A SYSTEMATIC APPROACH FOR USING PRECISION AGRICULTURE TOOLS FOR ON-FARM EVALUATIONS IN IOWA

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ABSTRACT

The competitive nature of modern agriculture requires constant refinements of many crop production management decisions. Precision agriculture tools (PAT) can allow growers to rapidly evaluate different management practices across large areas at a relatively low cost. But a systematic approach and a decision-making process describing how to utilize different PAT for on-farm evaluations have not been yet developed and adopted. This presentation will focus on how approximately 300 Iowa growers use digital aerial imagery, replicated strip trials (RST), and guided plant testing to evaluate a wide range of fertilizer and manure management practices, tillage, crop management, and different plant protection products on corn and soybean every year. About 30 grower groups were formed across the state to evaluate different agronomic topics. Specific protocols were developed for conducting RST, collecting, processing and analyzing trial data, and summarizing results. Every winter, grower group meetings were held to discuss results of >500 RST and identify new and relevant research topics. The results of individual evaluations, summaries for individual groups and summaries across the state were publically available on the website. Annual winter conferences attracted > 500 attendees to learn the statewide results, summarize, and develop evaluation strategies for the next year. The data were also summarized and published in a bi-monthly magazine. Four examples of 2009 statewide evaluations were presented: “Injected Liquid Swine Manure plus 50”, “Injected Liquid Swine Manure with Nitrification Inhibitor”, “Spring Applied Urea Ammonium Nitrate Solution (UAN) with Nitrification Inhibitor”, and “Headline Fungicide on Soybean”.

Keywords: precision agriculture tools, on-farm evaluations, replicated strip trials, and nitrogen fertilizer management.

INTRODUCTION

Precision agriculture tools (PAT), including yield monitors, remote sensing, GPS guidance systems, variable rate planting, and variable rate fertilizer applications, have gained popularity among growers. The potential to increase profitability is the primary reason that drives adoption of these tools and technologies in production agriculture. The basic premise is that input calibration information or recommendations related to how, when, and where each tool has the potential to increase profit are well known and reliable (Hatfield, 2000). In practice, however, many of the current recommendation systems growers rely on are not adequate for these purposes because they were developed by using a limited amount of calibration data, because the conditions under which they were developed do not usually represent those experienced by growers, and most importantly, because effects of other factors such as rainfall and geography are very difficult to incorporate into the general recommendations for using PAT.

While there has been a large effort by public and private institutions during the last decade to develop the general recommendations for using PAT, the majority of Iowa growers still do not know how to use these recommendations to make profit. An alternative approach for using the general recommendations for different inputs is to utilize PAT for evaluating various practices commonly used by growers (Blackmer and Kyveryga, 2008). Instead of assuming that growers have the best recommendations for using PAT, a more practical approach would be to measure yield differences in field-scale on-farm evaluations by using two-treatment replicated strip trials (RST) and verified by late-season digital aerial imagery. For RST, one treatment can represent a normal or common practice and the other can represent an alternative or new practice (i.e., reduced or increased fertilizer, manure rate, plant population or a new product or technology). Such evaluations would enable individual growers to assess how their current practices perform and gradually refine and optimize their practices. They would also allow researches to pool data from many groups of growers to evaluate practices on a large scale.

On-farm RST using PAT can be used to evaluate many different management practices: fertilizer and animal manure management, fungicide and insecticide applications, tillage, and others. For example, a long-term study was conducted to identify management zones or categories in yield response to nitrogen (N) fertilizer within spatially variable corn fields (Kyveryga et al., 2008). Two near-optimal N fertilizer rates with a difference of 28 kg N ha^{-1} were applied across fields to study which soil or terrain attributes could be used to delineate management zones in corn yield response and whether these zones were stable over time. This method for studying spatial variability in yield response is simple and more grower friendly and can be done easily on many fields and farms compared with relatively few fields under the traditional method for conducting controlled multiple-rate N response trials (Kyveryga et al., 2009). Based on a number of variables that can affect crop management and their interactions, small plot trials also cannot be used to evaluate N management practices.

Another recent large-scale study that showed how on-farm evaluations can be conducted by using corn stalk nitrate testing guided by late-season digital aerial imagery to compare different nitrogen fertilizer and manure management practices across Iowa (Kyveryga et al., 2010). About 35 grower groups were organized to survey >700 corn fields annually for two years. The relative differences in pre-harvest corn N status were identified between different management categories based on N fertilizer forms and timing of application, soil drainage classes and soil types, previous crop and amount of spring rainfall. This is important because few if any states address these factors in their recommendations (Sawyer et al., 2006).

Although there are other examples showing how PAT can be utilized in on-farm evaluations, there is a growing need for outlining a systematic approach and decision-making process describing how different PATs can be used in on-farm evaluations.

The objective of this report is to present several examples showing how groups of growers in Iowa utilize PAT to systematically evaluate different management practices in corn and soybean production.

MATERIALS AND METHODS

On-farm RST were conducted on growers' fields across Iowa in 2009. Each trial had two treatments applied in alternated strips going through the length of the fields in > three replications, covering from 8 to 12 ha. Some trials had the treatments applied across 25 to 32-ha fields. The treatments were applied by growers and the width of the treatments ranged from 5 to 30 m to match the width of growers' application equipment and combine header. Treatment locations were recorded by GPS or guidance systems.

Late-season digital aerial imagery was acquired from each trial to verify treatment locations and visually inspect for application errors and other problems commonly found within fields. Growers harvested trials with combines equipped with yield monitors. Yield observations were cleaned by removing extreme data points that were below and above two SD from the mean yield for a trial. Additional yield values were removed that were located at some distance at the beginning and the end of the trial, around waterways, grass buffers or flooded areas. Extreme values in grain moisture and combine speed were also eliminated. Yield differences were calculated as differences between two treatment means for each trial.

For RST evaluating N fertilizer and manure practices, the late-season corn stalk nitrate test was used to estimate the average corn N status and determine the effects of treatments on corn N uptake (Binford et al., 1992). Eighteen sampling areas (nine within each treatment) were selected within each trial using late-season digital aerial imagery and digital soil maps (Blackmer and Kyveryga, 2008). The stalk nitrate test provided a cross check on the N status in addition to the aerial imagery and yield response data.

Spatially interpolated average monthly rainfall data (4-km grids) were downloaded from the Iowa Environmental Mesonet, Agronomy department, Iowa State University (http://mesonet.agron.iastate.edu/). Each trial was assigned rainfall values from a rainfall grid located nearest the trial.

Mean yield responses (yield differences between two treatments) for individual trials were used in the exploratory statistical analysis. The overall treatment effect was tested by analysis of variance across all trials in each evaluation category. The mean yield responses were presented as cumulative probability distributions. A cumulative probability distribution shows the probability that a given treatment gives a yield response at or below a given value. The distribution represented only the sample of trials, which was considered a random sample within the state or a specific geographic area, and could be used with the caution to interpolate the results to other fields and areas that did not have RST.

RESULTS AND DISCUSSION

"Injected Liquid Swine Manure plus 50" Evaluations in 2009

These on-farm evaluations were conducted to identify when and where injected swine manure applications to corn (Zea mays L.) should be supplemented with additional commercial N fertilizer. Liquid swine (Sus scrofa L.) manure was injected in fall at rates that would normally supply enough total N to maximize yields. The manure strips were compared with strips that received additional sidedress applications of 56 kg N ha^{-1} or 50 lb N/acre of anhydrous ammonia or UAN application. All trials were corn after soybeans and located across the state. The average manure N rate was 195 kg N ha^{-1} or 176 lb N/acre, which was about 20-25% higher than the currently recommended N manure rate for corn after soybean based on total N content in manure.

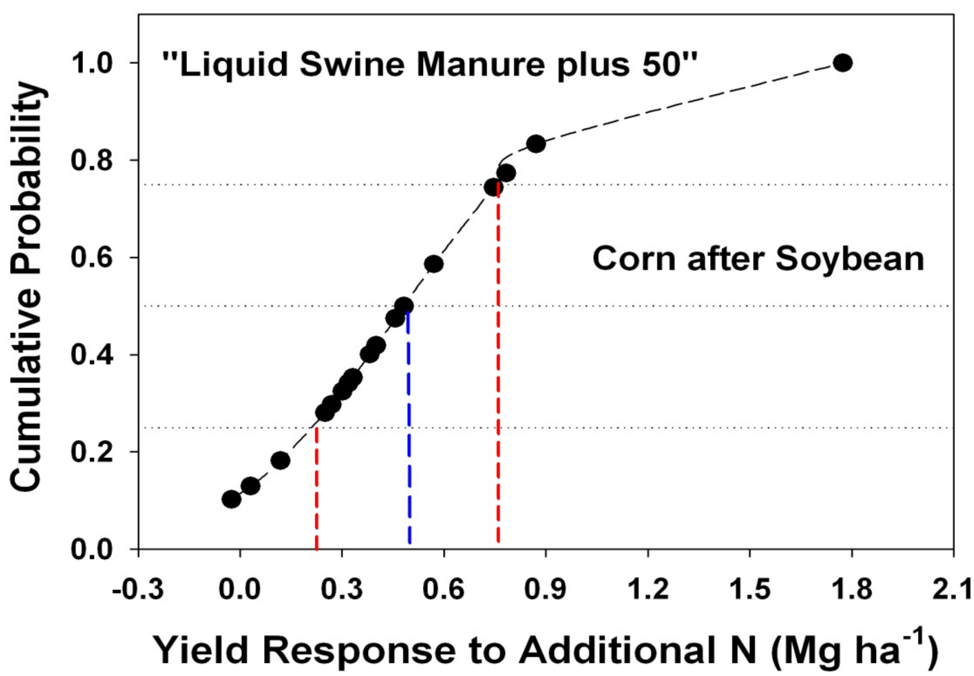

Figure 1. Cumulative probability distribution of yield responses observed from additional N fertilizer in "Injected Liquid Swine Manure plus 50" on-farm evaluations in 2009.

Across 18 trials, the mean yield response to the additional N was statistically significant ($p<0.01$). The median yield response was about 0.5 Mg ha^{-1} or 8 bu/acre; 25% of trials had a yield response of < 0.2 Mg ha^{-1} or 3.5 bu/acre, and 75% of trials had yield response of < 0.7 Mg ha^{-1} or 11 bu/acre (Fig. 1). About 60% of trials had a profitable yield response: >0.35 Mg ha^{-1} or >6 bu/acre. This is important because the incremental N addition was about the recommended N rate. Because of the steep and linear shape of the cumulative distribution curve, the mean yield responses were evenly distributed between 0 and 1 Mg ha^{-1}. The distribution was skewed to the right due to one trial having a relatively large yield response >1.8 Mg ha^{-1}. There were no significant effects of total N rates applied with manure, cumulative spring or summer precipitation on the yield response. The late-season stalk nitrate test showed that additional N decreased the percentage of samples tested in the deficient category by 15% (data not shown).

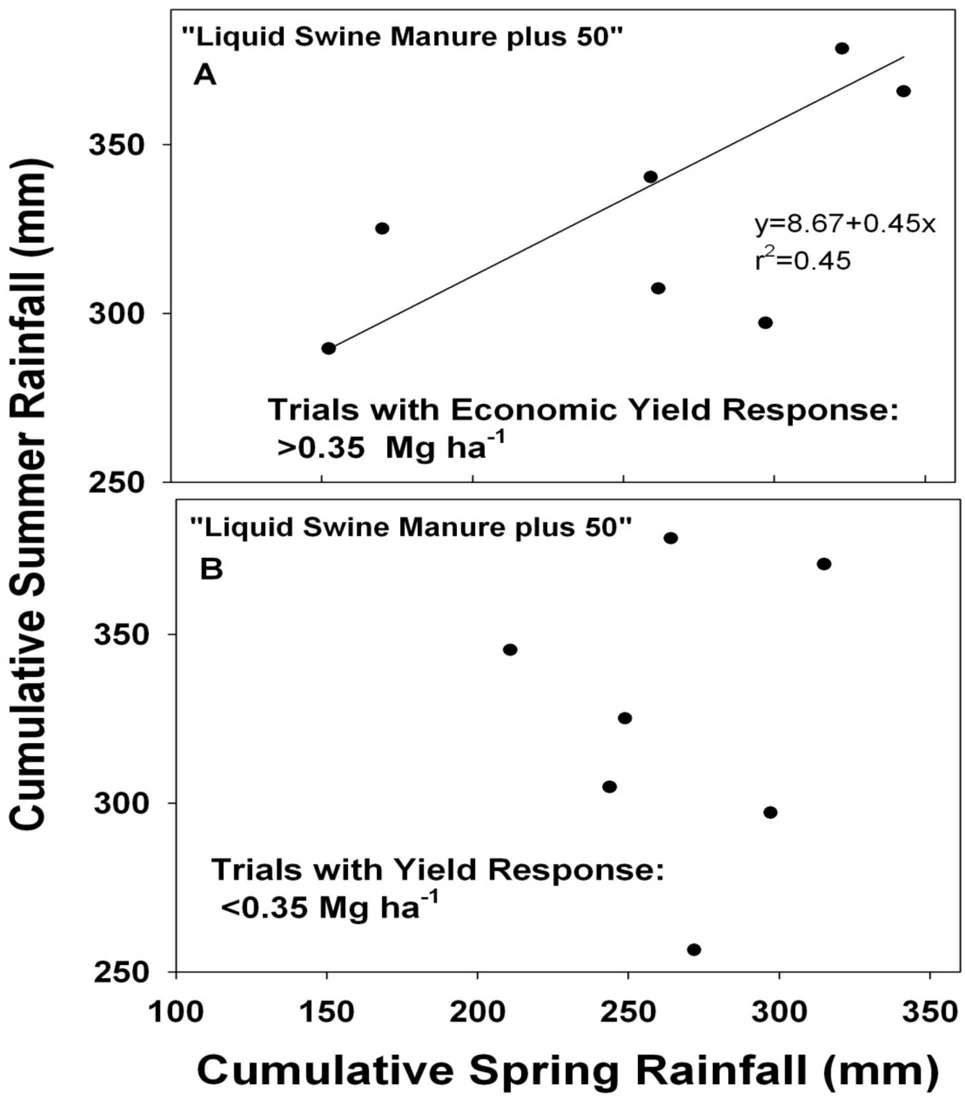

Figure 2. Relationship between cumulative spring and summer rainfall for two categories of trials based on economic yield responses observed in "Injected Liquid Swine Manure plus 50 "on-farm evaluations in 2009.

Economic yield responses were observed only in trials that had a positive correlation (r^2=0.45) between spring and summer rainfall (Fig. 2A). Because below normal minimum and maximum average daily temperatures and above normal summer rainfalls (from June through August) in 2009 (data not shown), some N losses could have occurred during the summer or the increased yield potentials could have increased the corn N demand.

In recent years in Iowa, economic yield responses to additional commercial N have been frequently observed on manured fields likely due to: 1) large variability in manure application rates and uncertainty as to amount of N available from the manure in the first year; 2) large N losses from the manure as a result of above normal spring rainfalls; and/or 3) high nitrification rates of N applied with manure because it is often applied when soils are relatively warm in the fall.

Injected Liquid Swine Manure with Instinct in 2009

Because most of N in liquid swine manure is in the ammonium form, reducing rates of nitrification of this N may help reduce N losses. Instinct, an encapsulated formulation of the nitrification inhibitor, nitrapyrin, can be used with liquid animal manure or UAN applications. On-farm evaluations were conducted to identify where and when the use of the nitrification inhibitor with manure can results in profitable yield responses. The majority of trials were located in Central Iowa.

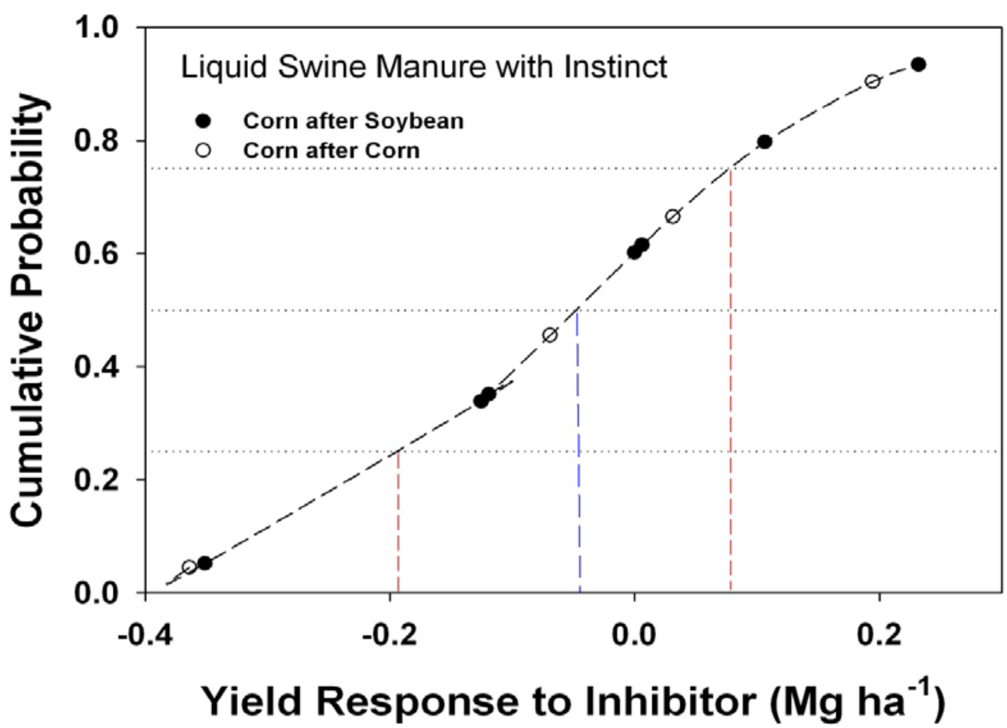

Figure 3. Cumulative probability distribution of yield responses observed by using nitrification inhibitor with fall-applied injected liquid swine manure in 2009.

Across 11 trials, the mean yield response to the inhibitor was not statistically significant. The yield responses tended to be normally distributed (Fig. 3). The medial yield response was about -0.06 Mg ha^{-1} or -1 bu/acre; about 25% of trials had a yield response of < -0.2 Mg ha^{-1} or <-3 bu/acre and about 75% of trials had a yield response of <0.13 Mg ha^{-1} or <2 bu/acre. Only two trials had a profitable yield response: >0.13 Mg ha^{-1} or >3 bu/acre. There were no significant effects of the previous crop, total organic N applied with the manure or the timing of manure application on the yield response. While about 50% of stalk nitrate samples tested deficient, the inhibitor did not have a significant effect on plant N uptake (data not shown). This observation is important because the optimal conditions for observing an economic yield response to the inhibitor is under N stress.

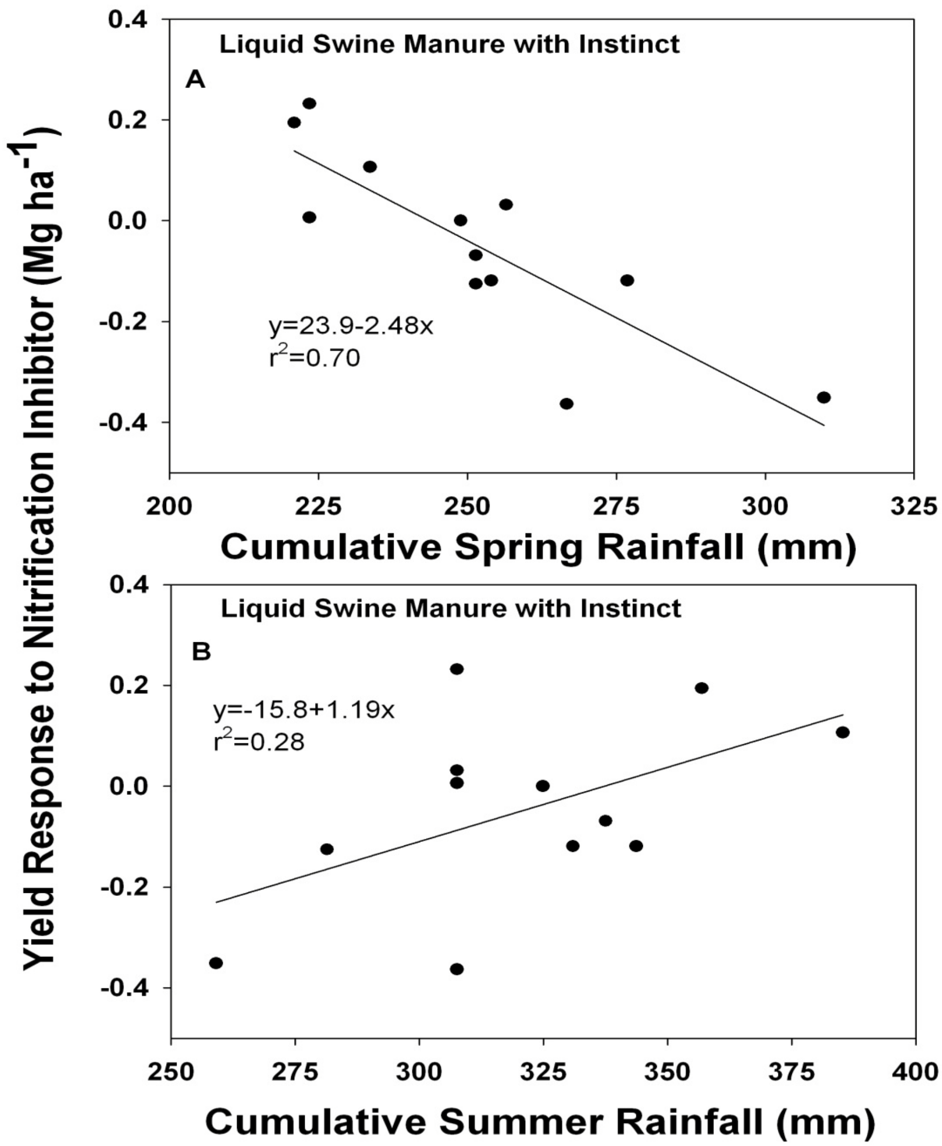

Figure 4. Effects of cumulative spring and summer rainfall on yield responses observed by using nitrification inhibitor with fall-applied liquid swine manure.

Surprisingly, there was a strong negative correlation (r^2=0.70) between yield response to the inhibitor and cumulative spring rainfall (Fig. 4A). This probably indicates that the fields receiving more spring rainfall stayed cooler than those receiving less spring rainfall. Because spring 2009 had record low minimum and maximum average daily temperatures (data not shown), it is likely that the cooler soils reduced nitrification rates of manure N and, therefore, reduced the inhibitor's effect on nitrification. There was a moderate positive correlation (r^2=0.28) between yield response to the inhibitor and summer cumulative rainfall (Fig. 4B). This suggests, similar as in "Injected Liquid Swine Manure plus 50" evaluations, that above-normal summer rainfalls may have increased yield potentials and plant demand for N.

Spring-applied UAN with Instinct Inhibitor in 2009

Spring UAN applications, especially pre-plant weed and feed UAN, have become more common in Iowa, but N losses can be substantial in years with above average spring rainfall (Blackmer and Kyveryga, 2008; Kyveryga et al., 2010). This category of on-farm RST was conducted to determine whether using a nitrification inhibitor with spring-applied UAN can reduce N losses and increase corn yields. UAN was broadcast and then incorporated into the soil before planting corn. The UAN rates ranged from 30 to 180 lb N/acre, depending on the previous crop and growers' N management practices.

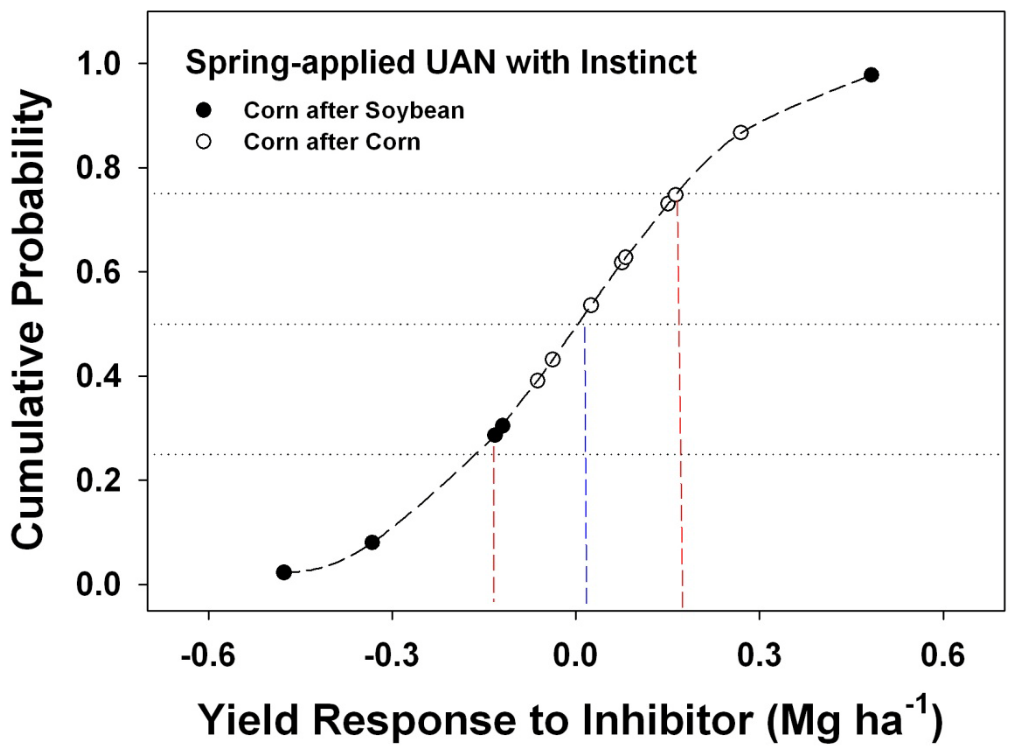

Figure 5. Cumulative probability distribution of yield responses observed from using nitrification inhibitor with spring-applied UAN in 2009.

The effect of the inhibitor was not statistically significant across all trials. The yield responses tended to be normally distributed (Fig. 5). The medial yield response was about 0 Mg ha^{-1}; about 25% of trials had a yield response of < -0.2 Mg ha^{-1} or <-3 bu/acre and about 75% of trials had a yield response of < 0.13 Mg ha^{-1} or < 2 bu/acre (Fig. 5). Only two trials had a profitable yield response. The effect of previous crop was not statistically significant, but four of five trials where corn followed corn had negative yield responses. The corn stalk nitrate test showed no effect of the inhibitor on corn N uptake (data not shown).

Headline Fungicide on Soybean in 2009

Headline fungicide evaluations on soybean (*Glycine max* (L.) Merr.) were done to identify the economic effect of fungicide applications on soybean yield. Headline belongs to the Strobilurin Group of preventive fungicides. Forty six trials having replicated strips with and without Headline were located across the state. The fungicide applications were done by using ground or aerial method. The timing of the application ranged from R1 through R3 soybean growth stage.

Across 46 trials, the effect of Headline on soybean yields was statistically significant ($p<0.01$). Yield responses tended to be normally distributed (Fig. 6).The median yield response was 0.14 Mg ha^{-1} or 2 bu/acre; about 25% of trials had a yield response of <0.04 Mg ha^{-1} or <0.6 bu/acre and about 75% trials had a yield response of <0.24 Mg ha^{-1} or <3.7 bu/acre. The mean yield response were evenly distributed between 0 and 0.3 Mg ha^{-1}, but four trials had a relatively large yield increase of >0.5 Mg ha^{-1}.

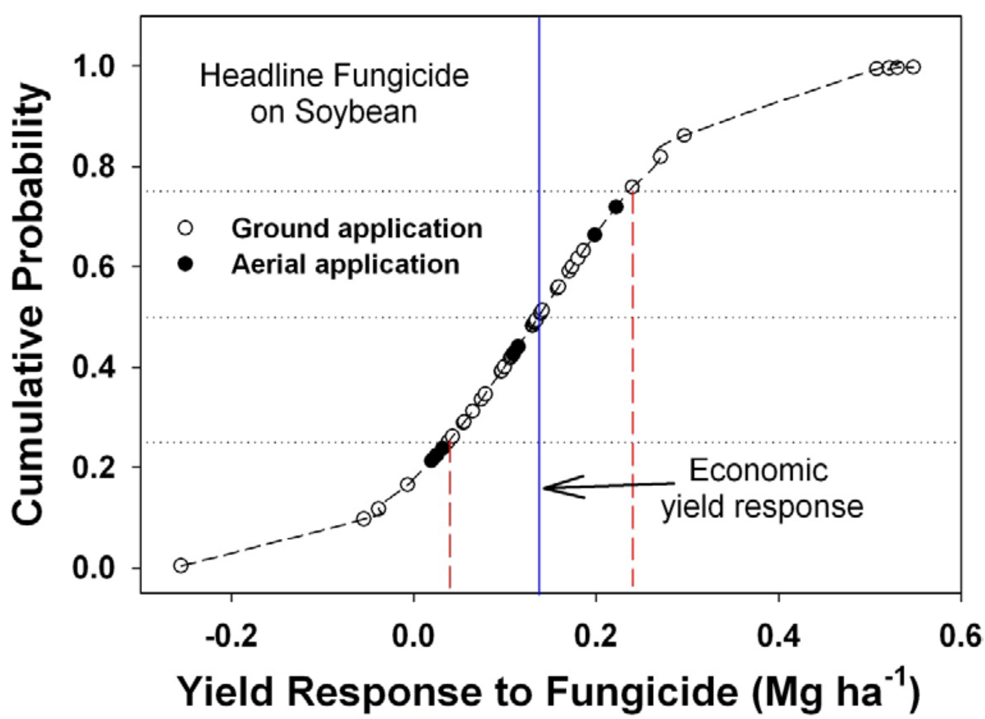

Figure 6. Cumulative probability distribution of yield responses observed in 46 on-farm evaluations of fungicide on soybean in 2009.

Half of the trials had an economic yield response: >0.14 Mg ha^{-1}. These results suggest that these on-farm evaluations of Strobilurin fungicide on soybean were more sensitive for detecting significant economic yield responses than those done in small controlled experiments conducted at fewer locations in 2005 and 2006 in Iowa (Swoboda and Pedersen, 2009).

Method and timing of the fungicide application had no effects on soybean yield. There was a weak negative correlation (r^2=0.08) between August rainfall and the yield response to the fungicide (data not shown). This indicates that Headline may have helped soybean to increase water use efficiency in late summer. Other studies have shown that Strobilurins often had some physiological plant effects even without the presence of soybean diseases (Grossmann et al., 1999).

Systematic Approach for On-Farm-Evaluations

About 30 grower groups were formed across Iowa to evaluate different agronomic topics and management practices in corn and soybean production. Specific protocols were developed to conduct RST and collect, process, analyze, and summarize RST results. The protocols were posted on the On-Farm Network website (www.isafarmnet.com). Grower group meetings were conducted every winter to discuss results of >500 evaluations and identify new, relevant, and site-specific research topics. The results of individual evaluations, summaries for individual groups, and summaries across the state were publically available on the website. Annual winter conferences attracted > 500 attendees to learn and discuss the statewide results, summarize, and develop evaluation strategies for the next year. The data were also summarized and published in a bi-monthly magazine, in peer-reviewed scientific journals, and presented at various scientific conferences.

CONCLUSIONS

Precision agriculture tools can be used successfully to evaluate a wide range of management practices in corn and soybean production in Iowa. We described how such evaluations can used in a systematic way where many growers use the same protocol across the state, but evaluation objectives can be modified to site-specific conditions of a group of growers within a specified area. The data of individual evaluations are processed, pooled, and analyzed by using the same statistical methodology and quality control method. Four statewide evaluation examples were presented to show the specific objectives, scale, data analysis, and result interpretations.

ACKNOWLEDGEMENTS

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