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## **Field corn tests to examine anhydrous ammonia manifold variability**

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**Abstract.** Field experiments were conducted to measure variation in yield, stalk-N concentration, and the N content of harvested grain, for corn with anhydrous ammonia (NH<sub>3</sub>) fertilizer. N was applied with the conventional, Vertical-Dam, Rotaflow™, and FD-1200 prototype manifolds with an application rate goal of 84 kg N/ha (75 lb N/ac). Applications were with each outlet on the manifold plumbed to one applicator knife (normal), and with manifold outlets redirected so that some knives received no NH<sub>3</sub> while other knives received twice the rate goal (modified).

For two years of the study, NH<sub>3</sub> was applied and a third year had only the residual of the previous year. Rows were harvested singly to record harvest yield and take a grain sample.

Results showed a positive correlation between N application rate and stalk-N concentration for all three years. No correlation between N content of grain and other factors was observed. For one site-year, measured yields between the two application arrangements were significantly different for all manifolds. Small variations in application rate between the normally plumbed manifolds did not result in statistical yield differences.

**Keywords.** Anhydrous ammonia, nitrogen, fertilizer, NH<sub>3</sub>, yield, corn, applicator

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## Introduction

With an increase in population in the postwar 1950's came an increased need for food crop production in the United States. This era accelerated the use of commercially purchased nitrogen (N), phosphorous (P), and potassium (K) as three primary nutrients needed for corn plant growth. N is usually the most limiting of the three primary nutrients for growth in corn.

Modeling of future corn production in Midwestern states has projected an increase in production of close to 70% above current production levels in the next 30 years. This value was estimated taking into account the current exponential rate at which new technology is increasing yields (Reilly & Fuglie 1998). With increasing productivity and fertilizer requirements comes concerns about the management of nutrients and keeping them in the root zone.

One of the keys to realizing this yield increase is future input and output prices, including the pricing and incentives that exist to reduce environmental damages stemming from crop production (Reilly & Fuglie, 1998). As nitrate ( $\text{NO}_3\text{-N}$ ) leaching and over application of N fertilizers play a vital role in environmental damage, control and efficient use of N fertilizer will be prominent in the ability or inability of producers to achieve these future production figures.

As noted by Baker and Johnson (1981), "It is expected that the trend of increasing N use will continue unless use is controlled by high costs and/or energy shortages." A controlling factor that may not have been considered 25 years ago is the possibility of governmental regulation to control N fertilizer application rates and monitor tile effluent and surface runoff.

One of the many fates of field-applied N fertilizer is leaching loss as  $\text{NO}_3\text{-N}$ , which is of environmental, economic, and energy-conservation concern. Leaching losses of N, as  $\text{NO}_3\text{-N}$ , are most significant when the amount of fertilizer applied exceeds the crop N requirement (Roth and Fox, 1990). Baker and Johnson (1981) showed that up to 55% of stream flow in the Skunk River in central Iowa can be attributed to farm field tile drainage, depending on rainfall and other meteorological conditions. In multiple fields with N applications rates from 56 to 116 kg/ha (49 to 104 lb/ac), total losses of N as  $\text{NO}_3\text{-N}$  from the tile lines ranged between 26 and 48 kg/ha (23 and 43 lb/ac). Nitrogen fertilizer in this study was applied as prilled urea and incorporated with spring tillage.

Jaynes et al. (2001) and Goldstein et al. (1998) have shown that increased  $\text{NH}_3$  application rates result in increases in  $\text{NO}_3\text{-N}$  in tile effluent. Goldstein et al. (1998) continued on to show that  $\text{NH}_3$  applied to corn had the highest  $\text{NO}_3\text{-N}$  concentrations in tile effluent of a number of crop and fertilizer combinations including hay, oats, corn, and soybeans, with either manure or  $\text{NH}_3$  as the fertilizer. A change of fertilizer type from manure to  $\text{NH}_3$  resulted in a seven to ten times increase in the  $\text{NO}_3\text{-N}$  concentration in the tile effluent from the field.

Many experiments over the past 50 years have shown a correlation between N fertilizer application rates and corn yield. Liang and MacKenzie (1994) found that the response of yield, grain N, and total N uptake were related to N application rate. Increasing application rate of  $\text{NH}_3$  has been shown repeatedly to increase corn yields in many soil types and climates (Stehouwer and Johnson 1990, Stevenson and Baldwin 1969).

Cerrato and Blackmer (1990) showed that N concentration in grain tended to increase with increasing rates of N application. However, they were unable to find any basis for determining critical N concentrations based on N concentrations in grain. Therefore, they found that N concentrations in grain did not provide a reliable indicator of the N status of corn. This result is contradictory to work done by Pierre et al. (1977). In Iowa soils, they found that values of grain N above 1.52 % usually indicated sufficient soil N for maximum yields. The data of grain N versus relative yield as a percent of maximum was fitted using a quadratic model function.

End-of-season cornstalk N content has also been used as an indicator tool for determining N status in corn at harvest time. This tool gives an after the fact look at plant growth, but is very valuable in future planning for N fertilizer needs. Stalk sample  $\text{NO}_3\text{-N}$  concentrations fall into four categories: low (less than 250 ppm N), marginal (250 to 700 ppm N), optimal (700 to 2000 ppm N), and excess (greater than 2000 ppm N). Within the optimal range yield may increase without a change in stalk sample  $\text{NO}_3\text{-N}$  concentration. In the excess category, there is luxury uptake and even as uptake increases, it does not usually increase yields (Blackmer and Mallarino, 1996).

Brouder et al. (2000) stated that in comparisons made between stalk  $\text{NO}_3\text{-N}$  analysis and N concentrations in grain, stalk analysis was superior to grain analysis for distinguishing sufficiency from

excess. In the study, both linear response with plateau and binary logistic regression were used. Both had high success rates at determining deficiency from sufficient observations.

To evaluate corn yield response to N application, Cerrato and Blackmer (1990) found that the quadratic plus plateau model fit the data best but not significantly better than others models compared. For predicting the economic optimum fertilization rate, the quadratic plus plateau model was the most accurate (i.e. it best described the overall yield response observed).

Nafziger et al. (2001) found that the quadratic plateau model best fit yield responses to N fertilization in Illinois in 2000 at the majority of research sites examined. The quadratic plateau model for yield response has become the commonly accepted model in corn and serves to accurately predict yield and the economic optimum fertilization rate.

As of 1997, 85% of all NH<sub>3</sub> manufactured was used in some form of fertilizer for agriculture (Appl, 1999). In Iowa in 1999, 98% of corn received N fertilizer at an average application rate of 141 kg/ha (126 lb/ac) for the growing season (Sands, 2000). Of the commonly used straight material sources of N, NH<sub>3</sub> accounted for more than 40% of the total amount of N applied (Sands, 2000). Through recent fluctuating prices and supplies, anhydrous ammonia has remained the number one N fertilizer due to low cost and high N content (82% N by weight).

Recent studies have shown wide variations in the amount of fertilizer applied between knives of common NH<sub>3</sub> applicators (Boyd et al., 2000, Schrock et al., 2001, Kerkman and Colvin, 1997). The conventional manifold has been in use for over forty years and is very common on applicators today. All three sources found high coefficients of variation (CV) with the conventional manifold. Values for the conventional manifold were in excess of 15%.

These errors in application, in conjunction with variable NH<sub>3</sub> prices and water quality concerns have increased interest in equipment designed to apply NH<sub>3</sub>. Better control of the material will be essential to allow NH<sub>3</sub> to be used in precision farming techniques with variable rate applications.

A study was conducted to examine corn response to different rates of NH<sub>3</sub> fertilizer placed equal distances from each row, as it would be in a side-dress application to measure yield effects and possible cost savings to producers from reduced NH<sub>3</sub> application variation.

The objectives were:

1. To determine if yield variations occurred due to uneven application of NH<sub>3</sub>.
2. To examine possible residual effects of uneven application in a second growing season.
3. To evaluate *grain % N* and *stalk-N concentration* for correlation with yield and application rate.

## Materials and methods

During the 2000 and 2001 growing seasons, experiments were implemented to evaluate yield effects of variability of NH<sub>3</sub> rate across the application swath in corn (*Zea Mays* L.). In 2000, field location was at the Iowa State University Boyd Farm in Boone County, Iowa. In 2001, the Boyd Farm plots were planted to corn again without fertilizer application to look at residual effects of NH<sub>3</sub> application, and a second site was added for NH<sub>3</sub> application on first year corn. The second site, on the Iowa State University Marsden-Paulsen farm, was approximately 0.8 km (0.5 mi) east of the site at the Boyd farm.

The plots at the Boyd farm were recorded as Boyd 2000 and Boyd 2001 for the first and second year respectively. Marsden-Paulsen 2001 was the name for plots that received NH<sub>3</sub> at the Marsden-Paulsen farm during that growing season.

The Boyd farm location had Nicollet loam and Clarion loam soil types and the Marsden-Paulsen location had Clarion loam. Precipitation, recorded at the Agricultural Engineering Research Center (AERC), near the farm locations was 59-cm (23.3-in) in 2000, and 81-cm (31.8-in) in 2001. Both Boyd 2000 and Marsden-Paulsen 2001 were planted to soybeans in the year preceding the study.

Before planting, soil sample cores were taken to measure NO<sub>3</sub>-N concentration in the soil. Ten cores were taken in an "X" pattern across the field. Each core was divided into samples at three depths, 0-30 cm, 30-60 cm, 60-90 cm. Samples from all cores were composited at each depth and multiple composites were analyzed at the Iowa State University Soil Testing Laboratory.

Each experimental area was tilled with a fall chisel plow and a spring field conditioner. All three experiments were planted with DeKalb DK 551 variety field corn. Seed population for Boyd 2000 and Marsden-Paulsen 2001 was 71,400 seeds per hectare (28,900 seeds/ac). At Boyd 2001, a slipped chain

drive on the planter resulted in a population of approximately 93,900 seeds per hectare (38,000 seeds/ac).

Plot length was 91.5-m (300-ft). 200 rows of corn with 0.76-m (30-in) spacing were planted in two blocks. Extra rows were left on either side of the plot rows when possible to reduce any possible edge effects on yields. Experimental units or plots were individual rows 0.76-m by 91.5-m (30-in. by 300-ft).

Within seven days of planting,  $\text{NH}_3$  was applied. Application was made with a DMI Nutri-placr 3250 applicator (DMI, Goodfield, IL). The applicator was an 11 knife, 3-point-hitch mounted toolbar with single disk openers ahead of the injection knives. Application of  $\text{NH}_3$  was made to the crop at the center point between each row, 38-cm (15-in) from each row. Measurement of placement of the  $\text{NH}_3$  band directly after application showed that the error in application location was approximately  $\pm 5$ -cm (2-in).

### Treatments

Three manifolds were used each year to apply  $\text{NH}_3$ . For Boyd 2000, a conventional manifold (Continental 3497, Continental  $\text{NH}_3$  Products, Dallas, TX), a small housing Vertical-Dam manifold (Continental MVD, Continental  $\text{NH}_3$  Products, Dallas, TX), and a Rotaflow™ manifold (H. I. Fraser Ltd., NSW, Australia) were used. For the Marsden-Paulsen 2001 experiment, the conventional, Vertical-Dam and a prototype FD-1200 manifold (CDS John Blue Co, Huntsville, AL) were used. Each of the manifolds was plumbed to have 11 outlet ports evenly spaced around the circumference of the manifold. Figure 1 shows the manifolds used.

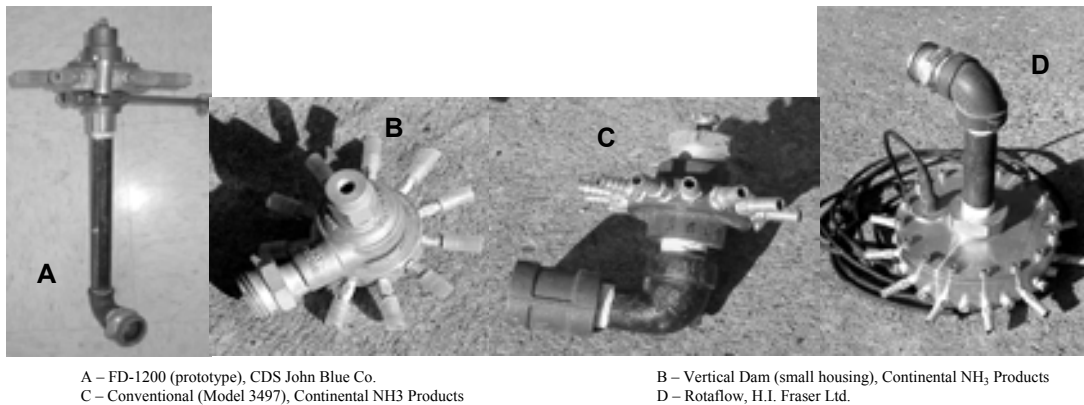


Figure 1. Manifolds used in study

The applicator was outfitted to take a sample of the  $\text{NH}_3$  as it flowed from the manifold to the knife. Boyd et al. (2000) details a complete description of the equipment. The system allowed for the measurement of the flow of  $\text{NH}_3$  while moving through the field. With each manifold installed on the applicator and plumbed with standard 0.95-cm (0.38-in) inside diameter hoses, a test run was done to determine application rate. The application rate goal was 84 kg N/ha (75 lb N/ac). This application rate was selected to hopefully increase measurable variation in yield and other N status indicators by increasing stress on the corn plant as compared to more common higher application rates in corn.

The regulator used on the applicator was a John Blue Nitropacer (CDS John Blue Co., Huntsville, AL). The regulator was adjusted so that the average application rate across the 11 knives was approximately 84 kg N/ha (75 lb N/ac). Once the application rate was within 5% of the application goal, three passes were made with that manifold. Each of the manifolds was used for three replicated application passes in a normal plumbing configuration with one outlet from the manifold connected to one application knife. Adjacent manifold outlets were connected to adjacent knives.

To calculate the estimated application rate for each row of corn plants, the average of the two rates applied on either side of that row was used. It was not felt that a single test pass would give a completely accurate picture of the variation in distribution from outlet to outlet. To define the application rate used in data analysis, the following steps were taken:

1. The average application rate from the one test run at the time of planting was used as the overall rate for the plots.
2. Using data collected from the manifolds at an earlier date at the same application rate and with similar tank pressures with multiple replications, the application ratios were determined by taking the application rate from each knife and dividing it by the average for all 11 knives.
3. That ratio was then multiplied by the average application rate measured at the time of planting (step 1).

In this way, the overall application rate was used from the time of planting while being able to incorporate manifold outlet variability data with multiple replications.

Variation in application rate based on earlier experiments was very pronounced with the conventional manifold, while the other manifolds had less outlet-to-outlet variation. To increase the variation in application, a second set of treatments were applied with each manifold with the  $\text{NH}_3$  from two high-flow manifold outlets intentionally combined at a single knife to create a considerably greater variation across the swath of the applicator. To achieve this, applicator shanks 8 and 9 were outfitted with knives with two application tubes. The flow from knives 3 and 4 was directed to the additional tubes on knives 8 and 9. This resulted in the one row between knives 3 and 4 receiving an application rate of 0 kg N/ha, and one row between knives 8 and 9 receiving an application at least twice the average application rate. This also created four intermediate application rates. Those rows between knives 2 and 3, and knives 4 and 5 received an application approximately one half the average with the modified plumbing.

After all applications had been made, each area between the rows was tracked over by a tractor. This procedure was done to ensure that all rows were compacted approximately the same amount to reduce possible preferential flow of water through untracked rows and subsequent  $\text{NO}_3\text{-N}$  leaching. The experiments were cultivated once in June for weed control.

To measure variations in yield between application rates, the experimental areas were harvested one row at a time. After completing the row, the total weight of the harvested grain was recorded as well as the grain moisture content (%). In addition, in 2001 a sample of the grain from the plot was taken for nitrogen analysis. Header height on the combine was adjusted to leave 60-cm (24-in) of corn stalk in the field. Grain was harvested at or below 17% moisture and yields adjusted to 15.5% moisture. Yield was calculated by weight of grain harvested divided by the area of the plot.

Grain samples were processed by the Iowa State University Grain Quality Lab for percent protein and results converted to percent nitrogen in the grain by the equation:

$$\text{Grain Nitrogen (\%)} = \text{Grain Protein (\%)} / 6.25$$

Comparisons were made using the PROC REG function of SAS v. 8.2 (SAS, Cary, NC) to determine if the slope of the best fit line and the intercept of regressions comparing application rate, yield, % N in grain, and stalk-N concentration were statistically different than zero at  $\alpha=0.05$ . Due to seasonal and spatial variations in each experiment, correlations were only made within the boundaries of a single site-year combination (i.e. experiment).

Based on Cerrato and Blackmer (1990) and Nafziger et al. (2001), a quadratic plateau model was applied to the yield results for each of the experiments. The quadratic plateau model was based on the equations:

$$(1) \quad y = a + bx + cx^2 \quad \text{if } x < x_0$$

$$(2) \quad y = p \quad \text{if } x \geq x_0$$

where: a, b, c are parabolic variables  
p is the plateau value  
 $x_0$  is the joint point

these conditions imply that

$$x_0 = -b / 2c$$

$$p = a - b^2 / 4c$$

Parameters of this equation were evaluated with the PROC NLIN function in SAS V. 8.2. This function used an iterative process to fit the model to the data, calculating the parameters of the parabolic function and the joint point,  $x_0$ , for the plateau. To determine if there was any perceptible error in the model fitting, a correlation was made to quantify the variation between the model line yield and the actual yield. This was also used to examine the assumption that the N uptake was split evenly between the two rows adjacent to the application band. If this 50 percent assumption was not valid, this comparison would exhibit some noticeable variations away from the model line in plots where the difference between application rates on opposite sides of the row were high, i.e. a row that had a zero application on one side and an excess rate on the other.

To compare manifolds, the yield results of the three treatment replications with each manifold and plumbing configuration were averaged and statistically compared, and column charts created to visually examine the difference in row yield with each manifold.

## Results and discussion

### Boyd 2000 – Crop response to $\text{NH}_3$

The model yield plateau (figure 2) was reached at 8.31 Mg/ha (132.2 bu/ac) and the application rate of  $\text{NH}_3$  at the plateau point was 118 kg N/ha (105 lb N/ac). The model parameters for the quadratic function were  $a = 8.47$ ,  $b = -0.0028$ , and  $c = 0.00001$ . Because the yield plateau was below the intercept ( $a$ ), and the  $b$  coefficient was negative, the quadratic plateau model had a slightly negative slope. This model fit indicated no yield response to  $\text{NH}_3$  application rate.

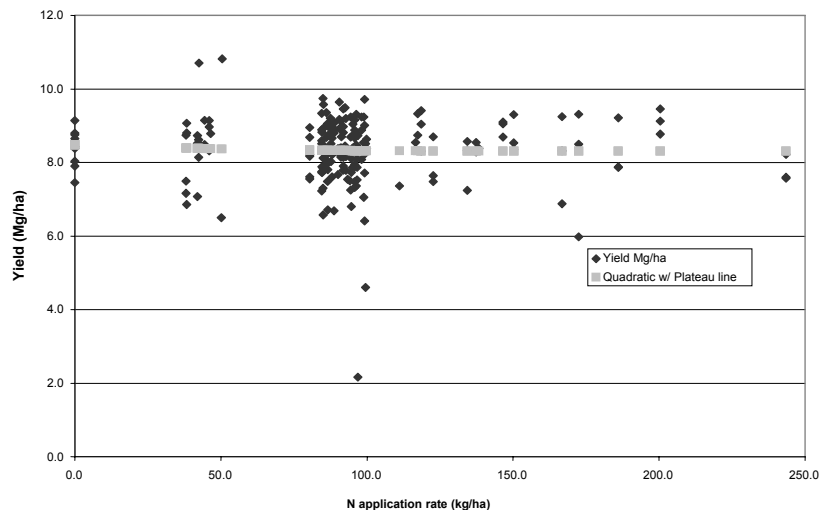


Figure 2. Yield Response to application at Boyd 2000

The 2000 growing season was dry in central Iowa with below normal yields in many areas. Corn dried to harvest moisture in the field by September 15, resulting in early harvest. Yield response may have not been measurable due to limited N uptake by corn plants under moisture stressed growing conditions.

To evaluate how well the quadratic plateau model fit the yield data and to evaluate the assumption that 50% of the corn plant N uptake came from each side of the row, figure 3 was developed. Values of zero on the X axis were produced when the quadratic plateau model yield and the actual yield were the same. Values at or near 1.0 on the Y axis had the same or similar application rates on either side of the row. Values near zero on the Y axis had a high ratio between application rates (i.e. 30 kg N/ha / 200 kg N/ha = 0.15). Values at zero on the Y axis had a zero application rate on one or both sides of the row.

The data points in figure 3 were nearly evenly distributed on both sides of the model line at 0.0. At the zero ratio point, values ranged from -2.5 to 1.9 Mg/ha (-40 to 30 bu/ac). This distribution, spread to both sides of the model line for a wide range of ratios supports the assumption that averaging the application rate on either side of the row was acceptable for the Boyd 2000 experiment.

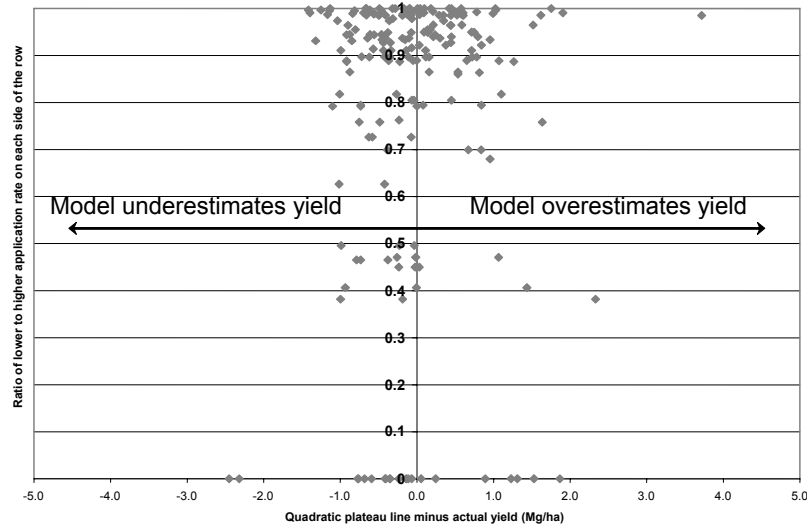


Figure 3. Yield model error distribution for Boyd 2000

Stalk-N concentration measured at harvest was compared to the N application rate and to the corn yield by row (figure 4). Over half of the samples exceeded the 700 ppm  $\text{NO}_3\text{-N}$  concentration to be considered optimal, and only 7 samples were in the excess category above 2000 ppm  $\text{NO}_3\text{-N}$  (Blackmer and Mallarino, 1996). There was a significant positive slope correlation between stalk-N concentration and N application rate. The intercept value was not significantly different than zero.

Corn plot yield did not increase stalk-N concentration (figure 5). The majority of the data points were grouped tightly together with a few outlier points noticeably affecting the slope. The slope had a very low correlation coefficient and was not significantly different than zero.

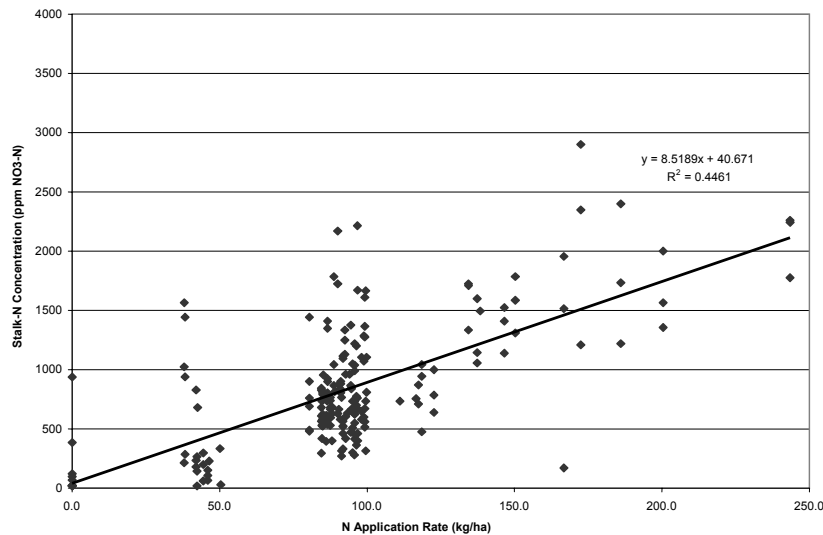


Figure 4. Stalk-N versus N application rate for Boyd 2000

### Boyd 2000 – Yield response to manifold variation

Each manifold treatment (conventional, Vertical-Dam, and Rotaflow<sup>™</sup>) was repeated three times in both normal and modified plumbing arrangements. The average yield results for corn rows within each manifold treatment were used to develop graphs of N application rate and yield. Figure 6 shows the application rate of N from each knife on the applicator, and the yield of the rows within the width of the applicator for the normal plumbing arrangement the conventional manifold for Boyd 2000. Application rates varied by 70 kg N/ha (63 lb N/ac), and yield varied by 1.03 Mg/ha (16.4 bu/ac). The results of the modified plumbing conventional manifold are shown in figure 7. The variation in N

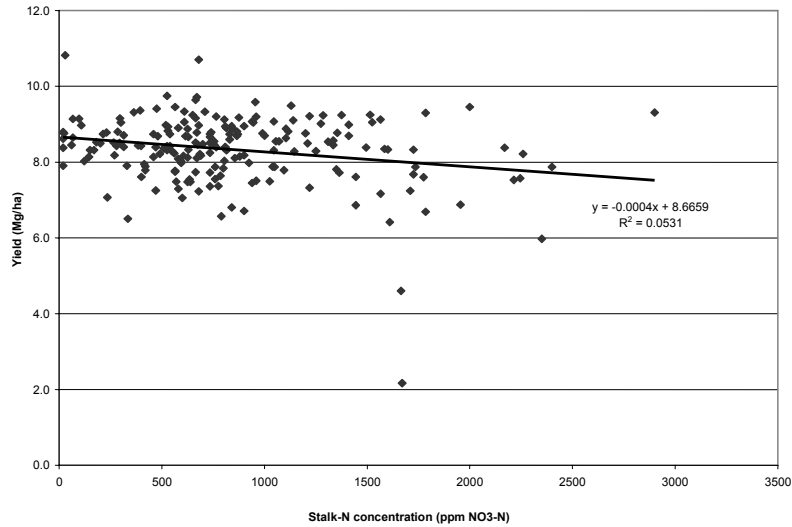


Figure 5. Yield versus stalk-N concentration for Boyd 2000

application rate from 0 to 250 kg N/ha (223 lb N/ac) made no significant difference in the average yield of the treatment. There was no reduction in yield at the 0 kg N/ha rate, nor was there an increase at the 250 kg N/ha rate.

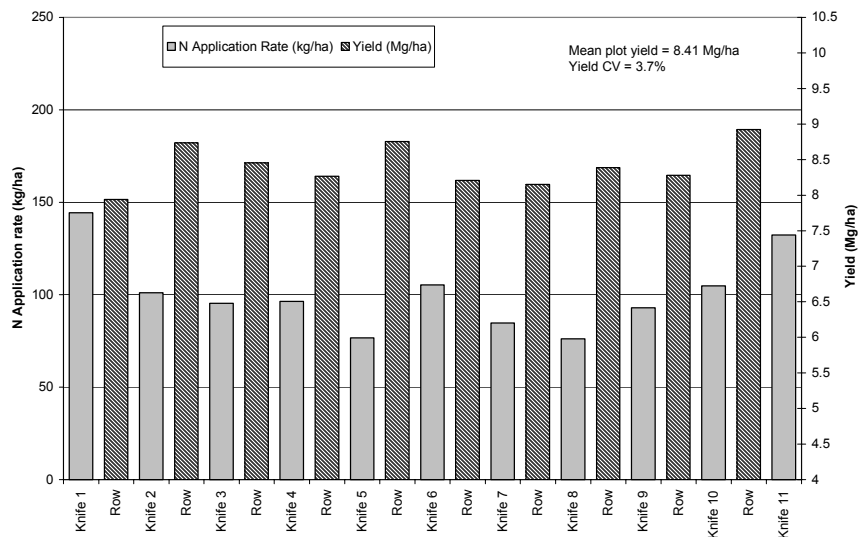


Figure 6. N application rate and yield for normal conventional manifold for Boyd 2000

The CV's of the yield were similar between the two treatments, 3.7% for the normal conventional and 3.0% for the modified conventional manifold plumbing.

Yield comparisons were also made for the Vertical-Dam and the Rotaflow™ manifolds. The Vertical-Dam manifold had a less distribution variation from the manifold than the Conventional manifold. The CV for the yield across the applicator swath was 8.8% for the normal Vertical-Dam, and 2.4% for the modified Vertical-Dam. There was a significant difference between the average yields; the modified plumbing Vertical-Dam had a 0.89 Mg/ha (14.2 bu/ac) higher average yield



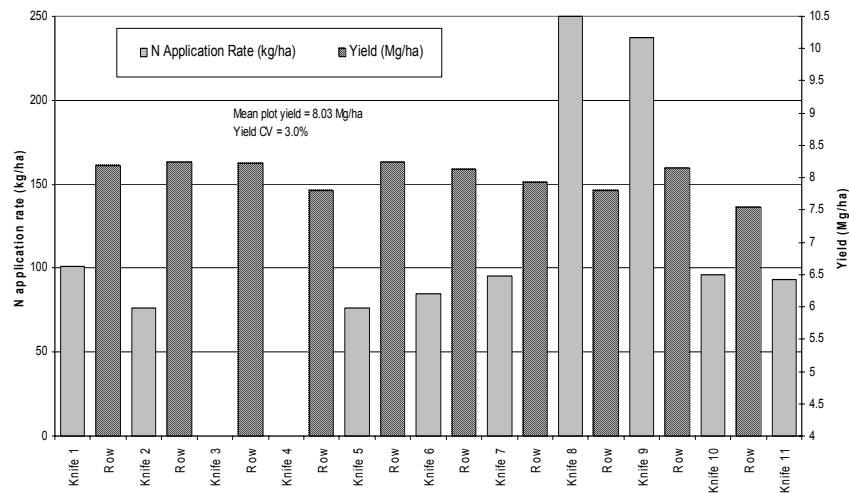


Figure 7. N application rate and yield for modified conventional manifold for Boyd 2000

than the normal Vertical-Dam. Reduced or increased yields in individual rows due to wide variations in application rate were not observed.

Corn yields were nearly identical between the normal and modified Rotaflow™ manifolds. No indications of variation in yields due to variations in application rate were seen on the modified plumbing treatment. Yield CV was slightly lower with the modified plumbing Rotaflow™ manifold. This response would not be expected and no relationship between application rate and yield was observed for the Rotaflow™ manifold in the Boyd 2000 experiment.

The manifolds were also compared by plumbing arrangement, using the yield data from all three manifolds. The normal conventional manifold had significantly greater yield than the normal Vertical-Dam manifold. The modified Vertical-Dam yield was also significantly higher than the yields of the other two modified manifolds. The normal Vertical-Dam manifold had the lowest average yield of any of the treatments while the modified Vertical-Dam had the highest. The yield of the modified Vertical-Dam was significantly higher than the modified Rotaflow™ or the modified Conventional, but the maximum variation of CV of yield between the three treatments was only 1.1%. This would indicate that the variation in application rate across the applicator was not the primary factor affecting yield. There may have been sufficient N available in the soil for all three treatments and the application of N only supplied excess N, which was not needed during the 2000 growing season.

A comparison of all normal plumbing manifolds to all modified plumbing manifolds showed no statistical difference in yield.

### Boyd 2001 – Crop response to NH<sub>3</sub>

The treatments of the Boyd 2001 experiment were from the residual N remaining in the soil from the Boyd 2000 experiment. For analytical purposes, the application rates from Boyd 2000 were used. Yield response to N application, when modeled with a quadratic plateau model, resulted in a response very similar to that of the Boyd 2000 experiment. The plateau line intercept was -2.67 kg N/ha (-2.38 lb N/ac) at a yield of 6.1 Mg/ha (97 bu/ac). This resulted in all application rates, including the 0 kg N/ha rate being on the plateau line of the model. These results indicated that no correlation between N application rate and yield was evident.

The variation between the actual yield and the model line showed no distinct signs of a trend, either high or low. There was a mild shift towards the model overestimating the yield on the rows with a zero ratio. The majority of the zero ratio data points were clustered between +/- 1.0 Mg/ha. Stalk-N concentrations were greatly reduced from 2000 to 2001. No concentration exceeded 700 ppm NO<sub>3</sub>-N, and all samples were either low (0-250 ppm NO<sub>3</sub>-N) or marginal (250-700 ppm NO<sub>3</sub>-N) according to Blackmer and Mallarino (1996). The slope of the best fit linear line was significantly different from zero and crossed the X axis at approximately 50 kg N/ha. Yield was not significantly correlated to stalk-N concentration, and comparisons of % N in the grain to application rate, stalk-N concentration, and yield resulted in no significant correlations.

### Boyd 2001 – Yield response to manifold variation

All of the comparisons made between manifolds and arrangements in the Boyd 2001 experiment were not significant.

Yields were greatly reduced, with an average reduction of 26%, or 2.1 Mg/ha (34 bu/ac) from the Boyd 2000 experiment. There was no yield difference between the normal and modified conventional manifolds. However, a noticeable reduction in yield in the rows with a zero application was seen on the modified plumbing conventional manifold. While a decrease in row yield at the zero application rate occurred, no increase in row yield due to the excessive application rate was seen. The yield CV increased from 6.6% for the normal plumbing to 12.8% for the modified plumbing, but only resulted in a 0.37 Mg/ha (5.9 bu/ac) reduction in yield.

Comparison of the Vertical-Dam manifold plumbing arrangements showed no significant difference in yield. Consistent with the conventional manifold, there was an increase in yield CV with the modified plumbing on the Vertical-Dam, but average yield increased numerically with the modified plumbing on the Vertical-Dam.

The yield difference was not significantly different between plumbing arrangements for the Rotaflow™, but the modified plumbing treatment showed a numeric decrease in yield in rows of low or zero application and an increase in yield in rows with high application rates. Average yield for the plant rows between knives 8 and 10 for the modified plumbing Rotaflow™ were 23% higher than the average plot yield.

The Rotaflow™ manifold treatment was the only modified plumbing treatment to have both a reduction in yield at rows with zero application and an increase in yield at rows with high application.

### Marsden-Paulsen 2001 – Crop response to NH<sub>3</sub>

Yield response evaluated with the quadratic plateau model resulted in a positive correlation between yield and N application rate (figure 8). The slope of the quadratic regression portion of the model was significantly different than zero. The model fitting analysis resulted in quadratic parameters of  $a = 7.41$ ,  $b = 0.037$ , and  $c = -0.00017$ . The yield plateau was 110 kg N/ha (98 lb N/ac) with a yield of 9.42 Mg/ha (150 bu/ac).

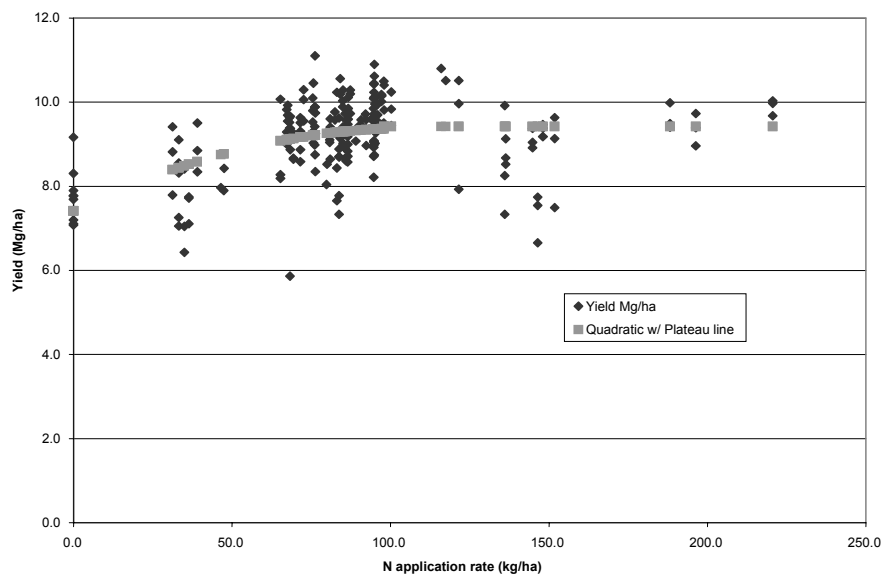


Figure 8. Yield Response to application at Marsden-Paulsen 2001

Examination of differences between the model yield and the actual yield showed a slight bias towards overestimation of the yield by the model for N application ratios lower than 0.5 (figure 9). This result indicates that when there are large discrepancies between the amount of N applied to each side of the row, the model tended to over estimate the yield, as actual yields were less than those predicted by the model. This may suggest that in this situation root growth or N movement within the soil could not

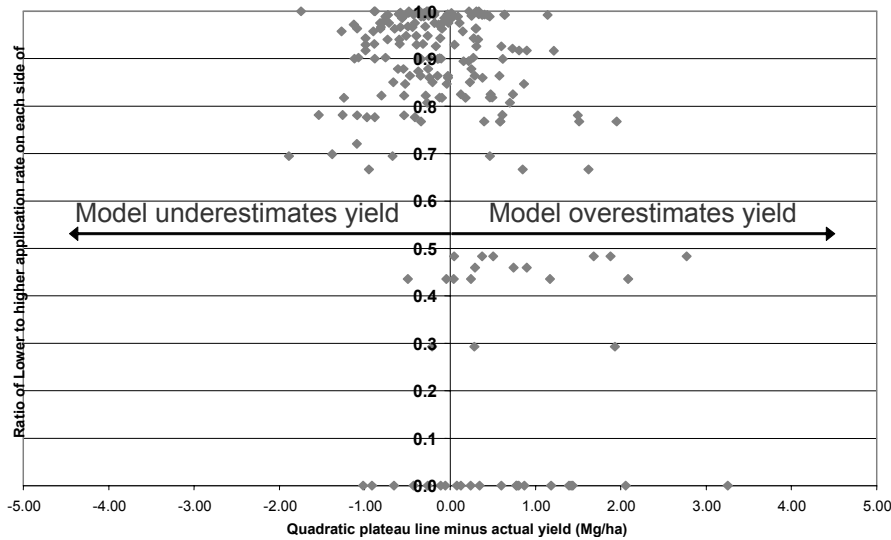


Figure 9. Yield model error distribution for Marsden-Paulsen 2001

compensate for the variations. The majority of zero ratio points fell within  $\pm 1.0$  Mg/ha, with five plot yield values exceeding an overestimation of 1.0 Mg/ha (15.9 bu/ac).

Stalk-N concentrations were much higher than in the Boyd 2001 experiment, but lower than the Boyd 2000 experiment. The majority of the samples were in the low and marginal classifications, with less than a quarter of the samples exceeding 700 ppm  $\text{NO}_3\text{-N}$ . Even with a large number of samples with low concentrations, there was a significant positive correlation between stalk-N concentration and N application rate. An increase of 1 kg N/ha resulted in a 10.4 ppm  $\text{NO}_3\text{-N}$  increase in stalk-N concentration. Similar to the Boyd 2001 experiment, the best fit line intercepted the N application rate at approximately 50 kg/ha. Below that application rate, no correlation was detected. Yield was not significantly correlated to stalk-N concentration.

The comparison of % N in the grain samples to the N application rate resulted in a significant slope. No significant correlation between yield and % N in the grain samples was found. Although the correlation coefficient is small ( $R^2 = 0.1129$ ), a significant positive correlation (i.e. non-zero slope) between stalk-N concentration and % N in the grain samples was found. This plot relationship also had a very mild slope with a tight grouping of data points.

### Marsden-Paulsen 2001 – Yield response to manifold variation

Comparison of yield for the conventional manifold resulted in a significant difference in plot yield between normal and modified plumbing arrangements. The modified plumbing resulted in a 7.4% reduction in yield and a 2.3 percentage point increase in yield CV (the equivalent of a 46% increase in yield CV). In addition, yield influences are noted with varying application rate. Plot rows receiving no N were approximately 10% lower than the average yield and those with excess N application (235 kg N/ha (210 lb N/ha)) were up to 15% higher than the average yield. Figures 10 and 11 plot the conventional manifold applications and yield.

The Vertical-Dam manifold plots showed very similar results to the conventional manifold plots. The modified plumbing Vertical-Dam manifold plots produced a statistically significant 7.6% decrease in average yield and an increase of 5.3 percentage points in yield CV compared to the normal plumbing treatment. The general trend of decreased yield on zero application rows and a mild increase in yield on the high application rate rows was present. Analysis of the FD-1200 prototype manifold test plots showed a statistically significant decrease of 11.9% in yield and an increase of 4.9 percentage points (220% increase) in yield CV with the use of the modified plumbing. The modified plumbing configuration for the FD-1200 prototype manifold had a reduction in yield with the zero N application rate rows but did not have noticeable increase in yields at the highest N application rates.

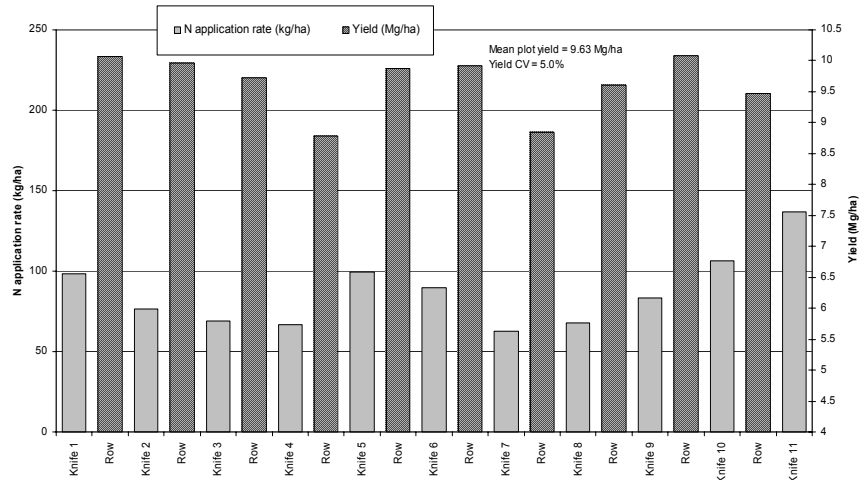


Figure 10. N application rate and yield for normal conventional manifold for Marsden-Paulsen 2001

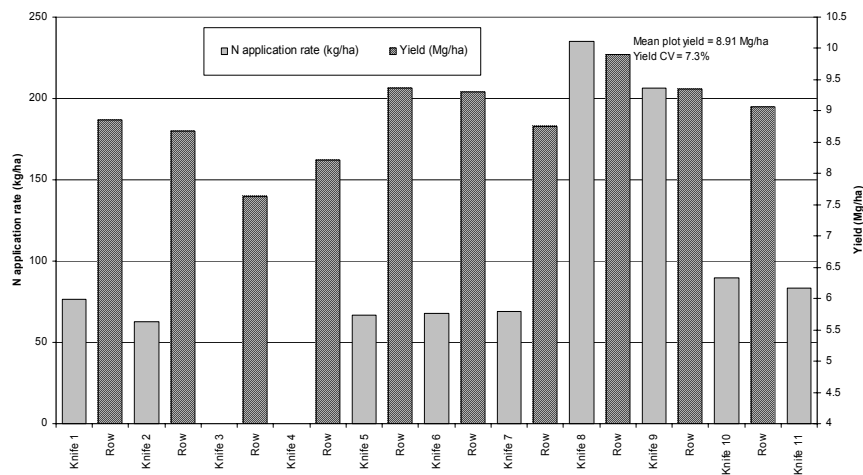


Figure 11. N application rate and yield for modified conventional manifold for Marsden-Paulsen 2001

As each of the manifolds had statistically significant higher yields with the normal plumbing, comparison of all normal manifold treatments against all modified manifold treatments also showed a significant reduction in average yield. Analysis comparing the normal manifold treatments to each other showed no significant yield difference; nor did comparison of the three modified manifold treatments amongst themselves.

### Economic advantages to reduced application variation

Yield study results showed no relationship between yield and N application at the Boyd site for either the year of application, or the year after application, and a positive relationship at the Marsden-Paulsen site 2001. A common question by producers is “Can I afford to switch to a new manifold?” Based on data collected at the Marsden-Paulsen site, an example calculation was made to show a process for estimating the expense of using an older style manifold in terms of excess  $\text{NH}_3$  applied above the application goal.

The conventional manifold (#3497, Continental  $\text{NH}_3$  Products, Dallas, TX) and the Vertical-Dam Manifold (Small Housing (MVD), 11 outlet ring, Continental  $\text{NH}_3$  Products, Dallas, TX) were compared. These two manifolds were compared because the conventional is the standard manifold that has been used for the past few decades, and the Vertical-Dam is a newer, low-cost manifold designed to improve distribution and is the most commonly available replacement. Current retail prices are \$50 for a 14 outlet Conventional manifold and \$175 for a Vertical-Dam housing and 10-14 outlet ring. A savings in  $\text{NH}_3$

material cost of \$125 or more would allow for this manifold upgrade. Other new manifolds being introduced in or considered for the retail market are priced in the \$400-\$1600 range. Cost recovery for these manifolds could be estimated in a similar manner to the following example. Normally plumbed manifolds were used for a production situation.

One method is to compare the yield response from each manifold treatment. Both manifolds had application rates that very nearly averaged the application goal of 84 kg N/ha (75 lb N/ac). None of the normally plumbed manifolds were significantly different, so yield response was not a factor with the difference in manifold treatment yield only 0.14 Mg/ha (2.2 bu/ac). The higher average plot yield was recorded with the conventional manifold. The conventional manifold had a higher yield CV than the Vertical-Dam. In this example, there is no yield advantage to Vertical-Dam use, and there would be no cost recovery for changing to the Vertical-Dam manifold.

Another method for comparing the variation in application of two manifolds is to compare their application rate at each knife at a baseline value, for this example, the application goal of 84 kg N/ha (75 lb N/ac) is used. Both sets of application rates are normalized to the 84 kg N/ha (75 lb N/ac) application goal.

Under-application of N stresses crop production. Ensuring that every outlet delivers a minimum of the application goal eliminates crop stresses. Often producers add "insurance"  $\text{NH}_3$  because of the common perception that  $\text{NH}_3$  manifolds are inherently uneven in application. Applying  $\text{NH}_3$  more evenly could help to reduce the excess  $\text{NH}_3$  applied. Raising the lowest outlet to the application goal on each manifold allows a cost of excess material to be calculated and compared.

On the conventional manifold, after normalization, the manifold outlet with the least flow only applied 60 kg N/ha (54 lb N/ha) with the average application rate for the entire applicator at 84 kg N/ha (75 lb N/ac). To raise the lowest manifold outlet to the application goal would require an additional 24 kg N/ha (21 lb N/ac). As all manifold outlets use the same supply through the regulator, to increase one outlet, all other outlets are assumed to increase by the same amount.

For the Vertical-Dam manifold, the lowest outlet output applied was 66 kg N/ha (59 lb N/ac). Only 18 kg N/ha (16 lb N/ac) would need be applied in addition to meet the application goal. The difference between the two manifolds was 6.0 kg N/ha (5.3 lb N/ac), or 7.2 kg  $\text{NH}_3$ /ha (6.4 lb  $\text{NH}_3$ /ac).

Using a cost of anhydrous ammonia of \$225.00 per ton (2000 lbs) equals \$0.25 per kg  $\text{NH}_3$  (\$0.11 lb  $\text{NH}_3$ ). At this rate, the cost savings of material with the Vertical-Dam manifold to meet the application goal with all knives would be \$1.82/ha (\$0.74/ac) or \$368 on 202 ha (500 ac) of  $\text{NH}_3$  application.

A more even application rate across the outlets would result in an even greater cost saving with a new manifold. If a new manifold at the application rate goal had its lowest knife output at 80 kg N/ha (71.4 lb N/ac). Only an additional 4 kg N/ha (3.6 lb N/ac) would need be applied. This would result in a cost saving of over \$1,200 when compared to the conventional manifold on the example farm.

Purchasing a new manifold may be cost effective on larger farm operations. The second method indicates that the capital cost of the manifold may be recovered in less than 202 ha (500 ac). The first method, however, did not show any yield advantage to switching to the more expensive manifold and there may be no cost savings.

## Conclusions and recommendations

Based on the data collected and analyzed from varied field conditions, the following conclusions can be supported:

1. A relationship between corn grain yield and N application rate was seen at one of the two experimental sites. At the other site, no correlation was seen between the factors during the application year or the following season without N application (residual N only).
2. Stalk-N concentration was positively correlated with N application rate for all three experiments. Neither stalk-N concentration or % N in the grain were correlated to yield.
3. Corn yield differences between normally plumbed manifold configurations were not statistically different. When manifolds were modified to include rows with zero and 2X rates, yields were statistically lower for one of the two experimental sites. Differences in yield between the modified plumbing manifolds were not statistically significant.

4. Because small variations between application rates did not affect yield, and moderate over application did not result in any yield increase, the “insurance” application could be eliminated, assuming that the minimum application rate is met. Manifolds with less variation in application rate between knives allow for lower application rates to be applied and still have all knives meet a minimum application goal. At \$225/ton of NH<sub>3</sub>, \$1.82 per hectare (\$0.74/ac) in NH<sub>3</sub> cost may be eliminated by reducing variation by using a Vertical-Dam manifold rather than conventional manifold. With sufficient application area, the savings in NH<sub>3</sub> material cost can offset the purchase price of a new manifold.

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