SOLID MANURE APPLICATION: TOWARD A SOPHISTICATED SPREADER

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Introduction

Two generations of low-cost chemical fertilizer and the differentiation of crop from livestock farming have given manure a bad name, even among farmers. With increasing awareness and concern about the air and water impacts of improper manure management, it is imperative that both crop and livestock farmers once again consider manure as a resource rather than a waste (Fleming et al., 1998). To fully realize these benefits will require some changes in farming systems, technologies, and practices, and regulation is likely to be an even larger factor driving these changes than it is today. But unless these strategies generate on-farm benefits and address the farmer's fundamental constraints, they are unlikely to be widely adopted or conscientiously implemented.

The principal use of manure, both today and for at least the immediate future, will be as a nutrient fertilizer for plants. Although this traditional use is widely recognized as beneficial, it faces new challenges with changes in the structure of agricultural production. With the increasing specialization of crop and livestock farmers, most crop farmers no longer generate their own manure for crop nutrient needs, while many livestock farmers lack the land base necessary to fully utilize the manure they produce. Although nutrient management plans commonly result in arrangements to transfer manure across farm boundaries, the crop producer has to compare this option with synthetic fertilizer use. Livestock farmers also have the option of synthetic fertilizer, and often supplement manure with other fertilizers to insure optimum crop yield. Relative to manure, synthetic fertilizers have the following advantages:

1. Nutrients can be balanced to match crop demand
2. Nutrients are stable and easily stored on site for use on demand
3. Nutrient concentrations are specified and consistent
4. Pathogens are not a concern in storage or on the field
5. Nutrients are concentrated and cheap to transport and apply
6. Application equipment distributes it relatively uniformly and efficiently
7. Little odor associated with storage or application
8. Dramatic negative impact on water quality is unlikely

This list of advantages of synthetic fertilizer could serve as specifications for a manure/organic fertilizer manufacturing and utilization process. Several existing technologies can help achieve these requirements, although there are some areas where additional innovation will be required (Richard and Choi, 1999; Richard, 1999). This paper focuses on item 6 in the list above, and discusses the opportunities and challenges to applying manure uniformly and efficiently.

Variability in manure application is one of the main reasons farmers are reluctant to take full credit for nutrients in their manure management plans. With those manure management plans increasingly mandated by governmental regulations, and with the increased marketing of high value composts for agricultural production, farmers have both environmental and economic incentives to use accurate equipment. Unfortunately, the solid manure application equipment available today is not very effective at achieving this goal. This is clearly one of the most important opportunities for technical innovation, as improved application accuracy is critical to efficient manure use.

Recent Spreader Research

Liquid slurry equipment has recently been the subject of increased technical evaluation (e.g. Hanna et al., 1999). Load cells and flowmeters have been used to monitor and assist rate control of liquid application equipment (Holmes, 1998). Glancy et al. (1997) used a combination of strain gages and microprocessor control of delivery augers to improve rate control of a spinner-type spreader for industrial wastes. Lague (1991) developed a spreader for semi-liquid dairy manure with a tiltable tank and vibrating distribution manifold. Most manure exited from two center outlet openings on the manifold and it had coefficients of variation across the swath of 64% to 74%. Lague (1991) recommended future development to lower variation across the swath.

Solid manure production and application is on the increase with new solid and bedded manure handling systems and new products such as compost. Historically, solid spreader design has focused on disposal rather than fertilization. Spreader distribution needs improvement if applicators are to have confidence in applying a required rate rather than overapplying manure or fertilizer to make up for poor distribution. The lack of equipment capable of providing a uniform application has restricted wide acceptance of substituting solid manure nutrients for commercial fertilizer (Wilhoit et al., 1993).

Malgeryd and Wetterburg (1996) investigated several physical properties of manure and suggested that spreading characteristics of solid manure are determined by dry matter content and bulk density. They did not investigate particle size although experience from granular fertilizer distribution indicates that this may also be important. Field testing is desirable for testing fertilizer distribution as considerable variation may occur from external influences such as field irregularities and wind (Sogaard and Kierkgaard, 1994).

Limited study of solids equipment indicates significant deficiencies in application uniformity, both in the direction of travel (i.e. rate control) and across the swath. Evaluating a spinner-type spreader distributing poultry litter, Wilhoit et al. (1993) found a coefficient of variation of 50% across the swath when the spreader was operated at the manufacturer's recommended 12.2 m (40 ft) swath width. Because most material was applied near the center of the spreader, they noted a reduced coefficient of variation was possible if the operator was willing to reduce swath width under 9.1 m (30 ft). Glancey and Adams (1996) were able to lower the coefficient of variation for seven discrete outlets of a sidedress poultry manure applicator to a range of 15% to 19%, but only with an individual feed auger to each outlet and pre-processing of litter with an on-board beater. They recommended that future work address the broadcast characteristics of beater-type spreaders to improve distribution of dry waste materials.

Checking ten spreaders in the field, Davis and Meyer (1998) found a 30% coefficient of variation of manure in the direction of travel and off-center spread patterns across the swath in seven of the spreaders. Similar results were observed in preliminary tests sponsored by the Leopold Center of three conventional spreaders last spring. Coefficient of variation across the swath averaged 100% and 108% for two rear discharge spreaders and 66% for a side discharge spreader. Although the side discharge spreader had a lower coefficient of variation, its pattern tended to be more off-center as heavier particles were thrown further from the spreader. Typical distributions are shown in figures 1 - 3 for the spreaders.

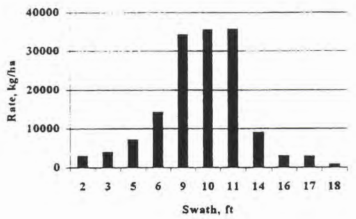

Fig. 1. Rear discharge 1

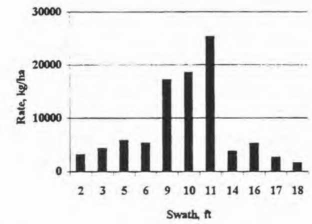

Fig. 2. Rear discharge 2

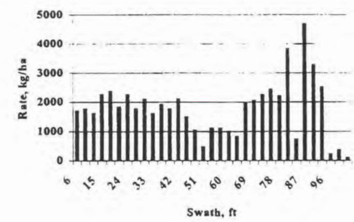

Fig. 3. Side discharge

These results suggest that farmers are not mistaken when, as is frequently the case, they do not take full credit for the nutrients in the manure they apply (Nowak et al., 1998). When the nutrient value experienced by individual crop plants differs from the average application rate by 30, 50 or 100% there are potentially many nutrient stressed plants (and a similar number experiencing nutrient excess) if the average value is used. In this situation the rational decision is to discount manure nutrients, but this is contributing to overapplication and generating a variety of water quality concerns. Without equipment that effectively addresses this issue of application uniformity, both crops and the environment suffer.

Summary and Future Needs

To efficiently replace commercial fertilizer with manure, crop producers must be assured of a fairly uniform and controlled rate of application. Spreading manure accurately enough that farmers can realistically expect (and take) full credit for manure nutrients will be critical in the coming years. While we certainly need to train spreader operators in everything from calibration to compensating for wind, operator skill cannot transform the nature of equipment built for the old animal waste disposal paradigm. Current solid manure application equipment simply does not adequately address uniformity requirements and application rate control. It is time to take a more sophisticated approach to the ancient art of manure application – opportunities for innovation abound.

References

Davis, J. G. and R. B. Meyer. 1998. Manure spreader uniformity and calibration methods. Proceedings, Animal Production Systems and the Environment, Des Moines, IA, pp. 157-162, July 19-22, 1998.

Fleming, R.A., B.A. Babcock, and E. Wang. 1998. "Resource or waste? The economics of swine manure storage and management." *Review of Agricultural Economics* 20(1):96-113.

Glancey, J. L., S. Seymour, C. Bohman, R. Sheeman, and J. Posselius. 1997. Development of a precision industrial spreader for the land application of solid wastes. American Society of Agricultural Engineers, St. Joseph, Michigan. Paper No. 971081.

Glancey, J. L., and R. K. Adams. 1996. Applicator for sidedressing row crops with solid wastes. Transactions of the ASAE 39(3):829-835.

Hanna, H. M., D. S. Bundy, J. C. Lorimor, S. K. Mickelson, S. W. Melvin, and D. C. Erbach. 1999. Effects of manure application equipment on odor, residue cover, and crop. American Society of Agricultural Engineers, St. Joseph, Michigan. Paper No. 991062.

Holmes, B. J. 1998. Accurate manure spreading - state of the art. In: *Manure Management in Harmony with the Environment and Society* Proceedings. The Soil and Water Conservation Society, West North Central Region. February 10-12, Ames, IA. pp. 340-342.

Lague, C. 1991. Design of a semi-liquid dairy cattle manure spreader/injector. Applied Engineering in Agriculture 7(6):655-660.

Malgeryd, J., and C. Wetterberg. 1996. Physical properties of solid and liquid manures and their effects on the performance of spreading machines. Journal of Agricultural Engineering Research 64(4):289-298.

Nowak, P., R. Shepard, and F. Madison. 1998. Farmers and manure management: a critical analysis. In: *Animal Waste Utilization: Effective Use of Manure as a Soil Resource*, edited by J.L. Hatfield and B.A. Stewart. Ann Arbor Press, Chelsea, MI, USA. pp 1-32.

Richard, T.L., and H.L. Choi. 1999. Eliminating Waste: Strategies for Sustainable Manure Management. *Asian-Aus. J. Anim. Sci.* 12(7):1162-1169.

Richard, T.L. 1999. Moving Manure: Economic and Agronomic Incentives for Environmental Stewardship. In: *Proceedings of the Animal Residuals Management Conference*. Water Environment Federation, Alexandria, VA. *In press.*

Sogaard, H. T., and P. Kierkegaard. 1994. Yield reduction resulting from uneven fertilizer distribution. Transactions of the ASAE 37(6):1749-1752.

Wilhoit, J. H., C. W. Wood, K. H. Yoo, M. Y. Minkara. 1993. Evaluation of spreader distribution patterns for poultry litter. Applied Engineering in Agriculture 9(4):359-363.