MANURE SAMPLING AND SPREADER CALIBRATION: TESTING OUR RECOMMENDATIONS

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INTRODUCTION

The purpose of this work was to evaluate whether the innate variability of manures and the difficulty in achieving a uniform spread negate the recommendations often made by land-grant universities to sample manure and calibrate manure spreaders.

MATERIALS AND METHODS

Manure Sampling Study

The objectives of this study (Davis et al., 2002) were 1) to measure the variability within stockpiles of various animal manures and determine the number of sub-samples needed to characterize the nutrient content within a 10% probable error and 2) to compare Colorado manure analyses to the table values we have been using in our publications, which come from Midwestern data.

Ten sub-samples (approximately 0.5 qt each) from each of five manure stockpiles (beef, dairy, horse, sheep, and chicken) were collected. Each stockpile was sampled from a different farm. Two samples were taken from the top and two from each side of each stockpile (north, south, east, and west). For each pair of samples, one was taken shallowly (1 ft), and one was taken more deeply (3 ft). For the side samples, one of each sample pair was taken from the middle and one from near the bottom of the stockpile. Each sub-sample was analyzed separately for dry matter (D.M.), total nitrogen (N), ammonium (NH_4-N), nitrate (NO_3-N), phosphorus (P), and potassium (K) to determine the variability within the pile. Collected data and the following equation were used to determine the number of sub-samples needed.

$$n = t^2CV^2/p^2$$

where t=Student's t value (for a 95% confidence interval, n=10 and degrees of freedom=9, t=2.26), CV=coefficient of variation expressed as a decimal, and p=probable error expressed as a decimal (0.10 for 10% error).

Beef, dairy, horse, sheep, and chicken manures were sampled in order to compare Colorado manure analyses to Midwestern table values. Six to ten different livestock operations were sampled for each manure type. Each sample was a composite of six 0.5 qt sub-samples taken from different locations and depths within the stockpile. The D.M., total N, NH_4, P_2O_5, and K_2O values measured in these samples and manure sample means from each farm tested in the within-stockpile variability experiment described above were combined into a database. Results were compared to values previously used in Colorado extension publications which came from Midwestern manure samples.

Spreader Calibration Study

The objectives of this study (Davis and Meyer, 1998) were 1) to compare the Tarp Method and the Swath Width and Distance Method for manure spreader calibration, 2) to measure the variability among tarps in the Tarp Method and to calculate how many tarps would be required to achieve 10% probable error, 3) to evaluate the uniformity of the spread patterns and measure the swath widths of the manure spreaders, and 4) to compare the measured application rates from both the Tarp Method and the Swath Width and Distance Method with the stated goals of the operators.

We worked with ten different operators of manure spreaders. All of the spreaders were truck-mounted. We used eight tarps, three 10 x 12 ft tarps lined up in a row in the direction of travel for the Tarp Method and five 5 x 10 ft tarps lined up side-by-side perpendicular to the direction of travel (with the 10 ft direction going in the direction of travel). The tarps were each weighed with a hanging scale prior to laying them out. After laying the tarps out, we measured the weight of the full manure spreader using a set of four wheel-load scales or a drive-on scale at the feedlot source. Then, the operator drove over the tarps while spreading manure. Each tarp was weighed with the manure on it using a hanging scale, and the tarp weight was subtracted from the manure plus tarp weight to calculate the net weight (weight of manure only). The empty manure spreader was also weighed, and the manure weight was calculated by subtracting the empty spreader weight from the full spreader weight. The average capacity of the trucks was 15.4 tons of manure, but the capacity ranged from 12.3 to 20.6 tons.

For the Tarp Method, the net weight in lbs was divided by the area of the tarp (120 sq ft), multiplied by 43,560 sq ft/acre and divided by 2000 lbs/ton to calculate the application rate in tons/acre. The coefficient of variation was calculated for the three tarps, and the number of tarps required to achieve 10% probable error was calculated using the equation shown above.

The lb per tarp measurements were graphed as a function of tarp location as part of the Swath Width and Distance Method. Using the graph, we did a field estimate of swath width by predicting the location where the application rate would be 50% of the maximum. Swath width was subsequently calculated based on determination of the slope of the line from the middle tarp to the inner tarps, and then calculating the distance from the center which would receive 50% of the maximum application rate. We used a measuring wheel to measure the distance that manure was spread on from each truck load. The average travel distance per load was 0.45 miles, with a range of 0.31 to 0.56 miles. Then we calculated application rate by dividing the weight of the manure in tons by the receiving area in square feet (swath width times distance) and then converting to tons/acre by multiplying by 43,560 sq ft per acre. We defined an off-center spread pattern as one where the difference between the inner tarps was greater than 50% of the lower weight, and calculated which manure spreaders resulted in off-center spread patterns.

The Tarp Method, Swath Width and Distance Method, and operator goals were compared using analysis of variance and the Least Significant Differences Mean Separation Test at $p \leq 0.05$. The average spread pattern and comparison of field estimated and calculated swath width were evaluated similarly.

RESULTS AND DISCUSSION

Manure Sampling Study

The variability of samples within a manure stockpile differed for the various constituents. Ammonium and nitrate had the greatest coefficients of variation due to their relatively low concentrations. The greater the coefficients of variation, the greater the number of sub-samples required for useful analysis. For example, to achieve probable error within 10% for a beef manure stockpile, one would need 17 sub-samples to characterize total N, 20 sub-samples for P, 32 for K, 121 for NH_4-N, and 692 sub-samples for NO_3-N.

For solid manures, it seems possible to estimate the total N, P, and K in a stockpile within 10% probable error with a moderately intensive sampling plan (collecting 21-27 sub-samples and combining them to form one composite sample). However, to characterize the NH_4-N and NO_3-N levels in order to predict N availability to crops, the required sub-sample number becomes impractical (>100).

In addition to CVs, another measure of similarity is the confidence interval (C.I.), which is a measure of the probability that a sample will fall within an upper and lower limit. For the one case in which we had over 100 samples (solid beef manure), the 90% C.I.s were quite narrow. For example, the mean total N content was 23 lb/ton, with a C.I. of 21-24 lb/ton. We can interpret this to mean that nine out of ten beef manure stockpiles will have a N content between 21 and 24 lb/ton.

Based on our information, we recommend a minimum of 25 farms for manure database creation in the Mountain West in order to achieve 90% C.I. ranges of 10% D.M. and 10 lb/ton for the nutrients. Including 72 farms in each database (for each manure type) would reduce the ranges in the 90% C.I.s to 5% D.M. and 5 lb/ton for each of the nutrients.

The solid manures sampled from Colorado operations differed in comparison with those we previously used in our extension publications, which originated from sources in the Midwest. The dry matter contents of the Colorado manures were consistently higher than those reported from the Midwest. On a wet weight or "as is" basis, the Colorado manures had higher total N contents in four out of five cases. Ammonium was lower in all of the Colorado manures on a wet weight basis. Colorado P_2O_5 and K_2O contents were higher than Midwestern data for all manure types, when evaluated on a wet weight basis.

The semi-arid and windy climate of Colorado probably leads to greater evaporation of water and volatilization of NH_3^o from manure stockpiles, resulting in the higher dry matter values and lower contents of NH_4-N in all of the manures. Phosphate and K_2O contents are probably greater in Colorado manures because of the concentration effect from the greater loss of water. This concentration effect also occurs with organic N, causing the increase in total N content in most of the manures.

Spreader Calibration Study

The Swath Width and Distance Method resulted in significantly higher measured application rates than the Tarp method. When a spreader truck was driven over the tarps, the tarp width was effectively reduced due to being pulled in by the weight of the truck. The data was corrected for this shrinkage, and the Tarp Method still resulted in lower measured values.

The coefficient of variation (CV) for the weights on the three tarps used in the Tarp method ranged from 17-56%, with an average CV of 30%. We used relatively large tarps for the Tarp method, because the larger the tarp, the lower we expect the CV to be. Only two of the ten test cases had CVs > 40%.

We calculated that three tarps result in 39% probable error, and five tarps result in 30% probable error. In other words, if the goal of the operator is to spread 20 tons manure/acre, three tarps would result in measured values from 12-28 tons/acre, and five tarps would result in measured values of 14-26 tons/acre. Since using five or less tarps results in so much error, we do not have sufficient confidence in the Tarp Method. We determined that 46 tarps would be required to achieve 10% error in measured application rate by the Tarp method.

On average, the spread patterns were centered. However, seven out of ten spreaders had patterns which were off-center. One of these seven cases could potentially be attributed to strong winds. Another one of the spreaders had one side with 7.5 times the amount of manure on it than the other side. Some of the trucks did not seem to be loaded evenly, but trucks were loaded according to common procedure; therefore, the unevenness of the spreading could be partially attributed to asymmetrical loading and partially attributed to the need for adjustment and improvement of manure spreaders.

Calculated swath widths ranged from 7.5 ft to 16.1 ft, with an average of 11.1 ft. With swath widths less than 10 ft, using 10 ft x 10 ft tarps would be inadequate for swath width determination. The calculated swath widths were not significantly different from those estimated in the field.

On average, neither the Tarp method nor the Swath Width and Distance method were significantly different from the application rate goal of the operator. Three of the operators stated their goals in ranges of 5 tons/acre, and, in these cases, we used the middle of the range for the comparison. Nonetheless, the operators are generally achieving their stated application rates, with $p \leq 0.05$.

Both of the methods tested here were too variable to be useful. Of course, manure spreading is innately variable, and evaluating a large area from small tarps whether for swath width determination or actual application rate calculation only works if the spreading is uniform. Although we did not evaluate the Loads per Field Method (in which the operator counts the number of loads delivered to a field of known area and multiplies by the average weight of a load), since this method encompasses the entire spreading area and does not involve the use of small tarps, we would expect the variability to be less with this method. Rather than emphasizing spreader calibration, we should focus on improving manure spreader design to be more uniform and checking spread patterns and overlap distances in order to improve uniformity of applications.

CONCLUSIONS

Manure varies within and among livestock operations due to different feeding and management practices. Table values can replace site-specific sampling if enough ($\geq$72), local sample numbers were used to develop those table values. Otherwise, if you are uncertain of the source of the table values, site-specific manure sampling remains valuable. Be sure to take a minimum of six sub-samples per stockpile (20-25 would be better but may not be a reasonable expectation) in order to have some level of confidence in the analysis.

Manure spreading is also a variable process. The Tarp Method for spreader calibration does not adequately capture that variability. The Swath Width and Distance Method is usefully for determining necessary overlap distance to reduce application variability. It is important to weigh manure loads, load spreaders evenly, overlap properly, and count loads applied per field to get a decent estimate of application rate.

Although agronomic manure application rate can be done very precisely, the innate variability of manure and manure spreading require us to be reasonable in our expectations. Annual soil sampling provides a critical feedback loop to adjust manure utilization practices from year-to-year.

REFERENCES

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