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# Chemical weed control in soybeans planted in nontilled wheat stubble

Tommy Shields Henard

To the Graduate Council:

I am submitting herewith a thesis written by Tommy Shields Henard entitled "Chemical weed control in soybeans planted in nontilled wheat stubble." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Larry S. Jeffery, Major Professor

We have read this thesis and recommend its acceptance:

Joe S. Alexander, L. N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

March 1, 1970

To the Graduate Council:

I am submitting herewith a thesis written by Tommy Shields Henard entitled "Chemical Weed Control in Soybeans Planted in Nontilled Wheat Stubble." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Larry S. Jeffery
Major Professor

We have read this thesis
and recommend its acceptance

Joe S. Alexander
L. N. Skold

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

# CHEMICAL WEED CONTROL IN SOYBEANS PLANTED IN NONTILLED WHEAT STUBBLE

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A Thesis

Presented to

the Graduate Council of

The University of Tennessee

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Tommy Shields Henard

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ABSTRACT

A study was made to (1) determine whether soybeans (*Glycine max* (L.) Merr.) could be grown successfully in wheat stubble as part of a double-cropping system, (2) test different combinations of herbicides for weed control, (3) determine the effects of burning versus non-burning of straw on soybean vigor and weed population, and (4) determine by bioassay if herbicide residues persisted at the end of the growing season.

At Knoxville herbicide treatments effectively controlled weeds throughout the growing season but at Springfield only through the sixth week. Weed control at Springfield failed completely by the end of the growing season. The best weed control ratings were recorded on the DCPA (dimethyl 2,3,5,6-tetrachloroterephthalate) plus paraquat (1,1'-dimethyl-4,4'bipyridinium ion) treatment, linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] plus paraquat treatment and the alachlor [2-chloro-2',6'-diethyl-N-(methoxy ethyl) acetanilide] plus linuron plus paraquat treatment. The poorest weed control was recorded on the amiben (3-amino-2,5-dichlorobenzoic acid) and the amiben plus paraquat treatments. At Knoxville, percent weed control was higher on the burned plots than on the nonburned plots.

At Springfield, soybeans showed an extreme loss of vigor by the end of the growing season; however, at Knoxville, soybeans remained vigorous throughout the growing season. Extreme loss of vigor at Springfield was attributed to increasing weed competition.

Soybean yields on herbicide-treated plots averaged only 4 bushels

per acre as compared to 18 bushels on the conventional seedbed plus cultivation treatment. The low yields on herbicide treated plots were due to weed competition and insufficient rainfall. At Knoxville, yields on herbicide treated plots averaged 38 bushels per acre as compared to 45 bushels on the conventional seedbed plus cultivation treatment.

At Knoxville, a bioassay with crimson clover (*Trifolium incarnatum* L.) and wheat (*Triticum aestivum* L.) seedlings indicated that no toxic herbicide residues remained in the soil at the end of the growing season.

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# CHAPTER I

## INTRODUCTION

Soybean acreage in Tennessee is approximately 1 1/4 million acres at the present. A number of Tennessee farmers are following a double-cropping system with small grain and soybeans. The possibility of obtaining two crops in a single growing season has made this an attractive practice in spite of numerous hazards inherent in the system. Difficulties associated with this practice include: (1) inadequate soil moisture following small grain harvest and seedbed preparation, (2) the difficulty of obtaining a suitable stand of soybeans, (3) severe weed competition, and (4) the short growing season remaining for the soybeans. Any combination of practices that would reduce the time interval between small grain harvest and soybean planting, conserve soil moisture, and reduce weed competition would increase the probability of obtaining a profitable soybean crop. Planting soybeans directly in undisturbed small grain stubble using chemical weed control appears to be a feasible solution to these problems and would reduce soil erosion resulting from seedbed preparation and cultivation.

The objectives of this study were fourfold: (1) to determine whether soybeans could be grown successfully in wheat stubble as part of a double-cropping system, (2) to test different combinations of herbicides for weed control, (3) to determine the effects of burning versus nonburning of straw on soybean vigor and weed population, and (4) to determine by bioassay if herbicide residues persisted at the end of the growing season.

# CHAPTER II

## LITERATURE REVIEW

### I. Minimum Tillage in Soybean Production

Considerable research has been done on the minimum tillage practice of growing corn (*Zea mays* L.) without cultivation in chemically killed sod. However, growing soybeans (*Glycine max* (L.) Merr.) without cultivation in small grain stubble or on chemically killed sod is a relatively new concept.

McAlister (24) reported the use of a minimum tillage lister-planter that prepared the seedbed, distributed the fertilizer, and planted the soybeans in small grain stubble in one operation. He suggested that factors favoring lister planting of soybeans without burning the straw or using conventional turnplow tillage are: soil moisture conservation, improved tilth, maintainance of organic matter, and lower production costs.

Beale and Langdale (4), working in South Carolina, found that differences in yield due to tillage practices were not significant. Also, tillage and residue management had no marked influence on soil temperature and available moisture. They concluded that burning the straw before planting soybeans had no significant effect on yields. Soybean stands were increased somewhat if the straw was burned or removed from the soil surface.

Mullins (27), in work at the Milan Field Station in West Tennessee, found that different methods of seedbed preparation following wheat harvest such as (1) no tillage, (2) conventional plowing and discing, (3) discing only, and (4) chisel plowing had no significant effect on yields of soybeans.

He also conducted an experiment to determine the effects of burning versus nonburning of straw with different methods of seedbed preparation on soybean yields. Data from the first year showed that soybean yields were higher on the burn treatments, but the second year only slight increases in yield occurred for the burn treatments.

Barrows and Fitzgerald (3) reported the successful production of soybeans in a Ladino clover (*Trifolium repens* L.) sod killed with dinoseb (4, 6-dintro-o-*sec*-butylphenol) applied once before planting and as a directed spray after planting. Soybean yields of 20 bushels per acre were obtained.

Brown (7) was unable to control fescue sod with herbicides sufficiently well to permit good soybean growth at anytime during the growing season. Although the herbicide treatments resulted in poor sod control, weed control was excellent. Brown also reported that soybean plant vigor was not good on chemically treated plots. He attributed this reduction of plant vigor to competition from the sod.

A greater probability of obtaining high yields of soybeans exists when they are planted soon after small grain harvest. Smith (34) found that soybeans planted on a well prepared seedbed after June 15 yielded significantly less than those planted before June 15. Peters (30), working in Tennessee, found there was an average reduction in soybean yields of 0.36 bushels per acre for each day planting was delayed after June 1.

McKibben (25) suggested that the shorter growing season for soybeans imposed by a double cropping system improved the possibilities for season-long herbicidal weed control. This control can be enhanced by narrow row spacing which, at the same time, may increase yields. Working in Illinois, he found that a 20-inch row spacing with Wayne and Amsoy soybean varieties gave equal or larger yields than did a 30-inch row spacing when the same number of plants per foot of row were involved. Narrow row spacing for soybeans sown after small grain harvest may also be justified because of a decrease in plant height which often occurs with late planting dates. Leffel (21) in Maryland found that the decrease in plant height with a delay in planting was greater for late maturing varieties. However, Peters (30) in Tennessee found that soybean plant height at maturity was relatively constant for all varieties in spite of a 30-day range in time of planting.

Research has shown that certain varieties of small grain and soybeans are better adapted to a double-cropping system than others. Peters (30), working in Tennessee, found that when soybeans were planted late, maturity of all soybean varieties was delayed. The delay in maturity was greater for the early varieties than for late varieties. Kent, Clark 63, and Hill soybean varieties were the most suitable for a double-cropping system in Tennessee. For double-cropping purposes, Barsoy barley (*Hordeum vulgare* L.) and Kent soybeans was the best combination of varieties. Hartwig (16), Leffel (21), Osler and Carter (29), Torrie and Briggs (37) and Weiss (39) found that late planting affected time of maturity of early soybean varieties more than late varieties. However, Henson and Carr (17) found that in Mississippi late planting had less effect on earlier varieties than on late varieties.

Some of the advantages for minimum tillage in soybeans may be the same as for minimum tillage in corn production. Moody (26) stated that the minimum tillage approach to growing corn affords excellent soil and water conservation. Plant residues form a mulch which protects the soil from erosion, reduces moisture losses from evaporation and runoff, and increases infiltration of summer rains into the soil.

## II. Herbicides

### Alachlor

Alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] is a recent addition to the herbicide market. Alachlor is recommended for use as a preemergence spray for control of most annual grasses and certain broadleaved weeds. Evans (11) found that soybeans are highly tolerant to preemergence treatment.

Alachlor is non-volatile and 148 ppm soluble in water. Weed control activity has been shown over a wide range of climatic conditions and soil types (11). Alachlor persists in the soil at herbicidal concentrations for 10 to 12 weeks (11).

### Amiben

Amiben (3-amino-2,5-dichlorobenzoic acid) is a root-absorbed preemergence herbicide for selective control of annual grasses and broadleaved weeds. The physiological basis for selectivity of amiben has not been proven, but it inhibits root development of seedling weeds (18).

Plants susceptible to amiben have been found to translocate more amiben than do tolerant plants, although the roots of both plants absorb the herbicide. Colby (9) found that soybeans possess considerable tolerance to amiben even when directly exposed to the herbicide. Swan and Slife (35) stated that soybeans grown in soil treated with 3 pounds acid equivalent per acre of amiben were not retarded in growth and that this rate gave effective weed control.

Sheets (32) found that amiben in water solution decomposes rapidly when exposed to light. Slow but definite photochemical alteration occurred when dry amiben was exposed to light, but this phenomenon has not been found to occur in soils (26).

The average persistence of amiben in the soil when applied at recommended rates is approximately 6 to 8 weeks (18). Amiben is 700 ppm soluble in water and is leached rapidly by heavy rain on sandy soil (18). Linscott (22) found that soil absorption of amiben is closely associated with organic matter content. Also, amiben is degraded by soil microorganisms (18).

DCPA

DCPA (dimethyl 2,3,5,6-tetrachloroterephthalate) is a phthalic acid derivative used as a preemergent herbicide to control many annual grasses and broadleaved weeds.

Mazur (23) found in bioassays that DCPA reduced root and shoot growth of sensitive plants. Other facts about the mode of action of DCPA were not found in the review of literature.

DCPA is adsorbed by the organic matter of soils and has an average half life of 100 days in most soils (18).

Jones (19) found that DCPA would accumulate in the soil or produce residual toxicity to oats when applied at 6.0 pounds active ingredient per acre. Jones reported that when DCPA was applied for three consecutive years at higher than the recommended rates of 10 and 20 pounds per acre in Tennessee, residues were toxic to oats and the degree of injury appeared to become more severe each year.

Schweize and Holstun (31) found that residues from DCPA, applied at 8 pounds per acre, were not toxic to oats, soybeans or cotton sown 22 weeks after application.

## Dinoseb

Dinoseb (4,6-dintro-o-sec-butylphenol) is a contact herbicide which can be used for both preemergence and postemergence weed control.

Dinoseb prevents the synthesis of adenosine triphosphate (ATP) thus inhibiting plant growth. Dinoseb stimulates respiration but ATP synthesis stops (1).

Barrows (2) found that little or no translocation of dinoseb occurs within plants. Rapidly growing, succulent plants are more susceptible to dinoseb than are older, more mature plants (2).

Hanson (15) applied dinoseb as a directed spray to soybeans at various stages of growth. Varying degrees of injury occurred, but by the bloom and pod-set stages no evidence of injury was visually present. Maturity was not delayed.

Dinoseb leaches rapidly in the soil and microbial breakdown has been demonstrated (18). The average persistence of dinoseb is 2 to 4 weeks when applied at recommended rates.

Klingman (20) reported that dinitros applied at the rate of 6 to 9 pounds active ingredient per acre lasted only 3 to 5 weeks. Hence, no residual carryover is expected from one season to the next.

Linuron

Linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] has both preemergence and postemergence activity. Sufficient soil moisture must be present to move linuron into the root zone if it is to be effective as a preemergence herbicide. When applied to the soil, linuron is absorbed by the roots and translocated upward in the plant where it inhibits the Hill reaction of the photosynthetic process (28).

When linuron is applied postemergence it burns plant foliage. Phytotoxicity of this herbicide can be significantly increased by the addition of surfactants to the spray mixture (38).

Microorganisms are the primary factor in the disappearance of linuron from soils (18). Dubey (10) found that the faster breakdown of linuron in soils with high organic matter content was partially due to higher microbial activity.

At recommended rates the average persistence of linuron is about 4 months (18). Sheets (33) reported that linuron exhibited short residual activity and should not be hazardous to sensitive crops in rotation systems.

Paraquat

Paraquat (1,1'-dimethyl-4,4'bipyridinium ion) is an effective contact herbicide which kills plant tissue rapidly (5). In short-time studies of duckweed (Lemma minor L.) it was determined that paraquat caused a stimulation in respiration and an inhibition in photosynthesis (13). Paraquat salts bring about rapid death to a wide range of plant species in the light, though death occurs slowly in the dark. Chlorophyll is required to produce the high phototoxicity of paraquat in the light (1). In presence of light, paraquat forms a free radical within the plant, and in the presence of oxygen produces peroxide radicals. Plant death occurs as a result of peroxide radicals degrading proteins or other macro-molecules in the cell protoplasm (1). In the absence of light, respiration produces free paraquat radicals which slowly cause plant death (1).

Bovey and Davis (5) found that leaf necrosis was delayed at least 48 hours when treated leaves were exposed to low temperatures of 5°C as compared to higher temperatures of 25°C.

Photochemical decomposition of paraquat is rapid, thus soil residues are no problem. In a greenhouse experiment, Funderburk (13) found that ultraviolet light degraded more than 75 percent of the $C^{14}$ labeled paraquat within 96 hours. Clay particles strongly absorb paraquat, fixing it in an inactive form (18).

Feater and McIlvenny (12) applied paraquat immediately before sowing autumn and spring cereal crops in pasture and weedy stubble. No injury occurred and yield was not decreased when compared to the cultivated check.

## Naptalam

Naptalam (N-1 naphthylphthalamic acid) is a selective preemergence herbicide for the control of a wide range of annual grasses and broadleaved weeds.

The mode of action of naptalam has not been established, but it causes a loss of geotropic response to auxins. Naptalam disturbs the polar transport of endogenous auxins which may be the cause for loss of geotropic and phototropic responses (1).

Naptalam gives effective weed control for 3 to 8 weeks when applied at 4 pounds active ingredient per acre (18).

Naptalam leaches rapidly in highly porous soils and in silt loam soils or after heavy rains (18). Naptalam is non-volatile, photostable, and subject to slow microbial breakdown.

Ogle (28) found that soil retention of naptalam was positively correlated with the base exchange capacity and organic matter content of the soil.

# CHAPTER III

## MATERIALS AND METHODS

This study was conducted in two parts. An experiment was conducted in 1968 at the Highland Rim Experiment Station near Springfield and in 1969 at the Plant Science Farm near Knoxville. At both stations soybeans followed wheat (*Triticum aestivum* L.) in a double-cropping system. At Springfield, the wheat was mowed close to the soil level and removed before planting soybeans. At Knoxville, the wheat was mowed at a 12-inch height.

At Springfield a randomized complete block design with nine treatments (i.e., eight herbicide treatments and a conventional seedbed plus cultivation treatment) was used (Table 1). Each treatment was replicated four times. A split block design with four replications was used at Knoxville. The main blocks were methods of straw removal and weed control. Wheat straw was removed by hand or by burning. Weed control methods consisted of nine herbicide treatments and a conventional seedbed plus cultivation treatment (Table 2). The herbicides used have shown promise for preemergence weed control. The contact herbicide paraquat and a surfactant were added to a number of the herbicide treatments to kill emerged weeds present at planting time.

At Knoxville, alachlor, a promising new herbicide, was added and dinoseb as a single treatment was discontinued. Linuron plus surfactant, as a postemergence treatment to control yellow nutsedge,

Table 1. Treatments used for weed control in soybeans grown in wheat stubble at Springfield, 1968

| Treatment | Rate lb/a |
|---|---|
| Amiben | 3.0 |
| Amiben + Paraquat | 3.0 + 0.5 |
| DCPA + Paraquat | 8.0 + 0.5 |
| Dinoseb | 6.0 |
| Dinoseb + Paraquat | 6.0 + 0.5 |
| Linuron | 0.5 |
| Linuron + Paraquat | 0.5 + 0.5 |
| Naptalam + Dinoseb | 3.0 + 1.5 |
| Conventional Seedbed + Cultivation | ------ |

Table 2. Treatments used for weed control in soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| Treatment | Rate lb/a |
| --- | --- |
| Alachlor | 2.0 |
| Alachlor + Linuron | 2.0 + 0.5 |
| Alachlor + Linuron + Paraquat | 2.0 + 0.5 + 0.5 |
| Alachlor + Paraquat | 2.0 + 0.5 |
| Amiben + Paraquat | 3.0 + 0.5 |
| DCPA + Paraquat | 0.5 + 0.5 |
| Linuron | 0.5 |
| Linuron + Paraquat | 0.5 + 0.5 |
| Naptalam + Dinoseb | 3.0 + 1.5 |
| Conventional Seedbed + Cultivation | ----- |

(*Cyperus exculentus* L.) was applied as a directed spray to all plots where the stubble was not burned.

The soil of the experimental area at Springfield was classified as Dickson silt loam and at Knoxville as Sequatchie silt loam. At each location, 200 pounds per acre of 0-20-20 fertilizer was applied to the soil in a broadcast treatment. Inoculated soybeans of the Lee variety were planted on June 21 at Springfield and on June 13 at Knoxville. All preemergence herbicide treatments were applied on the day after planting. The postemergence treatment of linuron was applied on the nonburn plots at Knoxville on August 28.

Weed control ratings were made on all plots, using a 0 to 100 percent rating scale with 0 percent indicating no weed control and 100 percent complete kill of weeds. Weed control ratings were made at Springfield on July 10, July 31, and November 19, and at Knoxville on July 16, August 8, August 28, and October 16.

At Knoxville weed counts per random square yard of each plot were made on July 24 and August 19 and dry weight of weeds per random square yard taken on August 19.

Crop vigor ratings were made with 0 indicating maximum plant vigor and 10 indicating complete kill of the crop. The conventional seedbed plus cultivation treatment was the control. Crop vigor ratings were made at Springfield on July 10, July 31 and November 19, and at Knoxville on July 24, August 8 and August 28. Soybean height at maturity was recorded on October 15 at Knoxville.

Yield data were obtained from soybeans harvested from a ten-foot section of the two center rows of each plot at Springfield on November 19 and at Knoxville on November 10. A shorter section was harvested from a few plots at Knoxville due to occasional skips in soybean stand and then corrected to an equal ten-foot section.

A bioassay of the herbicide treatments at Knoxville was conducted in a greenhouse experiment. One-quart milk cartons, laid on their sides with the top side cut out, were used as containers for soil samples taken from the top 2 inches of each field plot. A randomized split block design with nine treatments replicated three times was used. Herbicides and burn versus nonburn were the main treatments.

On November 10 two indicator crops, wheat and crimson clover (*Trifolium incarnatum* L.), were planted. After germination, plants were thinned to seven per carton to promote maximum growth. On January 14, seedlings of wheat and crimson clover were harvested and dry weights determined after oven drying.

# CHAPTER IV

# RESULTS AND DISCUSSION

## I. Springfield

### Weather Conditions

Sufficient moisture was present for soybean germination. July rainfall was normal. Rainfall was less than one fourth of normal during August, a critical month of the growing season (Table 3). Rainfall distribution was poor throughout the growing season and not adequate for high yields.

### Action of Herbicides

Weed populations were low at time of planting. Average ratings for broadleaf weed control in soybean plots on July 10 and July 31 were above 88 and 73 percent respectively (Table 4). Average ratings for grass weed control on July 10 and July 31 were above 70 and 60 percent respectively (Table 5). This excellent weed control had diminished by the end of the growing season to 0 percent on all herbicide treatments. The predominant weed species present at the end of the growing season were foxtail (*Setaria viridis* L.), ragweed (*Ambrosia artemisiifolia* L.), and large crabgrass (*Digitaria sanguinalis* L.).

Of the three herbicides applied, with and without paraquat, amiben was the only one in which the addition of paraquat substantially increased the control of broadleaved weeds (Table 4).

Table 3. Rainfall data (inches) for the Highland Rim Experiment Station at Springfield, 1968

| Day of Month | June | July | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|
| 1 | | | | .02 | | |
| 2 | .68 | .05 | .01 | | | |
| 3 | .28 | | | | .25 | |
| 4 | | | | .11 | 1.30 | .22 |
| 5 | | | | .62 | | |
| 6 | | | | | | |
| 7 | | | .03 | .07 | .73 | .03 |
| 8 | | | | | 1.01 | .19 |
| 9 | | .95 | | | .01 | .02 |
| 10 | | | | .10 | | .01 |
| 11 | | | .42 | | .33 | |
| 12 | | | | | | .09 |
| 13 | | | | | | |
| 14 | | | .28 | | | |
| 15 | | | | | | |
| 16 | | | .05 | .12 | | .44 |
| 17 | 1.6 | .03 | | .47 | | |
| 18 | | | | .42 | .06 | .23 |
| 19 | | | | .52 | | .03 |
| 20 | | | | | | |
| 21 | | | | | | |
| 22 | | | | | | |
| 23 | | | | | | |
| 24 | | | | | | |
| 25 | | | | .59 | | .27 |
| 26 | 1.59 | | | | | |
| 27 | .07 | .33 | | | | .06 |
| 28 | | 1.35 | | | | 3.52 |
| 29 | | .20 | | | | .46 |
| 30 | | .15 | | | | |
| 31 | | | | | | |
| Total | 2.28 | 3.28 | .79 | 3.04 | 3.69 | 5.64 |
| 10 Yr. Average | 3.25 | 3.72 | 3.86 | 2.87 | 2.32 | 3.28 |

Table 4. Percent broadleaf weed control in soybeans grown in wheat stubble at Springfield, 1968

| Treatment | % Control of Broadleaf Weeds July 10 | July 31 | Nov. 19 |
|---|---|---|---|
| Amiben | 88 | 73 | 0 |
| Amiben + Paraquat | 98 | 88 | 0 |
| DCPA + Paraquat | 100 | 95 | 0 |
| Dinoseb | 95 | 85 | 0 |
| Dinoseb + Paraquat | 95 | 88 | 0 |
| Linuron | 98 | 88 | 0 |
| Linuron + Paraquat | 100 | 90 | 0 |
| Naptalam + Dinoseb | 95 | 80 | 0 |
| Conventional Seedbed + Cultivation | 100 | 100 | 100 |

Table 5. Percent grass weed control in soybeans grown in wheat stubble at Springfield, 1968

| Treatment | % Control of Weedy Grasses | | |
|---|---|---|---|
| | July 10 | July 31 | Nov. 19 |
| Amiben | 70 | 58 | 0 |
| Amiben + Paraquat | 88 | 85 | 0 |
| DCPA + Paraquat | 93 | 93 | 0 |
| Dinoseb | 83 | 63 | 0 |
| Dinoseb + Paraquat | 95 | 68 | 0 |
| Linuron | 85 | 60 | 0 |
| Linuron + Paraquat | 90 | 80 | 0 |
| Naptalam + Dinoseb | 85 | 60 | 0 |
| Conventional Seedbed + Cultivation | 100 | 100 | 100 |

However, the addition of paraquat to amiben, dinoseb, and linuron increased grass weed control by approximately 14 percent early in the growing season (Table 5). The increased weed control by the addition of paraquat was probably due to the contact kill of existing weeds by paraquat at the time of spraying.

The DCPA plus paraquat and the linuron plus paraquat treatments gave the highest percentage of weed control and amiben alone the lowest.

## Soybean Vigor

At Springfield, soybeans treated with DCPA plus paraquat failed to germinate or died in the seedling stage. This phenomenon was unexpected and cannot be accounted for since this herbicide combination is not normally toxic at the recommended rate at which it was applied.

Early in the growing season soybean vigor was good. Soybean vigor ratings did not exceed 1.0 on July 10, or 2.5 on July 31 (Table 6). However, by November 10 vigor ratings ranged from 3.8 to 7.8 indicating reduced vigor of soybeans. The reduction of plant vigor apparently was the result of increased weed competition because: (1) soybean vigor on herbicide treatments decreased as weed control increased, (2) soybeans grown in the conventional seedbed plus cultivation treatment showed no loss in vigor, and (3) they were much higher yielding than those on herbicide treatments (Table 7).

## Soybean Yield

At Springfield, soybean yields on all herbicide-treated plots

Table 6. Average ratings for crop vigor in soybeans grown in wheat stubble at Springfield, 1968

| Treatment | Crop Vigor | | |
|---|---|---|---|
| | July 10 | July 31 | Nov. 19 |
| Amiben | 0.2* | 2.2 | 7.8 |
| Amiben + Paraquat | 0.7 | 1.5 | 3.8 |
| DCPA + Paraquat | 10.0 | 10.0 | 10.0 |
| Dinoseb | 1.0 | 2.5 | 6.5 |
| Dinoseb + Paraquat | 0.2 | 1.5 | 5.5 |
| Linuron | 0.2 | 2.0 | 5.3 |
| Linuron + Paraquat | 0.0 | 1.0 | 4.0 |
| Naptalam + Dinoseb | 1.0 | 2.5 | 6.3 |
| Conventional Seedbed + Cultivation | 0.0 | 0.0 | 0.0 |

*0 = Maximum vigor; 10 = complete kill.

Table 7. Yield of soybeans grown in wheat stubble at Springfield, 1968

| Treatment | Yield bu/a |
|---|---|
| Amiben | 3.3 |
| Amiben + Paraquat | 6.3 |
| DCPA + Paraquat | --- |
| Dinoseb | 3.5 |
| Dinoseb + Paraquat | 3.1 |
| Linuron | 3.6 |
| Linuron + Paraquat | 5.7 |
| Naptalam + Dinoseb | 2.6 |
| Conventional Seedbed + Cultivation | 18.3 |
| LSD .05 level | 3.76 |

were extremely low. Excluding the DCPA plus paraquat treatment which failed to germinate, yields ranged from 2.6 to 6.3 bushels per acre (Table 7). The yield of the conventional seedbed plus cultivation treatment was 18.3 bushels per acre. This yield was exceptional considering the lateness of planting and the below-normal precipitation. The low yields of soybeans on the herbicide treated plots were probably due to severe weed competition since there was no visual evidence of herbicide injury.

## II. Knoxville

### Weather Conditions

Abundant moisture was present for soybean germination. Rainfall for all months of the growing season was normal or above normal and adequate for high yields (Table 8).

### Effect of Burning and Nonburning of Straw

Weed control on the nonburned plots averaged 73 percent and on the burned plots 85 percent for five observations from July 16 to October 16 (Table 9). This represents a weed control difference of 12 percent. The less adequate weed control on the nonburned plots may be attributed to the partial interception of the herbicides by the wheat stubble at the time of spraying, thus reducing the amount of herbicides reaching the soil (Figure 1).

To further verify the visual weed control ratings, dry weights of the weeds per random square yard of each plot were taken on August 19. Average weight of weeds was 20 grams per square yard for

Table 8. Rainfall data (inches) for the agricultural experiment station at Knoxville, 1969

| Day of Month | June | July | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|
| 1 | | | | .08 | | .83 |
| 2 | 1.78 | | | | .05 | .48 |
| 3 | .24 | | 1.01 | | | |
| 4 | | | .38 | | | |
| 5 | | | .26 | | | |
| 6 | | | | .07 | | .02 |
| 7 | | .20 | | | .17 | |
| 8 | .30 | .06 | | | .35 | |
| 9 | | .59 | | .13 | | |
| 10 | | .10 | | | | |
| 11 | | | .10 | | | |
| 12 | | .35 | | | | .38 |
| 13 | | .12 | | | | |
| 14 | | | | | .05 | .46 |
| 15 | .46 | | | | | |
| 16 | | | .80 | | | |
| 17 | | | | | | |
| 18 | | | | .95 | | |
| 19 | .10 | | .08 | | | .70 |
| 20 | | | .18 | 1.98 | | |
| 21 | .18 | 1.01 | | | 1.15 | |
| 22 | | .33 | 2.96 | | | |
| 23 | 1.24 | .50 | | 1.11 | | |
| 24 | 1.46 | .35 | | .10 | | .10 |
| 25 | 1.24 | .10 | | | | |
| 26 | | .10 | | | .40 | |
| 27 | | | | | | |
| 28 | | | | | | .02 |
| 29 | .38 | | | | | |
| 30 | | | | | | |
| 31 | | | | | | |
| Total | 7.38 | 3.81 | 5.77 | 4.42 | 2.17 | 2.99 |
| 10 Yr. Average | 3.33 | 4.82 | 3.46 | 2.54 | 2.61 | 3.24 |

Table 9. Percent weed control in soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| | % Weed Control | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | July 16 | | Aug. 8 | | Aug. 19 | | Aug. 28 | | Oct. 16 | | Season Average |
| | B* | NB* | B | NB | B | NB | B | NB | B | NB | |
| Alachlor | 93 | 80 | 90 | 69 | 89 | 79 | 90 | 62 | 94 | 81 | 82 |
| Alachlor + Linuron | 86 | 79 | 83 | 73 | 86 | 70 | 88 | 66 | 90 | 80 | 80 |
| Alachlor + Linuron + Paraquat | 96 | 84 | 94 | 73 | 93 | 69 | 91 | 75 | 90 | 85 | 85 |
| Alachlor + Paraquat | 88 | 80 | 85 | 70 | 83 | 66 | 86 | 65 | 86 | 81 | 79 |
| Amiben + Paraquat | 86 | 68 | 66 | 58 | 69 | 54 | 69 | 46 | 84 | 81 | 68 |
| DCPA + Paraquat | 84 | 80 | 70 | 65 | 80 | 66 | 78 | 64 | 74 | 75 | 74 |
| Linuron | 86 | 76 | 76 | 61 | 87 | 65 | 62 | 76 | 85 | 81 | 73 |
| Linuron + Paraquat | 88 | 81 | 90 | 83 | 84 | 69 | 78 | 61 | 86 | 72 | 79 |
| Naptalam + Dinoseb | 93 | 84 | 86 | 80 | 86 | 73 | 80 | 79 | 84 | 76 | 82 |
| Conventional Seedbed + Cultivation | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| Average Burned and Nonburned | 89 | 79 | 82 | 70 | 84 | 69 | 80 | 66 | 86 | 79 | |

*B = Burned stubble; NB = nonburned stubble.

Figure 1. Soybeans growing on burned wheat stubble in foreground and nonburned in background at Knoxville, 1969.

the burned plots and 45 for the nonburned (Table 10). These results provide additional evidence that the burned plots provided more effective weed control than did the nonburned plots.

The predominant weeds were yellow nutsedge and carpetweed (Mollugo verticillata L.). Other weeds, honeyvine milkweed (Ampelanus albidus L.), curly dock (Rumex crispus L.), and large crabgrass, were sporadic in occurrence. Yellow nutsedge weed counts made on July 24 and August 19 showed an average of 1.7 and 5.0 plants per square yard on burned and nonburned plots respectively (Table 11). An average of 2.6 and 5.4 carpetweed plants per square yard were found on the burned and nonburned plots respectively (Figure 2).

Differences also occurred in soybean vigor due to burning versus nonburning of straw. Average soybean vigor was 0.5, 0.7, and 1.0 for burned plots and 0.2, 0.2, and 0.0 for nonburned plots for the three observations from July 24 to August 28 respectively (Table 12). Soybean vigor ratings for the nonburned plots show that there was only a slight loss of vigor throughout the growing season. Soybean vigor ratings for the burned plots showed an appreciable loss of vigor between the July 24 and the August 28 observation. The vigorous growth of soybeans on the nonburned plots as compared to that on the burned plots may have been due to the preservation of moisture in the soil by the mulching effect of the unburned straw. From visual observation, there appeared to be more moisture at the soil surface during dry periods of the growing season in the nonburned plots than in the burned plots.

Height of soybeans at maturity was measured on October 15.

Table 10. Dry weight of weeds in soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| Treatment | $gm/yd^2$ | |
|---|---|---|
| | Burned | Nonburned |
| Alachlor | 15 | 46 |
| Alachlor + Linuron | 10 | 36 |
| Alachlor + Linuron + Paraquat | 2 | 34 |
| Alachlor + Paraquat | 22 | 21 |
| Amiben + Paraquat | 30 | 86 |
| DCPA + Paraquat | 49 | 47 |
| Linuron | 23 | 78 |
| Linuron + Paraquat | 27 | 23 |
| Naptalam + Dinoseb | 4 | 34 |
| Conventional Seedbed + Cultivation | -- | -- |
| Average | 20 | 45 |

Table 11. Average number of yellow nutsedge and carpetweed growing in soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| | Weeds/yd$^2$ | | | |
|---|---|---|---|---|
| | Yellow Nutsedge | | Carpetweed | |
| Treatment | July 24 | Aug. 19 | July 24 | Aug. 19 |
| | Burned Stubble | | | |
| Alachlor | 0.8 | 1.3 | 1.8 | 1.5 |
| Alachlor + Linuron | 0.8 | 0.8 | 2.3 | 1.8 |
| Alachlor + Linuron + Paraquat | 0.3 | 0.0 | 2.5 | 1.5 |
| Alachlor + Paraquat | 0.0 | 3.0 | 0.7 | 0.0 |
| Amiben + Paraquat | 2.7 | 1.0 | 2.3 | 1.5 |
| DCPA + Paraquat | 4.5 | 2.8 | 9.8 | 4.5 |
| Linuron | 2.0 | 1.7 | 5.5 | 3.0 |
| Linuron + Paraquat | 2.5 | 1.3 | 5.2 | 1.5 |
| Naptalam + Dinoseb | 2.0 | 3.8 | 0.8 | 0.5 |
| Conventional Seedbed + Cultivation | --- | --- | --- | --- |
| Average | 1.7 | 1.7 | 3.4 | 1.8 |

Table 11. (Continued)

| Treatment | Weeds/yd² Yellow Nutsedge July 24 | Weeds/yd² Yellow Nutsedge Aug. 19 | Weeds/yd² Carpetweed July 24 | Weeds/yd² Carpetweed Aug. 19 |
|---|---|---|---|---|
| | Nonburned Stubble | | | |
| Alachlor | 7.5 | 6.0 | 14.0 | 6.0 |
| Alachlor + Linuron | 4.5 | 6.0 | 2.5 | 1.8 |
| Alachlor + Linuron + Paraquat | 0.3 | 8.0 | 2.5 | 1.8 |
| Alachlor + Paraquat | 2.0 | 1.8 | 8.0 | 3.8 |
| Amiben + Paraquat | 1.7 | 7.0 | 3.0 | 1.5 |
| DCPA + Paraquat | 7.0 | 6.0 | 19.0 | 4.0 |
| Linuron | 6.0 | 15.0 | 6.0 | 2.0 |
| Linuron + Paraquat | 2.5 | 3.5 | 5.2 | 1.3 |
| Naptalam + Dinoseb | 0.3 | 4.0 | 2.3 | 1.8 |
| Conventional Seedbed + Cultivation | --- | --- | --- | --- |
| Average | 3.5 | 6.4 | 6.9 | 4.0 |

Figure 2. Increased weed competition in soybeans on nonburned straw in foreground as compared to burned straw in background at Knoxville, 1969.

Table 12. Vigor ratings for soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| | Soybean Vigor | | | | | |
|---|---|---|---|---|---|---|
| | July 24 | | Aug. 8 | | Aug. 28 | |
| Treatment | B* | NB* | B | NB | B | NB |
| Alachlor | 0.8 | 0.3 | 1.0 | 0.0 | 1.1 | 0.0 |
| Alachlor + Linuron | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| Alachlor + Linuron + Paraquat | 0.0 | 0.0 | 0.3 | 0.0 | 1.2 | 0.0 |
| Alachlor + Paraquat | 0.7 | 0.3 | 0.5 | 0.5 | 0.5 | 0.0 |
| Amiben + Paraquat | 0.8 | 0.3 | 1.0 | 0.3 | 1.2 | 0.0 |
| DCPA + Paraquat | 0.5 | 0.0 | 0.5 | 0.0 | 0.8 | 0.0 |
| Linuron | 0.8 | 0.0 | 0.5 | 0.3 | 1.5 | 0.2 |
| Linuron + Paraquat | 0.8 | 0.3 | 1.3 | 0.0 | 1.5 | 0.2 |
| Naptalam + Dinoseb | 0.5 | 0.3 | 1.0 | 0.3 | 1.1 | 0.0 |
| Conventional Seedbed + Cultivation | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Average Burn and Nonburn | 0.5 | 0.2 | 0.7 | 0.2 | 1.0 | 0.0 |

*B = Burned stubble; NB = nonburned stubble.

Soybeans grew to an average height of 64 and 71 centimeters on the burned and nonburned plots respectively (Table 13). Taller soybeans on the nonburned plots may have been due to the previously mentioned mulching effect of the straw.

At Knoxville, soybean yields were excellent. The burned and nonburned plots had an average yield of 36 and 40 bushels per acre respectively (Table 14). The yield differences were nonsignificant at the .05 level of probability, but there was a trend for the soybeans on the nonburned plots to be higher yielding than soybeans on the burned plots. The yield of the treatment with a conventional seedbed plus cultivation was 44 bushels per acre. The trend for soybeans to yield higher on the nonburned plots was expected since they grew more vigorously (Table 12) and were taller at maturity (Table 13). Apparently advantages resulting from the stubble remaining on the soil surface outweighed the advantage of more effective weed control on the burned plots.

## Action of Herbicides

Weed populations were low at the time of planting and spraying. Weed control was good at the end of the first month after planting, averaging 89 and 79 percent for the burned and nonburned plots respectively (Table 9, page 25). However, weed control dropped to an average of 82 and 68 percent on the burned and nonburned plots respectively, for the August 8, August 19, and August 28 observations (Table 9). By the time of the October 16 observation weed control was better due to the disappearance of summer annual weeds. At the time of harvest the field was practically weed free.

Table 13. Height of soybeans at maturity grown in burned and nonburned wheat stubble at Knoxville, 1969

| Treatment | Soybean Height (cm) | |
|---|---|---|
| | Burned | Nonburned |
| Alachlor | 64 | 74 |
| Alachlor + Linuron | 60 | 71 |
| Alachlor + Linuron + Paraquat | 65 | 71 |
| Alachlor + Paraquat | 65 | 68 |
| Amiben + Paraquat | 64 | 69 |
| DCPA + Paraquat | 64 | 71 |
| Linuron | 61 | 70 |
| Linuron + Paraquat | 60 | 69 |
| Naptalam + Dinoseb | 65 | 74 |
| Conventional Seedbed + Cultivation | 66 | |
| Average | 64 | 71 |

Table 14. Yield of soybeans grown in burned and nonburned wheat stubble at Knoxville, 1969

| | Soybean Yield bu/a | | |
|---|---|---|---|
| Treatment | Burned | Nonburned | Combined |
| Alachlor | 31.2 | 39.6 | 35.2* b |
| Alachlor + Linuron | 43.7 | 43.0 | 43.4 a |
| Alachlor + Linuron + Paraquat | 36.9 | 42.1 | 39.5 ab |
| Alachlor + Paraquat | 40.0 | 42.3 | 41.0 ab |
| Amiben + Paraquat | 31.2 | 36.1 | 33.6 b |
| DCPA + Paraquat | 37.0 | 35.3 | 36.2 ab |
| Linuron | 32.4 | 39.9 | 36.1 ab |
| Linuron + Paraquat | 33.3 | 35.6 | 34.5 b |
| Naptalam + Dinoseb | 39.5 | 44.0 | 41.7 a |
| Conventional Seedbed + Cultivation | 44.8 | | |
| Average | 36.1 | 39.8 | 37.9 |

*Yields followed by the same letter are not significantly different at the .05 level of probability.

Linuron and alachlor were applied with and without paraquat. The linuron plus paraquat treatment gave 7 percent better weed control than did linuron alone. However, the alachlor treatment had 3 percent more effective weed control than the alachlor plus paraquat treatment.

The alachlor plus linuron plus paraquat treatment with a weed control rating of 85 percent was the most effective of all chemical weed control treatments (Table 9, page 25). The amiben plus paraquat treatment was the least effective with a weed control rating of only 68 percent.

No apparent injury or decreased vigor of soybeans resulted from herbicide treatments. Soybeans remained vigorous throughout the growing season even though slight differences in vigor developed between burned and nonburned plots. These differences were not attributed to herbicide treatments.

At Knoxville, differences in soybean yields between the burned and nonburned plots were nonsignificant; however, yield differences among herbicide treatments were significant at the .05 level of significance (Table 14). Yields were significantly highest on the alachlor plus linuron and naptalam plus dinoseb treatments, 43.4 and 41.7 bushels per acre respectively. Yields were significantly lowest for the alachlor, linuron plus paraquat, and amiben plus paraquat treatments: 35.2, 34.5, and 33.6 bushels per acre respectively. The conventional seedbed plus cultivation treatment produced 44.8 bushels per acre. This yield was comparable to the yields obtained from the two highest yielding herbicide treatments.

Bioassay of Herbicide Treatments

At Knoxville, a bioassay of the herbicide treatments was conducted in a greenhouse experiment. Dry weight determinations of wheat and crimson clover seedlings were nonsignificant at the .05 level of probability for herbicide treatments and burned versus nonburned treatments (Table 15). Plants grew vigorously and no herbicide injury was observed (Figure 3). Thus, it was concluded that no toxic residues of the herbicides remained in the soil at the end of the growing season.

Table 15. Dry weight of crimson clover and wheat seedlings used in the bioassay of residues from herbicides applied in burned and nonburned wheat stubble at Knoxville, 1969*

| Treatment | Dry Weight, gm/plot | | | |
|---|---|---|---|---|
| | Burned | | Nonburned | |
| | Crimson Clover | Wheat | Crimson Clover | Wheat |
| Alachlor | .28 | .23 | .25 | .28 |
| Alachlor + Linuron | .37 | .31 | .31 | .32 |
| Alachlor + Linuron + Paraquat | .31 | .23 | .25 | .25 |
| Alachlor + Paraquat | .27 | .25 | .28 | .27 |
| Amiben + Paraquat | .27 | .23 | .30 | .28 |
| DCPA + Paraquat | .31 | .27 | .23 | .23 |
| Linuron | .30 | .30 | .28 | .27 |
| Linuron + Paraquat | .25 | .25 | .17 | .23 |
| Naptalam + Dinoseb | .30 | .27 | .20 | .32 |
| Average | .30 | .26 | .25 | .28 |

*Weights of the seedlings grown in soil samples from the untreated cultivated plots were .25 and .26.

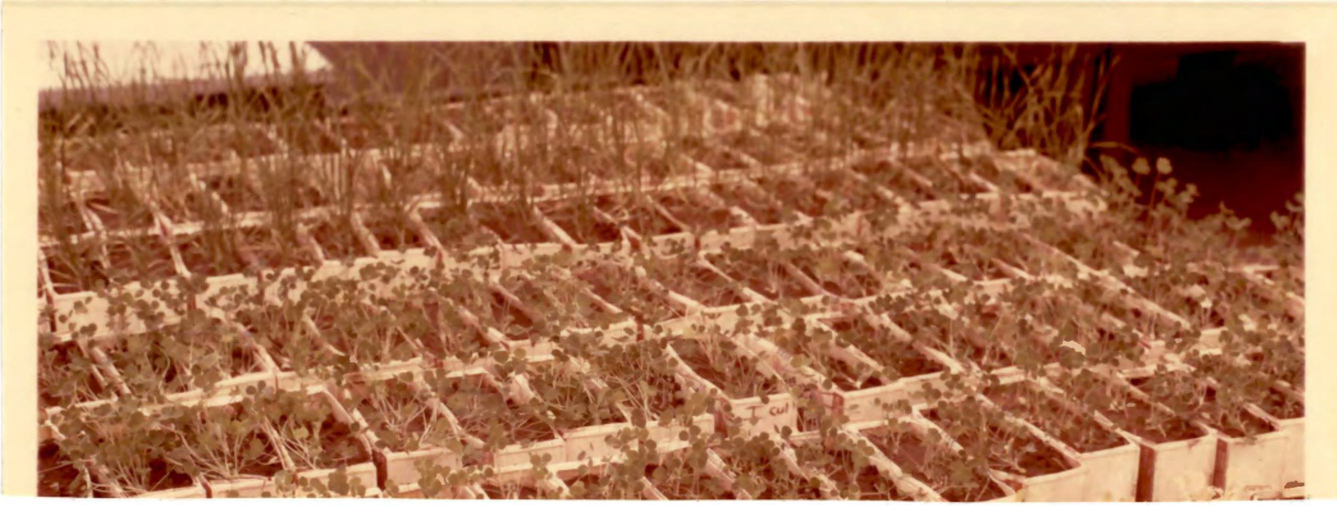

Figure 3. Bioassay of herbicide treatments in a greenhouse experiment using crimson clover and wheat seedlings at Knoxville, 1969.

## CHAPTER V

## SUMMARY AND CONCLUSIONS

Soybeans were grown in a double-cropping system following wheat harvest. Soybeans were planted at two locations in wheat stubble using different herbicide combinations for weed control. Observations were taken on weed control and for soybean vigor and yield. At Knoxville, burning versus nonburning of straw was added to observe advantages or disadvantages of the two practices. A bioassay was conducted in a greenhouse experiment at Knoxville to determine if there were toxic herbicide residues.

At Springfield, herbicide treatments controlled weeds effectively through the sixth week after planting, but by the end of the growing season weed control had diminished to 0 percent. At Knoxville weed control was effective throughout the growing season. These differences in weed control at the two locations may have been the result of population differences of weed species and climatic conditions.

The best weed control was obtained on the DCPA plus paraquat and linuron plus paraquat treatments at Springfield and on the alachlor plus linuron plus paraquat treatment at Knoxville.

At Knoxville, percent weed control was higher on the burned plots than on the nonburned plots. The number and dry weight of weeds per square yard were higher on the nonburned plots.

At Springfield, soybeans showed an extreme loss of vigor by the end of the growing season. However, at Knoxville, soybeans remained vigorous throughout the growing season even though soybeans on the burned plots were slightly less vigorous. The differences in vigor was attributed to differences in weed competition at the two locations.

Soybean yields at Springfield were extremely low due to the inadequate distribution and quantity of rainfall and severe weed competition. Soybean yields on herbicide-treated plots averaged only 4 bushels per acre as compared to 18 bushels per acre on conventional seedbed plus cultivation treatment.

The quantity and distribution of rainfall was sufficient at Knoxville for high yields, and weed competition was not a problem. Soybean yields on herbicide treated plots averaged 38 bushels per acre as compared to 45 bushels per acre on the conventional seedbed plus cultivation treatment. Soybeans on the nonburned plots yielded slightly more than those grown on the burned plots.

At Knoxville, a bioassay with crimson clover and wheat seedlings indicated that no toxic herbicide residues remained in the soil at the end of the growing season.

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## LITERATURE CITED


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