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Verifying liquid manure hydraulic distribution

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Introduction

Liquid manure application in Iowa typically takes place in fall after harvest in preparation for the following crop year. Manure is either transported and land applied with tank wagons and/or directly pumped and land applied using a dragline system. Application rate, gallons per acre, is typically controlled by flow control actuators operated by on-board rate controllers which co-process the drive speed, tool-bar width, and the flow meter reading with the operator input of application rate. This system ensures that the desired application rate is achieved for manure application. The manure is supplied to a distribution manifold after it passes through the flow control valve. The manifold is responsible for distribution of the liquid manure to different points on the tool-bar.

Manifolds can be mounted on tank wagon tool-bars or dragline tool-bars. A distribution manifold, typically has an inlet through which it receives the manure supply, a chamber, and several outlets through which the manure is distributed to the tool-bar points. Different manifolds have different configurations in terms of the inlet size & location, chamber size, and the size, number, and location of outlets. Each manifold has its own performance capabilities in terms of how uniformly it distributes liquid manure and the application rate it can effectively manage.

Calibrating the application rate in terms of gallons per acre (gpa) does not specify how uniformly the manure is being distributed within the tool-bar swath. This calibration, which can be achieved with the area-volume method, is essential to ensure the manifold chamber is pressurized to the extent possible by receiving the appropriate flow rate in gallons per minute (gpm). The area-volume calibration of liquid manure tank wagons is explained in detail in the Iowa State University Extension and Outreach Publication AE 3601 (a revised version of PM 1948). Application rate with draglines can be calibrated with a similar method using the area measurement with the flow rate measurements from the flow meter. Such calibration, however, does not characterize any variability that may exist between the amount of liquid manure discharged to different points on the tool-bar. A calibration of a specific application rate may still be achieved where a few tool-bar points may not be applying any manure while other tool-bar points may be applying twice or three times the application rate.

Variability in the manifold discharge can be significant when the manifold chamber is not pressurized under low application rate conditions. Liquid swine finishing manures are beginning to test relatively high values of total nitrogen per 1,000 gallons. Secondly, the Maximum Return to Nitrogen Rate (MRTN; ISUEO, 2016 and Sawyer et al., 2006) Calculator is showing lower total nitrogen need for a corn crop in corn-soybean rotation than was previously calculated with the yield goal method. High manure nitrogen test values coupled with lower total nitrogen need is resulting in manure application rates to be lower than what they have been in the past for liquid swine finishing manure. Low application rates can influence how variable a manifold performs in its discharge to the different tool-bar points. High variability can lead a producer to believe that manure nutrients are not available to match the crop needs. This can lead a producer to commit to an expenditure of supplementing additional nutrients. Excessive nutrients on the field can lead to water quality issues as related to surface water and sub-surface drainage water. It is, therefore, essential to verify hydraulic distribution of liquid manure applicator manifolds across the tool-bar swath.

Verifying hydraulic distribution

Coefficient of Variation (CV) is used by American Society of Agricultural and Biological Engineers (ASABE) to measure uniformity of pesticide sprayers. The coefficient of variation methodology was also used by Hanna et al. (2004) to test the uniformity of spreaders for dry manure. The same CV can be used to determine the distribution of liquid from different outlets of a manure application manifold as it is a better statistical measure than the mean absolute error. Absolute error only measures the difference between the average outlet discharge and measured outlet discharge. The coefficient of variation measures the variation across the different tool-bar points as the manifold outlets are connected to these points with discharge hoses. This measurement is a measurement of variation in the direction transverse to the direction of travel. The coefficient of variation across the manifold outlets can be defined by Equations 1, 2, and 3 as:

$$CV = 100 * (\sigma / \bar{Q}) \quad\text{..(1)}$$

$$\sigma = \sqrt{\frac{\Sigma(Q_i - \bar{Q})^2}{(n-1)}} \quad\text{..(2)}$$

$$\bar{Q} = \frac{\Sigma Q_i}{n} \quad\text{..(3)}$$

where CV is the coefficient of variation, σ is the standard deviation, $\bar{Q}$ is the arithmetic average flow rate from all outlets, Q_i is the flow rate of the ith outlet, and n is the total number of manifold outlets. When using Equation 1, low CV refers to better uniformity.

Testing a manifold

Discharge from tool-bar points can be collected for a given time period and measured for variability. A coefficient of variation can then be calculated to ascertain the variability across the tool-bar swath. Using this concept, six tank-mounted and three dragline manifolds were tested in summer of 2015 and 2016 using water. Discharge hoses were connected together to a wooden beam to allow for simultaneous collection and stoppage (Figure 1). Water from the discharge hoses was collected for 15 seconds in fifty-five gallon straight wall drums. Height of the water collected in the drums was measured and converted into gallons using a calibration curve. Using the pre-determined drive speed and the tool-bar swath, the amount of water collected was converted to the application rate (gpa). Manifolds were tested, using tractor control settings, for application rates ranging from 2,000 gpa to 6,000 gpa. In certain cases, a lower application rate of 1,000 gpa was also tested. Manifolds were tested under three different slope settings of 0, 3, and 6% to simulate the tool-bar travel across the slope in a field.

Figure 1. Fifty-five gallon drums arranged underneath the discharge hoses to compare variability across the tool-bar swath.

Manifold testing results

Manifold 1, 5, and 8 test results showed significantly higher coefficient of variation (Figure 2) at lower application rates. Increasing the application rate improved the CV but was never less than 10%. These results indicate that it is not feasible to achieve low CV with these three manifolds for the application rates tested in this experiment. Each manifolds tested in this experiment had different shapes along with different number and size of outlets, and different location of the inlet. As such, each manifold is independent for its performance capabilities in terms of the coefficient of variation. Each manifold is potentially capable of achieving CV of 10% or less depending upon the flow rate (gallons per minute) passing through it. Certain manifolds, by design, can achieve CV of 10% or less at lower application rates whereas certain other manifolds achieve it at higher application rates. Effect of slope on the coefficient of variation showed no clear trend as it increased for certain manifolds where as it decreased for others. Arora et al. (2016) discussed the six-tank mounted manifolds and concluded that lower application rates with CV of less than 10% are feasible with appropriate choice of manure distribution manifolds. Additional research conducted in Summer of 2016 indicates the same is feasible for dragline manifolds. This will help producers to land apply liquid swine manure effectively. Better distribution of manure nitrogen can further help to reduce the need of land applying supplemental nitrogen as side-dressing in spring, thus, resulting in cost savings as well as water quality benefits.

Conclusions

- Coefficient of variation was less than 20 percent for three manifolds tested for five application rates for all three slope settings. Two of the nine manifolds tested with coefficient of variation less than 10 percent for most of the corresponding test settings.

- Results of the testing indicate that caution should be exercised to select the appropriate manifold when applying manure such that the lowest possible coefficient of variation is achieved.

- Slope had a large effect on the coefficient of variation in case of certain manifolds. The results were variable and did not show a direct correlation in how the CV changed with increase in slope.
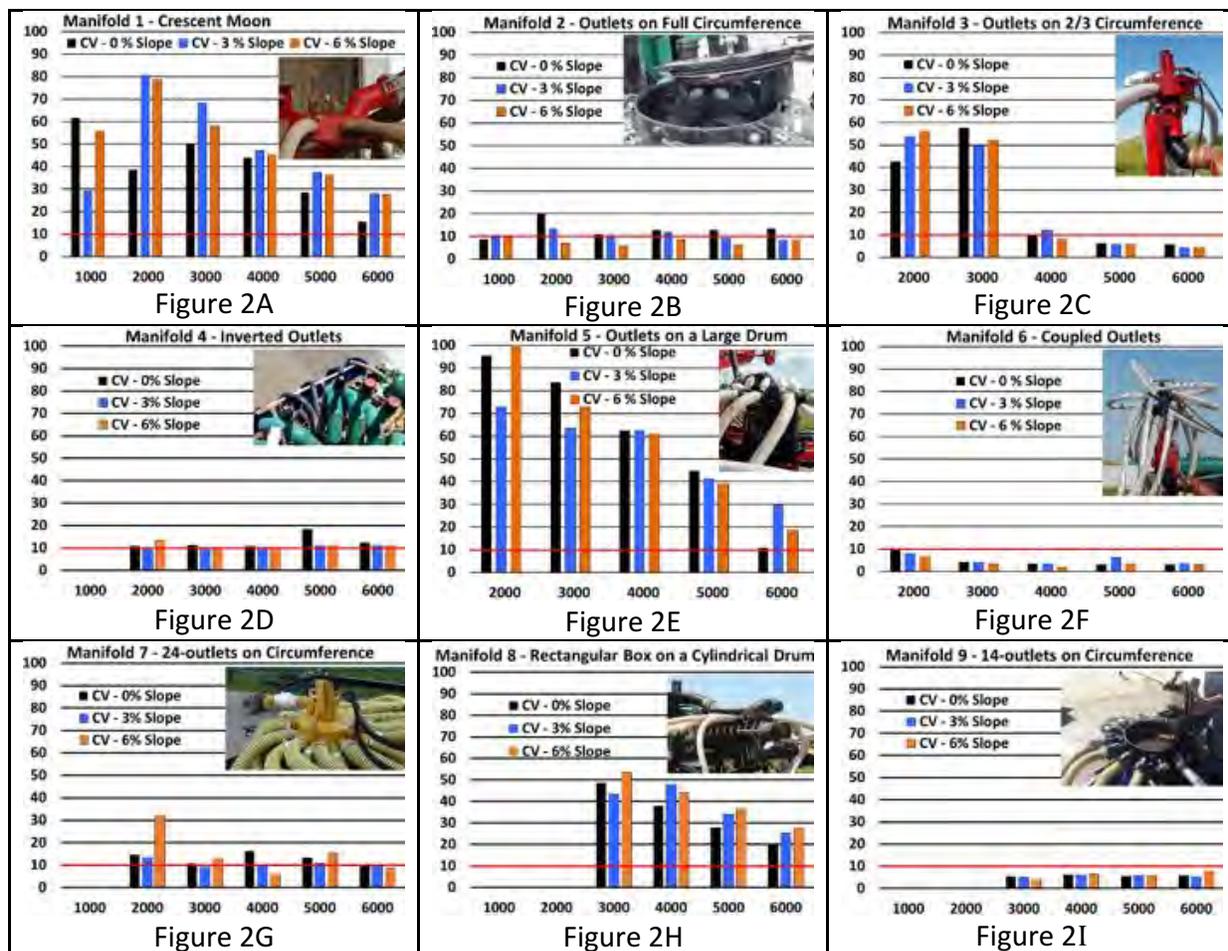
Figure 2. Nine different manifolds tested during Summer of 2015 and 2016. Coefficient of variation (%) is plotted on the x-axis and application rate in gallons per acre is plotted on the y-axis. Application rate(s) for which no data is plotted indicates rate lock was not achieved during testing as per the testing protocols.

Acknowledgements

References

Arora, K. and Andersen, D. S. 2016. Coefficient of Variation of Discharge from Liquid Manure Applicator Distribution Manifolds. Paper presented at the ASABE Annual International Meeting, Disney's Coronado Springs Convention Center, Orlando, Florida, USA. 17 - 20 July, 2016. ASABE meeting paper number 162460271. (doi: 10.13031/aim.20162460271)

Hanna, H. M., T. L. Richard, and Quick, G. R. (2004). Optimizing solid manure application by improving distribution. Pp 55-58. Leopold Center Progress Report Volume 13. Leopold Center for Sustainable Agriculture, Iowa State University, Ames, Iowa 50011. Leopold Center Completed Grant Reports. Available on-line at http://lib.dr.iastate.edu/leopold_grantreports/219 and viewed: June 9, 2016.

ISUEO (2016). MRTN On-line Calculator. Iowa State University Extension and Outreach, Ames, Iowa 50011. Available on-line at http://cnrc.agron.iastate.edu/nRate.aspx and viewed: June 9, 2016.

Sawyer, J., Nafziger, E., Randall, G., Bundy, L., Rehm, G., and Joern, B. (2006). Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. PM 2015. Iowa State University Extension and Outreach, Ames, Iowa 50011. Available on-line at https://store.extension.iastate.edu/Product/Concepts-and-Rationale-for-Regional-Nitrogen-Rate-Guidelines-for-Corn and viewed: June 9, 2016.