.4 c
Metribuzin + Glyphosate	0.8+1.1	"	2	0	0	14.8 a
No-Till Check	---	---	0	0	0	12.3 ab

*Weeks after treatment that visual ratings were made. Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.

**Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

ences in the treatments designated as conventional-till check and no-till check. Crabgrass and pigweed stands were erratic and thus the ratings for these checks varied. Soybean yields varied but were probably affected more by the scattered heavy populations of silverleaf nightshade and horsenettle than by the herbicide treatments.

Wheat was drilled in all plots after soybean harvest. Harvest of the wheat in June, 1977 showed very few yield differences between treatments (Table V). However, the profluralin and metribuzin sequential combination at their higher rates did reduce the yield to less than that of the no-till check.

After wheat harvest, conventional-till plots were treated as described and profluralin and metribuzin applied as in 1976. The no-till tank-mix treatments of metribuzin + glyphosate were applied immediately after planting of the soybeans. The no-till planter did a very good job of cutting through the wheat stubble and grasses present.

Plains coreopsis (*Coreopsis tinctoria* Nutt.), witchgrass (*Panicum capillare* L.), and crabgrass were present in the wheat stubble. Conventional-tillage destroyed all of these weeds before planting. The no-tillage treatments contained glyphosate which destroyed most of the plains coreopsis but only burned some of the grasses (Table V). A rating taken 4 weeks after treatment showed very little to moderate control of witchgrass with the metribuzin + glyphosate combination. A later rating (9 weeks after treatment) showed very little control at even the higher rates of the herbicides. Crabgrass was not adequately controlled by either of the no-till treatments (Table V). Crabgrass was controlled throughout the season in the conventional-tillage plots. Carpetweed was also present in the conventional-till checks but was

TABLE V

WHEAT YIELD AND WEED CONTROL FOR TILLAGE SYSTEMS IN 1977

Treatment	Rate (kg/ha)	Treatment Stage	Wheat Yield (hl/ha)	Visual Evaluations* Coreopsis	Witchgrass		Crabgrass	Carpetweed
				4**	4	9	9	9
Conventional-Tillage								
Profluralin, Metribuzin	0.8,0.4	PPI,Pre	20.9 ab[†]	-	-	-	9	10
Profluralin, Metribuzin	0.8,0.8	"	21.3 ab	-	-	-	9	10
Profluralin, Metribuzin	1.7,0.4	"	22.8 a	-	-	-	10	10
Profluralin, Metribuzin	1.7,0.8	"	19.3 b	-	-	-	10	10
Conventional-Till Check	---	---	22.1 ab	-	-	-	0	0
No-Tillage								
Metribuzin + Glyphosate	0.4+1.1	Pre	22.3 ab	9	2	0	1	-
Metribuzin + Glyphosate	0.8+1.1	"	21.1 ab	9	5	3	6	-
No-Till Check	---	---	22.9 a	2	0	0	2	-

*Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.

**Weeks after treatment that visual ratings were made.

†Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

completely eliminated by the profluralin, metribuzin sequential treatments. Carpetweed was not present in the no-tillage plots.

Soybeans emerged to a very good stand in the no-till plots but did not emerge adequately in the conventional-till plots. A hard rain fell after planting which caused packing of the soil in the conventional-tilled plots so that the soybeans had to be replanted. At the time of the original planting, the soil was very dry down to 30 cm so that the soybeans had to survive with seasonal rainfall only (Table VI). Due to poor grass control in the no-till treated and check plots, the soybeans suffered very severely due to competition from the weeds (Table VII). Yields were higher in the conventional-tilled plots due to the good weed control achieved by the herbicide treatments. Due to low soil moisture throughout the soybean season, even the best yields were very low. Greater stored soil moisture resulting in higher soybean yields might have been attained had wheat not been grown previous to the soybean crop.

No-Tillage Continuous Double Cropping

Several herbicide combinations were compared for their weed control in soybeans planted in wheat stubble. Hophornbeam copperleaf (*Acalypha ostryaefolia* Riddell) and pigweed (*Amaranthus* spp.) emerged throughout the 1976 season. Visual ratings were made to evaluate the weed control achieved. Tank-mix combinations including glyphosate or paraquat with either oryzalin or alachlor along with metribuzin or linuron provided adequate control of copperleaf throughout the season (Table VIII). Combinations of paraquat or glyphosate plus alachlor also gave control of copperleaf but the combinations of paraquat or glyphosate plus

TABLE VI

DISTRIBUTION AND LONG TERM AVERAGE RAINFALL FOR THE TILLAGE SYSTEM COMPARISONS AT HASKELL, OKLAHOMA

Month	Rainfall (cm)						Long Term Average
	Day*		1976	Day*		1977	
January			0.36			0.00	4.62
February			1.83			2.67	5.23
March			8.05			7.98	8.56
April			18.21			6.88	12.07
May			7.04			11.40	12.65
June	15	0.81	8.13	25	2.16	6.09	12.90
	18	0.30		26	1.14		
	24	1.14		29	2.79		
	29	0.43					
	30	2.16					
July			7.85			8.89	9.47
August			6.05			7.75	6.71
September			9.02			17.86	11.28
October			5.18			7.16	9.07
November			3.33			5.00	7.52
December			3.58			2.39	6.52
TOTALS			78.61			84.10	106.33

*Daily rainfall is given for a period immediately following herbicide treatments.

TABLE VII

SOYBEAN EVALUATIONS FOR TILLAGE SYSTEMS IN 1977

Treatment	Rate (kg/ha)	Treatment Stage	Soybean Rating* 4**	Soybean Rating* 9	Soybean Yield (hl/ha)
Conventional-Tillage					
Profluralin, Metribuzin	0.8,0.4	PPI,Pre	-	0	8.4 a
Profluralin, Metribuzin	0.8,0.8	"	-	0	9.1 a
Profluralin, Metribuzin	1.7,0.4	"	-	0	8.7 a
Profluralin, Metribuzin	1.7,0.8	"	-	0	9.5 a
Conventional-Till Check	---	---	-	4	5.7 ab
No-Tillage					
Metribuzin + Glyphosate	0.4+1.1	Pre	4	8	0.6 c
Metribuzin + Glyphosate	0.8+1.1	"	1	4	2.6 bc
No-Till Check	---	---	8	9.5	0.0 c

*Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.
**Weeks after treatment that visual ratings were made.

TABLE VIII

NO-TILL SOYBEAN WEED CONTROL IN 1976 WITH SEVERAL HERBICIDE COMBINATIONS

Treatment	Rate (kg/ha)	Copperleaf		Pigweed	
		4*	7*	4*	7*
Glyphosate + Oryzalin + Metribuzin	0.8+1.1+0.4	10**	9	10	9
Glyphosate + Oryzalin + Linuron	0.8+1.1+0.8	9	9	10	8
Glyphosate + Alachlor + Metribuzin	0.8+2.2+0.4	10	9	9	5
Glyphosate + Alachlor + Linuron	0.8+2.2+0.8	9	8	10	8
Paraquat + Oryzalin + Metribuzin	0.6+1.1+0.4	9	8	10	9
Paraquat + Oryzalin + Linuron	0.6+1.1+0.8	8	8	10	9
Paraquat + Alachlor + Metribuzin	0.6+2.2+0.4	10	8	10	6
Paraquat + Alachlor + Linuron	0.6+2.2+0.8	8	8	10	8
Paraquat + Oryzalin	0.6+1.1	5	4	10	9
Paraquat + Alachlor	0.6+2.2	8	7	9	8
Glyphosate + Oryzalin	0.8+1.1	4	6	10	9
Glyphosate + Alachlor	0.8+2.2	9	7	10	7
No-Till Check	---	0	2	0	3

*Weeks after treatment that visual ratings were made.
**Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.

oryzalin did not. All treatments provided excellent control of pigweed when evaluated 4 weeks after the herbicide application. Pigweed control was not sustained to 7 weeks after application by combinations of glyphosate + alachlor, glyphosate + alachlor + metribuzin, and paraquat + alachlor + metribuzin.

The soybeans were planted in wheat stubble using the no-till planter. The rows were planted parallel to the old wheat rows. In some cases the soybeans were drilled in an old wheat stubble row. In these places, the seeds were not covered properly and thus did not germinate sufficiently. The soybeans were planted later (July 10) than normal and did not yield very high (Table IX). Injury to the soybeans was noted as only slight leaf burn early in the season by most treatments containing metribuzin. Soybean yields were higher than the check in all herbicide treated plots except when treated with the combinations of paraquat + oryzalin, paraquat + alachlor and paraquat + alachlor + metribuzin.

After soybean harvest and a light disking, wheat was planted to the area in rows perpendicular to the soybean rows. Yields were taken in the spring of 1977 and indicated no effects by any of the herbicide treatments (Table X).

Soybeans in 1977 were seeded directly into the remaining stubble perpendicular to the old wheat stubble rows. This provided a good stand of soybeans and was not inhibited by the stubble as was the case in 1976 when the beans were planted parallel to the wheat rows.

Lambsquarter (Chenopodium album L.) was present at wheat harvest and was clipped by the combine to approximately 30 cm from the soil surface. Very few leaves remained at the bottom of these plants

TABLE IX

NO-TILL SOYBEAN RESPONSE TO SEVERAL HERBICIDE COMBINATIONS IN 1976

Treatment	Rate (kg/ha)	Soybean Rating (0-10)	Soybean Yield (hl/ha)
Glyphosate + Oryzalin + Metribuzin	0.8+1.1+0.4	1*	7.4 a-c**
Glyphosate + Oryzalin + Linuron	0.8+1.1+0.8	1	7.7 a-c
Glyphosate + Alachlor + Metribuzin	0.8+2.2+0.4	0	7.0 a-c
Glyphosate + Alachlor + Linuron	0.8+2.2+0.8	0	8.0 a-c
Paraquat + Oryzalin + Metribuzin	0.6+1.1+0.4	1	7.9 a-c
Paraquat + Oryzalin + Linuron	0.6+1.1+0.8	0	8.4 ab
Paraquat + Alachlor + Metribuzin	0.6+2.2+0.4	1	5.9 cd
Paraquat + Alachlor + Linuron	0.6+2.2+0.8	0	7.6 a-c
Paraquat + Oryzalin	0.6+1.1	1	6.5 a-d
Paraquat + Alachlor	0.6+2.2	0	6.2 b-d
Glyphosate + Oryzalin	0.8+1.1	0	7.6 a-c
Glyphosate + Alachlor	0.8+2.2	0	8.8 a
No-Till Check	---	0	4.8 d

*Visual ratings are based on a scale of 0-10 with 0 being no plant injury and 10 being complete plant kill or elimination.

**Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

TABLE X

NO-TILL WHEAT YIELDS AND SOYBEAN WEED CONTROL IN 1977 WITH SEVERAL HERBICIDE COMBINATIONS

Treatment	Rate (kg/ha)	Wheat Yield (hl/ha)	Lambsquarter			Copperleaf	
			2*	7*	#/m^2	7*	#/m^2
Glyphosate + Oryzalin + Metribuzin	0.8+1.1+0.4	25.9 a**	9	8	2.3 ab**	9	2.4 a**
Glyphosate + Oryzalin + Linuron	0.8+1.1+0.8	27.3 a	9	8	3.0 ab	5	11.6 ab
Glyphosate + Alachlor + Metribuzin	0.8+2.2+0.4	23.7 a	8	7	2.3 ab	7	3.1 a
Glyphosate + Alachlor + Linuron	0.8+2.2+0.8	24.3 a	9	8	0.5 a	7	5.4 ab
Paraquat + Oryzalin + Metribuzin	0.6+1.1+0.4	27.3 a	10	9	0.3 a	7	6.5 ab
Paraquat + Oryzalin + Linuron	0.6+1.1+0.8	25.8 a	10	9	0.4 a	7	10.9 ab
Paraquat + Alachlor + Metribuzin	0.6+2.2+0.4	23.2 a	9	8	2.0 ab	9	3.0 a
Paraquat + Alachlor + Linuron	0.6+2.2+0.8	22.8 a	9	7	0.4 a	5	4.7 a
Paraquat + Oryzalin	0.6+1.1	25.6 a	8	6	2.0 ab	0	26.0 bc
Paraquat + Alachlor	0.6+2.2	24.7 a	8	5	2.0 ab	2	12.8 ab
Glyphosate + Oryzalin	0.8+1.1	26.8 a	6	4	1.2 ab	0	36.9 c
Glyphosate + Alachlor	0.8+2.2	25.6 a	7	3	5.8 b	3	13.5 ab
No-Till Check	---	24.3 a	0	1	14.7 c	5	10.4 ab

*Weeks after treatment that visual ratings (0-10) were made.
**Weed counts were taken 11 weeks after treatment. Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

leaving little leaf surface area for contact with the herbicides. At 2 weeks after treatment, the lambsquarter showed little or no green foliage when treated with all combinations containing three herbicides and combinations of paraquat plus either oryzalin or alachlor (Table X). Glyphosate plus either oryzalin or alachlor did not adequately control lambsquarter. Seven weeks after treatment, regrowth of the lambsquarter was noticeable in many of the treated plots. Combinations containing only paraquat or glyphosate plus oryzalin or alachlor did not maintain their weed suppression. Eleven weeks after treatment weed counts were taken. All treatments reduced the lambsquarter count below that found in the check plots. Although the plants were not measured for growth, the lambsquarter plants were generally smaller in those plots treated with combinations of three herbicides.

Hophornbeam copperleaf infested the area throughout the season. A visual rating was made 7 weeks after herbicide application (Table X). The ratings were based on the plots treated with paraquat or glyphosate plus oryzalin since those plots had the most copperleaf. Paraquat plus alachlor and glyphosate plus alachlor treated plots also had more copperleaf present than in the check plots. The combinations of glyphosate + oryzalin + metribuzin and paraquat + alachlor + metribuzin provided copperleaf control. A count of the copperleaf plants present 11 weeks after herbicide application generally coincided with the earlier visual rating. Only the plots treated with glyphosate + oryzalin had significantly greater amounts of copperleaf than did the check plots. The check plots did not have copperleaf present in amounts as great as in many of the treated plots probably due to the heavy competition by lambsquarter present in the check plots.

Morningglory (Ipomoea spp.) seems to be increasing in the area but was too erratic to evaluate.

Soybeans were evaluated throughout the 1977 season. A visual rating indicated weed competition resulting in stunting of the soybeans in the check plots and in plots treated with combinations of paraquat or glyphosate plus oryzalin or alachlor (Table XI). A soybean plant count indicated little difference among herbicide treatments. However, measurement of soybean heights indicated all treatments reduced the weed pressure somewhat, thus releasing the soybeans for greater growth than that of the soybeans in the check plots. Soybean height was generally greater in plots treated with combinations of three herbicides. Soybean yield was also higher in treated plots when compared to the check. The combinations of three herbicides resulted in higher soybean yields than those plots treated with only two herbicides. Soybean yields were higher in 1977 than in 1976 and may be partly attributed to the planting of soybeans in 51 cm rows rather than 102 cm rows employed the previous year. However, soybean planting was three weeks earlier in 1977 than in 1976, which increased the growing season. Rainfall was also greater in 1977 (Table XII).

Wheat was planted to the entire no-till area after soybean harvest in the fall of 1977. A John Deere 25 cm spaced hoe drill was adapted with fluted coulters to cut through the old wheat and soybean stubble. This provided good seed placement without any cultivation prior to the seeding. The wheat was observed the following spring of 1978. No injury to the wheat was noticeable. A dense stand of lambsquarter was present in all plots (Table XIII). Horseweed [Conyza canadensis (L.) Cronq.] was present in all plots and seemed to be more abundant in the

TABLE XI

NO-TILL SOYBEAN RESPONSE IN 1977 TO SEVERAL HERBICIDE COMBINATIONS

Treatment	Rate (kg/ha)	Soybean			
		Rating 7*	Plant Count (#/ha)	Height (cm)	Yield (hl/ha)
Glyphosate + Oryzalin + Metribuzin	0.8+1.1+0.4	0	225,946 ab**	61 ab**	23.1 a**
Glyphosate + Oryzalin + Linuron	0.8+1.1+0.8	0	229,981 ab	61 ab	21.0 a
Glyphosate + Alachlor + Metribuzin	0.8+2.2+0.4	0	225,946 ab	59 a-c	21.2 a
Glyphosate + Alachlor + Linuron	0.8+2.2+0.8	0	250,155 a	62 ab	20.6 a
Paraquat + Oryzalin + Metribuzin	0.6+1.1+0.4	0	229,981 ab	63 a	20.4 a
Paraquat + Oryzalin + Linuron	0.6+1.1+0.8	0	197,703 b	63 a	22.6 a
Paraquat + Alachlor + Metribuzin	0.6+2.2+0.4	0	258,224 a	63 a	19.4 a
Paraquat + Alachlor + Linuron	0.6+2.2+0.8	0	217,877 ab	58 a-c	19.9 a
Paraquat + Oryzalin	0.6+1.1	1	221,911 ab	50 cd	14.2 b
Paraquat + Alachlor	0.6+2.2	1	213,842 ab	50 cd	12.5 bc
Glyphosate + Oryzalin	0.8+1.1	1	189,633 b	46 de	10.4 bc
Glyphosate + Alachlor	0.8+2.2	0.5	229,981 ab	51 b-d	12.9 bc
No-Till Check	---	2	189,633 b	39 e	8.5 c

*Ratings were taken 7 weeks after treatment and are based on a scale of 0-10.
**Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

TABLE XII

DISTRIBUTION AND THE LONG TERM AVERAGE RAINFALL FOR THE NO-TILLAGE CONTINUOUS DOUBLE CROPPING STUDY AT BIXBY, OKLAHOMA

	Rainfall (cm)						Long Term
Month	Day*		1976	Day*		1977	Average
January			0.00			2.16	3.91
February			1.78			4.01	4.14
March			7.19			8.74	6.60
April			14.12			5.26	9.96
May			6.20			12.75	11.84
June			4.27	24	2.11	9.47	11.56
				26	1.07		
				28	4.45		
				30	0.76		
July	16	3.45	6.93			8.43	9.40
	29	2.03					
August	03	5.16	8.51			7.65	7.11
	08	0.53					
September			7.98			21.74	11.10
October			4.98			5.08	8.15
November			1.63			6.83	6.55
December			2.79			1.78	4.83
TOTALS			66.37			93.90	95.05

*Daily rainfall is given for a period immediately following herbicide treatments.

TABLE XIII

WEEDS PRESENT IN THE SECOND YEAR OF WHEAT IN THE NO-TILLAGE CONTINUOUS DOUBLE CROPPING STUDY

Treatment	Rate (kg/ha)	Horseweed	Lambsquarter	Volunteer Wheat
Glyphosate + Oryzalin + Metribuzin	0.8+1.1+0.4	4*	√	
Glyphosate + Oryzalin + Linuron	0.8+1.1+0.8	5	√	
Glyphosate + Alachlor + Metribuzin	0.8+2.2+0.4	4	√	
Glyphosate + Alachlor + Linuron	0.8+2.2+0.8	4	√	
Paraquat + Oryzalin + Metribuzin	0.6+1.1+0.4	5	√	
Paraquat + Oryzalin + Linuron	0.6+1.1+0.8	4	√	
Paraquat + Alachlor + Metribuzin	0.6+2.2+0.4	2	√	
Paraquat + Alachlor + Linuron	0.6+2.2+0.8	3	√	
Paraquat + Oryzalin	0.6+1.1	4	√	
Paraquat + Alachlor	0.6+2.2	3	√	
Glyphosate + Oryzalin	0.8+1.1	1	√	√
Glyphosate + Alachlor	0.8+2.2	3	√	√
Check	---	1	√	√

*Number are visual ratings of 0-10 with 0 indicating no plant reduction and 10 being complete plant kill or elimination.
√=indicates that the weed was present in appreciable amounts.

check plots and plots previously treated with glyphosate + oryzalin. Volunteer wheat was also present in the check plots and plots treated with glyphosate + oryzalin and glyphosate + alachlor.

Milk Stage Pre-Harvest Wheat Treatments

At the time of wheat harvest, many weeds may be present and may have attributed to wheat yield reductions. They may have also removed much soil moisture that may be needed for the succeeding soybean or other crop in a double cropping system. Phenoxyalkanoic herbicides such as 2,4-D, MCPA and others may be used in wheat but are usually restricted to use before the boot stage or after the milk stage of wheat maturity. Many spring annual weeds emerge at or after this general time period. An experiment was conducted to determine how early in the development of wheat may it be sprayed with herbicides such as paraquat and glyphosate without damage to the wheat. Wheat was sprayed at the milk stage of development (Table XIV). Both paraquat and glyphosate reduced wheat yields significantly at the 5% level of Duncan's new multiple range test. Paraquat reduced yields to only half that of the check. Paraquat also reduced the grain size which is indicated by the low test weights. Both herbicides caused a lighter color of the wheat plants at maturity.

Effects of Straw Cover and Carrier Volume on Herbicide Phytotoxicity

Pigweed was the only weed which emerged in this study. Combinations of glyphosate + metribuzin, glyphosate + oryzalin, and glyphosate + oryzalin + metribuzin as preemergence applications did an excellent

TABLE XIV

WHEAT SUSCEPTIBILITY TO HERBICIDES APPLIED TO THE MILK STAGE OF WHEAT

Treatment	Rate (kg/ha)	Test Weight (kg/hl)	Yield (hl/ha)
Paraquat	0.6	62.6 b*	21.1 c*
Paraquat	1.1	60.0 b	20.4 c
Glyphosate	1.1	75.5 a	31.1 b
Glyphosate	2.2	75.5 a	27.2 b
Check	---	78.0 a	42.2 a

*Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

job of controlling the mixture of pigweeds which were found in abundance in the check plots (XV). The straw cover and the two water carrier volumes did not affect the control of these pigweeds. The hoe timing was taken and affirms the excellent weed control by all of the herbicide combinations. It took 1 to 2 hours/hectare to hoe any of the treated plots. This compares to the 28 to 30 hours/hectare required to hoe the check plots.

All treatments containing metribuzin caused soybean stand reduction and leaf burn. Visual ratings indicated injury to the soybeans regardless of whether the plots were bare or straw covered. However, in every herbicide combination with each carrier volume level, less injury occurred to the soybeans when the straw was present on the plots. Later in the season, soybean stunting was also evident in the treated plots. The injury from combinations of oryzalin and glyphosate was a bending of the soybeans at the base of the stem, starting a few days after emergence. Later in the season many of these plants broke off and died. Only slight stand reduction was noticed in the plots with the straw cover. Soybean yields were higher in all plots covered with straw. Water volume affected soybean yield in only one instance; glyphosate + metribuzin at 1.1 + 0.4 kg/ha applied to bare soil yielded more soybeans when treated at 140 l/ha than 374 l/ha water volume.

Even though the check plots were hand weeded twice, the pigweeds presented enough competition to reduce the soybean yields.

This study indicated herbicide rates selected were too high for the soil type. However, it does point out that the straw may catch part of the chemical and prevent it from reaching the soil. If weeds had been a major problem and lower herbicide rates had been used,

TABLE XV

EFFECTS OF STRAW AND WATER ON HERBICIDE PHYTOTOXICITY

Treatment	Rate (kg/ha)	Water (l/ha)	Cover	Pigweed 2*	Soybean 2*	Soybean 10*	Hoe Time (hr/ha)	Yield (hl/ha)
Glyphosate + Metribuzin	1.1+0.4	140	Straw	10†	2	½	1.5 a**	12.9 a**
"	1.1+0.4	140	Bare	10	6	4	1.0 a	10.8 a-d
"	1.1+0.4	374	Straw	10	4	2	1.0 a	11.5 a-c
"	1.1+0.4	374	Bare	10	6	5	1.0 a	7.0 e-h
Glyphosate + Metribuzin	1.1+0.8	140	Straw	10	5	4	1.0 a	8.7 c-f
"	1.1+0.8	140	Bare	10	10	8	1.0 a	3.0 j
"	1.1+0.8	374	Straw	10	7	4	1.0 a	6.4 f-i
"	1.1+0.8	374	Bare	10	9	8	1.0 a	3.1 j
Glyphosate + Oryzalin	1.1+1.1	140	Straw	10	0	1	2.0 a	13.1 a
"	1.1+1.1	140	Bare	10	1	5	1.5 a	8.2 d-g
"	1.1+1.1	374	Straw	10	0	1	1.5 a	13.2 a
"	1.1+1.1	374	Bare	10	2	6	1.2 a	5.5 g-i
Glyphosate + Oryzalin	1.1+2.2	140	Straw	10	0	2	1.5 a	9.6 b-f
"	1.1+2.2	140	Bare	10	2	7	1.5 a	3.7 i-j
"	1.1+2.2	374	Straw	10	0	2	1.0 a	10.6 a-d
"	1.1+2.2	374	Bare	10	4	7	1.2 a	2.9 j
Glyphosate + Oryzalin + Metribuzin	1.1+1.1+0.4	140	Straw	10	3	2	1.0 a	12.3 ab
"	1.1+1.1+0.4	140	Bare	10	7	7	1.0 a	3.0 j
"	1.1+1.1+0.4	374	Straw	10	4	2	1.0 a	10.1 a-e
"	1.1+1.1+0.4	374	Bare	10	6	6	1.0 a	4.1 h-j

TABLE XV (CONTINUED)

Treatment	Rate (kg/ha)	Water (l/ha)	Cover	Pigweed 2*	Soybean 2*	Soybean 10*	Hoe Time (hr/ha)	Yield (hl/ha)
Check	---		Straw	0†	0	3	27.9 b**	6.6 f-i**
Check	---		Bare	0	0	3	30.1 b	6.4 f-i

*Weeks after treatment that rating was made.

**Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

†Visual ratings are based on a scale of 0 to 10 with 0 being no plant injury and 10 being complete plant kill or elimination.

poorer weed control might have been evident in the plots covered with straw. This effect might necessitate the need for higher herbicide rates or greater water volume to obtain effective weed control in a no-tillage or minimum-tillage system.

Effects of Removing Wheat Stubble After Mowing

Soybeans germinated and emerged to a good stand in the area where the straw was left on the field. In the area where the straw had been removed, the soil dried so rapidly that the soybeans sprouted but most dried up and died before soybean emergence. A soybean plant count taken 3 weeks after planting showed greater plant emergence in all plots where straw was present (Table XVII). The soybeans were visually rated 6 weeks after planting and were still found to be in much better condition in the area where the straw was present (Table XVI).

Four herbicide combinations applied in three water carrier volumes were evaluated for their control of large crabgrass [Digitaria sanguinalis (L.) Scop.] and pigweed. Much of the crabgrass was present at the time of herbicide application. Combinations of glyphosate + metribuzin and glyphosate + oryzalin gave much better control of the crabgrass than did combinations of paraquat with either metribuzin or oryzalin (Table XVI). In the area where the straw had been removed, crabgrass control was best when treated with glyphosate + oryzalin. However, oryzalin gave no better control than did metribuzin in the area where the straw was present. Control was generally better in the area with the straw remaining. Perhaps the mowing of the stubble caused a smothering effect on some of the grass. Pigweeds became abundant especially in those plots where most of the crabgrass was

TABLE XVI

VISUAL RESPONSE OF SOYBEAN AND WEEDS TO HERBICIDE COMBINATIONS IN MOWED STUBBLE REMOVED OR PRESENT

Treatment	Rate (kg/ha)	Water (l/ha)	Straw	Visual Ratings (0-10)* Soybean	Crabgrass	Pigweed
Glyphosate + Metribuzin	1.1+0.4	140	Removed	7	4	5
Paraquat + Metribuzin	0.6+0.4	"	"	8	1	8
Glyphosate + Oryzalin	1.1+1.1	"	"	5	8	7
Paraquat + Oryzalin	0.6+1.1	"	"	9	0	7
Glyphosate + Metribuzin	1.1+0.4	280	"	7	5	3
Paraquat + Metribuzin	0.6+0.4	"	"	7	2	9
Glyphosate + Oryzalin	1.1+1.1	"	"	5	8	7
Paraquat + Oryzalin	0.6+1.1	"	"	8	0	9
Glyphosate + Metribuzin	1.1+0.4	374	"	6	5	3
Paraquat + Metribuzin	0.6+0.4	"	"	8	1	9
Glyphosate + Oryzalin	1.1+1.1	"	"	5	8	8
Paraquat + Oryzalin	0.6+1.1	"	"	7	2	9
Check	---	-	"	10	1	2
Glyphosate + Metribuzin	1.1+0.4	140	Present	0	9	9
Paraquat + Metribuzin	0.6+0.4	"	"	2	3	10
Glyphosate + Oryzalin	1.1+1.1	"	"	1	9	9
Paraquat + Oryzalin	0.6+1.1	"	"	3	2	10
Glyphosate + Metribuzin	1.1+0.4	280	"	1	9	8
Paraquat + Metribuzin	0.6+0.4	"	"	1	5	10
Glyphosate + Oryzalin	1.1+1.1	"	"	0	9	9
Paraquat + Oryzalin	0.6+1.1	"	"	1	3	10

TABLE XVI (CONTINUED)

Treatment	Rate (kg/ha)	Water (l/ha)	Straw	Visual Ratings (0-10)*		
				Soybean	Crabgrass	Pigweed
Glyphosate + Metribuzin	1.1+0.4	374	Present	0	8	5
Paraquat + Metribuzin	0.6+0.4	"	"	1	5	10
Glyphosate + Oryzalin	1.1+1.1	"	"	1	9	9
Paraquat + Oryzalin	0.6+1.1	"	"	1	4	10
Check	---	-	"	3	1	2

*Ratings were taken 6 weeks after treatment. Ratings are based on a scale of 0 to 10 with 0 being no plant injury and 10 being complete plant kill or elimination.

TABLE XVII

MEASUREMENTS OF SOYBEAN RESPONSE TO HERBICIDE COMBINATIONS IN MOWED STUBBLE REMOVED OR PRESENT

Treatment	Rate (kg/ha)	Water (1/ha)	Straw	Count #/ha	Height (cm) 3*	Height (cm) 7*	Yield (hl/ha)
Glyphosate + Metribuzin	1.1+0.4	140	Removed	56,487 de**	5.4 e**	21.1 ef**	0.0 f**
Paraquat + Metribuzin	0.6+0.4	"	"	70,205 de	9.8 b-e	22.0 ef	0.0 f
Glyphosate + Oryzalin	1.1+1.1	"	"	108,535 cd	7.7 e	23.5 ef	0.4 f
Paraquat + Oryzalin	0.6+1.1	"	"	52,048 de	8.3 de	20.8 ef	0.0 f
Glyphosate + Metribuzin	1.1+0.4	280	"	64,556 de	6.8 e	24.8 ef	0.3 f
Paraquat + Metribuzin	0.6+0.4	"	"	100,465 cd	9.3 c-e	22.0 ef	0.2 f
Glyphosate + Oryzalin	1.1+1.1	"	"	100,062 cd	8.3 de	22.5 ef	0.8 f
Paraquat + Oryzalin	0.6+1.1	"	"	69,801 de	8.8 de	19.8 ef	0.0 f
Glyphosate + Metribuzin	1.1+0.4	374	"	89,975 d	9.0 de	23.9 ef	0.2 f
Paraquat + Metribuzin	0.6+0.4	"	"	67,784 de	6.8 e	21.9 ef	0.0 f
Glyphosate + Oryzalin	1.1+1.1	"	"	117,411 cd	8.3 de	28.5 de	1.3 ef
Paraquat _ Oryzalin	0.6+1.1	"	"	75,046 de	8.2 de	20.5 ef	0.0 f
Check	---	-	"	6,052 e	4.9 e	16.1 f	0.0 f
Glyphosate + Metribuzin	1.1+0.4	140	Present	263,469 a	15.4 a	43.0 ab	7.0 ab
Paraquat + Metribuzin	0.6+0.4	"	"	229,578 ab	13.9 a-c	39.5 a-c	4.2 cd
Glyphosate + Oryzalin	1.1+1.1	"	"	233,612 ab	14.7 a	43.9 ab	8.4 a
Paraquat + Oryzalin	0.6+1.1	"	"	202,141 ab	15.5 a	33.1 b-d	2.1 d-f
Glyphosate + Metribuzin	1.1+0.4	280	"	209,404 ab	15.3 a	40.9 a-c	6.2 a-c
Paraquat + Metribuzin	0.6+0.4	"	"	246,120 ab	15.0 a	41.7 a-c	4.2 cd
Glyphosate + Oryzalin	1.1+1.1	"	"	233,612 ab	14.9 a	40.4 a-c	8.4 a
Paraquat + Oryzalin	0.6+1.1	"	"	222,315 ab	15.4 a	36.0 b-d	2.6 d-f

TABLE XVII (CONTINUED)

Treatment	Rate (kg/ha)	Water (l/ha)	Straw	Count #/ha	Height (cm)		Yield (hl/ha)
					3*	7*	
Glyphosate + Metribuzin	1.1+0.4	374	Present	242,488 ab**	17.3 a**	41.2 a-c**	5.8 a-c**
Paraquat + Metribuzin	0.6+0.4	"	"	231,191 ab	16.7 a	41.0 a-c	3.9 c-e
Glyphosate + Oryzalin	1.1+1.1	"	"	213,842 ab	14.4 ab	41.9 a-c	6.4 a-c
Paraquat + Oryzalin	0.6+1.1	"	"	227,156 ab	16.2 a	48.1 a	4.4 b-d
Check	---	-	"	167,039 bc	13.1 a-d	38.1 bc	1.9 d-f

*Weeks after treatment that height measurements were made.
**Numbers followed by the same letter are not significantly different at the 5% level of Duncan's new multiple range test of significance.

controlled. Therefore, treatments of paraquat with either metribuzin or oryzalin caused greater control of the pigweed. This was probably due to the lack of control of the crabgrass which seemed to choke out most of the pigweeds.

A measurement of the height of the soybeans was taken at 3 and 7 weeks after planting. Both measurements indicated taller soybeans in the area where the straw was left on the field (Table XVII). This may be due in part to the ability of the straw in retaining moisture and seeming to cause better weed control. Rainfall for the first 7 weeks after planting was 7.1 cm.

Due to the late planting of the soybeans, low moisture during the season, and severe weed competition, the soybeans did not yield very high (Table XVII). Yields were much greater in the area covered with wheat stubble. The soybeans yielded little or none in the area where the straw had been removed. The soybeans yielded best in those plots treated with glyphosate + metribuzin or glyphosate + oryzalin. Water volume did not seem to affect the weed control or soybean yield by any of these herbicide combinations.

General Discussion

Conventional-tillage systems were found to provide better weed control and soybean yield than the no-tillage system. Conventional-tillage removed all the weed vegetation before the planting of the soybeans. The no-tillage herbicide treatments used did not adequately remove the weeds present and therefore the soybeans suffered severely. Adding a residual grass type herbicide to the no-till treatments might have provided the necessary weed control for soybean production.

Double cropping seemed to be a risk at one location due to the low soil moisture after wheat harvest. Each individual farmer must decide each year whether there is soil moisture available for soybean production.

Several herbicide combinations may provide adequate weed control in a no-tillage soybean production system. Combination of a foliar active herbicide, to provide control of weeds present at wheat harvest, and one or two residual type herbicides for control of grass and broadleaf weeds throughout the soybean growing season will be needed.

Weeds that are present at wheat harvest may be destroyed with paraquat or glyphosate providing that the harvesting of the wheat does not remove all or most of the weed foliage. These large weeds might be controlled better with paraquat or glyphosate applied before wheat harvest since more weed foliage would be available for herbicide contact. However, wheat may be injured if either of these chemicals are sprayed at the milk stage of wheat. A later application, perhaps during the soft dough stage of development, might not injure the wheat. However, further research needs to be conducted. Research needs to be conducted using various herbicides or combinations of herbicides applied to wheat in the late tillering or early elongating stages of growth. At this time of the year (early spring) many annual weeds emerge in wheat. Chemical control of these weeds would provide more available soil moisture for the wheat during its development and for the soybeans at planting time. These herbicides need to maintain weed control throughout the soybean season without causing harmful residual effects to the succeeding wheat crop.

No-tillage crop production provides a stubble mulch which helps to conserve moisture needed for soybean germination at planting. It also reduces the evaporation of moisture after rainfall throughout the soybean growing season. Removing wheat stubble after harvest may provide winter feed for cattle but may also remove the mulch needed for moisture retention in the soil. Soybean stand count was higher when the wheat straw was left on the field. A light rainshower just after planting of the soybeans caused the soybeans to emerge in the straw covered area. In the area which had the straw removed, the soil dried so fast that most of the soybeans did not emerge. Weed control with herbicide combinations was better in the straw covered area. This may possibly be due to the ability of a greater soybean population to better compete with the weeds. Reduced light in the straw covered area might also reduce the emergence of weed seedlings.

The straw may possibly affect the length of residual weed control. Since straw catches some of the applied herbicide it may reduce the weed control and/or duration of weed control. The presence of wheat stubble reduced the injury to soybeans by herbicides used at rates higher than recommended for the particular soil type. Weed control might be affected similarly. Further research needs to be conducted to determine the effects of straw on weed control. Herbicide rates may need to be adjusted for longer weed control in the soybean season without harming the following wheat crop.

Water carrier volume did not seem to affect the weed control. However, the water volume might affect the weed control when the foliage is clipped low by the combine leaving only a few lower leaves for herbicide contact. Combining higher from the soil surface would permit more leaf contact for herbicides but might also hinder planting of the soybeans due to the excess stubble.

The effect of wheat and soybean stubble on disease and insect incidence needs to be evaluated. Long term continuous no-tillage double cropping may cause an increase in disease pathogens and insects due to the stubble being more condusive to the overwintering of these pests.

The no-tillage double cropping experiments need to be continued for several years to determine if a weed shift occurs. If this occurs, herbicides used may need to be changed to give control of the weeds which emerge as serious pests. If diseases and insects become a problem or perennial weeds emerge, rotation from no-tillage to conventional-tillage for one season may be needed.

Due to the later planting of soybeans when double cropped behind wheat, narrower rows than the conventional 102 cm rows increases the number of plants per hectare which often allows for higher yields. In addition, the narrow rows permit earlier shading which reduces weed competition and soil moisture evaporation. Wheat is also planted later than normal in a double cropping system and therefore will not have as many tillers. Increased seeding rates may increase the wheat yields.

CHAPTER V

SUMMARY

Long term field studies were established to evaluate tillage systems for double cropping of soybeans and wheat. Conventional-tillage soybean production gave better weed control than the no-tillage herbicide treatments of glyphosate + metribuzin. Poor weed control with the no-tillage treatments caused a reduction in soybean yield compared to the conventional-tilled soybean yields.

Several herbicide tank-mix combinations were evaluated for weed control and crop tolerance in no-till double cropped soybeans. Combinations of glyphosate or paraquat plus oryzalin or alachlor plus metribuzin or linuron at rates recommended for the particular soil type provided better control of copperleaf and lambsquarter than did combinations of only glyphosate or paraquat plus oryzalin or alachlor. Soybean yield was statistically higher in plots treated with any one of the three-herbicide combinations. Soybeans yielded more in 51 cm row spacings planted at 0.9 hl/ha than in 102 cm row spacings when planted at 0.7 hl/ha.

Wheat yield and grain test weight were reduced by treatments of paraquat and glyphosate at 0.6 and 1.1 kg/ha, respectively, when they were applied to wheat in the milk stage of development. Paraquat reduced the yields more than did the glyphosate.

Soybean stand, height, and yield were much greater in no-till wheat stubble mowed and left on the field rather than being removed. Weed control was also better in the plots with the straw remaining. However, the better weed control may be due to greater soybean competition in the straw area. Tank-mix combinations of glyphosate + oryzalin or glyphosate + metribuzin provided better control of crabgrass present at planting than did combinations of paraquat + oryzalin or paraquat + metribuzin.

Leaf burn and stand reduction occurred when soybeans were treated with excessive rates of metribuzin. Oryzalin caused a bending of the soybean plants at the base of the stem. Injury occurred to soybeans planted in both bare soil or straw covered soil. However, injury was much less in plots covered with straw resulting in greater soybean yields. The straw appeared to catch part of the chemical and prevent it from reaching the soil. With the herbicide rates used, weed control was excellent but lower herbicide rates might not have provided this control in the straw covered plots. Water volume did not affect the injury to the soybeans or weeds.

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