Title: Evaluating land waste application machinery to meet odor and environmental objectives
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Abstract:

Field experiments in no-till soybean and corn residue were conducted to evaluate six liquid swine manure application methods. The methods were: injection with a conventional 1) knife or 2) sweep, 3) incorporation with tandem disk after broadcast application, 4) broadcast application, 5) injection with a narrow-profile knife, and 6) surface application behind row cleaners. The row cleaner and all injection treatments used finger-closing wheels. Air samples over the soil surface were obtained during and after application and residue cover and yield were measured. Odor level was measured by the amount of air dilutions to reach odor threshold. Placement of material into the soil was evaluated with dye.

Incorporation techniques typically reduced odor level by a factor of three to ten as compared to a broadcast application. A day after application, odor was greatly reduced and often indistinguishable from that of untreated soil. Differences among application methods were more pronounced in soybean residue. Application by the narrow-profile knife, row cleaner, and conventional knife maintained soybean residue cover better than other incorporation methods and limited odor similar to these methods. Although cover is reduced over winter, greater soybean residue cover remains after planting with fall than spring applications. Differences among methods in odor level and residue cover were less in corn. All incorporation techniques reduced odor levels and knife incorporation maintained corn residue cover after planting similar to broadcast application. For both crops, broadcast application maintained the greatest residue cover, but had the highest odor level. Material was incorporated five to seven inches deep by the knife, sweep, and narrow knife; two to three inches deep by the tandem disk and row cleaner; and at the surface by broadcast application. Corn yield was generally greater for spring application by incorporated treatments.

Introduction:

Odor from swine operations faces increased public scrutiny. Manure spreading operations have been identified as producing more annoying odor to near-by residents than odor from the livestock facility itself. Some mixing of animal waste with soil can reduce odor as compared to a broadcast application with no incorporation or mixing. In fact, injection techniques may reduce odor to a background level equivalent to odor from an unmanured soil surface.

From a productivity standpoint, mixing manure nutrients with soil through injection or incorporation has resulted in higher yields and reduced nutrient losses in runoff and volatilization to the environment. Unfortunately, although manure injection has been widely adopted as a best management practice to control odor, and minimize runoff and nutrient loss, injection also disturbs soil and reduces residue cover. Maintenance of residue cover is important since a majority of acres are in high-residue systems. More than one in five Iowa row crop acres during 1994 were planted in a no till system; additionally, three of every four acres were planted leaving a soil-protecting surface residue cover. Injection systems reduce corn residue cover. Fragile soybean residue cover is even more difficult to maintain with injection. Applying manure after soybeans and before corn to utilize manure nitrogen is a common practice. Satisfactory methods are necessary to apply manure in an odor-limiting, nutrient-conserving manner with equipment while still maintaining residue cover and soil productivity.

Objectives:

1. Determine the ability of land manure application machinery to reduce odor threshold and to limit emission of ammonia and hydrogen sulfide.
2. Determine the effects of land manure application machinery on reducing surface residue cover.
3. Determine the ability of land manure application machinery to minimize surface exposure of applied material and to adequately distribute manure within the soil profile.

Procedures:

Research with NPPC grant funds was initiated during fall 1996 under project #1607. Treatments included four commercial methods: injection with a 1) two-inch wide knife or 2) 16-inch wide sweep, 3) surface broadcast application, and 4) broadcast application with disk incorporation. One alternate method, row cleaner, applied manure under surface residue and on the soil surface. This was accomplished by moving residue from a narrow strip with a row cleaner, applying manure in a narrow surface band, and then returning residue over the band with closing wheels. A second alternate method injected manure in a shallow band behind a narrow-profile knife designed to minimize soil disturbance.

Two separate field experiments in undisturbed (no till) soybean and corn residue were used each crop season to evaluate changes in residue cover and crop yield. Swine pit manure was field applied at a rate of 5,000 gal/ac at an applicator speed of 5 mi/hr. All six treatments were used in five replicated blocks during both fall and spring (pre-plant) application periods. Residue cover was measured before and after application treatments and also after planting by the line-transect method. Soil was left undisturbed between harvest and planting except for manure application. Crop yield was measured at harvest for all treatments except row cleaner. Because only a single interrow area received a row cleaner manure application on plots of that treatment, a measured yield area for this treatment was not available.

Fig. 1 Odorous air sample being collected by field collection system.

Four additional experiments were used to evaluate odor emission of the six application methods during fall and spring application periods. Manure was applied with the same methods, application rates and seasonal timing as the residue experiments on both undisturbed soybean and corn residue. Odorous air samples were collected from the surface directly after the manure was applied and also one day after treatment (or later depending on field weather conditions). Odor evaluation was conducted in three replicated blocks in order to complete air sampling during a single day's weather conditions in the field. Odorous air was collected using a portable field collection system (figure 1). The procedure for collecting a sample was to blow charcoal-filtered air at a velocity of five mi/hr through a Plexiglas duct that was open at the bottom exposing the air to the manured soil surface. An odorous air sample was drawn from near the end of the duct by transporting air via plastic tubing to a plastic sample bag that opened within a container subjected to a vacuum. The odorous air sample was then transported from the field to a dynamic olfactometer for evaluation of odor threshold, and ammonia and hydrogen sulfide concentrations. Odor level was measured in odor units. Odor units are the average number of dilutions of fresh air required to obtain an undetectable odor (below threshold) for four odor panelists.

The ability of equipment to incorporate applied material below the soil surface and monitor distribution within the soil was studied in another experiment by application of a dye mixture. All treatments were applied in three replicated blocks. A bare soil surface and blue dye/water mixture were used to allow areas of dye to be observed in the soil. Photographs of the soil surface and of soil cross-sections perpendicular to injector travel were analyzed for distribution of the application.

Results:

Data were analyzed statistically. Within columns of the tables of results, different letters following values indicates that there is a 95% certainty that treatment values are different.

The percentage of residue cover remaining after all treatments is shown in tables one and two. Broadcast application with no incorporation had the greatest residue cover. Although spring applications allowed residue cover to remain undisturbed over winter, less soybean residue cover was present after most field operations with a spring application strategy. In fragile soybean residue cover, the two alternative application methods (row cleaner and narrow knife) and the conventional knife, left about 20 percentage points more cover than a sweep or disk incorporation, but about 25 percentage points less cover than the broadcast only treatment. After planting, differences were less but still measurable.

Table 1. Soybean residue cover (percent)

Treatment	1996-7 After manure application	1996-7 After planting	1997-8 After manure application	1997-8 After planting
Season				
Fall	68a	55a	44a	43a
Spring	45b	43b	32b	30b
Application				
Broadcast	82a	72a	68a	47a
Row cleaner	69b	54b	42b	43ab
Narrow knife	63c	54b	33cd	37bc
Disk incorporate	31f	27c	17e	22d
Sweep	40e	34c	28d	33c
Knife	52d	53b	38bc	38bc

In corn residue, the range of differences between treatments was narrower. Also, in the less-fragile corn residue, the advantage of the two alternative systems to leave more residue cover was not as apparent. There was still a tendency, however, for the alternative treatments and conventional knife to leave more residue cover than the disk or sweep treatments. After manure application, the sweep treatment left about 30 percentage points less residue cover and the row cleaner, narrow knife, and knife treatments about 20 percentage points less residue cover than did the broadcast treatment. The disk treatment reduced cover much less the first year than the second year. After planting, the knife treatment had residue cover similar to the broadcast treatment. Other treatments had less cover and reacted differently in their ability to maintain residue each year.

Corn yield varied among application treatments and timings, but soybean yield did not (table three). Treatments with incorporation generally had greater corn yield than a broadcast application. Corn yield tended to be greater for spring application treatments than fall application treatments (statistically different the first year).

The odor units measured from air above the soil after manure application on soybean and corn residue are shown in tables four through seven. Different ambient weather and soil conditions as well as odor panel sensitivity differences preclude any direct comparison of odor emission between the four individual fall and spring applications. The odor detection limit of the dynamic olfactometer used for measurement was 43 odor units for the fall 1996 application, 12 odor units for the spring 1997 and fall 1997 applications, and 23 odor units for the spring 1998 application. Cold, windy weather after the fall 1996 application precluded obtaining air samples the day after application from the corn residue experiment and also from one replication of the soybean residue experiment. Air samples were taken from all plots of both soybean and corn experiments five days after the 1996 fall application when air temperature had warmed to above 50°F.

Table 2. Corn residue cover (percent)

Treatment	1996-7 After manure application	1996-7 After planting	1997-8 After manure application	1997-8 After planting
Season				
Fall	77a	60	60	43
Spring	62b	57	62	39
Application				
Broadcast	89a	70a	86a	50a
Row cleaner	71b	60bc	70b	34de
Narrow knife	68b	54cd	60c	43bc
Disk incorporate	65b	50d	30e	30e
Sweep	57c	54cd	50d	40cd
Knife	67b	63ab	68bc	49ab

Table 3. Crop yield of manure application treatments (bu/a)

Treatment	Crop: Corn 1997	Crop: Corn 1998	Crop: Soybean 1997	Crop: Soybean 1998
Season				
Fall	101b	138	33	50
Spring	114a	147	35	52
Application				
Broadcast	87c	132b	36	51
Narrow knife	110ab	145ab	35	52
Disk incorporate	103b	153a	32	52
Sweep	119a	141ab	33	52
Knife	118a	140ab	34	48

When manure was applied on soybean residue, odor from the broadcast application was statistically greater than all other applications at the time of both spring applications and one day after the 1996 fall application. The day of application, broadcast application odor levels were always numerically highest. In the 1997 fall application, odor from the broadcast application was statistically greater than all other treatments but the knife application. As indicated by the amount of air required to dilute the odor to a threshold (odor units), odor level from the broadcast application required four to ten times the dilution to equal odor level from most other applications at or near application during the fall 1996, spring 1997, and spring 1998 applications. At the fall 1997 application, the range of odor levels across treatments was narrower, however statistical differences were measured (table five). Odor levels were considerably lower one day after application (five days in fall 1996) and treatment differences were less. Odor levels were often indistinguishable from odor of untreated soil. In some cases, odor levels were lower than the detection limit.

Table 4. Odor measured from 1996-97 manure application on soybean residue (odor units)

Treatment	Fall			Spring	
	At application	1 day after application	5 days after application	At application	1 day after application
Broadcast	807	876a	63	140a	40
Row cleaner	185	52b	43	61b	44
Narrow knife	173	64b	60	12b	36
Disk incorporate	65	53b	43	26b	13
Sweep	94	60b	43	35b	16
Knife	256	113b	43	33b	43
Untreated soil					12

Table 5. Odor measured from 1997-98 manure application on soybean residue (odor units)

Treatment	Fall		Spring	
	At application	1 days after application	At application	1 day after application
Broadcast	162a	94	1451a	211
Row cleaner	81d	114	45b	158
Narrow knife	85cd	97	181b	87
Disk incorporate	121bc	96	302b	98
Sweep	102bcd	109	181b	64
Knife	128ab	98	257b	72
Untreated soil		94	241b	84

At application on corn residue, broadcast treatment odor level was usually statistically greater than other treatments. With only a single exception (knife, fall 1996), broadcast odor level was numerically greater than all other treatments. Broadcast odor level at application was statistically greater than all treatments during spring 1998. During fall 1996 there was a trend for the conventional knife, broadcast, and narrow knife treatments to be more odorous. During the 1997 spring application, the broadcast and row cleaner treatments produced about four times the odor level of the conventional knife, sweep, and disk incorporation treatments, while the narrow knife produced about twice the level. At the fall 1997 application, the range of odor levels across treatments was narrower (table seven). Odor level from the broadcast application was statistically greater than all other applications except the disk incorporation. When odor was measured one day after application (five days in fall 1996), measured odor values were comparable to that of odor from an untreated soil surface or near the detection limit.

Table 6. Odor measured from 1996-97 manure application on corn residue (odor units)

Treatment	Fall		Spring	
	At application	5 days after application	At application	1 day after application
Broadcast	389	43	216a	30
Row cleaner	67	43	188ab	30
Narrow knife	247	70	106bc	38
Disk incorporate	75	43	56c	25
Sweep	57	43	25c	26
Knife	502	53	16c	18
Untreated soil				12

Table 7. Odor measured from 1997-98 manure application on corn residue (odor units)

Treatment	Fall: At application	Fall: 1 days after application	Spring: At application	Spring: 1 day after application
Broadcast	183a	115	1604a	196
Row cleaner	100bc	86	385b	82
Narrow knife	82c	109	181b	85
Disk incorporate	157ab	91	273b	60
Sweep	122bc	76	136b	38
Knife	116bc	105	121b	73
Untreated soil		118	241b	94

During the fall 1996/spring 1997 crop season ammonia was not detected in any of the air samples above soybean residue and was detected in only two of 72 samples above corn residue. These detections were 0.6 and 1.3 ppm on the day of the 1996 fall application. Because of the low detection rate, ammonia was not measured during the second crop season. No hydrogen sulfide was detected (250 ppb detection limit) in any sample above soybean or corn residue during the first crop season. Additional equipment was obtained, however, to measure hydrogen sulfide to a lower 1 ppb detection limit for the fall 1997 and spring 1998 applications. Hydrogen sulfide concentration of air above the broadcast treatment was numerically greater than all other treatments (statistically greater in five of the eight comparisons, table eight). Other treatments had relatively low concentrations of hydrogen sulfide, often near or below the detection limit.

Incorporation and distribution by various treatments was done by computer image analysis of dye placement into the soil. Images from the plots showed that large amounts of dye were present on the surface with broadcast application, but that almost no dye was detected on the surface with sweep, knife, or narrow knife injection. The centroid of dye placed by these injection techniques was five to seven inches below the soil surface. The row cleaner and disk incorporation treatments both accomplished a shallow incorporation of the dye. These treatments had a small amount of dye visible on the surface and the centroid of dye was two to three inches below the surface.

Table 8. Hydrogen sulfide measured from fall 1997 and spring 1998 manure applications (ppb)

Treatment	Soybean				Corn			
	Fall 1997		Spring 1998		Fall 1997		Spring 1998	
	At applica-tion	1 day after appl.	At applica-tion	1 day after appl.	At applica-tion	1 day after appl.	At applica-tion	1 day after appl.
Broadcast	77a	13a	88	11a	96a	1	50	10a
Row cleaner	0b	0b	4	0b	18b	2	3	0b
Narrow knife	0b	0b	2	0b	0b	0	37	0b
Disk incorporate	5b	1b	0	0b	31b	1	0	0b
Sweep	0b	1b	1	0b	3b	1	0	0b
Knife	0b	1b	1	0b	18b	1	0	0b
Untreated soil		2b	0	0b		1	0	0b

Discussion

As expected, a broadcast (only) application left the most residue cover, but also produced odor levels that were often several times greater than most incorporation treatments (as measured by dilution to threshold). Some incorporation methods effectively reduced odor, yet minimized residue burial compared to others.

When manure application was in fragile soybean residue, there was a greater range among treatments in the amount of soybean residue cover left, and a distinct odor reduction when any treatment other than broadcast was used. The two alternative treatments, narrow knife and row cleaner, had better retention of residue cover than disk or sweep incorporation treatments and emitted moderate amounts of odor comparable to commercial incorporation treatments. They performed well in soybean residue compared with the commercial applications and may have future potential benefit to the swine industry. Among the commercial incorporation techniques of knife, sweep, and disk incorporation, the knife left more residue cover, with hardly any increase in odor compared to the incorporation with sweep or tandem disk.

Corn residue cover remaining after manure application was less dependent on application technique. The conventional knife, narrow knife, and row cleaner treatments tended to leave more residue cover than the sweep or disk treatments but less than the broadcast treatment. After planting, residue cover in conventional knife treatment was greater than other incorporation treatments and similar to that of broadcast. Odor emission in corn residue was generally lower for all incorporation treatments other than broadcast application. Comparing odor emission above corn residue among incorporation treatments, however, no trend was discernible when the results of different applications were compared. Residue coverage and odor emission from the two alternative treatments did not seem to differ as much from other incorporation treatments in corn residue as in soybean residue.

Summary

Recommendations based on this data are:

If odor during application is a concern, avoid broadcast application. Most methods involving some soil incorporation reduced odor levels by 20 to 90% from the odor level emitted after broadcast application. Odor level reduced over time and was often statistically indistinguishable with odor from untreated soil within a single day and in some cases near detection limits.

The choice of a manure incorporation method in soybean residue is more critical to maintaining cover than choice of a method in corn residue. Of the commercial methods observed, a conventional knife left more soybean residue than a sweep or tandem disk. Two alternative methods using a narrow-profile knife or row cleaner left more residue cover after application than commercial methods, and maintained odor reduction. In corn residue, few differences were noted comparing commercial incorporation treatments. After planting, residue cover remaining in the knife treatment was comparable to that in the broadcast application. Treatments other than broadcast almost always reduced odor, however, the ability to reduce odor relative to each other was not consistent.

If odor during application is not a concern and nutrient loss from surface placement can be tolerated, broadcast application maximizes residue cover.