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Slot Injection of Herbicides

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ABSTRACT

INJECTION of thiocarbamate herbicides into a slot created by a coulter was evaluated during a 3-year study in southeastern Nebraska. Control of shattercane, the dominant weed, with the slot injector was similar to conventional double disk incorporation. In both tilled and untilled surface conditions, the slot injector placed the herbicide into the soil with minimal disturbance of the soil and residue. Herbicides which are normally broadcast applied were band applied, reducing chemical costs by two-thirds.

INTRODUCTION

Weed control has been a major concern for row crop producers considering conservation tillage methods. The use of preplant incorporated herbicides, which control many of the grassy weeds, is generally eliminated in reduced tillage systems. Therefore, other application methods for using normally incorporated herbicides to control problem weeds are needed to increase the acceptance of conservation tillage.

Thiocarbamate herbicides, widely used for weed control in row crops, must be incorporated immediately when used in liquid form. Gray and Weierch (1965) found that 15 min after applying EPTC on the soil surface, approximately 17% evaporated from a dry sandy loam soil (1% moisture). When soil moisture content was 17%, losses increased to about 40%. Losses were also higher during sunny days and higher temperatures. Tandem disk harrows have been shown to provide excellent incorporation of herbicides with two diskings providing the best uniformity (Knake et al., 1967; Lal and Reed, 1977). Tandem disk harrows, however, cut up and bury crop residue, thus increasing the potential for soil erosion.

Several methods which place herbicides beneath the soil surface have been evaluated. A conventional spray nozzle, mounted beneath a blade, sprayed herbicide rearward into the void created as the soil passed over the blade (Wooten et al., 1962). Holstun et al. (1963) acheived good weed control in cotton using a layer of herbicide placed on both sides of the plant row. Both of these methods were used in cleanly tilled surface conditions. Placing herbicides beneath the soil surface reduced volatilization losses when compared to surface applied herbicides that were incorporated (Holstun, 1966).

More recently, a machine has been successfully used in high residue conditions to inject herbicide at 1400 kPa upward into the soil as it passed over the blade of a sweep plow (Solie et al., 1983). Weed control was comparable to that of conventional double disk incorporation. This method may be a viable incorporation alternative for producers in the Great Plains where the sweep plow is commonly used. However, in a 3-year study conducted in north central Nebraska, weed control with herbicides injected by the sweep plow was generally less than that of the other incorporation methods and tended to be more erratic (Todd et al., 1984). The herbicides were applied in the spring into moist soil. For heavier soils in the Midwest which tend to be wet in the spring, farmers and some implement manufacturers feel that the use of the sweep plow may smear the soil, creating an inpervious layer. In western Nebraska, Mielke et al. (1984) found that below 7.6 cm, the sweep plow treatment had lower hydraulic conductivities than either a moldboard plow or no-till treatment. The data, along with observed tillage layers, suggested that soil smearing with a sweep plow could be a problem.

An alternative to placing herbicides in layers beneath the soil surface is the placement of mobile herbicides in thin lines parallel to the plant row. Wooten et al. (1966) developed a subsurface applicator with a shoe-type knife which used an orifice to place the herbicide directly behind the knife. The knife method provided satisfactory weed control when mobile herbicides were used. However, the knife method was evaluated only in prepared seedbeds and scouring was a problem in moist, heavier soils. To evaluate this type of applicator in residue conditions, Dowler and Hauser (1970) developed a similar machine with a narrow shank behind a smooth rolling coulter. A coulter/shank spacing of 9 cm provided good weed control when a thiocarbamate herbicide was used with 375 L/ha of carrier.

Attempts have been made to directly inject herbicides into an undisturbed soil surface using a solid stream. Arya and Pickard (1958) conducted laboratory research on high pressure (7000 to 27,500 kPa) injection of diesel oil. Penetration depth of the solid stream from a stationary nozzle ranged from 10 to 18 cm in coarse sands. They concluded that nozzles should be placed as close to the soil surface as possible and that thin solid streams of herbicide would be more effective than using extreme pressure in securing penetration. Direct injection of herbicides at 560 L/ha and 700 kPa proved

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unsatisfactory for field conditions because there was insufficient penetration of the soil by the solid stream (Fenster, 1983)*. Penetration depth was about 1 cm into a sandy soil.

OBJECTIVES

The objectives of this research were to construct a prototype applicator capable of injecting herbicide into a slot opened by a coulter and to evaluate this herbicide placement method using thiocarbamate herbicides.

APPLICATOR DESCRIPTION

Placement of mobile herbicides in lines beside the row has not been readily accepted because of problems with knives operating in residue and problems with soil penetration with direct injection of solid streams. To overcome these problems, a rolling coulter was placed in front of solid stream nozzle to cut residue and form a slot in the soil to allow herbicide penetration.

A band rather than broadcast applicator was desired to minimize both machine and herbicide costs. To achieve a band of weed control, two 46 cm diameter, smooth coulters with nozzles were mounted 12.7 cm apart and centered on the row. With the diffusion of thiocarbamate herbicides, it was assumed that this would produce a band of weed control approximately 25 cm wide. The coulters were mounted on two tool bars and staggered, one 76 cm in front of the other. Each coulter was independently mounted on separate spring loaded swing arms to allow operation on uneven surface conditions. Cutting depth of each coulter was limited to 7.6 cm by a depth control band mounted on the side of the coulter away from the row.

Solid stream nozzles were used to direct the spray into the slot opened by the coulters. Aluminum orifice plates, normally used in flow regulators, were used as the solid stream nozzles. The openings in the orifice plates used were: 0.46 mm diameter for 100 L/ha at 700 kPa; 0.51 mm for 100 L/ha at 350 kPa; 0.64 mm for 200 L/ha at 700 kPa; and 0.76 mm for 200 L/ha at 350 kPa, all at a ground speed of 4 km/h. The nozzles were placed approximatley 2.5 cm behind the coulter and 2.5 cm above the soil surface and attached rigidly to the coulter swing arm (Fig. 1). When the nozzle was placed further from the coulter or soil surface, the solid stream tended to diffuse and be deflected by residue and soil falling back into the slot.

*Personal communication regarding unpublished research data. C. R. Fenster is Professor Emeritus, University of Nebraska.

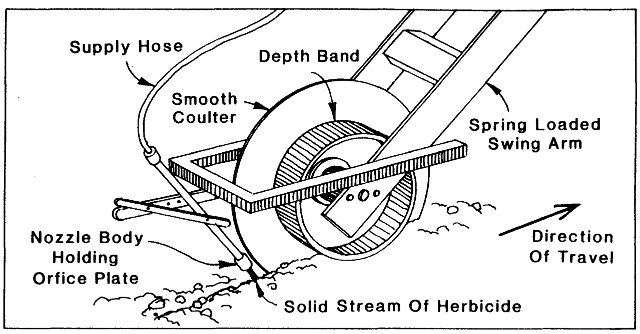

Fig. 1—Nozzle and coulter arrangement used for slot injection of herbicides.

A roller pump was used to provide pressures of 350 and 700 kPa. All sprayer components used on the applicator were readily available stock items. After herbicide application, the slots were closed by gauge wheels on the planter units as the planting operation directly followed herbicide application.

An initial design had the two smooth coulters mounted 12.7 cm apart on a common shaft. This arrangement of the coulters had problems with soil and residue accumulating between the coulters. Soil tended to stick to the coulters eventually creating a bridge between them. In no-till conditions, root masses from the previous crop plugged the space between the coulters almost instantly. The staggered arrangement eliminated these problems.

PROCEDURE

Experimental plots were laid out on a site having a history of shattercane at the University of Nebraska Rogers Memorial Farm near Lincoln. Each year, plot locations were in different areas of the shattercane infested field to avoid potential year to year interactions. The plots were laid out in an area where no shattercane control herbicide had been applied in the previous 2 years. Thus, the shattercane population was large and relatively uniform. The soil was in the Sharpburg Series (Typic Argiudoll, fine montmorillonitic, mesic) and typical of soils found in southeastern Nebraska.

All planting was done with a John Deere 7000 Max-Emerge† six row planter equipped with coulters. There was no crop cultivation performed in any of the plots to remove shattercane between the rows until after the final weed counts were taken each year. Because of this, crop yields were not taken as the shattercane between the rows competed with the growing crop. In general crop production, crop cultivation would have been performed at an early date, reducing the competition.

Duncan's Multiple Range test was employed for the statistical analyses. The 10% level ($p=0.10$) was used to determine significant differences.

Pressure and Carrier Volume Studies, 1983 and 1984

The slot injector was evaluated in tilled and untilled surface conditions in corn residue. The tilled surface plots were disked twice before applying the herbicide treatments. Within each surface condition, two herbicides were used for corn production using two injection pressures with two carrier volumes.

The herbicides† applied were Sutan+ 6.7E (butylate + R-25788) and Eradicane Extra 6E (EPTC + R-25788 + R-33865). Each chemical was applied at a broadcast equivalent rate of 4.5 kg_{ai}/ha in 1983 and 6.7 kg_{ai}/ha in 1984 with carrier volumes of 100 and 200 L/ha. The slot injector was operated at pressures of 350 and 700 kPa and at a ground speed of 4 km/h.

In addition, the slot injector was used in soybean production in 1984 in both surface conditions. Vernam 7E (vernolate) was applied at a broadcast equivalent rate of 3.4 kg_{ai}/ha using a carrier volume of 200 L/ha at 700 kPa.

No-chemical check treatments were used for assessing weed control on both the tilled and untilled surfaces.

†Use of trade names is for descriptive purposes only, endorsement is not implied.

Additionally, conventional double disk incorporated treatments using each herbicide were used for comparison on both surface conditions using carrier volumes of 100 and 200 L/ha for the corn plots and 200 L/ha for the soybeans. Fan nozzles at 200 kPa were used to apply the herbicides before double disk incorporation.

Plots were 2.3 m wide (three 76 cm rows) by 4.9 m long and were replicated six times for each treatment. In 1983, a completely randomized design was used. In 1984, plots were completely randomized within each herbicide. The herbicides for shattercane control were applied and corn was planted on July 7, 1983 and on May 14, 1984. Vernam was applied and soybeans were planted on June 8, 1984.

Additional plot management to suppress broadleaf weed pressure or to help create uniform conditions was the same on all treatments each year within crop. In 1983, Roundup (glyphosate) was sprayed to kill existing vegetation approximately 2 weeks prior to applying the treatments. In 1984, 1.1 kg_{ai}/ha of atrazine was broadcast applied for broadleaf weed control in corn production area approximately 4 weeks prior to applying treatments with an additional 1.1 kg_{ai}/ha applied 3 days after planting. Counter 15G (terbufos) was band applied with the planter at a rate of 1.1 kg_{ai}/ha for insect control in 1984. The soybean production area was sprayed with Roundup to kill any existing vegetation 1 week prior to applying the treatments. Sencor (metribuzin) was broadcast applied on all soybean plots at 0.43 kg_{ai}/ha immediately after planting.

Weed counts were taken 10, 21 and 42 days after planting. Only shattercane was counted as it was the major weed problem. A frame 25 cm wide and 133 cm long was centered lengthwise on the row and a weed count was taken within the frame. Each time three counts were taken within a plot, one per row, and combined to give a total count area of one square meter.

Depth and Spacing Studies, 1985

The slot injection applicator was modified to allow comparison of different herbicide placement depths and spacings. The plot area established in soybean residue was sprayed with 2.2 kg_{ai}/ha atrazine and 1.1 kg_{ai}/ha Bladex (cyanazine), disked and field cultivated 10 days before applying the treatments. Corn plots (2.3 m wide by 11.3 m long) were replicated four times in a completely randomized design. Eradicane Extra was slot injected at a rate of 6.7 kg_{ai}/ha broadcast equivalent at 520 kPa with 200 L/ha carrier using an orifice opening of 64 mm and a ground speed of 3.7 km/h. Depth bands on the coulters were adjusted to place the herbicide at either a 5 or 7.6 cm depth.

Coulter spacings of 10, 12.7 and 15.2 cm apart, centered on the row, were used at each depth. Double disk incorporated and no chemical checks were included for comparison purposes. The application of Eradicane Extra and corn planting were on May 22, 1985. Weed control was evaluated by an Extension Weeds Specialist 14 and 26 days after planting. Subjective visual observations of weed control were made on both dates and on the second date, actual weed counts per square meter was taken within a 20 cm band, centered on the row.

RESULTS AND DISCUSSION

Pressure and Carrier Volume Studies, 1983

Although a field site was selected which had a history of shattercane infestation, the shattercane population among plots was variable. The weed population was very low averaging 15.2 weeds/m^2 in the no-chemical, untilled check after 42 days. Hot and dry weather in the summer of 1983 resulted in low shattercane germination rates.

At the 10% significance level, there were no differences in weed counts for any of the Sutan+ application methods. Weed control using slot injection at either carrier volume or injection pressure was comparable to disk incorporation. There was a trend toward a higher weed count, 20.8 weeds/m^2, in the tilled surface because the disk tended to incorporate or plant the weed seeds while no-till left most of the seeds on the soil surface. Averaged across herbicide application methods and the three weed count dates, the weed control was 69% on the tilled surface and 80% on the untilled surface when compared to the no-chemical check.

Similar results were obtained for application methods using Eradicane Extra. For the 21 day weed count, disk incorporation in the tilled surface had better weed control than slot injection at 700 kPa with a carrier volume of 100 L/ha. With only this exception, there were no statistical differences in weed counts between slot injection and disk incorporation. Averaged across herbicide application methods and the three weed counts, the weed control was 80% on the tilled surface and 86% on the untilled surface.

Pressure and Carrier Volume Studies, 1984

Shattercane populations for the no-chemical checks after 42 days were as high as 1120 weeds/m^2 for the tilled surface and 1010 weeds/m^2 for the untilled surface (Table 1). Unusually large rainfall amounts in the spring and summer of 1984 contributed to this extreme weed pressure.

Although differences in shattercane populations were significant in only one of six comparisons in the tilled surface, slot injection of Eradicane Extra tended to have less weed control than disk incorporation. When averaged across dates, carrier volumes, and injection pressures, weed control on the tilled surface was 74% for slot injection treatments and 90% for disk incorporation. For the untilled surface, disk incorporation had significantly lower shattercane populations than both slot injection treatments in two of six comparisons (Table 1). The 200 L/ha slot injection treatments tended to have better control than the 100 L/ha slot injection treatments.

There were very few statistical differences in the weed counts for the Sutan+ application methods indicating that slot injection had weed control comparable to disk incorporation (Table 2). In both the tilled and untilled surface conditions with 200 L/ha carrier volume, there was a trend of better weed control with slot injection than with disk incorporation.

Sutan+ was not as effective in controlling shattercane as Eradicane Extra at the 10 and 21 day week counts. However, at the 42 day count, weed control for the two herbicides were similar.

In the soybean plots, weed counts for the different

TABLE 1. WEED COUNTS AND PERCENT CONTROL FOR VARIOUS HERBICIDE APPLICATION METHODS AND DIFFERENT SURFACE CONDITIONS USING ERADICANE EXTRA (EPTC + R-25788 + R-33865) IN 1984

	Weed count					
	10 day		21 day		42 day	
Treatment	Weeds per m^2	Percent* control	Weeds per m^2	Percent control	Weeds per m^2	Percent control
Tilled surface						
100 L/ha						
slot injection-350 kPa	92 b	66	460 b	58	320 b	76
slot injection-700 kPa	74 b	72	400 b	63	300 b	74
double disk incorporate	1 c	99	140 b	87	150 b	87
no-chemical	270 a	—	1080 a	—	1120 a	—
200 L/ha						
slot injection-350 kPa	55 b	79	220 b	80	150 b	87
slot injection-700 kPa	79 b	71	270 b	75	140 b	87
double disk incorporate	7 b	97	170 b	84	110 b	90
no-chemical	270 a	—	1080 a	—	1120 a	—
Untilled surface						
100 L/ha						
slot injection-350 kPa	91 b	63	910 ab	30	390 bc	61
slot injection-700 kPa	72 b	71	730 b	43	500 b	51
double disk incorporate	1 c	99	170 c	87	150 c	86
no-chemical	250 a	—	1290 a	—	1010 a	—
200 L/ha						
slot injection-350 kPa	81 b	67	450 b	65	240 bc	77
slot injection-700 kPa	130 b	47	500 b	61	440 b	57
double disk incorporate	16 b	94	260 b	80	63 c	94
no-chemical	250 a	—	1290 a	—	1010 a	—

*Percent control to no-chemical check.

a,b,c: Values within each column for each carrier volume for a given surface condition having the same letters were not statistically different (Duncan's Multiple Range Test, 10% level). As presented, statistical comparisons of weed control among surface condition and carrier volume groups cannot be made.

TABLE 2. WEED COUNTS AND PERCENT CONTROL FOR VARIOUS HERBICIDE APPLICATION METHODS AND DIFFERENT SURFACE CONDITIONS USING SUTAN+ (butylate + R-25788) IN 1984

	Weed count					
	10 day		21 day		42 day	
Treatment	Weeds per m^2	Percent* control	Weeds per m^2	Percent control	Weeds per m^2	Percent control
Tilled surface						
100 L/ha						
slot injection-350 kPa	430 a	8	480 a	23	290 b	70
slot injection-700 kPa	420 a	11	620 a	1	300 b	67
double disk incorporate	260 a	44	440 a	29	200 b	77
no-chemical	470 a	—	630 a	—	900 a	—
200 L/ha						
slot injection-350 kPa	320 ab	33	480 a	23	150 b	83
slot injection-700 kPa	180 b	61	310 a	50	200 b	78
double disk incorporate	230 ab	50	540 a	14	440 b	52
no-chemical	470 a	—	630 a	—	900 a	—
Untilled surface						
100 L/ha						
slot injection-350 kPa	470 a	3	500 a	0	250 b	71
slot injection-700 kPa	360 a	25	410 a	14	250 b	71
double disk incorporate	250 a	49	290 a	38	180 b	79
no-chemical	480 a	—	470 a	—	870 a	—
200 L/ha						
slot injection-350 kPa	510 a	0	470 b	0	240 b	73
slot injection-700 kPa	280 a	43	410 b	13	250 b	72
double disk incorporate	530 a	0	980 a	0	630 ab	28
no-chemical	480 a	—	470 b	—	870 a	—

*Percent control compared to no-chemical check.

a,b,c: Values within each column for each carrier volume for a given surface condition having the same letters were not statistically different (Duncan's Multiple Range Test, 10% level). As presented, statistical comparisons of weed control among surface condition and carrier volume groups cannot be made.

TABLE 3. WEED COUNTS AND PERCENT CONTROL FOR VARIOUS APPLICATION METHODS AND DIFFERENT SURFACE CONDITIONS USING VERNAM (VERNOLATE) WITH 200 L/ha CARRIER IN 1984

	Weed count					
	10 day		21 day		42 day	
Treatment	Weeds per m^2	Percent* control	Weeds per m^2	Percent control	Weeds per m^2	Percent control
Tilled surface						
slot injection-700 kPa	20 b	85	29 b	91	17 b	95
double disk incorporate	8 b	94	4 b	99	13 b	96
no-chemical	140 a	––	330 a	––	370 a	––
Untilled surface						
slot injection-700 kPa	22 b	84	37 b	91	10 a	98
double disk incorporate	22 b	84	20 b	95	23 a	94
no-chemical	140 a	––	400 a	––	390 a	––

*Percent control as compared to no-chemical check.

a,b,c: Values within each column for a given surface condition having the same letters were not statistically different (Duncan's Multiple Range Test, 10% level).

herbicide application methods were not statistically different indicating that weed control with slot injection of Vernam was comparable to that of disk incorporation (Table 3).

Observed in both 1983 and 1984, the band of weed control was not as wide as assumed in the initial design of the applicator. Many plots had shattercane plants infringing on the edges of the 25 cm band and thus were included in the weed counts even though a band of control was evident. Some plots also had a distinct line of shattercane plants down the middle of the band. This indicated that the principle did work, but in the soil conditions encountered, the herbicide did not have enough lateral movement to achieve a 25 cm band of control.

Depth and Spacing Studies, 1985

For the 14 day weed control evaluation, the 15.2 cm coulter and nozzle spacing (7.6 cm from the row) for both the 5 and 7.6 cm depths had significantly poorer weed control than any of the other treatments with Eradicane Extra (Table 4). The 15.2 cm spacing at the 7.6 cm depth had significantly poorer weed control for the 26 day visual evaluation. With the 15.2 cm spacing, shattercane plants grew between the corn plants within the row in the center of the band. As observed in 1984, it appeared that the herbicide did not move far enough to provide a complete band of control. Weed control with slot injection at 10 and 12.7 cm spacing was the same as with disk incorporation and better than the no-chemical check. Visual observations showed that the herbicide provided good weed control in a 20 cm band rather than the initially assumed 25 cm band.

CONCLUSIONS

Slot injection of thiocarbamate herbicides provided weed control within a 20 to 25 cm band which was comparable to conventional double disk incorporation methods. The slot injector, working on tilled and untilled surface conditions, placed the herbicides into the soil with minimal disturbance of the soil and residue. The herbicide, injected into a 7.6 cm deep slot created by a coulter, diffused approximately 6 cm to each side. Thus, two coulters, 10 to 12 cm apart, centered on the row with herbicide injected behind them, should provide a band of weed control 20 cm wide.

Chemical costs could be reduced by two-thirds because slot injection allows normally broadcast thiocarbamate herbicides to be band applied. Placing the herbicide directly into the soil also eliminates the need for the two tillage passes normally required for incorporation. Fuel, labor and machinery costs are reduced while residue is left on the soil surface for erosion control.

Using slot injection permits thiocarbamate herbicides, to be used without tillage, making slot injection an ideal match for no-till and ridge-till systems. In addition, by mounting the slot injector on the planter, the application of thiocarbamate herbicides can be accomplished in a

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TABLE 4. PERCENT WEED CONTROL FOR VARIOUS SLOT INJECTION DEPTHS AND SPACINGS FOR ERADICANE EXTRA (EPTC + R-25788 + R-33865) IN 1985

	Percent weed control		
Treatment	14 day visual	26 day visual	26 day actual*
Slot injection			
5.0 cm depth			
10.0 cm spacing	95.3 a	95.8 a	89.4 a
12.7 cm spacing	95.8 a	94.8 a	94.7 a
15.2 cm spacing	86.8 b	91.5 a	85.5 a
7.6 cm depth			
10.0 cm spacing	95.0 a	93.3 a	92.7 a
12.7 cm spacing	96.3 a	97.8 a	93.8 a
15.2 cm spacing	83.8 b	81.8 b	61.1 a
Double disk incorporate	98.8 a	93.8 a	88.5 a
No-chemical	0 c	0 c	0 b

*Actual weed counts taken and percent control calcul: ted based on 114 shattercane plants per square meter average in the no-chemical check plots.

a,b,c: Values within each column having the same letters were not statistically different (Duncan's Multiple Range Test, 10% level). No statistical differences measured in weed control between depths for each spacing or between spacings for each depth for the injection treatments.

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one-pass planting system. Weeds between the rows could be controlled with timely crop cultivation. The cultivation operation makes this herbicide application method a good match for a ridge-or till-plant system where cultivation is necessary to rebuild the ridges.

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