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MANURE APPLICATION EFFECTS ON RESIDUE, ODOR, AND PLACEMENT

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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 knife or sweep, incorporation with tandem disk after broadcast application, broadcast application, injection with a narrow-profile knife, and 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 was 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 four to ten as compared to a broadcast application. Differences among application methods were more pronounced in soybean residue. Application by the narrow-profile knife, row cleaner, and to a lesser extent the conventional knife maintained soybean residue cover better than other incorporation methods and limited odor similar to other incorporation methods. Differences among methods in odor level and residue cover were less in corn. The knife and row cleaner methods maintained greater corn residue cover than other incorporation techniques, but were more variable in odor level. 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.

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 (Noren, 1986). 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 (Noren, 1986).

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 (Schmitt, 1995). 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. 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 (one and two) in undisturbed (no till) soybean and corn residue were used 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 will be measured at harvest.

Two additional experiments (three and four) were used to evaluate odor emission of the six application methods. 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 to five days after treatment depending on 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 (Huang et al., 1996) 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 (five) 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. If a different letter follows values within columns of the tables of results, there is a 95% certainty that treatment values are different.

The percentage of residue cover remaining after all treatments is shown in table 1. Although spring applications allowed residue cover to remain undisturbed over winter, less residue cover was present after most field operations with a spring application strategy. Broadcast application with no incorporation had the greatest residue cover. In fragile soybean residue cover the two alternative application methods (row cleaner and narrow knife) and to a lesser extent the conventional knife left about 25 percentage points more cover than a sweep or disk incorporation, but about 20 percentage points less cover than the broadcast only treatment.

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. After manure application, the sweep treatment left about 30 percentage points less residue cover and the other treatments about 20 percentage points less residue cover than did the broadcast treatment. After planting the knife and row cleaner treatments had about 10 percentage points less cover and other treatments about 15 percentage points less residue cover than the broadcast treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soybean After manure application</th>
<th>Soybean After planting</th>
<th>Corn After manure application</th>
<th>Corn After planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>68a</td>
<td>55a</td>
<td>77a</td>
<td>60</td>
</tr>
<tr>
<td>Spring</td>
<td>45b</td>
<td>43b</td>
<td>62b</td>
<td>57</td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast</td>
<td>82a</td>
<td>72a</td>
<td>89a</td>
<td>70a</td>
</tr>
<tr>
<td>Row cleaner</td>
<td>69b</td>
<td>54b</td>
<td>71b</td>
<td>60bc</td>
</tr>
<tr>
<td>Narrow knife</td>
<td>63c</td>
<td>54b</td>
<td>68b</td>
<td>54cd</td>
</tr>
<tr>
<td>Disk incorporate</td>
<td>31f</td>
<td>27c</td>
<td>65b</td>
<td>50d</td>
</tr>
<tr>
<td>Sweep</td>
<td>40e</td>
<td>34c</td>
<td>57c</td>
<td>54cd</td>
</tr>
<tr>
<td>Knife</td>
<td>52d</td>
<td>53b</td>
<td>67b</td>
<td>63ab</td>
</tr>
</tbody>
</table>

The odor units measured from air above the soil after manure application on soybean and corn residue are shown in tables 2 and 3, respectively. The odor detection limit of the dynamic olfactometer used for measurement was 43 odor units for the fall application and 12 odor units for the spring application. Cold, windy weather after fall 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 application when air temperature had warmed to above 50°F.
When manure was applied on soybean residue, odor from the broadcast application was statistically greater than all other applications at the time of spring application and one day after fall 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. Odor level decreased over time, however, and treatment differences were less. Odor levels of all treatments were considerably lower five days after fall application and just one day after spring application. In some cases, odor levels were lower than the detection limit or comparable to odor of untreated soil. Ambient weather and soil conditions preclude any direct comparison of odor emission from fall and spring applications, however, air temperature during spring application was approximately 10°F warmer and this may have increased the decay rate of odor emission from the soil surface. No ammonia or hydrogen sulfide was detected in any of the samples above soybean residue.

Table 2. Odor measured from manure application on soybean residue (odor units)

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

Odor levels measured above plots in corn residue immediately after fall application were more variable. This precluded detecting statistical differences, although there was a trend for the conventional knife, broadcast, and narrow knife treatments to be more odorous. During spring application, statistical differences were measured among treatments. 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. When odor was measured five days after application in the fall, and one day after application in the spring, measured odor values were near the detection limit or near that of odor from an untreated soil surface. Ammonia was detected in only two of 72 samples, both on the day of fall application, at levels of 0.6 and 1.3 ppm. No hydrogen sulfide was detected (0.25 ppm detection limit) in any sample.

Table 3. Odor measured from manure application on corn residue (odor units)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fall At application</th>
<th>5 days after application</th>
<th>Spring At application</th>
<th>1 day after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td>389</td>
<td>43</td>
<td>216a</td>
<td>30</td>
</tr>
<tr>
<td>Row cleaner</td>
<td>67</td>
<td>43</td>
<td>188ab</td>
<td>30</td>
</tr>
<tr>
<td>Narrow knife</td>
<td>247</td>
<td>70</td>
<td>106bc</td>
<td>38</td>
</tr>
<tr>
<td>Disk incorporate</td>
<td>75</td>
<td>43</td>
<td>56c</td>
<td>25</td>
</tr>
<tr>
<td>Sweep</td>
<td>57</td>
<td>43</td>
<td>25c</td>
<td>26</td>
</tr>
<tr>
<td>Knife</td>
<td>502</td>
<td>53</td>
<td>16c</td>
<td>18</td>
</tr>
<tr>
<td>Untreated soil</td>
<td>74</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Variability is unfortunately inherent when sampling in small, discrete areas with specific ambient temperature and wind conditions during application. Additional data are to be gathered under different field conditions in a second year. Such data will be useful to prove or modify these first year results.

Preliminary analysis of incorporation and distribution by various treatments was done by computer analysis of images 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.

Discussion

Because only a single year of field data has been measured, conclusions in this report should be regarded as preliminary. Field observations from a second year’s experimentation are underway. As expected, a broadcast (only) application left the most residue cover, but also produced odor levels 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 other 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 sweep treatment had less residue cover than other incorporation treatments immediately after application. After planting, residue cover in the row cleaner and conventional knife treatments was greater than other incorporation treatments. Odor emission in corn residue was generally low for the three commercial incorporation treatments of tandem disk, knife, and sweep with the exception of the fall knife application. The two alternative treatments did not seem to offer as much advantage over other incorporation treatments in corn residue as they did in soybean residue.

Summary

A second year of research is underway. Preliminary recommendations based on this year’s data are:

If odor during application is a concern, avoid broadcast application. Most methods involving some soil incorporation reduced odor level by a factor of four to eight. Odor level reduced over time and in some cases was at detection limits and statistically indistinguishable with odor from untreated soil within a single day.
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. The knife and row cleaner tended to leave more residue cover, but had greater variation in odor levels.

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

References

