SOIL INCORPORATION AND APPLICATION RATE OF SIX DINITROANILINE HERBICIDES FOR SHATTERCANE (SORGHUM BICOLOR (L.) MOENCH) CONTROL IN SOYBEANS (GLYCINE MAX (L.) MERRILL)

by

JEFFREY L. KUGLER

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Approved by:

[signature]
Major Professor

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INTRODUCTION

Heavy populations of shattercane (*Sorghum bicolor* (L.) Moench) in the Midwest have made continuous cropping of sorghum (*Sorghum bicolor* (L.) Moench) impractical. To control shattercane, farmers have found that rotating sorghum fields with soybeans (*Glycine max* (L.) Merrill) and using a selective herbicide give weed control. Dinitroaniline herbicides are recommended for control of shattercane; however, there are still many uncertainties about the factors that affect the uptake by shattercane of dinitroaniline herbicides.

Shattercane is a diverse weed species. Cross pollination, early maturity compared to sorghum and soybeans, and ease of shattering have contributed to the success of this weed species in row crop farming systems. Shattercane has adapted to the climatic conditions in the Midwest. Irrigation aided this adaption by decreasing the possibility of drought to row crops and weed populations. Early maturity and shattering allow shattercane to rid itself of newly formed seeds before sorghum or soybean harvest. Viable seeds on the soil surface are tilled into the soil following harvest. Shattercane seeds remain viable for years and continue to hamper row crop production.

Shattercane control by hand weeding is not feasible when heavy populations are present. Herbicide treatment, in addition to crop rotation, is the most feasible means of control. Shattercane control is influenced by the rates dinitroaniline herbicides are applied, dinitroaniline herbicide distribution, and depth to which the dinitroaniline herbicides are incorporated.

The purpose of this research was three-fold: 1) to determine an application rate of dinitroaniline herbicide needed for shattercane control without significantly affecting soybean growth on a silt loam soil; 2) to determine the depth of herbicide incorporation to control shattercane planted 2.4 and 12.0 centimeters (hereafter cm) deep; and 3) to determine the optimum depth of dinitroaniline incorporation to control shattercane distributed throughout a plow layer, 14.4 cm deep.

REVIEW OF LITERATURE

Traits of Shattercane

Furrer and Burnside (8) reported that shattercane, once a crop, now a weed, is a composite of many weedy sorghums. Shattercane, black amber, chicken corn, broom corn, and wild cane are common names for this weedy species.

Vinall, Stephens, and Martin (32) reported the first importation of black amber into the United States was by a nurseryman on Long Island, New York, in 1853. Later, a man at Dunreith, Indiana, purchased a few pounds of cane seed in Paris, France, and grew it in the United States. A single head from this crop was selected for its early maturity. This early maturing seed was then sold to customers in the western and southern states.

Snowden (30) observed that the chicken corn of the South had a dull purple to black spikelet at maturity. This weed was known for seed shattering and recurring in cultivated fields year after year.

Today shattercane is characterized by 1) producing viable seeds early in the growing season, 2) shattering before row crops are ready for harvest, 3) seedlings emerging from various soil depths, and 4) remaining dormant for extended periods. Possession of all four of these traits aid in shattercane persistence and make eradication difficult.

Burnside (4) reported viable shattercane seed is produced ten days after anthesis. Three days after harvest 53 per cent was germinative, at one month 84 per cent was germinative, and at 32 months 96 per cent was germinative.

Research by Karper and Jones (16) demonstrated that grain sorghum harvested in 1917 lost only 12 per cent of its viability after seven years. Ten years after harvest 50 per cent of the seed was viable.

Seed moisture content in combination with temperature can reduce seed viability. Robbins and Porter (27) report that grain sorghum seed would germinate at a moisture content of 50-60 per cent but the per cent germination was low. Germination damage to sorghum seed occurred when exposed to -28.9^{o}C temperature when seed moisture content was 22 per cent. However, sorghum seed with a moisture content of 16 to 19 per cent was not seriously injured when exposed to -28.9^{o}C temperatures.

Martin, Taylor, and Leukel (21) determined that soil temperature influenced sorghum germination. Soil temperatures below 25^{o}C reduced sorghum germination. There were no differences in sorghum emergence with soil temperatures of 25^{o}C at various seeding depths. Seedlings emerged from 3.8 and 6.4 cm depths as quickly as from 1.3 cm depth.

Karper and Quinby (17) noted shattering or seed shedding characteristics of shattercane result from the abscission at a callus. Two dominant genes control inheritance of a callus layer formation just below the seed where abscission takes place causing seed shattering.

A shattercane seedling can emerge from various soil depths. Plowing was one of the early practices for controlling shattercane. It was believed that if the seed was buried deep enough the problem would be eliminated. This theory proved to be incorrect.

Condray (7) noted no significant difference in shattercane emergence when planted at various depths from 2.5 to 20.3 cm. Differences in time of emergence between the shattercane planted 2.5 and 20.3 cm was 4 days. Jacques, Vesecky, Feltner, and Vanderlip (15) reported shattercane emergence was greater from 7.5 to 15.0 cm depths than 15.0 to 22.5 cm depths, but the number of viable seeds increased as depth of burial increased regardless of time buried. They concluded that shattercane seed has a dormancy mechanism requiring more than a temperature change such as light in breaking seed dormancy.

Gritton and Atkins (9) related grain sorghum dormancy to date of bloom. Greater dormancy was noted with those plants that bloomed late. Sorghum germination was greater three months after harvest compared to two weeks after harvest. Results of prechilling and scarification of sorghum seed were comparable to the three month waiting period after harvest.

Herbicide Incorporation and Site of Uptake in Shattercane

Thorough incorporation and distribution are important to maximize shattercane control when using the following dinitroaniline herbicides: butralin, dinitramine, fluchloralin, penoxalin, profluralin, and trifluralin. Lack of incorporation enhances herbicide breakdown and reduces activity because of ultraviolet irradiation and volatility. Wright and Warren (31) reported the trifluralin activity after exposure to sunlight for six hours significantly reduced herbicidal activity. There was less herbicidal degradation from soil during two to six hours of exposure to sunlight. Herbicide biological activity is influenced by incorporation depth, soil organic matter, soil moisture, and rates applied.

Depth of dinitroaniline soil incorporation influences the herbicide activity. Pieczarka, Wright, and Alder (26) determined incorporating trifluralin increased herbicide activity. Trifluralin incorporated at 0.56 kilograms of active ingredient per hectare (hereafter kg/ha) gave better weed control than 4.5 kg/ha preemerge. Knake, Appleby, and Furtick (20) reported shallow incorporation of trifluralin to a depth of 2.5 cm gave better green foxtail control than surface application.

Incorporation depth also influences herbicide persistence in the soil. Savage and Barrentine (28) indicated trifluralin persistence increased by deep incorporation as compared to shallow incorporation or surface application. Trifluralin was more effective and persistent when incorporated 7 to 10 cm than when left on or near the soil surface.

Implements determine how thoroughly the herbicide will be distributed and incorporated into the soil. Smith and Wiese (29) reported trifluralin required thorough soil incorporation with a disk to prevent loss by volatility. Two diskings were better than one. Four diskings further reduced trifluralin volatility. Oliver and Frans (23) showed no difference in weed control with trifluralin when incorporated with a power tiller or a ground-driven tiller.

Shattercane control was better when trifluralin was incorporated above rather than below the shattercane seed, Burnside (5) reported. Parker's (25) research illustrated trifluralin exerted action through direct uptake by the sorghum shoot. Zavesky (33) determined that the shattercane shoot was the site of trifluralin uptake. Harvey (12) found vapors of profluralin, trifluralin, fluchloralin, and dinitramine caused reductions in shoot growth of foxtail millet.

Hollist and Foy (13) found that organic matter had the strongest reducing effect on trifluralin phytotoxicity of any soil component. With organic matter removed, clay had little effect. However, in combination the two interacted synergistically. Horowitz, Hulin, and Blumenfeld (14) determined that when organic matter content was low, increasing clay content would increase the activity of trifluralin on the growth responses of sorghum. Sixty days after application 50 per cent of the original four parts per million (hereafter ppm) remained unleached in the soil.

However, Bardsley, Savage, and Childers (2) reported increased organic matter increased trifluralin toxicity because of greater absorption in the herbicide vapor phase. Trifluralin toxicity persisted 93 days after application.

Soil moisture is a contributing factor for vapor losses from dinitroaniline herbicides. Bardsley, Savage, and Walker (3) attributed trifluralin vapor loss to a greater proportion of soil moisture available resulting in more trifluralin in liquid form. They found that vapor losses were reduced in a soil at field capacity by placing trifluralin 1.3 cm below the soil surface.

Further, Ketchersid, Bovey, and Merkle (19) reported that light caused trifluralin to readily volatilize from wet soil but to remain rather stable on dry soil or in darkness on wet or dry soils.

After adsorption occurred, however, dinitroaniline herbicides exposed to high soil moisture were not susceptible to soil leaching. Anderson, Richards, and Whitworth (1) reported trifluralin leached in the soil in relatively minute amounts, and these amounts were not great enough to affect root growth of sensitive crops as long as 0.5 cm of untreated soil separated the seed from the treated soil.

Miller, Keeley, Carter, and Thullen (22) determined that trifluralin was confined to the tilled zone (upper 30 cm). Over a 4 month period 80 per cent of the residue was in the upper 15 cm of soil. Grain sorghum stands were reduced 15 months after herbicide application. Rates applied were double those suggested for weed control in a fine sandy loam soil.

Burnside (6) noted trifluralin persisted in a silty clay loam soil when applied at above-normal rates for one year or more. Normal application rates of trifluralin repeated annually on a silty clay loam soil caused no build-up in the soil.

Lack of soil moisture delays dinitroaniline herbicide breakdown and contributes to persistence. Hamilton and Arle (10) reported trifluralin reduced sorghum stands 80 per cent 30 months after application in arid soils.

Parka and Tepe (24) applied trifluralin four consecutive years and analysis of soil samples indicated no accumulation. The amounts of trifluralin steadily decreased in the soil with time.

Oliver and Frans (23) found no residue six months after trifluralin application in plots not incorporated and only minimal residues in plots where the chemical was incorporated 2.5 cm deep. Residues in plots where the chemical was incorporated 5.1 cm deep were moderate at 0.56 to 1.12 kg/ha and high at the 2.24 kg/ha.

Harvey (11) noted in 1971 significant decreases in soybean emergence between the higher applied rates of dinitroaniline herbicides: fluchloralin, 1.12 and 2.24 kg/ha; profluralin, 0.84 and 1.68 kg/ha; dinitramine, 0.56 and 1.12 kg/ha; and trifluralin, 0.84 and 1.68 kg/ha. In 1972 a significant decrease in soybean emergence was noted with only dinitramine.

Kennedy, Frans, and Talbert (18) reported dinitramine selectivity to soybeans was reduced with deep incorporation. However, the stunting of soybeans did not reduce yields.

METHODS AND MATERIALS

In 1974 and 1975 dinitroaniline herbicide activity on shattercane in soybeans was determined in field experiments conducted at the Ashland Agronomy Farm near Manhattan, Kansas. Growth chamber experiments were also used to evaluate activity.

Field experiments were carried out on a Muir silt loam with an organic matter content of 2.5 per cent and a pH of 6.7 at soil depth of 15.0 cm. A silt loam soil with 3.6 per cent organic matter and soil pH of 7.2 was used in all growth chamber experiments.

The soybean cultivar Williams, a semi-indeterminate with a group three maturity date and well-adapted for eastern Kansas growing conditions, was used in all experiments.

Depth of Dinitroaniline Herbicide Incorporation

For 1974 field studies, a shattercane-infested area was chosen for the depth of dinitroaniline herbicide incorporation study. The site was plowed 14.4 cm deep the fall of 1973. In spring the area was clean-tilled using shallow tillage operations to keep the site weed-free until herbicide application.

Each dinitroaniline herbicide was applied June 5 with a tractor-mounted spray boom, 144 cm long with nozzles 48 cm from the ground. Tractor speed at application was 5 kilometers per hour (hereafter kmph). Compressed air was used for herbicide agitation and spray pressure. The Tee-Jet 8004 stainless steel nozzles were operated with a spray pressure of 1.6 kilograms per square centimeter (hereafter ksc). The dinitroaniline herbicides were applied with water as an emulsifiable concentrate at the rate of 187.0 liters per hectare (hereafter l/ha).

Each dinitroaniline herbicide was incorporated immediately after herbicide application with two tandem diskings at 5 kmph. Cutting depth of the disks for the shallow incorporated herbicides was 4.8 cm and 14.4 cm for the deep incorporated herbicides. Plots were then harrowed at right angles to the direction of disking.

Plots were planted June 17 at a rate of 33 soybeans per meter of row at 4 kmph. All soybean seed was treated with Captan fungicide to prevent fungus infection prior to emergence. Soybeans were planted 4.8 cm deep with an Allis Chalmers flex planter with double disk openers.

The six dinitroaniline herbicide treatments and rates of application were butralin, 2.24 kg/ha; dinitramine, 0.56 kg/ha; trifluralin, 1.12 kg/ha; and fluchloralin, penoxalin, and profluralin, 1.4 kg/ha.

A randomized complete plot design was used with all treatments triplicated. Treatments consisted of two depths of incorporation, shallow (2.0-3.0 cm) and deep (6.0-8.0 cm), in combination with herbicides.

A weedy check plot was provided for each replication and two border rows on each side of each herbicide treatment were treated with 1.76 kg/ha of trifluralin. Each replication contained 13 plots and each individual plot consisted of 2 rows, 72 cm apart, 5.8 meters (hereafter m) long, oriented east and west. Visual shattercane control ratings, shattercane yields, and soybean yields were statistically analyzed. Visual shattercane ratings were taken using a scale 0 to 10. Plots with no stand reduction received a

0 rating, while complete shattercane stand reduction received a 10 rating.

All plots received one cultivation with a rolling cultivator eleven days after planting.

After the 1974 soybean harvest, the plot area was plowed to distribute the shattercane seed in the plow layer. Plot area was clean-tilled in the spring until herbicide application.

The dinitroaniline herbicides were applied and immediately incorporated July 1, 1975, in the same manner as 1974. Those plots receiving shallow incorporation were harrowed twice with a tine-toothed harrow in the same direction at a tractor speed of 10 kmph. The herbicides incorporated deep were tandem-disked twice. The second disking was performed at right angles to the first. Disking depth was 14.4 cm at a tractor speed of 5 kmph.

The deep incorporated dinitroaniline herbicide plots were harrowed with a spike harrow at right angles to the last disking at a tractor speed of 10 kmph. All plots received a final harrowing at right angles to the last operation with the tine-toothed harrow at a tractor speed of 10 kmph.

Plots were planted July 1 using an Allis Chalmers flex planter at 4 kmph at a rate of 33 beans per meter of row. All soybean seed was treated with Captan fungicide. The six dinitroaniline herbicide treatments and rates of application were butralin, 3.36 kg/ha; dinitramine, 0.56 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 kg/ha.

A randomized split block design with systematic arrangement of main effects was used with all treatments triplicated. Treatments consisted of two depths of incorporation, shallow and deep. Shallow incorporated plots were located in one block and deep incorporated plots in another block.

One weedy check plot was provided for each replication within each block. Each block contained seven plots and each individual plot consisted of 4 rows, 72 cm apart, 8.6 m long. Shattercane control ratings, shattercane yields, soybean yields, and soybean heights were statistically analyzed.

Tolerance of Williams Soybean to the X and 2X Rate of Six Dinitroaniline Herbicides on Silt Loam Soil

The X rate of the six dinitroaniline herbicides was determined by label recommendations and experimental information distributed by each producer.

For 1975 field studies, the plot area was clean-tilled until herbicide application. Each dinitroaniline herbicide was applied with a tractor-mounted spray boom, 288 cm long, with nozzles 48 cm from the ground. Application speed was 5 kmph. Compressed air was used for spray pressure and herbicide agitation. The Tee-Jet 8004 stainless steel nozzles were operated at a spray pressure of 1.7 ksc. The dinitroaniline herbicides were applied with water at the rate of 187.0 l/ha.

Each dinitroaniline herbicide was incorporated after application with two tandem diskings at 5 kmph. Both disking operations were carried out in the same direction through the field differing only by offsetting the second disking one half of the first disk width. The cutting depth of the disk was 14.4 cm which incorporated the herbicide 7.2 cm deep. Plot area was then harrowed parallel to the disking operation with a spike harrow.

Plots were planted at a rate of 33 soybean seeds per meter of row with an Allis Chalmers flex planter at 4 kmph. Planting depth was 4.8 cm. All soybean seeds were treated with Captan fungicide.

A randomized complete plot design was used with all treatments triplicated. Treatments consisted of the following six dinitroaniline herbicides applied at X and 2X rates: butralin, 3.36 kg/ha and 6.72 kg/ha; dinitramine, 0.56 kg/ha and 1.12 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 kg/ha and 2.8 kg/ha.

Each dinitroaniline herbicide 2X rate was compared to the X rate. The X rate of herbicide was used as the control plot. Twelve plots, 4 rows wide, 72 cm apart, 8.6 m long, constituted a block.

Visual ratings of injury were taken using a scale of 0 to 10, with no injury receiving a 0 rating and complete stand reduction or plant injury receiving a 10. Soybean height at maturity, yield, and injury ratings were statistically analyzed. This experiment was repeated four times at four locations on the Ashland Agronomy Farm near Manhattan, Kansas, throughout the growing season. Herbicides were applied and soybeans planted on May 16 at Location 1, June 20 at Locations 2 and 3, and June 27 at Location 4.

Tolerance of Williams soybean to the X and 2X rates of the six dinitroaniline herbicides on silt loam soil was evaluated in the fall of 1975 in an environmental chamber. A silt loam soil from the Ashland Agronomy Farm near Manhattan, Kansas, was used.

0.9 square meter (hereafter sq m) of soil 2.5 cm deep was treated with a dinitroaniline herbicide. A plywood frame 91 cm square with sides 2.5 cm high was used to measure the soil. The soil was spread out uniformly on a plastic tarpaulin 230 cm square.

Each dinitroaniline herbicide was applied with an 11.4 liter hand sprayer. The correct amount of active chemical was applied in 946 milliliters (hereafter ml) of water to the soil surface for each treatment. Herbicides were then incorporated into the soil by hand mixing on a plastic tarpaulin.

Treatments included two rates of each dinitroaniline herbicide. All herbicides were incorporated 4.8 cm and soybeans planted 2.4 cm deep. The experiment was terminated two weeks after herbicide application. A randomized complete plot design was used with all treatments triplicated. A control was used to check soybean germination and emergence. Soybean plant count and height were statistically analyzed.

The following X and 2X rates of each dinitroaniline herbicide were repeated twice in the environmental chamber: butralin, 3.36 kg/ha and 6.72 kg/ha; dinitramine, 0.56 kg/ha and 1.12 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 kg/ha and 2.8 kg/ha.

Figure 1 shows the manner in which each treatment was prepared. Soybeans were planted 2.4 cm deep with a 4.8 cm band of treated soil. Metal three-pound cans 17 cm high and 15 cm in diameter were used. Ten soybean seeds were used in each can. A 0.6 cm layer of sand was placed on the soil surface to retard evaporation. In the first run, a 12-hour photoperiod was used

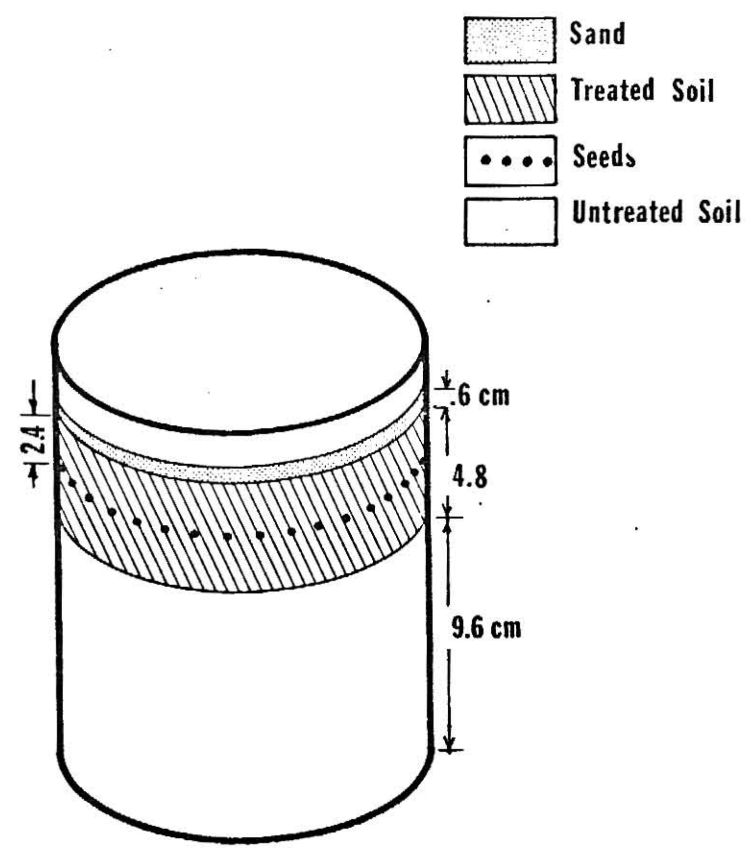

Fig. 1. Placement of treated soil with respect to soybeans.

with day temperatures of 33°C and night temperatures of 27°C. The temperatures were changed to 27°C day temperatures and 21°C night temperatures in the second growth chamber run.

Dinitroaniline Herbicide Depth of Incorporation Experiment

Dinitroaniline herbicide depth of incorporation studies were evaluated during the spring and summer of 1975 in an environmental chamber. A silt loam soil from the Ashland Agronomy Farm was used. Shattercane used was harvested from three heavily infested shattercane fields near Manhattan, Kansas, in the fall of 1974.

0.9 sq m of soil 2.5 cm deep was treated with a dinitroaniline herbicide. A plywood frame 91 cm square with sides 2.5 cm high was used to measure the soil. The soil was spread out uniformly on a plastic tarpaulin 230 cm square. Each dinitroaniline herbicide was applied with an 11.4 liter hand sprayer. The correct amount of active chemical was applied in 946 ml of water to the soil surface for each treatment. Herbicides were then incorporated into the soil by hand mixing on the plastic tarpaulin.

Experiments included 6 treatments with each dinitroaniline herbicide and terminated three weeks after shattercane planting. The experiment included three herbicide incorporation depths, 2.4, 4.8, and 7.2 cm, and two shattercane planting depths, 2.4 and 12.0 cm. A randomized complete plot design was used with all treatments triplicated. A control was included to check shattercane germination. Shattercane plant count, height, and weight were statistically analyzed.

Each of the following dinitroaniline herbicides and rates was repeated three times in the environmental chamber: dinitramine experiment, 0.56 kg/ha; and fluchloralin, penoxalin, and profluralin experiments, 1.4 kg/ha. Butralin experiment was repeated twice at 3.36 kg/ha and once at 2.24 kg/ha. Trifluralin experiment was repeated twice at 1.4 kg/ha and once at 1.12 kg/ha.

Shattercane was planted 2.4 cm deep with bands of treated soil of 2.4, 4.8, and 7.2 cm (Figure 2). Shattercane was planted 12.0 cm deep with bands of treated soil of 2.4, 4.8, and 7.2 cm (Figure 3). Metal three-pound cans 17 cm high and 15 cm in diameter were used. Twenty-five shattercane seeds were used in each treatment. Water was applied making soil conditions favorable for shattercane germination. A 0.6 cm layer of sand was placed on the soil surface to reduce evaporation, soil crusting and soil cracking. A 12-hour photoperiod was used in the environmental chamber with day temperatures of 33°C and night temperatures of 27°C.

During 1975, mini-plots, under field conditions, were used to determine the dinitroaniline herbicide incorporation depth needed to control shattercane. The mini-plot area was clean-tilled until dinitroaniline herbicide application.

Each mini-plot was 0.4 sq m. The perimeter was measured by a metal frame made out of 7.6 cm angle iron 0.6 cm thick. The surfaces of the angle iron were treated with a clear acrylic finish to provide a slick surface so soil would not adhere when the frame was removed when each mini-plot was completed.

The shattercane planting depth and herbicide incorporation depths were the same as those in the growth chamber experiments

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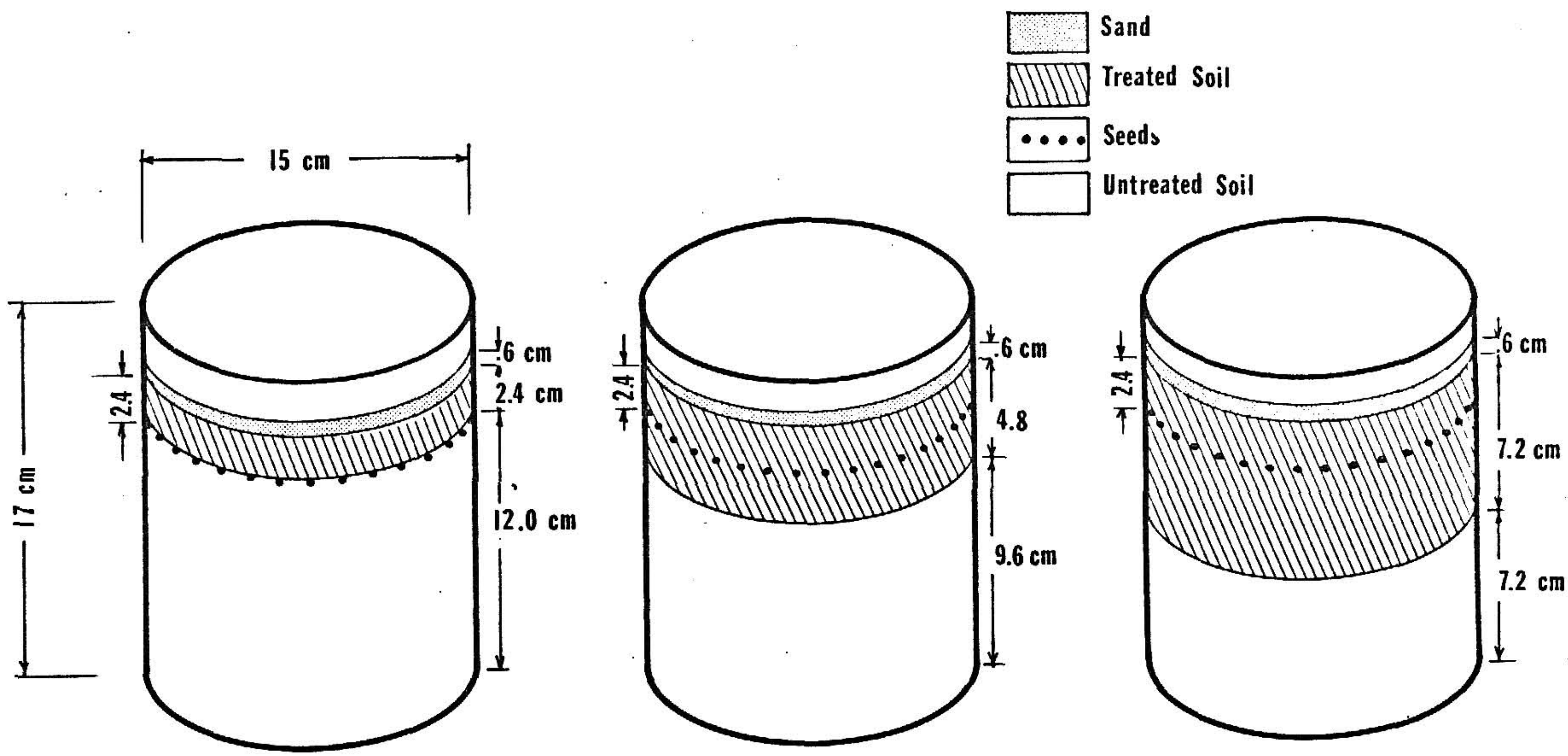

Fig. 2. Placement of treated soil with respect to shattercane seed.

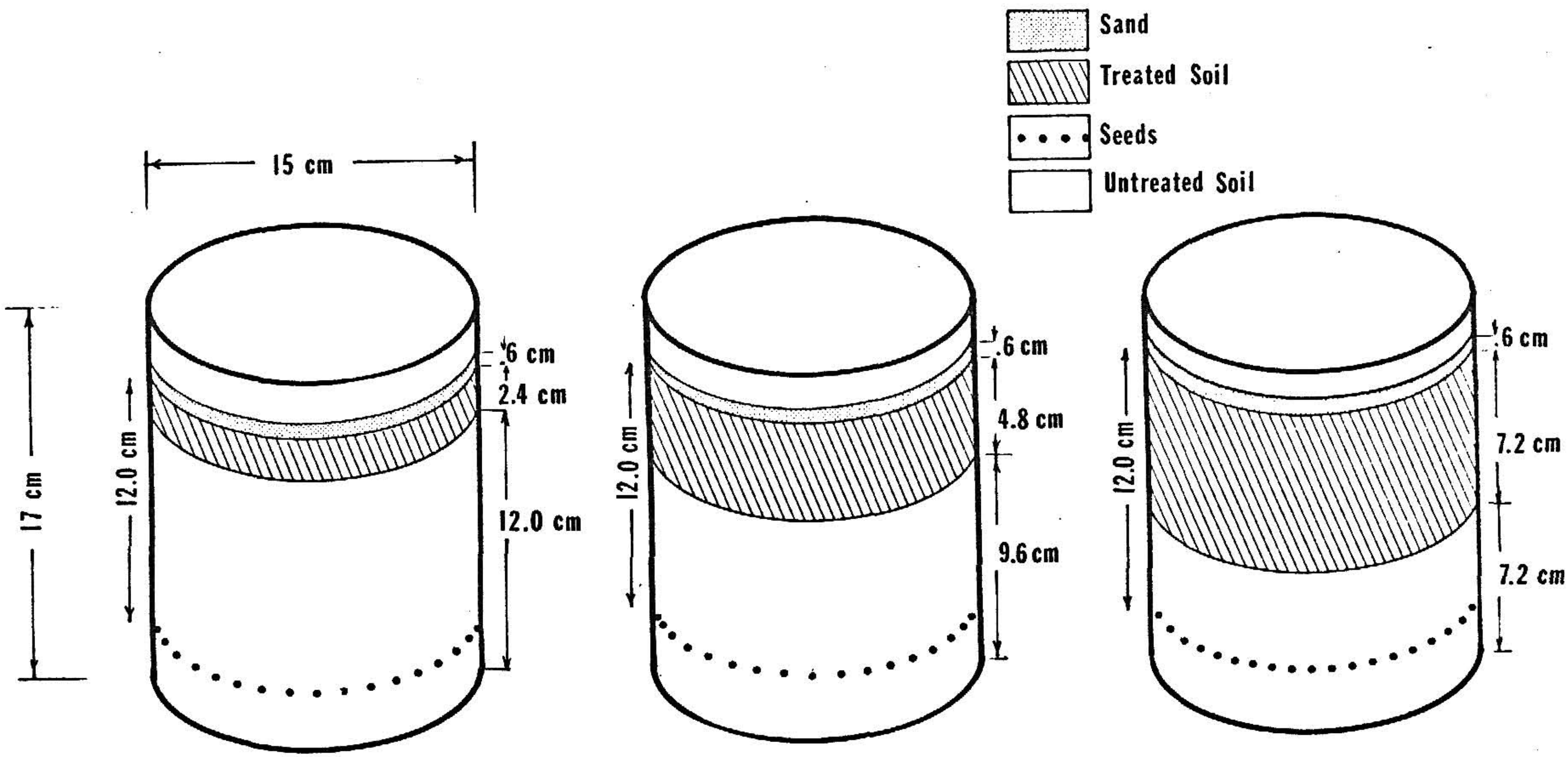

Fig. 3. Placement of treated soil with respect to shattercane seed.

(Figures 2 and 3). Fifty shattercane seeds were planted at each planting depth, 2.4 and 12.0 cm.

The dinitroaniline herbicides were applied with a spray paint gun powered by compressed air. A cone nozzle was used in the spray paint gun at 1.8 ksc. Water was used as a carrier for each dinitroaniline herbicide. Herbicides incorporated 2.4 cm were applied with water at a rate of 7410 l/ha. Herbicides incorporated 4.8 cm were applied with water at a rate of 9880 l/ha. Herbicides incorporated 7.2 cm were applied with water at a rate of 12,350 l/ha.

To induce shattercane germination, 0.7 cm of water was applied 2.4 cm below the soil surface.

The six dinitroaniline herbicide treatments and rates of application were butralin, 3.36 kg/ha; dinitramine, 0.56 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 kg/ha.

A randomized complete plot design was used with all treatments triplicated. Treatments consisted of three herbicide incorporation depths, 2.4, 4.8, and 7.2 cm, and two shattercane planting depths, 2.4 and 12.0 cm. One control plot was provided for each replication. Each replication contained 19 mini-plots. Shattercane plant counts were taken and statistically analyzed.

RESULTS AND DISCUSSION

Depth of Dinitroaniline Herbicide Incorporation

This experiment was initiated in 1974 to determine the dinitroaniline herbicide depth of incorporation needed to control shattercane in soybeans. However, there were no significant differences in shattercane control between herbicide treatments and depth of incorporation.

Soil compaction from shallow tillage operations prior to dinitroaniline herbicide application and soil moisture at field capacity made proper herbicide incorporation difficult. Insufficient herbicide incorporation and distribution resulted in inadequate shattercane control and low soybean yields (Table 1). Lack of shattercane control resulted in high shattercane plant population. Competition from shattercane for growth factors resulted in reduced soybean yields. The greater the population of shattercane, the smaller the plant both in height and weight. Decreased shattercane competition allowed taller and heavier plants. Shattercane production per plot was similar in all treated plots (Table 1). No statistically significant visual soybean injury was found between dinitroaniline herbicides in 1974.

Results from the dinitroaniline herbicide depth of incorporation study revealed statistically significant herbicide treatment differences between soybean yield and visual shattercane ratings in 1975 (Table 2). No statistically significant differences were found between individual herbicide treatments and incorporation depths.

Table 1. Effect of herbicide on average soybean yield, visual shattercane ratings, and shattercane yield for 1974.

Treatment	Rate (kg/ha)	Soybean Yield (kg/ha)	Visual Shattercane Rating	Shattercane Yield (Dry Weight) (kg/ha)
Butralin	2.24	1547	6.7	9.5
Dinitramine	0.56	945	6.8	11.2
Fluchloralin	1.40	1451	7.0	7.3
Penoxalin	1.40	1435	6.3	9.6
Profluralin	1.40	1129	6.0	10.3
Trifluralin	1.12	1516	6.8	6.9
No Treatment		593	1.6	16.4
LSD .05		n.s.	1.9	4.6

Table 2. Effect of herbicide on average soybean yield, visual shattercane ratings, and shattercane yield for 1975.

Treatment	Rate (kg/ha)	Soybean Yield (kg/ha)	Visual Shattercane Rating	Shattercane Yield (Dry Weight) (kg/ha)
Butralin	3.36	1794	5.4	1.1
Dinitramine	0.56	1962	6.8	1.2
Fluchloralin	1.40	2426	8.5	0.1
Penoxalin	1.40	2305	8.5	0.2
Profluralin	1.40	2439	8.4	0.2
Trifluralin	1.40	2177	9.3	0.2
No Treatment		1868	0.0	2.0
LSD .05		449	2.5	n.s.

Favorable soil conditions in 1975 allowed better herbicide incorporation. The trifluralin rate was changed from 1.12 to 1.4 kg/ha to conform with the label for shattercane control. D. A. Bush, Research Department, Amchem Products, Inc., recommended a change in rate of application of butralin from 2.24 to 3.36 kg/ha.

Dry conditions which prevailed six weeks after planting resulted in lower soybean germination and emergence. Deep tillage operations prior to planting depleted soil moisture in the deep incorporated plots. Lower soybean stands influenced soybean yield, height at maturity, and injury ratings (Table 3). Dry weather caused soybean leaf burn around the leaf perimeters in all herbicide treatments.

Table 3. Effect of herbicide incorporation depths on average soybean yield, height at maturity, and visual injury ratings for 1975.

Treatment Incorporation (cm)	Soybean Yield (kg/ha)	Height (cm)	Visual Injury Rating
2.0 - 3.0	2465	89.0	0.0
6.0 - 8.0	1814	80.3	0.8
LSD .05	240	2.4	0.6

Heavy infestations of greenbugs on shattercane seedlings, in addition to having initiated the experiment July 1, caused slow shattercane growth and less competition to soybeans. Visual shattercane ratings revealed better control when herbicides were incorporated deep (Table 4). Fewer shattercane seeds, which germinated

12.0 cm or deeper, emerged through the deep incorporated plots because shattercane seedlings were in contact with a greater band of herbicide treated soil. This allowed greater herbicide uptake than those seedlings emerging in shallow incorporated plots.

Table 4. Effect of herbicide incorporation depths on average visual shattercane ratings and yield for 1975.

Treatment Incorporation (cm)	Visual Shattercane Rating	Yield (Dry Weight) (kg/ha)
2.0 - 3.0	5.7	0.7
6.8 - 8.0	7.7	0.7
LSD .05	1.4	n.s.

Two of the six dinitroaniline herbicides, profluralin and trifluralin, have a labeled rate specified for use to control shattercane. The other four herbicides, butralin, dinitramine, fluchloralin, and penoxalin, were not labeled to control shattercane and were used at the recommended rate for the soil type.

Tolerance of Williams Soybean to the X and 2X Rate of Six Dinitroaniline Herbicides on Silt Loam Soil

Williams soybeans varied in tolerance to the X and 2X rates of the dinitroaniline herbicides (Table 5). Soybean yields were higher at Locations 2, 3, and 4 compared to Location 1. Later soybean planting date at Locations 2, 3, and 4 allowed the late summer rains to be utilized to a better degree for pod filling. Soybeans at Location 1 started to bloom in midsummer and did not benefit from later rains as did soybeans at the other locations.

The lowest yields were obtained from plots treated with dinitramine and fluchloralin.

Table 5. Effect of herbicides on average soybean yields from X and 2X experiment at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
	Yield (kg/ha)			
Butralin	2312	2825	2589	2709
Dinitramine	2126	2043	2689	2048
Fluchloralin	2202	2679	2871	2455
Penoxalin	2226	2477	2606	2583
Profluralin	2283	2700	2539	2733
Trifluralin	2425	2403	2390	2634
LSD .05	n.s.	394	n.s.	209

The 2X herbicide rate reduced soybean yield significantly at Locations 2 and 4 (Table 6). At Location 4 a statistically significant interaction between the X and 2X herbicide rates decreased soybean yields (Figure 4). No significant interaction was found at the other three locations.

Table 6. Effect of herbicide X and 2X rate on average soybean yields at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
	Yield (kg/ha)			
X Rate	2231	2779	2730	2647
2X Rate	2294	2264	2498	2408
LSD .05	n.s.	227	n.s.	121

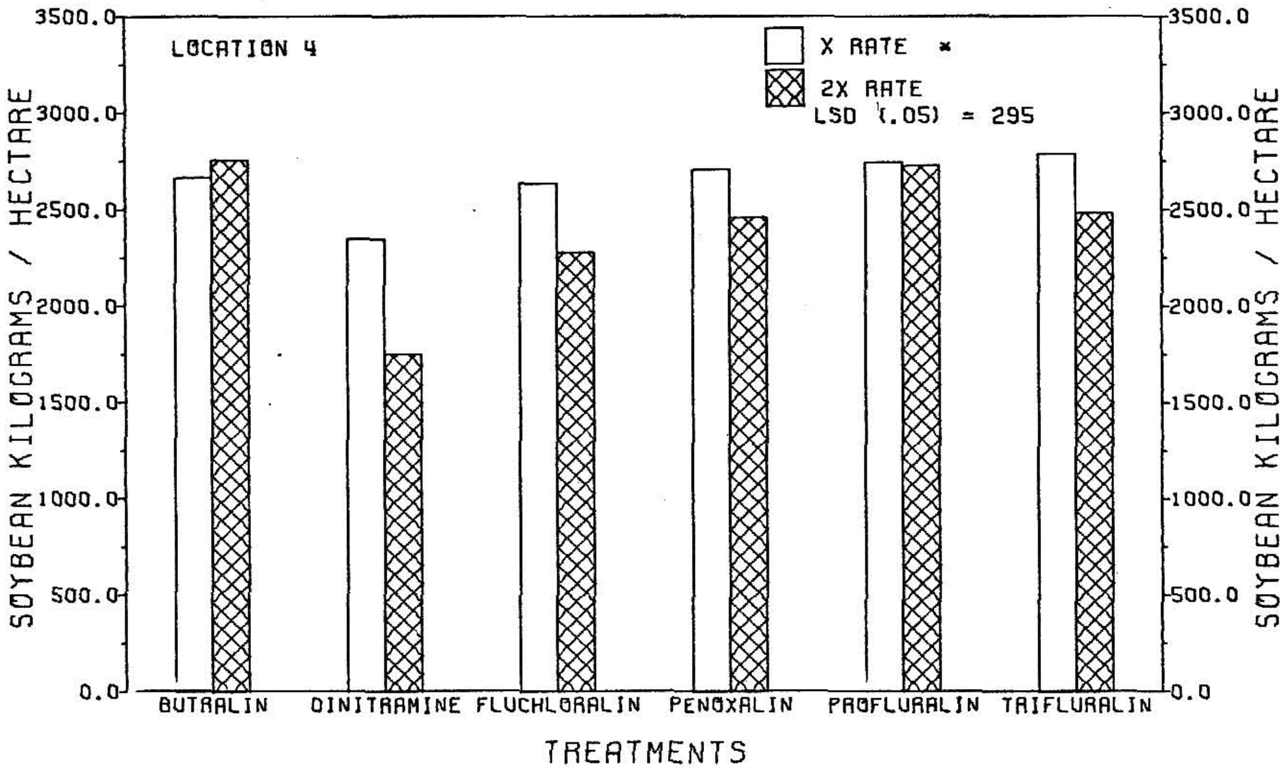

Fig. 4. Effect of X and 2X dinitroaniline herbicide rates on soybean yields for 1975.

*X and 2X herbicide rates are listed in the Methods and Materials.

Lesser corn stalk borer infestations at Locations 2, 3, and 4 caused stand reduction of 1 to 5 per cent. However, the insect damage was more influential in those plots having significant herbicide soybean stand reduction.

Soybean plant height was positively correlated to high yields (Table 7). As the herbicide rate increased, soybean height decreased (Table 8). No significant interaction between herbicide rates and soybean plant height was observed at any location.

Table 7. Effect of herbicides on average soybean plant height from X and 2X rate experiment at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
	Height (cm)			
Butralin	82.97	84.67	85.94	88.48
Dinitramine	76.20	80.43	79.59	80.86
Fluchloralin	82.13	90.59	85.94	85.94
Penoxalin	79.16	82.55	81.70	87.21
Profluralin	80.01	88.48	87.63	88.11
Trifluralin	80.86	81.28	83.40	87.63
LSD .05	n.s.	5.67	n.s.	3.57

Table 8. Effect of herbicide X and 2X rate on average soybean plant height at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
	Height (cm)			
X Rate	79.6	86.5	84.7	87.8
2X Rate	80.8	82.8	83.4	84.9
LSD .05	n.s.	3.3	n.s.	2.1

Dinitramine significantly retarded soybean emergence and reduced soybean stand and plant height at all locations (Table 9). No distinguishing soybean plant characteristics for dinitramine injury were apparent. In addition to dinitramine, penoxalin showed soybean plant stunting.

Table 9. Effect of herbicides on average visual soybean injury in X and 2X rate experiment at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
Butralin	0.00	0.00	0.00	0.00
Dinitramine	0.58	0.58	0.50	1.40
Fluchloralin	0.08	0.17	0.00	0.00
Penoxalin	0.25	0.42	0.08	0.00
Profluralin	0.00	0.00	0.00	0.00
Trifluralin	0.25	0.17	0.08	0.00
LSD .05	0.29	0.29	0.33	0.20

The 2X herbicide rate caused significantly more soybean injury than the X herbicide rate (Table 10). Locations 2 and 3 received 8.1 cm of rain the night following herbicide application and soybean planting. Heavy soil crusting occurred putting a stress on the soybean emergence.

Tillage operations before planting and dry weather following planting were possible factors contributing to reduced soybean germination and emergence at Location 4.

Dinitramine, penoxalin, and trifluralin applied at the 2X rate caused significant soybean injury (Figures 5 and 6). These herbicides have a narrower margin of safety when subjected to environmental conditions such as heavy rains and cool temperatures. Dinitramine is more injurious at the 2X rate than any of the other herbicides evaluated. The 2X rate of dinitramine should not be used to control shattercane in soybeans because of soybean injury incurred. The other five dinitroaniline herbicides evaluated at the 2X rate on Williams soybeans had sufficient margin of safety although the 2X rate is not needed for shattercane control.

Table 10. Effect of herbicide X and 2X rates on average visual soybean injury at four locations for 1975.

Treatment	Location 1	Location 2	Location 3	Location 4
X Rate	0.03	0.11	0.03	0.06
2X Rate	0.36	0.33	0.19	0.42
LSD .05	0.17	0.17	0.19	0.12

In the growth chamber, the six dinitroaniline herbicide X and 2X rates were evaluated on soybean plant height and soybean emergence. The first growth chamber run showed a statistically significant difference in average soybean plant height between the overall X herbicide treatments and the 2X herbicide treatments. However, there was no significant difference in the second growth chamber run. There were statistically significant differences in soybean plant height and herbicide treatments in the first growth chamber run but not in the second (Table 11).

Under cooler growing conditions, butralin and dinitramine significantly delayed and reduced soybean emergence (Table 12).

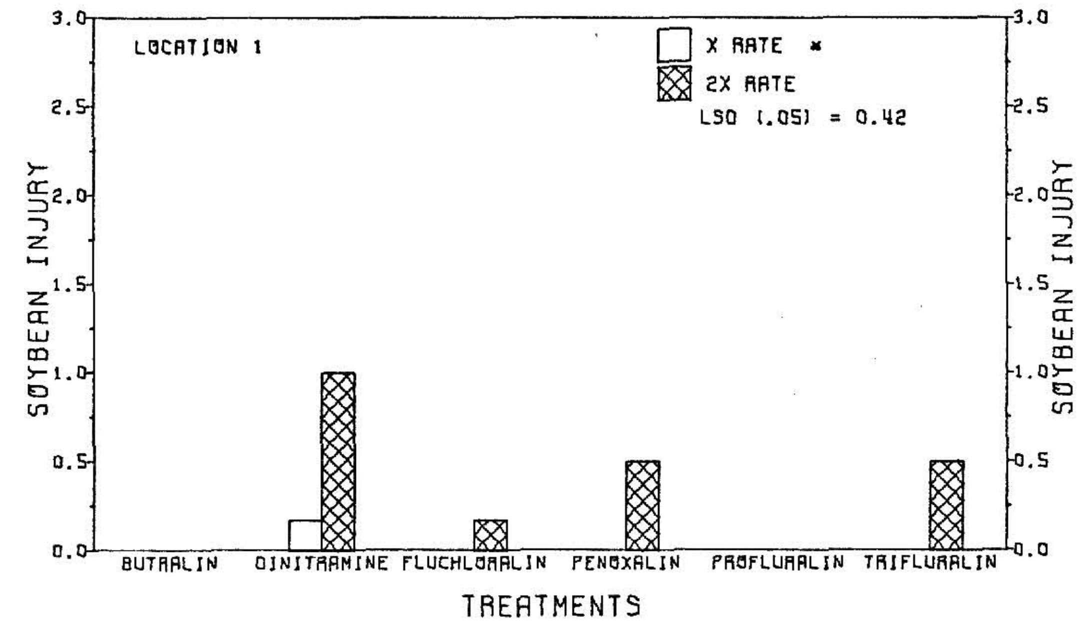

Fig. 5. Differences in soybean plant injury between the X and 2X rates of each dinitroaniline herbicide.

*X and 2X dinitroaniline herbicide rates are listed in the Methods and Materials.

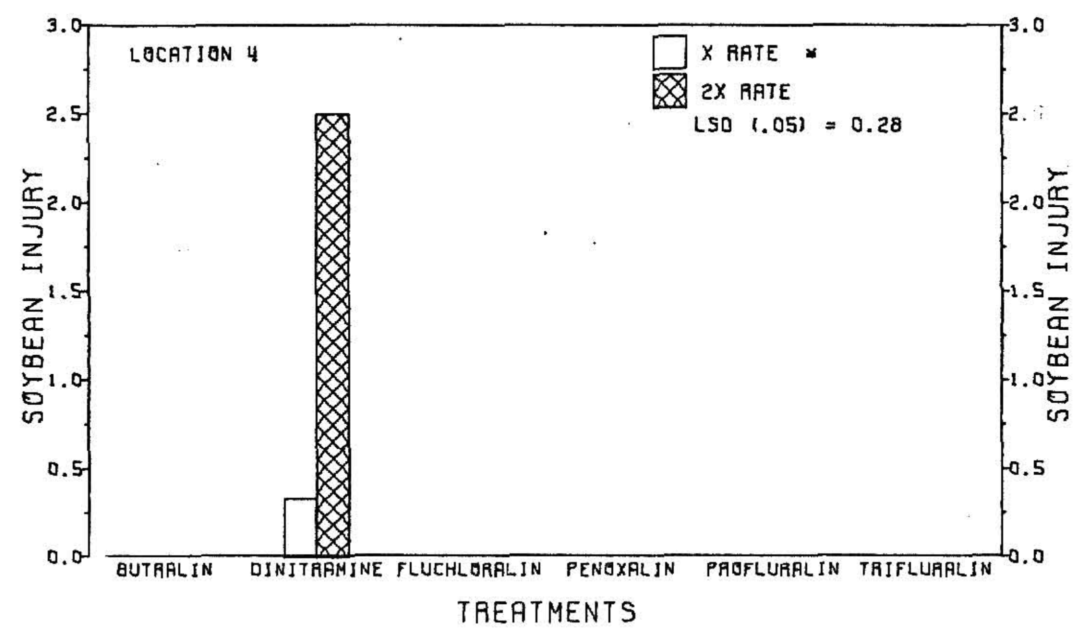

Fig. 6. Differences in soybean plant injury between the X and 2X rates of each dinitroaniline herbicide.

*X and 2X dinitroaniline herbicide rates are listed in the Methods and Materials.

Low temperature can have a detrimental effect on soybean germination and emergence when soil is treated with butralin or dinitramine.

Table 11. Effect of herbicides on average soybean height in first growth chamber experiment.

	Treatments							
	Butralin	Dinitramine	Fluchloralin	Penoxalin	Profluralin	Trifluralin	LSD .05	Control
Height, cm	22.4	17.4	12.6	22.1	12.0	10.3	4.3	22.2

Table 12. Effect of herbicides on average soybean plant count in second growth chamber experiment.

	Treatments							
	Butralin	Dinitramine	Fluchloralin	Penoxalin	Profluralin	Trifluralin	LSD .05	Control
Plant Count	3.7	3.0	5.3	5.8	6.2	5.8	1.9	6.5

Statistical analysis indicated significant difference between the first growth chamber run and the second run. This difference was attributed to temperature differences. The first run day temperature was 33°C and night temperature 27°C. The second run day temperature was 27°C and night temperature was 21°C. Lower temperatures create slower growing conditions allowing soybeans to be in contact longer with the herbicide-treated soil. Such conditions can possibly increase amount of herbicide uptake by the soybean plant. Low temperature conditions may be comparable to increasing herbicide rate under normal growing conditions. Between the two temperatures, significant differences in soybean emergence and height were found among herbicide treatments and rates.

Dinitroaniline Herbicide Depth of Incorporation Determination

Optimum dinitroaniline herbicide incorporation depth was determined to control shattercane distributed throughout the soil plow layer. Growth chamber experiments showed that shattercane can emerge from 2.4 cm as well as from 12.0 cm (Figures 7 through 12). Each figure represents averages of three growth chamber runs, nine replications in all.

All herbicides caused shattercane stunting, but severe stunting occurred at the 2.4 cm incorporation depth when shattercane was planted 12.0 cm deep.

Butralin, 3.36 kg/ha, and dinitramine, 0.56 kg/ha, gave low shattercane control compared to the other four dinitroaniline herbicides (Figures 7 and 8). Butralin caused shattercane leaf yellowing, plant stunting and leaf spiraling. Volatility of butralin and dinitramine caused slight shattercane stunting in the controls in the second run. Addition of circulation fans changed the growth chamber environment and decreased shattercane injury in controls in the third run.

Effective shattercane control was apparent with fluchloralin, profluralin, and trifluralin, 1.4 kg/ha (Figures 9, 11 and 12). These herbicides caused severe shattercane stunting, spiraling of the first shattercane leaves, and leaf yellowing. Moderate to slight volatility damage was noticeable in the controls before addition of circulation fans in the growth chamber.

Penoxalin, 1.4 kg/ha, gave moderate shattercane control (Figure 10). Moderate volatility injury occurred in controls in the second run.

All six dinitroaniline herbicides indicated the following trends. With shattercane planted 2.4 cm, the greater the herbicide incorporation depth, the less shattercane control and a lesser degree of shattercane stunting. This type of shattercane response to incorporation would indicate little of the herbicide was taken up through the root system of the shattercane plant resulting in a herbicide dilution effect with deeper incorporation. Shallow herbicide incorporation gave shattercane control when shattercane was located in the top few centimeters of soil.

With shattercane planted 12.0 cm, the greater the herbicide incorporation depth, the better the shattercane control. The greatest degree of shattercane stunting occurred at the 2.4 cm incorporation. Little or no shattercane emerged with herbicide incorporation of 4.8 cm or greater. This indicated that the dinitroaniline herbicides were taken up through the shattercane shoot system. No herbicide dilution effect was detected when the shattercane seed germinated below the herbicide incorporation depth.

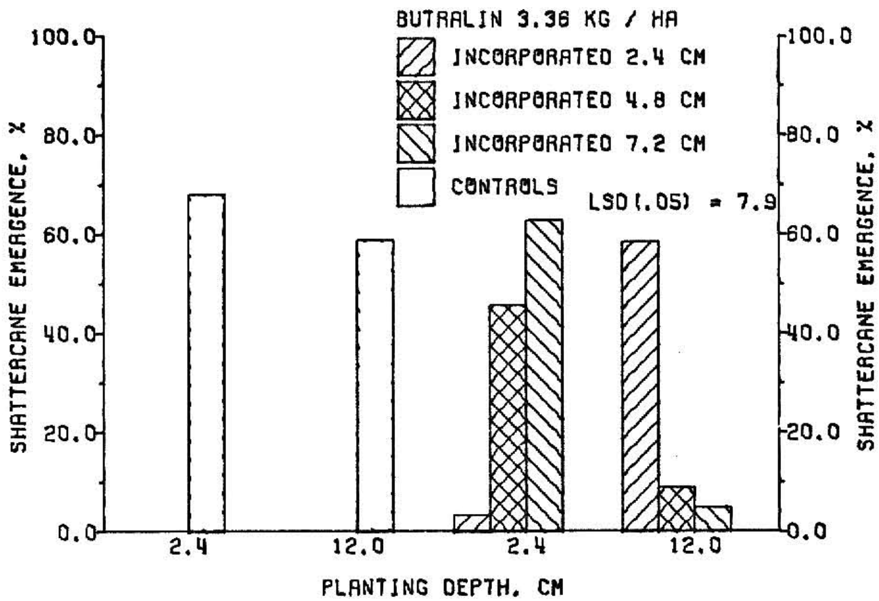

Fig. 7. Shattercane control with butralin incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

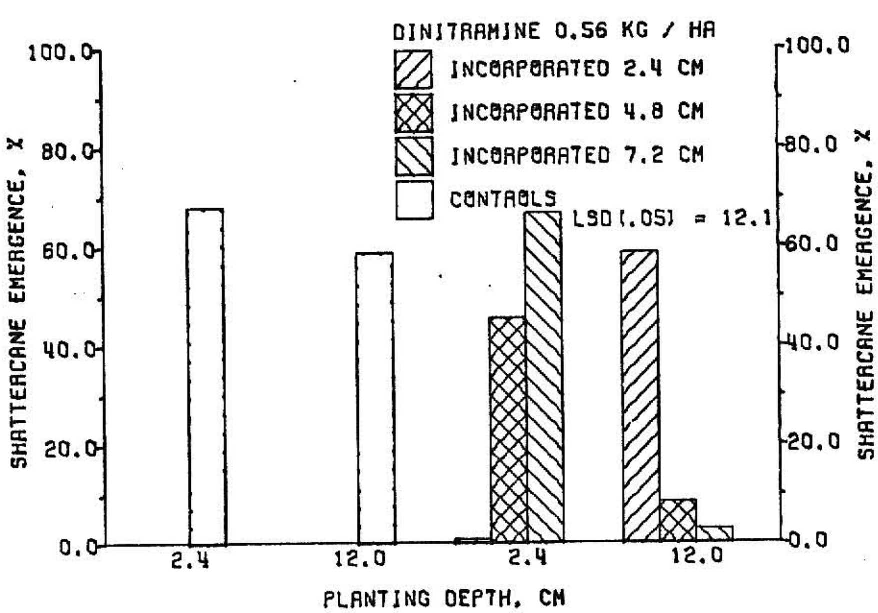

Fig. 8. Shattercane control with dinitramine incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

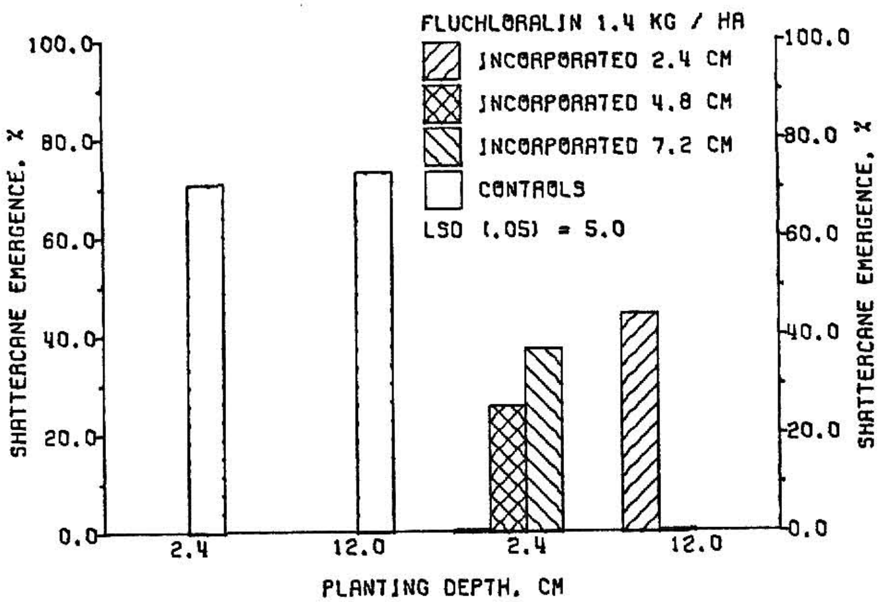

Fig. 9. Shattercane control with fluchloralin incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

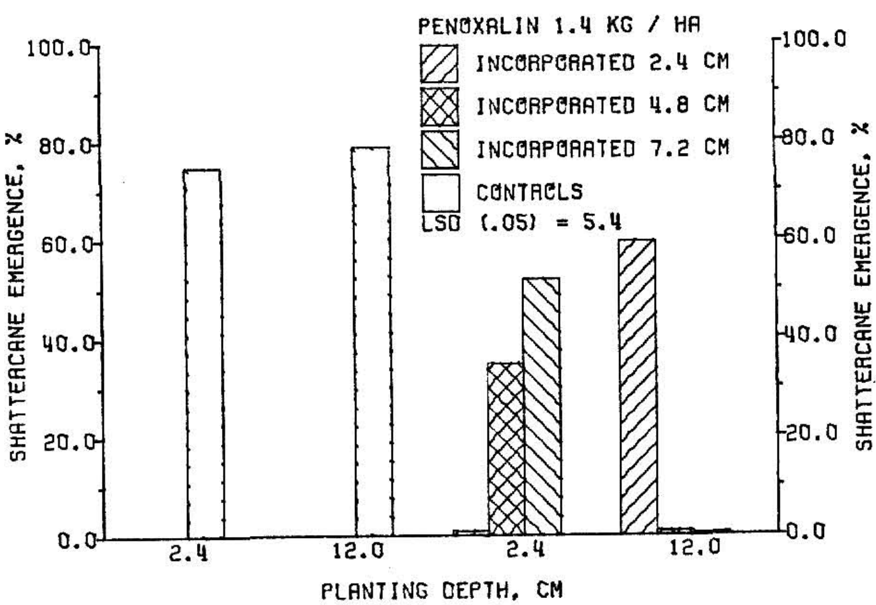

Fig. 10. Shattercane control with penoxalin incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

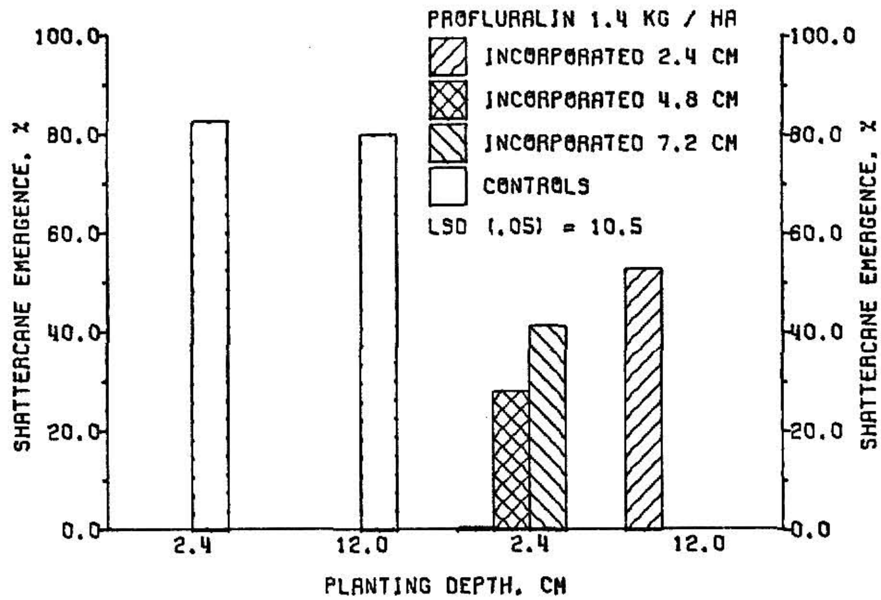

Fig. 11. Shattercane control with profluralin incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

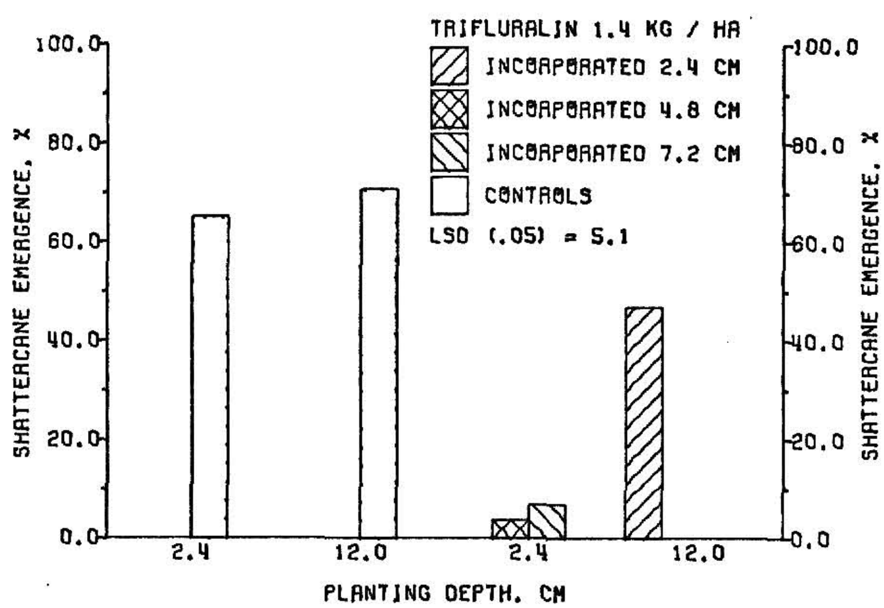

Fig. 12. Shattercane control with trifluralin incorporated at various soil depths and shattercane planted at 2.4 and 12.0 cm deep.

Growth chamber data indicated the optimum herbicide incorporation depth for the greatest degree of shattercane control at various shattercane planting depths was 4.8 cm.

Mini-plot data illustrated that more shattercane emerged from the 12.0 cm planting depth than from the 2.4 cm planting depth (Figure 13). The average number of shattercane plants that emerged from the control plots planted 2.4 cm was 44 and 23 when planted 12.0 cm deep. Conditions for shattercane germination were not favorable at the time of planting. Three weeks prior to planting, no rainfall was received. Four weeks after the experiment was initiated, measurable rainfall was recorded. The 0.8 cm of water applied at planting was not sufficient to create an environment favorable for germination. Shattercane was noted emerging after rainfall was recorded. Herbicide activity did not seem to be decreased over the four-week period.

The mini-plot experiment illustrated the trend of herbicide incorporation depth versus shattercane planting depth noted in the growth chamber experiments (Figure 14). This figure suggests an optimum herbicide incorporation depth of 4.8 cm, the same as that indicated by growth chamber experiments.

Dinitroaniline herbicides used in these studies provided various degrees of shattercane control. Grouped on the basis of herbicide activity, trifluralin, profluralin, and fluchloralin were most active on shattercane followed by penoxalin, butralin, and dinitramine.

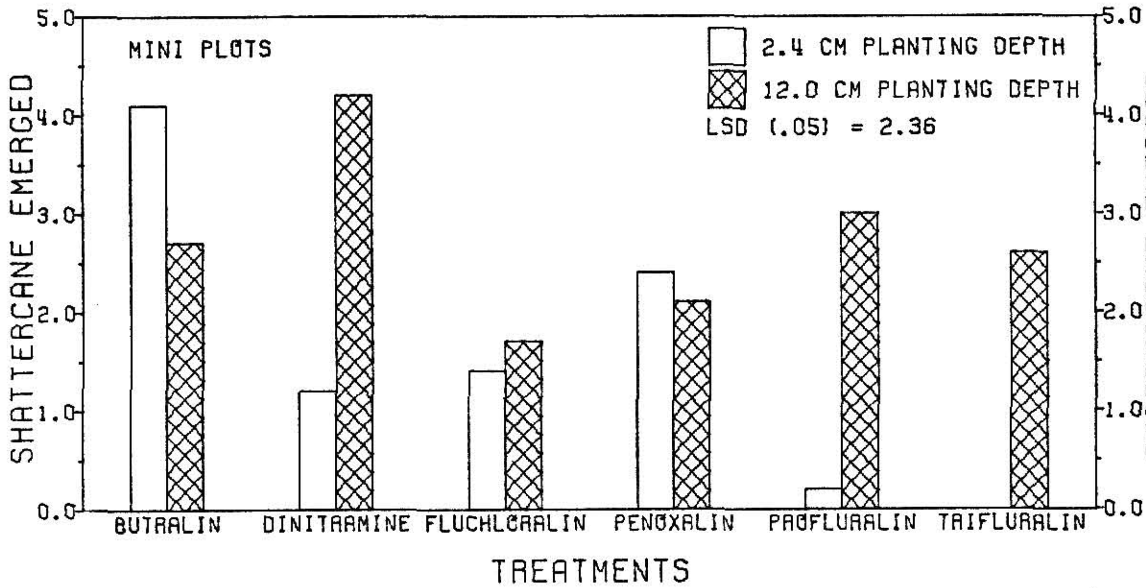

Fig. 13. Average number of shattercane plants emerged from two planting depths in mini-plots treated with six dinitroaniline herbicides.

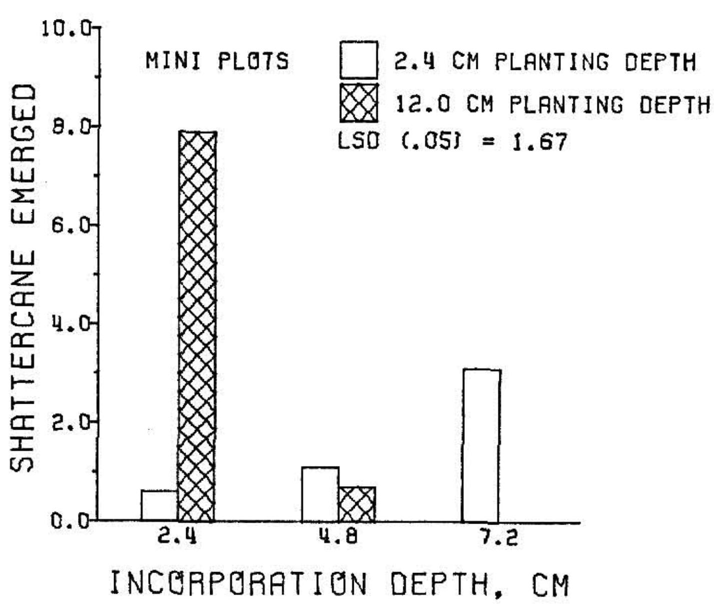

Fig. 14. Average number of shattercane plants emerged from two planting depths with various dinitroaniline herbicide incorporation depths.

EXPLANATION OF PLATE I

Shallow incorporation (2.0-3.0 cm) of penoxalin at 1.4 kg/ha gave moderate control of shattercane. All dinitroaniline herbicides evaluated at the shallow incorporation depth gave moderate control of shattercane.

EXPLANATION OF PLATE II

Deep incorporation (6.0-8.0 cm) of penoxalin at 1.4 kg/ha gave excellent control of shattercane. All dinitroaniline herbicides evaluated at the deep incorporation depth gave better control of shattercane compared to the shallow incorporation.

PLATE I

PLATE II

EXPLANATION OF PLATE III

The 2X rate of dinitramine, 1.12 kg/ha, caused 10-25 per cent injury to soybeans. All other 2X rates of dinitroaniline herbicides can cause injury to soybeans when subject to adverse environmental conditions such as cool temperatures and excess rainfall.

EXPLANATION OF PLATE IV

The X rate of dinitramine, 0.56 kg/ha, caused 0-5 per cent injury to soybeans. Fluchloralin, penoxalin, and trifluralin, 1.4 kg/ha, in combination with adverse environmental conditions, can result in injury to soybeans.

PLATE III

PLATE IV

SUMMARY

Experimental results showed that all six dinitroaniline herbicides controlled shattercane in soybeans. The rates of dinitroaniline herbicides needed to control shattercane in soybeans on a silt loam soil were the following: butralin, 3.36 kg/ha; dinitramine, 0.56 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 kg/ha. Grouped on the basis of herbicide activity, trifluralin, profluralin, and fluchloralin are most active on shattercane followed by penoxalin, butralin, and dinitramine.

Growth chamber and mini-plot experiments determined that incorporation of the herbicide at a depth of 2.4 cm controlled shattercane planted 2.4 cm deep and incorporation of the herbicide at 4.8 cm controlled shattercane planted 12.0 cm deep. The optimum depth of incorporation of dinitroaniline herbicide was 4.8 cm to control germinating shattercane seed throughout the plow layer.

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SOIL INCORPORATION AND APPLICATION RATE OF SIX DINITROANILINE HERBICIDES FOR SHATTERCANE (SORGHUM BICOLOR (L.) MOENCH) CONTROL IN SOYBEANS (GLYCINE MAX (L.) MERRILL)

by

JEFFREY L. KUGLER

B. S., Kansas State University, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

Shattercane germination from various soil depths differentiates it from many other weed seeds. Shattercane (Sorghum bicolor (L.) Moench) control in soybeans (Glycine max (L.) Merrill) is influenced by the depth the following six dinitroaniline herbicides are incorporated and rates of application: N-sec-butyl-4-tert-butyl-2,6-dinitroaniline (butralin), 3.36 kg/ha; N^4,N^4-diethyl-a,a,a-trifluoro-3,5-dinitrotoluene-2,4-diamine (dinitramine), 0.56 kg/ha; N-(2-chloro-ethyl)-2,6-dinitro-N-propyl-4-trifluro-methyl) aniline (fluchloralin), 1.4 kg/ha; N-(1-ethylpropyl-2,6-dinitro-3,4-xylidine (penoxalin), 1.4 kg/ha; N-(cyclopropylmethyl)-a,a,a-trifluoro-2,6-dinitro-N-propyl-p-toluidine (profluralin), 1.4 kg/ha; and a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine (trifluralin), 1.4 kg/ha.

Field and growth chamber experiments were evaluated on a silt loam soil using Williams soybeans and shattercane with various dinitroaniline herbicides, rates of application, and incorporation depths.

Growth chamber and field studies show that at a constant shattercane planting depth of 2.4 cm, shattercane control decreases as the herbicide incorporation depth increases. Shattercane control was excellent when dinitroaniline herbicides were incorporated 2.4 cm deep. When shattercane was planted 12.0 cm deep, its control increased as herbicide incorporation depth increased. However, at various shattercane planting depths, dinitroaniline activity was greatest when the herbicide was incorporated 4.8 cm deep.

Dinitroaniline herbicides used in this study provided various degrees of shattercane control. Grouped on herbicidal activity, trifluralin, profluralin, and fluchloralin were most active followed by penoxalin, butralin, and dinitramine.

Dinitroaniline herbicide X and 2X rate study was conducted to determine tolerance of Williams soybean to herbicides. The rates of application were butralin, 3.36 and 6.72 kg/ha; dinitramine, 0.56 and 1.12 kg/ha; and fluchloralin, penoxalin, profluralin, and trifluralin, 1.4 and 2.8 kg/ha.

Soybeans were tolerant to all X dinitroaniline herbicide rates. The 2X herbicide rate of dinitramine caused significant soybean injury, followed by trifluralin, fluchloralin, profluralin, penoxalin, and butralin.