IN-FIELD DETERMINATION OF ANHYDROUS AMMONIA APPLICATOR ACCURACY IN NEBRASKA

C.A. Shapiro, R. Weber, W. Kranz, and R. Grisso

ABSTRACT

Liquid and dry fertilizer applicators have been studied for their application patterns and precision. However, anhydrous ammonia (AA) applicators are generally considered less accurate. Due to the difficulty of calibration, actual application errors have not been documented. In order determine if AA applicators were delivering the intended application rate, a standard AA nurse tank was fitted with load cells, temperature, pressure, travel speed and travel distance sensors. Initial data from 55 farmer operated applicators indicated that there was a difference in the average application errors between applicators with electronically controlled flow monitors (4.7%) and pressure regulators, (-0.2%). In addition, the variability of the regulators (std dev = 17%) was much greater than the monitors (std dev = 7%).

INTRODUCTION

As producers fine tune their nitrogen application rates, application accuracy becomes increasingly critical. For example, when nitrogen rates are 30 percent greater than crop requirements, a 20 percent variation in application rate would go unnoticed. If application rates are equal to the economic optimum than a 20 percent variation could result in localized deficiencies and visually uneven corn (Zea mays) growth (Figure 1a).

Figure 1a shows the effect on yield of application variation in parts of the field that may receive less than the desired amount. This is shown as A in the figure 1a. Farmers intuitively realize that anhydrous ammonia output is variable and tend to increase the average rate of N applied in order to counteract the variability. Figure 1b shows the increased N applied so that the areas in the field with the lowest rates of N application receive at least the optimum N rate.

The hypothesis is that application errors result in increased N application. If solutions were found that would decrease application errors then increased farmer confidence would stimulate the use of application rates that included less of a cushion for application error. Figure 1c shows the effect of reducing the application error to 5 percent. Yield reductions are minimal and visual symptoms may not even appear. Figure 1d shows the difference in needed N rate given the same theoretical optimum N rate but accounting for the change in application variation.

In order for Best Management Practices to be adopted, producers need to be assured that they can apply their nitrogen needs precisely. Surveys with pesticide applicators have shown that only 25-35 percent of the applicators applied chemicals within 5 percent of their intended rate, (Grisso et al., 1988). No similar data have been collected for

---

For Presentation at the North Central Extension/Industry Soil Fertility Conference. St. Louis, MO, Nov. 18-19, 1992. Authors can be contacted at NEREC, Concord, NE 68728, 402-584-2261.

anhydrous ammonia applicators. Over 539,000 tons of anhydrous ammonia (AA) was used in Nebraska in 1990. The perceived opinion on application accuracy of AA was that it was not as precise as other farm chemicals. In order to determine if this was true a relatively quick way of calculating anhydrous ammonia output was needed under field conditions.

An instrumented AA nurse tank was developed that was capable of checking the calibration of AA applicators in the field. The system also monitors several variables that affect calibration. The instrumented system is portable and requires minimal setup time. This paper briefly describes the instrumentation and summarizes the data collected in 1991 and 1992. A detailed description of the instrumentation is being published in Weber et al. (1992). Once application errors are determined the next objective is to pinpoint the source of these errors and initiate extension and research programs to alleviate these problems.

MATERIALS AND METHODS

SYSTEM DESCRIPTION

Initially, data was collected by two data loggers (Polycorder 516C and Easy Logger 800, Omnidata) that monitored five sensors mounted on a 1000 gallon AA nurse tank. Data recorded include: tank and AA weight, travel speed, distance, and AA pressure and temperature as it leaves the nurse tank. In 1992 an updated version of the Easy Logger (Model 900) was installed which allowed recording with a single data logger.

Sensors

The following table is a list of what is being sensed, the sensor, its signal, and excitation. See diagram and pictures for location on nurse tank.

Sensed	Sensor	Signal	Notes
Weight	Four weigh bars	Differential ended analog	Each rated to 7480 lbs with 0.25% error at load
Pressure	Pressure Transducer	Differential ended analog	0-200 psi protected by steel isolating diagram & pulse dampener
Temperature	Thermistor	Signal ended analog	installed with stainless steel thermo-well
Speed	Fifth Wheel	Accumulated Pulses	magnetic pickup pulses/sec
Distance	Fifth Wheel	Accumulated Pulses	magnetic pickup

Mention of trade and company names are for the benefit of the conference attendees and do not infer endorsement or preferential treatment of the products by the University of Nebraska.

The Omnidata 900 data logger allows instrumentation to be scanned once per second. It is capable of single ended, differential-ended analog, digital Input/Output, and has frequency counter channels. It was found that 10 second intervals provided sufficient accuracy while limiting data storage requirements.

DATA COLLECTION AND ANALYSIS

The following process was used to collect the data: Individuals agreed to have their application rate tested. The weighing AA tank was brought to the field where AA was being applied, connected to applicator and then tank weighed. The equipment operator set the rig for intended application rate, AA was then applied, and then the nurse tank sat for 10 minutes for readings to stabilize. While the tank was sitting a survey was filled out by the farmer to acquire associated data.

Initial and final tank weights determine AA used. Each applicator run covered enough ground area to apply at least 250 lbs AA.

Application rate is determined by:

Eq. 1.

$$A_R = \frac{N_R C}{WS}$$

Where:
A_r= Nitrogen application rate per unit area, lbs ac^{-1}
N_r= Nitrogen discharge rate, lbs ac^{-1}
C = Constant, 8.25
W = Applicator swath width, ft
S = Speed, mph^{-1}

Application and speed errors are the difference between measured and intended rates:

Eq. 2.

$$e = \frac{measured - intended}{intended}$$

The relationship among different sources of error is:

Eq. 3.

$$1 - e_{ar} = \frac{1 - e_{nr}}{1 - e_s}$$

Where:
e_{ar}= Application rate error, decimal
e_{nr}= Discharge rate error, decimal
e_s = Speed error, decimal

Both the application and speed errors are determined from the data, the discharge error can then be calculated from:

Eq. 4.

$$e_{nr} = ((1 + e_{ar})(1 + e_s)) - 1$$

Pressure and temperature are not included in these calculations but are collected to be used along with responses to a survey to identify other potential errors. In the past two years 55 farmer-applicators were sampled using the above methods.

RESULTS

The objective was to determine how accurately anhydrous ammonia was being applied in Nebraska. At this point, the data has not been analyzed to determine between human error and equipment error.

A difference was found in the application errors between the units that used a pressure regulated orifice (regulators) and those with a heat exchanger and flow controller (monitors). Because the monitors changed output to compensate for the speed; variation speed and discharge errors are not independently related. Therefore, the speed and discharge errors should only be relevant to the regulators. But, it should be noted that there is a delay between speed sensing and output compensation; making a constant travel speed desirable.

Analysis of application errors using a t-test showed that the regulators and monitors were significantly different ($Prob > |t| = 0.048$). In addition, their variances ($Prob. > F = 0.009$), they were significantly different. Figure 2 shows distribution of errors when actual error values were used. The monitors had an average error of 5 percent compared to the regulators which had an error of 0 percent. However, the standard deviation of the regulator was 17 percent while the monitors were 7.4 percent. It should be noted though, that one monitor put out 25 percent more than intended increasing the monitor standard deviation.

Another way to analyze the errors is with absolute values. Since positive and negative errors cancel each other out, the absolute value (making all numbers positive) gives a way of seeing how far from the intended the applicators were. The monitors had an average error of 5.9 percent with a standard deviation of 6.3 percent compared to the regulators which had an average error of 13.1 percent with a standard deviation of 10.6 percent. This analysis is consistent with the first analysis, except that the average error for the monitor is less than for the regulators. (Note: Precision is equal to the reciprocal of the variance of the mean).

The data collected supports the ideas presented in the introduction. Regulated applicators on average do apply the intended rate. The range of rates in one field or many fields includes a number of areas where the actual application rate is either too high or too low. Due to this uncertainty, average rates are increased to compensate.

Another factor that may be contributing to application errors is the difficulty of calibrating applicators. Supplemental data collected at the time of our field data collection indicates that owners of monitors did a better job calibrating their equipment. The preferred method of calibrating an anhydrous ammonia applicator is by weighing the amount applied over a known area. Other methods include calculating the rate based on calibration curves and tables for the metering equipment, or using the percent fill gauge on the tank to determine anhydrous ammonia applied over a known area. Figure 3 shows that monitors are calibrated with the known area method more than the regulated units (Chi-Square Prob. < 0.0001).

CONCLUSION

The data collected supports the belief that anhydrous ammonia application can be quite variable. Surprisingly for regulated units, the positive and negative errors cancel out. The average application rates over many fields are what was intended. While flow controlled monitors have a slight tendency to over apply, they have much less variation. Thus applications with monitors can be made with more confidence since if there are errors they will be smaller.

Undoubtedly, part of the advantage of monitors is that they force the applicator to calibrate the equipment and provide accurate compensation for change in ground speed.

The use of this weighing anhydrous ammonia tank has helped focus attention on application uniformity. Increased application precision will have benefits to both the producer in minimized risk and to the environment since excess N will not be applied to minimize the effects of application variability.

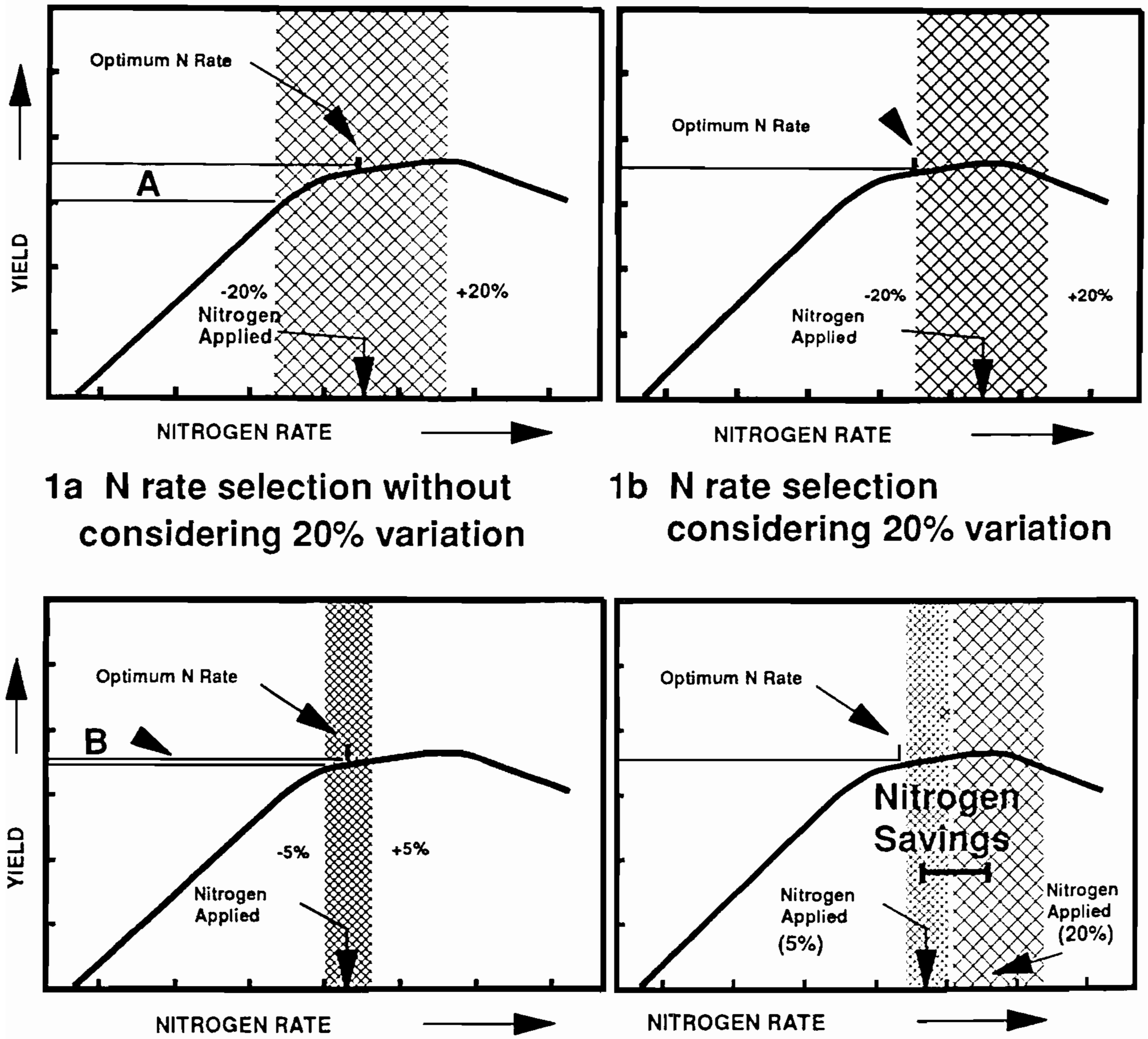
LITERATURE CITED

Weber, R.W., R.D. Grisso, W.L. Kranz, C.A. Shapiro, and J.L. Schinstock. 1992. Instrumenting a Nurse Tank for Monitoring Anhydrous Ammonia Application. Computers and Electronics in Agriculture. In Press.

Grisso, R.D., E.J. Hewelt, E.C. Dickey, R.D. Schneider and E.W. Nelson. 1988. Calibration accuracy of pesticide application equipment. Applied Engineering in Agriculture 4:310-315.

ACKNOWLEDGEMENTS

The authors wish to thank the following for their contributions: The National Fertilizer & Environmental Research Center of the Tennessee Valley Authority supplied partial funding for this project. Double Circle Farm Supply of Laurel, NE provided us a nurse tank for the initial phase of the project. Ron Cleveland, Communication Associate, Northeast Research and Extension Center, designed the visuals used in the slide presentation. Aurora Co-op of Aurora, NE supplied three tanks of anhydrous ammonia.



1a N rate selection without considering 20% variation

1b N rate selection considering 20% variation

1c N rate selection and effect of 5% variation

1d Effect of reduced variation on N rate selection

Fig. 1. Effect of application variability on selected nitrogen rate for optimum yields.

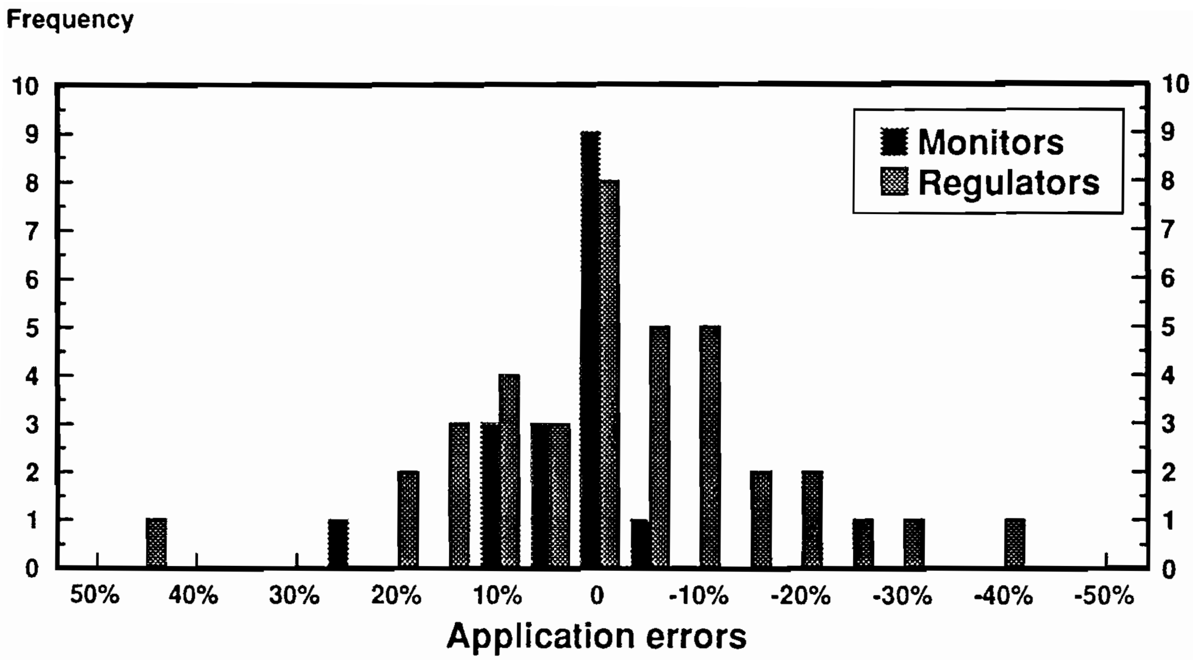


Fig. 2. Distribution of application errors between monitors and regulators. (Nebraska, 1992)

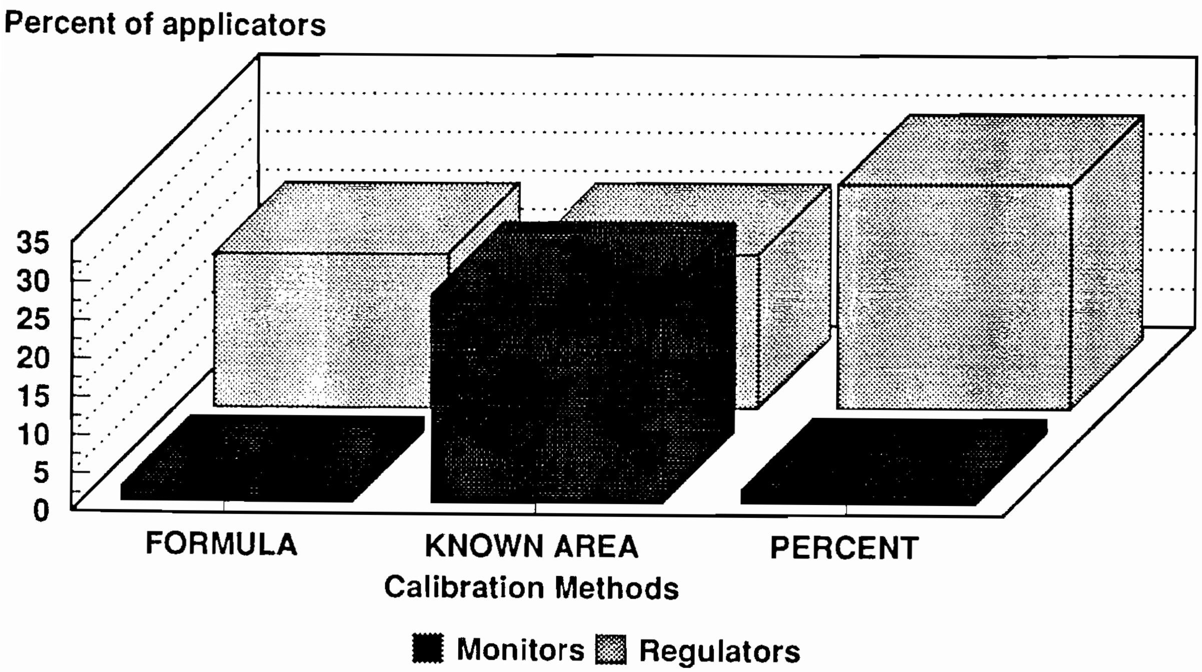


Fig. 3. Calibration method used by applicator type. Nebraska, 1991-1992.

PROCEEDINGS OF THE TWENTY-SECOND

NORTH CENTRAL EXTENSION - INDUSTRY

SOIL FERTILITY CONFERENCE

November 18-19, 1992, Holiday Inn St. Louis Airport

Bridgeton, Missouri

Volume 8

Program Chairman and Editor:

Ray Lamond
Department of Agronomy
Throckmorton Hall
Kansas State University
Manhattan, KS 66506