Optimizing Nutrient Stewardship Using Broadcast Fertilizer Application Methods

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Research from Auburn University suggests continued advancement in the capacity of spinning disk broadcast spreaders in order to increase the efficiency of the field operation has likely enhanced the risk for well known issues related to obtaining good uniformity in product spread patterns for common granular fertilizer blends. Recommendations are provided in order to increase awareness of this risk and ensure optimal results can be obtained from this popular fertilizer application method.

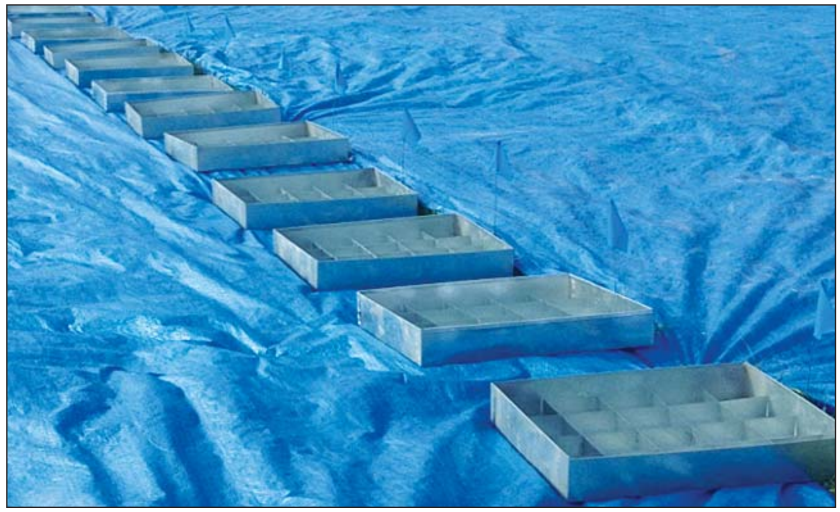

Illustration of pan layout prior to a spreader traversing the test area. Tarps are used to collect fertilizer in order to eliminate environmental risks at the test site.

Nutrient stewardship continues to be at the forefront for growers as they attempt to better manage costs and efficiently utilize inputs. Nutrient management is just one area of focus for growers, but can be a difficult task at the farm level to ensure that soil supply of nutrients meets crop demands. Precision agriculture practices such as precision soil sampling coupled with variable-rate fertilizer application technology has afforded growers the ability to spatially manage soil fertility levels; thereby better matching soil fertility levels with crop yield potential to maximize profitability. A primary benefit of precision agriculture is the ability to more accurately place fertilizers, which has been confirmed by science and practitioners under the assumption that equipment and technology are operating at peak performance.

In the U.S., spinner disc spreaders continue to be the primary means to apply granular fertilizers. Over the past 10 years, spinner spreader manufacturers have developed spreader beds and the associated hardware components to spread wider and independently meter and apply multiple products. They have also increased bed capacity to carry more material. Today, a majority of spreader manufacturers offer beds with stated spread widths between 80 and 100 ft. for fertilizer. Occasionally, a 120-ft spread width has been used for beds mounted on high clearance sprayer frames. In this same time period, the use of guidance technology on spinner spreaders has significantly increased, allowing the same paths to be traveled each time during field application. These advancements in both spreader design along with the use of precision ag technology have been a response to meet field capacity (A/hr) requirements of these machines to ensure timely application for efficient crop production.

While fertilizers can be applied as individual constituents or as a blend, blended fertilizer products are common in order to meet specified agronomic requirements while reducing spreading costs (e.g., minimizing trips across the field). We also know that design of spreader components (i.e., divider, discs, and vanes) influences material flow behavior and thereby distribution. However, the nature of blended fertilizers can make it difficult to spread uniformly due to varying physical properties of the N, P and K raw constituents, which can lead to segregation during application. Research has noted that particle size is the major contributing parameter impacting segregation (Bradley and Farnish, 2005; Bridle et al., 2004; Miserque et al., 2008; Smith et al., 2005) and spread distance of fertilizer. Research documents the potential for fertilizer segregation and its negative effect on production distribution (Miserque at al., 2008; Yule and Pemberton, 2009). The main point is that times have changed in the U.S. with the need to spread wider and use blended fertilizers to help manage costs. The idea of fertilizer segregation coupled with repeatable field traverses using guidance technologies, physical size of modern spreaders, and varying application rates increases the opportunity for cumulative application errors generating nutrient "streaking" within fields.

A study was conducted at Auburn University over the past two years to better understand the potential for blended fertilizer segregation as impacted by spreader hardware and fertilizer physical characteristics for spinner-disc spreaders. Two unique spreader setups were used to determine how hardware could impact segregation with a focus on how fertilizer interacted with the vanes and discs. These included different divider and vane designs.

Different fertilizer blends, which were readily available and used in central Alabama were investigated. The first blend has a grade of 17-17-17 with ammonium nitrate, DAP and potassium chloride (KCl) as the base constituents. The second blend was a 10-26-26 that included only DAP and KCl. Additional treatments included application rates of 200 and 400 lb/A and different spinner-disc speeds. Standard pan testing procedures (following ASABE Standard S341.3) were conducted to document distribution patterns. Field tests included

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; DAP = diammonium phosphate. IPNI Project #AL-21.

Table 1. Mean physical characterization for the different fertilizer components and blended products.

	Product	Grade, %	Mean d_{50}[a], mm	GSI[b]
Blend 1	Ammonium Nitrate	34 - 0 - 0	2.16	25
	DAP	18 - 46 - 0	3.22	17
	Potash	0 - 0 - 60	3.05	29
	Blend 1	17 - 17 - 17	2.87	32
Blend 2	DAP	18 - 46 - 0	3.17	14
	Potash	0 - 0 - 60	3.00	25
	Blend 2	10 – 26 - 26	2.97	19

a) d_{50} is the median particle size for the fertilizer.
b) GSI represents Granulometric Spread Index

capturing applied material with randomly placed collection pans across fields during a variable-rate application using the 17-17-17. Samples were also collected from the hopper and conveyor to establish that significant product segregation had not occurred prior to pan and field-testing. Analysis included both physical and chemical characterization using standard laboratory procedures while weighing material captured in pans to compute rate applied at a specific location. High-speed video was also utilized to evaluate particle behavior on the spinner-discs and vanes. This video was able to establish the amount of material being controlled on the vanes versus uncontrolled particles that ricocheted.

Pan and field tests indicated that fertilizer segregation is possible when applied in blended forms using spinner-disc spreaders. While segregation can occur due to loading and vibration during field application, our grab samples from the hopper and conveyer indicated than the level of segregation off the conveyor was minor and insignificant. Particle size analysis (**Table 1**) supported the notion that segregation occurred mainly due to size variability between the constituents.

Figure 1 provides the applied N-P_2O_5-K_2O mass fractions

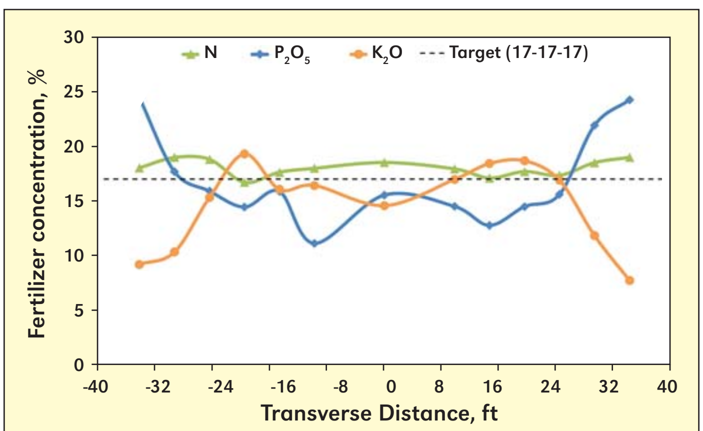

Figure 1. Example nutrient concentration across the spread width for Blend 1 (17-17-17) with a spreader setup at a 70 ft. spread width. Reported data are the mean of three pan tests.

across the swath for Blend 1 (17-17-17). The N mass fraction was consistent across the swath (p=0.4726; **Table 2**), but is a result of both ammonium nitrate and DAP contributing a source of N in Blend 1. These results are important to note

Table 2. ANOVA results for comparison of nutrient mass fractions across the swath based on pan testing.

Source	DF	Mean	Coefficient of Variation, %	Mean Square Error	p-Value
N	14	17.9	4.0	3.0	0.4726
P_2O_5	14	16.8	25.0	56.4	<0.0001
K_2O	14	14.7	26.0	59.1	0.0037

as the reason for uniform N across the swath. Observations of material collected in pans suggested that ammonium nitrate in the center transverse pan locations (-8 to 8 ft.) tended to be pulverized more than the larger N particles beyond these transverse distances. For pans on the pattern periphery (>25 ft. from the centerline), the source of N was primarily from DAP. Conversely, there existed a significant difference between the applied P_2O_5 and K_2O mass fractions ($p<0.05$; **Table 2**). DAP tended to be applied towards the end locations of the pattern with concentrations reaching 25%. DAP concentration was also higher at the center portion of the pattern generating a W-shaped pattern. Potash peaked on either side (20 ft. transverse locations) of the spreader centerline generating an M-Pattern. The point of these data is that segregation can become an error that is not detected by operators.

There were notable observations that fines, mainly from the ammonium nitrate, occurred at a disc speed of 800 rpm for Blend 1. Ammonium nitrate is not as dense as KCl or DAP so as the disc speed increased, this N source tended to explode into dust particles upon contact with the vanes. These dust particles, in the absence of wind, are applied along the centerline of the spreader causing a sharp peak in the distribution pattern. The 700 rpm results indicated only a slight trend to this effect, but were not significantly different from the 600 rpm results. The relevance of this result is that spinner disc speed and associated swath width should be considered when using an N source such as ammonium nitrate or urea in a blend. Results of this research suggest keeping the application width below 60 ft. unless pan tests indicate otherwise, or avoid using a triple blend. This recommendation is most critical when timing and uniformity of spread is especially important such as under high yielding conditions.

Blend 2 also generated similar concentration results for P and K across the spread width (**Figure 2**). These data indicated a consistent M-pattern for the P and a W-pattern for K at spinner disc speeds of 600, 700 and 800 rpm for this spreader and blended product. At the disc speeds tested for Blend 2, little or no fines were measured at the spreader center or on either side (10 ft.) indicating these disc speeds were not causing particles to explode. However, while not significant, the 800 rpm results did generate some fines suggesting that even higher disc speeds might cause an issue as found with Blend 1. While fertilizer segregation can occur due to various factors (i.e., loading, particle size variation, vibration, etc.), the presence of peaks and valleys across the swath width during pan tests indicate that distribution using spinner-discs and vanes can be a large contributor.

Field-testing using one spreader and Blend 1 under variable-rate application demonstrated how the issue of segregation could impact concentration uniformity. Applied nutrients were found to vary significantly from the expected rates in the fields except for N, which had a mean concentration of 17% and a CV less than 8.5%. The applied P_2O_5 and K_2O concentrations varied significantly with mean concentrations of 15% and 17%, respectively. While the overall mean concentration was near the target of 17%, the uniformity of spread (CV) ranged from 19.7% to 37.2% for P_2O_5 and 16.8% to 30.2% for K_2O.

Visual illustration of the resulting distribution from an individual pan test using Blend 1 (17-17-17). Note that the DAP particles (larger in diameter) were applied further out than the KCl (pink particles) and ammonium nitrate (white particles). While not clearly visible, the center three tubes contain the highest percentage of dust particles, which were mainly ammonium nitrate.

An important finding of this study was that level of segregation can be impacted by vane design and spinner-disc speed. Vane design can greatly impact segregation in two possible ways; 1) level of ricocheting and thereby uncontrolled material flow off the vanes and 2) the exit point and final particle velocity controlling the distance traveled (e.g., larger particles travel further). To increase spread width, one must increase spinner disc speed; however, this study established that risk of segregation also increased with disc speed. Some of this risk was associated with ricocheting of fertilizer particles off the vanes during initial contact. Fertilizer ricocheting represents an uncontrolled aspect of material flow, which negatively impacts the spread distribution since ricocheted particles land around the center of the spreader. Ricocheting is primarily due to vane design and not the spinner-disc based on this study with the top edge of the vane (e.g., first potential contact point for particles) significantly influencing level of ricocheting. Tests showed that 35% of the material flow off the conveyer could be ricocheted at 800 rpm with a vane design having a top edge that is forward facing and angled upwards. The level of ricocheting can be reduced in half or more by making the top edge, level or tapered backwards.

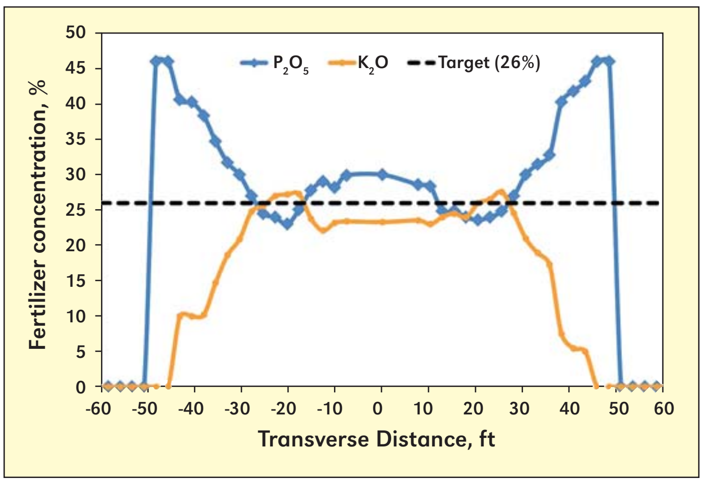

Figure 2. Nutrient concentration across the spread width for Blend 2 (0-26-26) with a spreader setup at a 70 ft. spread width. Reported data are the mean of three pan tests.

Summary

This study showed that segregation of blended fertilizers occurs, especially as spinner disc speeds or spread widths increase. Spreader hardware such as vane design can impact the level of segregation. However, this study documented this problem with only two different spreader setups, and may not exist with other setups or hardware configurations. One remaining concern is that repeated applications following the same spreader paths (e.g., use of GPS-based guidance) could result in soil fertility zones or streaks within fields. Therefore, variable-rate application of blended fertilizer could pose challenges in terms of accuracy and uniformity to meet target prescription rates. Three case studies that we reviewed in 2011 and 2012 established the issue of segregation by spreaders causing nutrient streaking in corn.

Adjustments were required to address this problem and uniformly apply granular fertilizers. Recommendations from this study would be: 1) due to the importance of similar particle size and density for blend constituents, avoid blending an N source with potash or phosphate sources unless spread width is sufficiently limited so as to prevent segregation—usually less than 50 ft., 2) use P and K sources with consistent particles sizes throughout the pile with no dust, and 3) double check through pan testing that 800 rpm or higher disc speeds are not causing significant product segregation or dust generation through particle ballistics. Spreader setup, maintenance, and calibration along with selection of the appropriate product to coincide with these parameters are as critical as ever to ensure uniform distribution as we seek to improve machinery and input efficiency. BC

Acknowledgements

The authors would like to thank the technical assistance from Dr. Steve Phillips along with financial support from IPNI, Alabama Wheat and Feed Grain Committee, and Alabama Soybean Producers.

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