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Optimizing solid manure application by improving distribution

Abstract
Improving the uniformity of manure distribution may make it a more effective substitute for commercial fertilizer and allow farmers to take proper nutrient credit for the manure. Manure-spreading equipment or application techniques may need to be modified to be more efficient.

Keywords
Agricultural and Biosystems Engineering, Nutrient management

Disciplines
Agriculture | Bioresource and Agricultural Engineering
Abstract: Improving the uniformity of manure distribution may make it a more effective substitute for commercial fertilizer and allow farmers to take proper nutrient credit for the manure. Manure-spreading equipment or application techniques may need to be modified to be more efficient.

Question & Answer

Q: How can farmers gain confidence in the reliability of nutrient distribution from spreaders?

A: This work shows what manufacturers need to know to improve equipment performance and what farmers need to know about using manure spreading equipment effectively.

Background

Effects of spreaders on solid manure distribution. Solid manure production and application have increased. The use of manure as a substitute for commercial fertilizer saves money for farmers and helps the environment. However, operators viewing the spread pattern left by solid manure spreaders often are frustrated to see a non-uniform application of material and may be reluctant to take full nutrient credit for the manure. Researchers speculate that because of the low value placed on manure in the past, much of today’s manure-spreading equipment has been designed for rapid disposal rather than effective fertilizer nutrient application.

The investigators established these objectives:

• Evaluate the uniformity of manure distribution from existing solid manure spreaders, and
• Provide recommendations for equipment operating strategies to improve uniformity of solid manure distribution on crop land.

Effects of variable distribution on crop nutrient uptake and yield. In addition to studying various distribution performance characteristics of manure spreaders, this project studied the yield capabilities of corn when manure is applied at different rates. While there have been many studies on the nutrient qualities of liquid manure, solid manure’s performance as a yield enhancer has not often been considered.

Objectives for this segment of the project were to measure the:

• Effect of different solid manure application rates on corn yield,
• Effect of different application rates on protein, starch, moisture content, oil, and density levels in the grain, and
• Relationship between the amount of manure

Rear-delivery spreader applying manure during application measurement.

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$23,448 for year two  
$25,800 for year one
applied to the land and the amount of nitrogen (N) taken up in the plant.

Particle size analysis and modeling of solid manure distribution. Being able to predict how far a spreader is able to throw different particle sizes of manure would help improve the design of manure spreaders. Particle size distribution is important because ballistic action on various particle sizes may cause them to travel different distances when thrown. The ability to model and predict spreader performance would allow analysis of changes in the overall spread pattern without having to build or modify a prototype spreader.

Objectives of this portion of the project are to:
• Measure particle size distribution at different distances from the beater and their relationship to the overall spread pattern of manure spreaders,
• Create a model to predict the distance different particle sizes are thrown from the manure spreader, and
• Compare the model to actual experimental data using spread patterns measured in the field.

Approach and methods
Effects of spreaders on solid manure distribution. Four different spreader configurations were used in five experiments. Among them were horizontal-drum, rear-delivery; two-beater, rear-delivery; one-beater, rear-delivery; and side-delivery. These types of spreaders were chosen because they represented a range of the two main types of spreaders (rear- and side-delivery) that are currently being used in many solid manure spreading applications.

Calibration of a solid manure spreader has not been standardized like that of commercial fertilizer spreaders. Much of what is known is based on granular fertilizer application; however, granular fertilizer has different physical characteristics than manure, which can affect the uniformity of distribution.

Spreader application was evaluated in replicated field trials for uniformity both across the swath and in the direction of travel. A procedure to measure distribution was patterned after a standard agricultural engineering tactic of using trays for gauging distribution uniformity and calibrating granular broadcast spreaders. The trays were laid out at evenly spaced intervals within each plot to collect the manure distributed by the spreader. Manure weight was determined by weighing each tray before and after distribution.

Effects of variable distribution on crop nutrient uptake and yield A study was conducted to measure the effects that different application rates within a typical spreader pattern may have on the yield and characteristics of corn. Specific indicators investigated include grain yield, moisture content, protein, oil, starch, and density (i.e. kernel density) contents in corn as well as any N stress on the crop as measured by stalk nitrate. The range of application rates for the experiment was based on the range of application rates measured from the distribution experiments and the nitrogen value of the manure. The manure was hand applied to the 35 plots using pitch forks to provide application similar to a spreader. Normal production practices were followed and no additional fertilizer was applied. The corn was hand-harvested from one of the inner rows in each plot, shelled, and sampled for various qualities. Stalks were analyzed for nitrogen content.

Particle size analysis and modeling of solid manure distribution. Two spreaders, one rear-delivery and one side-delivery, were used for this experiment. Spreader application rate is affected by apron speed (rear-delivery) or gate position (side-delivery) and was set at the highest rate for both spreaders. Two rows of collection trays were laid out in each plot. The manure was scraped from the trays into cloth bags for drying. Manure was separated for particle size analysis within a week of being collected. Each particle-size weight was recorded and analyzed for both rear-delivery and side-delivery spreaders.

A distribution model was developed based on experimental results from the side-delivery spreader. Because the beater of the rear-delivery spreader throws manure into each of the collection trays from various distances as the spreader passes over the trays, it was beyond the complexity of this initial modeling effort.

Results and discussion
Effects of spreaders on solid manure distribution. The load phase of the spreader (beginning, middle, and end) had little effect on the distribution of the manure across the swath. There was some variation in travel direction during the start up. The speed of the spreader apron did affect the spread pattern. Application rate increased at
higher speeds as did the uniformity across the swath. Most application occurred directly behind a rear-delivery spreader, so overlapping swaths by using travel lanes not much wider than the spreader was required to improve lateral distribution. Uniformity was similar for both one- and two-rear beater spread patterns. A full gate opening on a side-delivery spreader tended to improve across-swath uniformity as compared to a half-gate opening.

An adjustable deflector present on the side-delivery spreader redirected manure as it left the spreader. In one experiment, a mid-deflector position improved uniformity across the swath; however, this position decreased uniformity in another test. Poor uniformity across swaths for either rear- or side-delivery spreading generally improved when spread patterns were overlapped.

Effects of variable distribution on crop nutrient uptake and yield. Corn yield was significantly different, at the 95 percent confidence level, when comparing yield to the amount of manure applied. The four highest manure application rates resulted in yields that were statistically greater than yield from the control treatment using no manure. Protein level was significantly different at the 90 percent confidence level, although it was not as closely related to amount of manure applied. The levels of moisture content, oil, starch, and density in the corn kernels were not significantly different among treatments. Based on the generally high yields for 2002, the crop appeared to have enough nutrients for this growing season.

Particle size analysis and modeling of solid manure distribution. Particle sizes of 0.0254 m in diameter and larger made up the greatest portion (by weight) of the manure samples that were separated. Many different particle sizes were present in each of the trays collected at the designated distances from the side-delivery spreader. The particle size distribution for each spreader is very similar to the distribution pattern found when looking at the application rates. For the rear-delivery spreader, smaller particles may have been spread more uniformly within 1.9 m to 2.7 m of the spreader than the largest particles. Large particles were found in all trays for the side-delivery spreader, while the concentration of the smaller particles was found to be closer to the spreader.

Conclusions

Effects of spreaders on solid manure distribution. Application and uniformity graphs are useful in predicting uniformity of the spread pattern when choosing an overlap distance with a given application rate. The actual overlap for each piece of land should be determined individually based on the kind and properties of manure being spread, nutrient needs of the land receiving the manure, and also the laws and rules governing application. For rear-delivery spreaders, uniformity increased when swath width was not much wider than the spreader.

Effects of variable distribution on crop nutrient uptake and yield. Manure rates were applied on corn based on typical variability found across the swath, and application uniformity efforts on nutrient uptake and yield were measured. Average corn yield was very good. The ability to distinguish effects of different rates of manure application may have been limited by the good 2002 growing season. However, even under good growing conditions, results indicated that the manure does increase the yield if it is applied. The yield with no manure was 165 bu/ac, while the yield with a manure application rate of 30,000lb/ac (180 lb N/ac) was 199 bu/ac. No statistical effects of manure application rate were readily detected on the corn's moisture content, oil, starch, density, and protein. In this field test and at current fertilizer prices, manure could be applied up to 22,500 lb/ac (135 lb N/ac) and the fertilizer value of the manure would be recovered in increased corn yield.
Particle size analysis and modeling of solid manure distribution. A mechanistic model for manure particle flight based on the effects of gravity and air drag was created to predict the distance thrown for different densities of manure. The model was adjusted by particle density to throw the 80th percentile of the mass landing away from the beater for each particle size at the angle of maximum throw, 33°. The model over-predicted the distances for about half of the manure thrown. For the side-delivery spreader, the greatest amounts of large particles fell either close to the spreader or at the end of the spread pattern. The largest amounts of smaller particle sizes fell near the spreader for the side-delivery spreader.

Impact of results
Agri-cultural producers interested in using manure as fertilizer may be deterred because the pattern following manure spreading is more variable than that from the application of dry commercial, granular fertilizer. Knowledge of common manure spread patterns and how to improve them would increase farmer confidence in application and the ability to take credit for fertilizer nutrients.

Common spread patterns of rear- and side-delivery spreaders were measured. Effects of apron speed, gate opening, load phase, number of beaters, and deflector position were observed. Measurements of relative uniformity will help producers optimize application uniformity with an acceptable application rate.

Unless producers observe and carefully overlap their spreader pattern, manure variation is greater across the swath than in the travel direction. Although application costs of a less-nutrient dense manure are slightly greater, common commercial fertilizer production costs can be eliminated by growers who gain skill and confidence in more uniform manure application. Results of modeling work in this experiment will be useful in the future design of spreaders showing more uniformity in manure distribution.

Education and outreach
Efforts were directed toward crop consulting professionals, individual applicators, Extension personnel, and scientific peers. Articles for scientific journals are being prepared, and an ISU Extension bulletin on calibration and uniformity of solid-manure spreaders has been produced; PM-1941, Calibration and Uniformity of Solid Manure Spreaders.

Initial results on variability of solid manure application were shown to participants at the Integrated Crop Management Conference, National Custom Applicators Expo, ISU Northeast Research Farm field day, and Manure Application Equipment field day at the ISU Ag Engineering Research Center. Solid manure distribution also was reported on at a statewide dry manure certification meeting and in-service training session.

Later findings were shared at diagnostic clinics and in-service training sessions for field agricultural engineers and crop specialists. Improved application patterns based on applied research were presented at training for AgReliance crop professionals. Results were presented as part of the statewide commercial manure applicator certification training program. Nearly 800 commercial manure applicators and agricultural professionals have been informed about the results of this project.

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