BAND INJECTION OF HERBICIDES FOR REDUCING ENVIRONMENTAL LOSSES

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Introduction

Herbicides can be an important component for weed control in profitable crop production when selected and used properly. When herbicides are incorrectly applied, however, losses to the atmosphere, surface water, and ground water can be the result. Banding as opposed to broadcast application can reduce herbicide input, but losses of herbicides to the atmosphere during spray application can still be substantial, particularly on windy days (Tremwel, 1985). In addition, herbicide applied directly to crop residue is subject to greater volatilization losses (Burt, 1974; 1987). Crop residue with conservation tillage reduces water and sediment losses, and thus can be an effective tool for reducing herbicide runoff losses, although herbicides surface-applied to crop residue may be subject to greater volatilization and runoff losses (Baker et al., 1982; Baker and Johnson, 1979; Kenimer et al., 1987; Laflen et al., 1978).

With greater amounts of residue being left on the soil surface with conservation tillage, a problem arises of not being able to uniformly distribute or incorporate herbicides within the soil profile with tillage without destroying some of the residue (Colvin et al., 1981). In some cases this has resulted in higher herbicide application rates, thus resulting in increased herbicide losses into the surface and ground water (Hallberg, 1986).

Incorporation of herbicides into the soil profile can significantly reduce losses due to runoff, volatilization, and photodecomposition. Incorporation likewise often increases the effectiveness of weed control, since there is a higher probability that the herbicide will come in contact with the weed seedling or seed. With uniform placement of herbicide, there should be less chemical required for effective weed control.

Erbach et al. (1976) found greater weed control when herbicides granules were uniformly distributed within the soil profile. Uneven applications from commercial granule applicators theoretically required 2 to 4 times the rate necessary for weed control when compared to an even distribution of herbicide granules.

In a leaching study, Kay (1989) researched the effects of ridge tillage and application methods on agricultural chemical leaching by using leachate collectors placed 47 cm below the soil profile. Herbicides applied in the field study included metolachlor and atrazine. Kay found that broadcast application of both herbicides resulted in significantly higher percentage losses compared to band application during a 10 cm rainfall event. The maximum percent of band-applied atrazine that was lost with drainage water for the ridge-tilled plots was 0.55.

Since the goal of conservation tillage is to leave as much residue on the soil surface as possible to prevent erosion, incorporation of herbicides without reducing the surface residue is a major stumbling block. Recent and past research has looked at new methods of applying herbicides uniformly in the soil profile while destroying as little of the crop residue as possible (Bode and Gebhardt, 1969; Dawelbeit, 1983; Dowler and Houser, 1970; Ehmke, 1984; Fenster et al., 1962; Khalifa et al., 1983; Solie et al., 1983; Wooten and McWhorter, 1961; Wooten et al., 1966).

Considering the facts above, a herbicide band application system that would allow incorporation of herbicides, without spraying and without destroying the crop residue on the surface, would be an effective herbicide management tool. By using a point-injector cylinder with several spokes that poke through the soil (or crop residue, in the case of conservation tillage), herbicides could be accurately placed in the soil to give a pattern uniformly covering a specific banded area. This point injection system could be effective then in reducing herbicide inputs and losses to the environment during and after application.

Objectives

With an overall goal of efficiently applying herbicides in order to reduce environmental losses, the objectives for the portion of the study reported here were two-fold:

1. To develop and implement the design for a point injection system that could:

    (a) inject herbicides in the soil profile desired position without spraying,
    (b) incorporate the herbicide in a single pass through the field, and
    (c) leave the residue on the soil surface (with conservation tillage) virtually undisturbed.

2. To evaluate the use of this point injection system on weed control under field conditions.

Materials and Methods

Design and Construction

The concept design for applying herbicides with some type of point injection system is patterned after the point-injector fertilizer applicator developed at Iowa State University (Baker et al., 1989). This fertilizer applicator injects liquid fertilizer about 10 cm below the soil surface using a single wheel of 12 points spaced 20 apart at the tips. The advantages of this injector wheel "included fertilizer incorporation with low power requirements, minimum soil and residue disturbance, and additional timing and placement options for efficient fertilizer management."

In the initial phase of this project, an "applicator cylinder" for injecting pesticides (in a liquid form) into the soil was designed and constructed. This spoked wheel is similar to the point-injector fertilizer applicator (Baker et al., 1989), but with many more rows of spokes. The point-injector cylinder (PIC) was designed for band application of preemergent pesticides. Figure 1.1 shows the first configuration designed and fabricated for field testing. The second generation point injection cylinder is shown in Figure 1.2.

Both of these designs are made of an 17.8 cm high-density polyethylene rod, with a 3.8 cm brass axle. These materials have been chosen for their noncorrosive and low absorption characteristics. The points for injecting the pesticide are made of 0.48 cm brass rod. Design one (Figure 1.1) has a total of 44 points in four rows that cover a 20 cm band, with each point designed to have an effective radius of influence of 2.5 cm. The second design (Figure 1.2) has 176 points, with each point having an effective radius of 1.3 cm. The points extend 3.3 cm beyond the polyethylene rod with a 1.6 mm hole drilled to within 7.6 mm of the tip. At this point a 1.5 mm hole is drilled perpendicular to the bored hole to effectively inject the pesticide 2.5 cm below the soil surface (Figure 1.3). This depth has previously been found to be the optimum depth of soil incorporation for many of the common soil incorporated herbicides, such as: EPTC, trifluralin, atrazine, propachlor, and chloramben (Knake et al., 1967).

The hole for the injection was determined to be the most effective size in order to decrease the probability of plugging. This was determined using various size holes in field tests. The L-shaped channel in the points reduces the soil pressure exerted at the hole, therefore decreasing the chances for plugging.

The axle has a manifold on each side of the wheel that splits the liquid to each row of points (Figure 1.4). The axle is fed with liquid on each end through polyethylene tubing at pressures ranging from 140 to 551 kPa (higher pressures are possible). The points are offset so that only one point is injecting at a time. This way each point can effectively inject an equal volume of liquid. Injection takes place when the points are in alignment with the manifold opening in a down position. The scrapers shown in Figure 1.1 and Figure 1.2 are made of 4.8 mm flat steel, and are attached to keep residue, clods, rocks, and other debris from interfering with the function of the injector.

A third design varies every other point length in order to distribute the herbicides better within the soil profile. This design uses 2.5 cm and 1.3 cm point lengths (Figure 1.5). O-rings were also added 3 cm from each end of the axle to decrease the possibility of liquid pesticide escaping at the ends of the cylinder. The rest of the features are the same as the second design

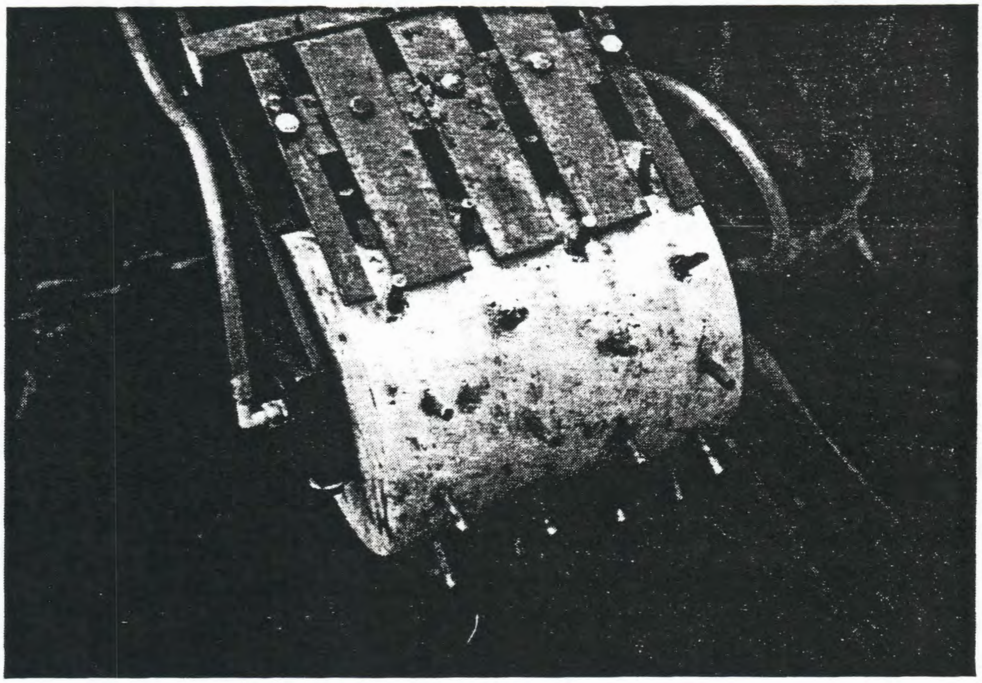

Figure 1.1: Point-injector cylinder with 5 cm point spacing

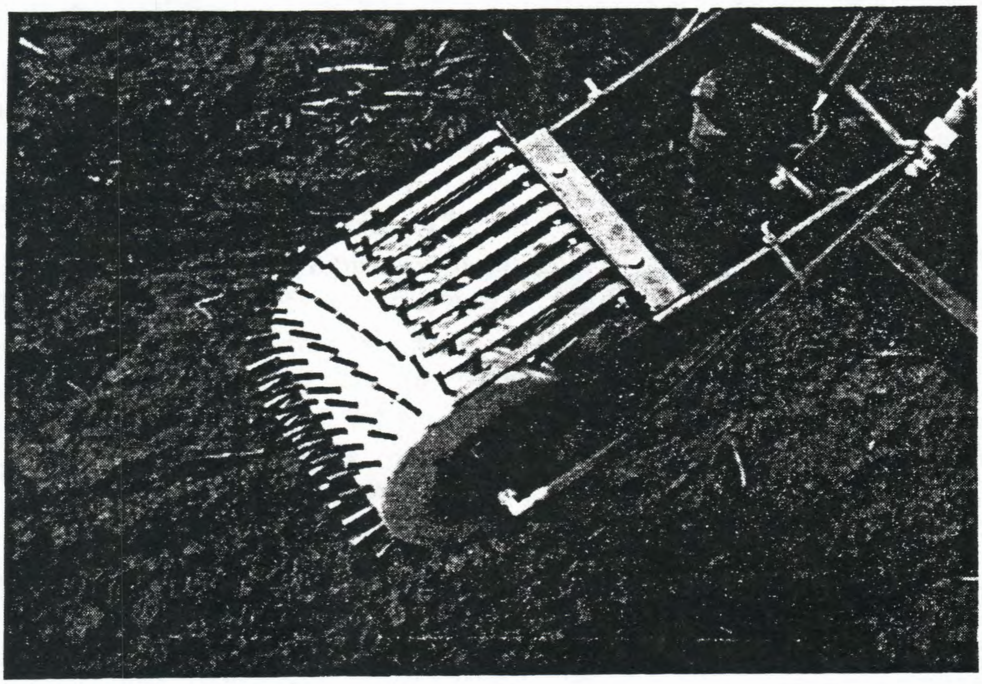

Figure 1.2: Point-injector cylinder with 2.5 cm point spacing

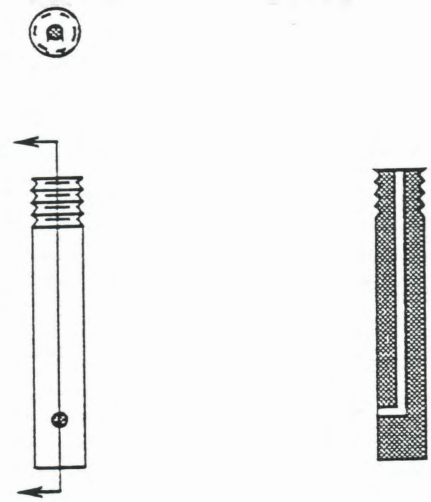

Figure 1.3: Injection point

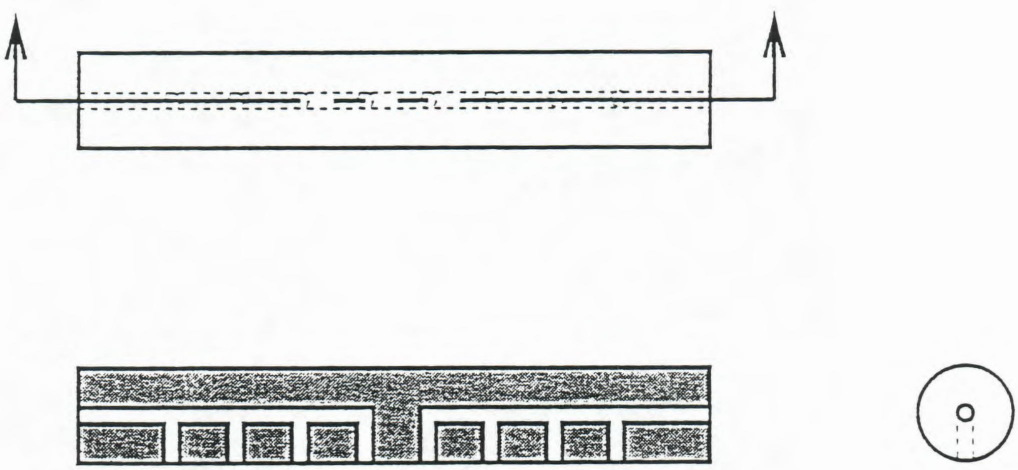

Figure 1.4: Point-injector axle

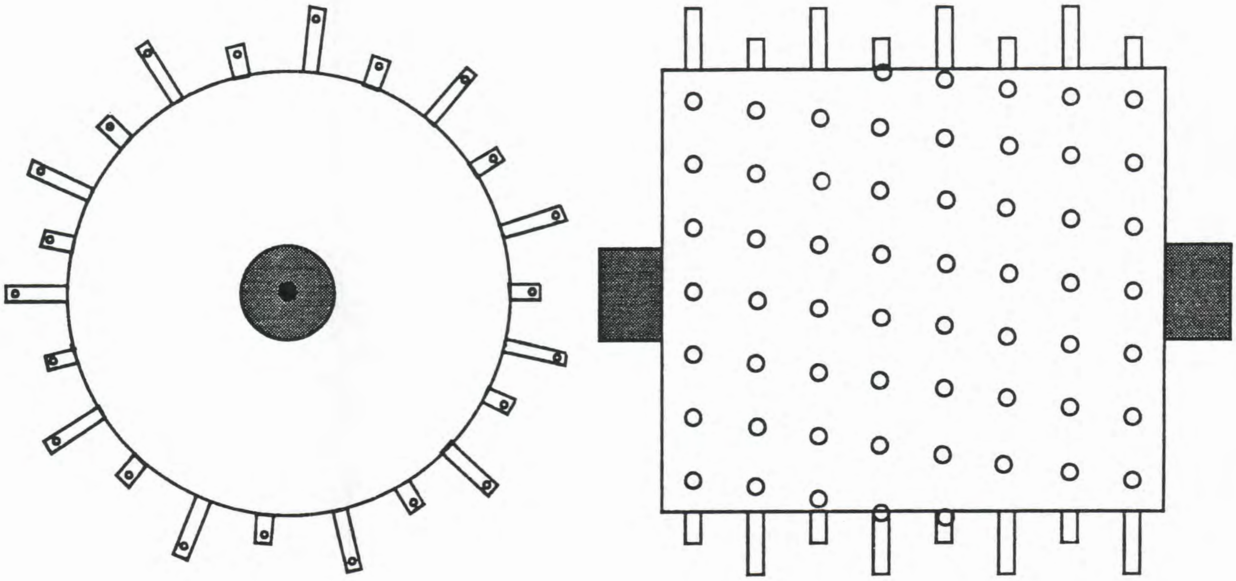

Figure 1.5: Varying point length design

Figure 1.6: Fourth generation design attached to a planter

A design with varying 2.5 cm and 5 cm point lengths was tested in the field, but point breakage occurred at the cylinder surface. Thicker point walls or stronger point material could make this design function better in the future.

During the summer of 1991 four new PIC's were constructed using 2.5 cm stainless steel points. These points were made from 6.35 mm hollow stainless steel rod with a 2.4 mm hole. The one end was spot welded and ground to a point, and the other end was threaded to mate with the polyethylene cylinder. Brackets were designed and manufactured to mount this new generation PIC to a five row planter for field testing. The total set up of this fourth generation PIC is shown in Figure 1.6.

Due to the labor involved with manufacturing the points, several design modifications have been considered. One version uses a tight fit screw for plugging one end of the hollow tubing, and leaves off the threading on the other end. The points would then be force fit into the polyethylene rod. This would allow more of the manufacturing to be done on a NC-lathe, thus saving time and money.

Effectiveness Studies - 1989

Work was performed in the summer of 1989 to develop preliminary information on the effect of herbicide injection in points on weed control. This initial study used atrazine, alachlor, propachlor, butylate, and EPTC on oats as a test species. The application for each of these herbicides was 2.2, 2.2, 2.2, 3.4, and 0.56, respectively. Webster oats were used as the test species, and were planted using a grain drill. The herbicides were all applied immediately after the oats were planted. Treatments included broadcast spray followed by disc incorporation, and band injection. A treatment with no herbicide applied was also included as a check. Four replications were made for each herbicide/treatment combination, requiring a total of 44 plots. The PIC used was design 1 (Figure 1.1), with the 5 cm point spacing. The PIC was pulled behind a tractor, attached to a spring loaded bracket system. The bracket system included set of pillow blocks that attached to each side of the axle to hold it in position. Oat counts within a 20 cm x 60 cm area were made in three positions within each plot 7, 14, and 21 days after planting and herbicide application.

The results from this effectiveness study and growth chamber study showed that the point spacing would have to be closer for the point injector to be more effective. Using the re-designed point-injection cylinder shown in Figure 1.2 with 176 spokes, a similar study was conducted (the 'sphere of influence' of each point had to have a radius of 1.3 cm to provide control over the total 20 cm banded area). Herbicides were either applied with a broadcast sprayer, followed by a disk, or the PIC to areas planted to a test species of Webster blend oats. The oats were planted with a broadcast oat seeder after field cultivation and then followed by a coulter-packer. Observations were made as to the relative control of the oats using the herbicides atrazine, EPTC, butylate, and trifluralin. The application rates applied were 2.2, 2.2, 3.4, and 0.56 kg/ha respectively. A spray or injection volume of 187 L/ha was used. A check treatment was also included for comparison. Four replications of each treatment were set up. The herbicides were tested individually to detect differences in spheres-of-influence, if any. Three 20 cm x 60 cm areas were set up within each plot for counting the oat population. Oat counts were made 11, 17, and 29 days after emergence.

Effectiveness Study - 1990

A similar effectiveness study was conducted in the field the following year (summer of 1990). This time two different PIC designs were used to apply the herbicides. The 176-point-injection cylinder with the uniform 2.5 cm injection depth was used with trifluralin, butylate, and EPTC. The other PIC used also had 176 points, but the points alternated from a 2.5 cm injection depth to a 1.3 cm injection depth. The new design was used with atrazine and alachlor. Each cylinder was attached to a spring-loaded cultivator sweep, that was attached to a 3-point hitch bar. Higher rates were used for most of the herbicides, and the spray or injection volume was increased to 561 L/ha. The increased volume was to help insure little or no plugging of the injection points. Application rates for atrazine, EPTC, butylate, and trifluralin were 3, 3, 3, 1.25 and 0.5 kg/ha respectively. With the exception of not coulter-packing the oats, the rest of the procedures were the same as the year before.

Effectiveness Study - 1991

In the spring of 1991, a 2.5-ha field was planted to corn using a five row John Deere planter with the fourth generation PIC's attached to it. Every other set of five rows were either band sprayed or band injected with alachlor and cyanazine behind the planter. A PIC was left off of the center row of the planter to represent a check treatment. Eight passes, 390 meters in length, were made with the PIC's and the band sprayers. Approximately 2.2 kg/ha and 2.9 kg/ha of each herbicide were applied to the band sprayed and band injected treatments, respectively. The difference was due to the higher line pressures required to insure no point plugging because of the high moisture content of the soil, and was not intentional. An injection volume of 842 L/ha was applied using line pressure of 410 kPa for 5 passes. The tractor and planter were moving at a velocity of 9.6 km/h. Two other injection passes using a line pressure of 210 kPa and a tractor speed of 6.4 km/h were made, thus the injection volume was 910 L/ha. The other pass was made using a line pressure of 280 kPa and a tractor speed of 8 km/h, with an injection volume of 690 L/ha. The field was treated with the burn down herbicide glyphosate with crop oil before planting. Weed counts were made 25 days after planting. Six weed counts in an area of 60 cm x 20 cm were made for each corn row.

Tables 1.1, 1.2, and 1.3 give the average oat counts for the application method and herbicide combinations. The oats counts are shown for 7, 14 and 21 days after planting and herbicide application. Seven days after herbicide application (Table 1.1), the herbicides propachlor, EPTC, butylate, and trifluralin were already starting to effectively control the oats when disk incorporated. Only butylate showed any significant difference from the check count, for the band-injected herbicides. By the fourteenth day after application (Table 1.2), all the disk-incorporated herbicides were showing adequate control. Atrazine, butylate, and trifluralin also showed significant control when band injected, but were significantly worse than the disked treatments. The final count (Table 1.3) shows that for all the herbicides, except propachlor, the disk incorporated treatments performed significantly better than the band injected treatments. Yet, atrazine, EPTC, and butylate did show significant differences when band injected as compared to the check treatment.

Although some effectiveness was found using the 5 cm point spacing, it was not as good as had been hoped for. It was at this time that a new design with a closer point spacing was created.

During the next effectiveness study, when using the second design with 2.5 cm point spacing, it was discovered that the injector showed some effectiveness in controlling the oats only when using butylate and EPTC. Little or no control was detected with trifluralin or atrazine. Oat counts within the 20 cm x 60 cm areas were made 17, 24, and 34 days after planting. Oat counts were taken later than that in the first study because of the dry soil conditions causing later germination of the oats. Tables 1.4, 1.5, and 1.6 show the average oat counts for the two application methods and the four herbicides applied. Atrazine, butylate, and EPTC for both application methods showed significantly lower oat counts in the rectangular test area when compared to the check areas. Trifluralin was found to be ineffective in controlling the oats when band injected, but was effective when sprayed and incorporated. Although the oat count for the sprayed/disked atrazine areas was high 17 days after planting, the count changed drastically by day 24. Within 24 days after planting, the sprayed/disked plot all had better control in comparison to the injected areas. Even so, there was no significant difference between the application methods on the oat control when using EPTC, atrazine, or butylate. EPTC gave by far the best control for both application methods. By day 34 after planting, no change in control from the previous count was noticeable for any of the herbicides and application methods.

It was determined that back-pressure at the injector points was causing smaller volumes of the herbicides to be applied. Less than the desired application rate was actually being applied in some cases, depending on the soil conditions. This problem was corrected and the study was run again the following year (1990).

The effectiveness study of 1990 was run as a completely randomized field study. Five herbicides were used; alachlor, atrazine, butylate, EPTC, and trifluralin. The application methods were band injection and broadcast spraying with disk incorporation. The average oat counts for 20 cm x 60 cm areas within the plots, two weeks and three weeks after planting and herbicide application, are given in Table 1.7 and Table 1.8, respectively.

No significant difference was found between the application methods for the herbicides atrazine, alachlor, butylate, and EPTC. This indicates that the band injector was equally effective in controlling oats when compared to the sprayed/disked treatment. For trifluralin, the sprayed/disked treatment was significantly more effective in controlling the oats. This could be due to the fact that trifluralin has a high adsorption coefficient, and is not highly mobile in the soil once incorporated. Since the point injector places the herbicide at a point, the trifluralin was not distributed uniformly within the soil profile enough to be as effective. Disking would distribute the herbicide more uniformly in the soil profile. EPTC had significantly better control for both application methods when compared to the other herbicide treatments.

It should be noted that design 2 (Figure 1.1) was used with the herbicides: butylate, EPTC, and trifluralin. Design 3 (Figure 1.2), with variable point lengths, was used with atrazine and alachlor.

Atrazine showed better control 14 days after planting for the band-injected plot, but seven days later no significant difference was found between the band-injected plots and the sprayed/disked plots. Shallow incorporation of atrazine and alachlor by the varied point length injector design was effective in controlling the oats. No comparison was made against the uniform 2.5 cm point length design to see if there would be a large difference in control, although this could be done in future studies.

Table 1.9 shows the results from the 1991 weed control effectiveness study. In this field study the injector wheels functioned very well, even in wet soil. The wheel worked best on the ridge when the top of the ridge was not disturbed, and the surface was dry. Soybean residue from the previous years crop caused no problems for the injector. The wheels did ball up with mud when passing through a wet mud hole that had just been field cultivated. This caused plugging of the points.

Although different application volumes and line pressures were used in the 1991 study with the PIC, approximately 2.9 kg/ha of alachlor and cyanazine was applied on all the plots. The band-sprayed plots had approximately 2.2 kg/ha of alachlor and cyanazine applied. The differences in application rate were not intentional. No significant difference was found between the two band application methods. Both methods gave good weed control within the banded area. Slightly better control can be seen with the band injector, but this could be due to the slightly higher application rate of alachlor and cyanazine.

Table 1.1: Herbicide application effectiveness when controlling oats in a field setting (7 days after planting), 5 cm point spacing, 1989

Application Method	Oat count for herbicide -				
	Atrazine	Butylate	EPTC	Propachlor	Trifluralin
Band Injected	34	28	33	38	34
Sprayed/Disked	32	4	2	29	16
Check	37	37	37	37	37
LSD, 5%	7	7	7	7	7

Table 1.2: Herbicide application effectiveness when controlling oats in a field setting (14 days after planting), 5 cm point spacing, 1989

Application Method	Oat count for herbicide -				
	Atrazine	Butylate	EPTC	Propachlor	Trifluralin
Band Injected	19	17	23	26	22
Sprayed/Disked	4	2	0.5	20	4
Check	28	28	28	28	28
LSD, 5%	6	6	6	6	6

Table 1.3: Herbicide application effectiveness when controlling oats in a field setting (21 days after planting), 5 cm point spacing, 1989

Application Method	Oat count for herbicide - Atrazine	Butylate	EPTC	Propachlor	Trifluralin
Band Injected	14	11	15	16	17
Sprayed/Disked	0.5	1	0	12	1
Check	22	22	22	22	22
LSD, 5%	7	7	7	7	7

Table 1.4: Herbicide application effectiveness when controlling oats in a field setting (17 days after planting), 1989

Application Method	Oat count for herbicide - Atrazine	Butylate	EPTC	Trifluralin
Band Injected	57	31	20	69
Sprayed/Disked	63	13	1	29
Check	77	77	77	77
LSD, 5%	7	7	7	7

Table 1.5: Herbicide application effectiveness when controlling oats in a field setting (24 days after planting), 1989

Application Method	Oat count for herbicide - Atrazine	Butylate	EPTC	Trifluralin
Band Injected	52	39	17	69
Sprayed/Disked	36	12	0	25
Check	74	74	74	74
LSD, 5%	19	19	19	19

Table 1.6: Herbicide application effectiveness when controlling oats in a field setting (34 days after planting), 1989

Application Method	Oat count for herbicide - Atrazine	Butylate	EPTC	Trifluralin
Band Injected	56	38	16	68
Sprayed/Disked	40	15	0	22
Check	74	74	74	74
LSD, 5%	18	18	18	18

Table 1.7: Herbicide application effectiveness when controlling oats in a field setting (14 days after planting), 1990

Application Method	Oat count for herbicide - Atrazine	EPTC	Alachlor	Butylate	Trifluralin
Band Injected	19	5	17	19	23
Sprayed/Disked	32	5	16	24	14
Check	41	41	41	41	41
LSD, 5%	11	11	11	11	11

Table 1.8: Herbicide application effectiveness when controlling oats in a field setting (21 days after planting), 1990

Application Method	Oat count for herbicide - Atrazine	EPTC	Alachlor	Butylate	Trifluralin
Band Injected	43	7	47	46	45
Sprayed/Disked	45	8	44	56	24
Check	72	72	72	72	72
LSD, 5%	18	18	18	18	18

Table 1.9: Herbicide application effectiveness when controlling weeds in a field setting (24 days after planting), 1991

Application Method	Oat count for herbicides Alachlor & Cyanazine
Band Injected	0.2
Band Sprayed	0.6
Check	8.7
LSD, 5%	1.1

Conclusions

1. A band-injection cylinder has successfully been designed and constructed for applying liquid herbicides into the soil profile up to 2.5 cm in depth. This system mechanically functions well at line pressures ranging from 140 to 410 kPa at speeds up to 9.6 km/h.

2. This band-injection system can incorporate herbicides in a single pass through the field while leaving the soil surface virtually undisturbed. The injector functioned effectively on both bare soil surfaces and soil covered with corn residue.

3. Using results from a growth chamber study and field effectiveness studies, a point spacing of 2.5 cm was determined to be better than a 5 cm spacing for the injector. Point spacings of 5 cm was found to be inadequate for the herbicides used.

4. No significant difference was found between band injection and band spraying methods in controlling oats for the herbicides atrazine, alachlor, butylate, and EPTC. Weed control was significantly higher for trifluralin when disk-incorporated versus injected.

5. Band injection using alachlor and cyanazine adequately controlled weeds in the band when applied behind a planter in a field study. No significant difference was found between the weed control for band injection vs. band spraying.

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