Effect on Residue Cover and Crop Yield of Manure Incorporation Equipment

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Species: Swine, Dairy, Beef
Use Area: Land Application
Technology Category: Manure injection/incorporation
Air Mitigated Pollutants: Odor, Hydrogen Sulfide

Description:

Odor from livestock production faces increased public scrutiny. Manure spreading has been identified as producing more annoying odor to nearby residents than does the livestock facility itself (Noren, 1986; Janni et al., 2000). Some mixing of animal manure with soil reduces odor as compared with a broadcast application with no incorporation (Noren, 1986). In some cases, injection techniques may be able to reduce odor to a background level equivalent to odor from an unmanured soil surface. From a crop productivity standpoint, mixing manure nutrients with soil through injection or incorporation often results in greater yields and reduced nutrient losses in runoff and volatilization to the environment (Sawyer et al., 1991; Schmitt et al., 1995; Warnemuende et al., 1999).

Although manure incorporation has been widely adopted as a best management practice to control odor and minimize runoff and nutrient loss, incorporation also disturbs the soil and reduces residue cover. Maintenance of residue cover is important for control of soil erosion. In some locations a majority of acres need to maintain high surface residue cover for adequate erosion protection. Soil-disturbing operations typically reduce residue cover (Colvin et al., 1986), however different soil-engaging tools (e.g. discs, knives) on an implement can partially mitigate the amount of residue buried (Hanna et al., 1995). Incorporation systems reduce corn residue cover (Block et al., 1995). Fragile soybean residue cover is more difficult to maintain than is corn residue cover. Applying manure after soybeans and before corn to utilize manure nitrogen in a U.S. Midwestern row-crop system is a common practice.

Mitigation Mechanism:

Odor mitigation is accomplished by placement of manure below or within the soil surface. Hanna et al. (2000) measured effects of six different liquid application techniques with swine manure in both fall and spring applications on odor, corn and soybean residue cover, and crop yield in a corn-soybean crop rotation. Application treatments included injection with a: 1) 30-mm (1.25-in.)-wide narrow or no-till-style knife, 2) 50-mm (2-in.)-wide chisel or 3) 410-mm (16-in.)-wide sweep. Other application treatments included: 4) surface broadcast with immediate tandem-disk-harrow incorporation, 5) banding manure under residue but on the soil surface (“under residue”),and as a control comparison, 6) surface broadcast. The under residue treatment consisted of parting surface residue with a set of finger-wheel row cleaners, applying a band of manure on the soil surface, then using a set of finger-type closing wheels to pull surface residue with incidental amounts of soil back over the applied manure band. Manure was injected at a depth of 130 mm (5 in.) by the chisel, sweep, and narrow knife treatments. Soil was tilled to a shallow depth of 76 mm (3 in.) by the tandem disk harrow in order to minimize residue burial in the disk incorporation treatment. In the under residue treatment, manure was surface applied, but underneath crop residue with minimal disturbance of the soil surface.

As expected, a broadcast (only) application without incorporation left the most residue cover, but also produced odor levels that were often several times greater than most incorporation treatments (as measured by dilution of air to a threshold odor that was barely detectable). Hydrogen sulfide concentration in air above the broadcast treatment was greater than incorporated treatments. Incorporation effectively reduced odor (Fig. 1), and the narrow knife, under residue, and chisel methods minimized residue burial (Fig. 2) compared with other methods. When manure application was in fragile soybean residue, there was a greater range among treatments for the amount of residue cover left than with corn residue. Incorporation of manure before a subsequent crop generally increased corn yield beyond that of a broadcast application, particularly in a low-yield year, and did not affect soybean yield.

In addition to mitigating odor, when manure is injected or incorporated tillage is performed. Excess tillage is undesirable because of impacts on fuel use, soil conservation, and soil structure. Soil loosening from manure injection may be helpful, however, in poorly drained or cold soils as a form of strip tillage if manure is injected deep enough (e.g. 13 – 15 cm, (5 – 6 in.) below the surface) to avoid problems with seed germination and early plant growth.

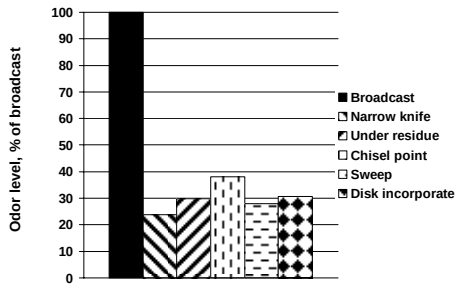

Figure 1. Odor level immediately after application in soybean residue.

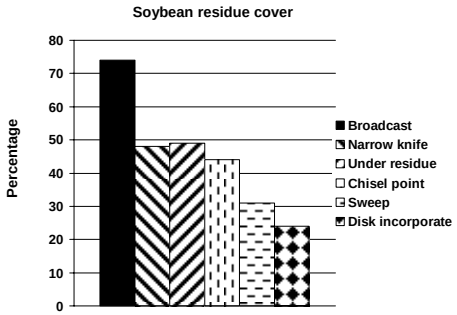

Figure 2. Residue cover after application in soybean residue

Applicability:

Injection of manure below the soil surface or incorporation of manure by mixing with surface soil should be utilized when odor is a concern. Concerns typically increase if neighbors or others not involved with the livestock operation will be subjected to odor during application and also with the application of swine manure. Most methods involving soil incorporation reduce odor levels by 20 to 90% from the odor level emitted after broadcast application.

The choice of a manure incorporation method in soybean residue is more critical to maintaining cover than in corn residue. Using a narrow-profile or “no-till” knife, or a single-disc opener tends to leave more residue than a disc-type system. When application is made in corn residue, there is less difference in the amount of residue cover remaining after treatments although they follow similar trends to those observed in soybean residue.

Limitations:

On land areas subject to erosion, serious consideration needs to be given to the type of injection or incorporation system used in order to limit burial of residue cover while still mitigating odor. In those cases where odor during application is not a concern and nutrient loss from surface placement can be tolerated, broadcast application minimizes residue cover destruction and required tractor power. Odor level reduces quickly with time and within a single day is often indistinguishable with odor from untreated soil.

Tractor power requirements increase with injection depth. Application with knives operating at 20 cm (8 in.) or greater depths may increase drawbar power requirement by 25%. Inject only as deep as required (e.g. 15 cm (6 in.)) to avoid problems with fertilizer burn on plant roots. If operating double-disc type systems where manure is incorporated in a dribble-band between discs using a shallow depth helps to maintain residue cover if manure can be placed between subsequent rows or at least 7 cm (3 in.) away from seed placement. Maintenance of injector styles is also a potential concern that should be evaluated. Single-disc type injectors tend to leave greater residue cover and minimize plant disturbance in pasture or hay, but have significant loading on disc bearings.

Cost:

Factors affecting costs include the initial cost of the application toolbar, annual usage rate, and increased tractor power requirement to pull the injection device. The following assumptions were made to calculate example costs for either a narrow (“no-till”) knife injector or double-disc incorporation applicator toolbar for use by a large-volume custom or smaller-volume private applicator:

- Annual application volume: custom - 20 million gallons, private - 3 million gallons
- Equipment life: custom - 5 years, private - 15 years
- Additional tractor power: disc - 30 hp, knife - 60 hp

Costs of using a double-disc or narrow knife application toolbar are in the range of $0.001 and $0.002 per gallon, respectively, for the higher-volume custom applicator example. Costs are $0.0015 and 0.003 per gallon, respectively, for the lower-volume private applicator example. Costs of using additional tractor power are roughly one-third to one-half of total costs at the smaller annual application volume, but over three-fourths of costs at the higher application volume. Diesel fuel was valued at $3 per gallon. If the pass of a field tillage implement is eliminated (e.g., strip tillage) because of application, costs of injection or incorporation may be negated by savings in the cost of the tillage pass.

Implementation:

In addition to evaluating the need for odor control, field conditions should be carefully assessed for potential soil erosion from reduction of residue cover. Soybean residue is more fragile and subject to burial than corn or small grain residue. Reducing operating depth, or if possible using an injector style creating less soil and residue disturbance, tends to reduce loss of the soil-protecting residue cover. A narrow-profile knife may have greater application costs due to the knife-toolbar costs and power requirement, but may more consistently limit residue burial than double-disc system. A double-disc system may reduce costs and offer flexibility in heavy, corn residue but be too aggressive in soybean residue unless operating depth can be adjusted to a shallow level.

Consider depth of tillage for injection or incorporation of manure. If manure will be injected as a point source “in the row” (i.e., in a zone of subsequent seed placement), manure should be at least 7 cm (3 in.) below seed depth. If manure is applied away from the seed zone between rows or broadcast incorporated diffusely into the soil, a shallow tillage generally causes few problems with the subsequent crop. Even light mixing to gain manure exposure to the soil tends to cut odor significantly below that of a broadcast application.

Wet soil conditions are often observed during spring and sometimes during fall application season. Regardless of application choice, if at all possible when using heavy tanker axle loads, avoid application when soil is at or near field capacity to reduce the potential for subsequent soil compaction problems.

Technology Summary:

Injection or incorporation application treatments other than broadcast almost always reduce odor during and immediately after application. Although the amount of odor reduction among various injection and incorporation treatments may be similar, the level of surface residue cover reduction is different. For land areas where erosion is a concern operating an application system with reduced soil and residue disturbance should be strongly considered. Costs of using injection or incorporation equipment are on the order of $0.001 to $0.003 per gallon applied depending on the type of equipment and annual volume applied. Additional application costs for using injection or incorporation equipment even in the upper end of this range are typically no greater than the cost of a secondary tillage pass. The choice of injection or incorporation style should be strongly influenced by balancing the needs for odor control, residue cover maintenance, and fertilizer placement for the subsequent crop.

Additional Resources:

Manure and Tillage Management http://www.extension.iastate.edu/Publications/PM1901G.pdf

Acknowledgments:

Project support was provided in part by the National Pork Producers Council, Iowa Pork Producers Association, Top Air Manufacturing, Inc., and the Iowa Agricultural Experiment Station.

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