COMPARISON OF NITROGEN RECOMMENDATION MODELS FOR CORN IN TWO CROPPING SYSTEMS

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Abstract

Several models exist to generate N recommendations, and the model selected can have both economical and environmental implications. A study was initiated in 1998 to compare the response of corn to N in two cropping systems (corn following corn and corn following soybeans). All plots received a starter N rate of 45 kg N ha^{-1} (2 x 2 placement), and five rates of sidedress N (0, 22, 90, 157, and 224 kg N ha^{-1}) were applied at growth stage V6 either as anhydrous ammonia or urea-ammonium nitrate (UAN). Three different regression models were evaluated, 1) maximum yield, 2) maximum return, and 3) linear-plateau, to compare N recommendations. Nitrogen recommendations based on a maximum yield model may tend to result in environmental degradation; while N recommendations based on the maximum economic return model may result in less environmental impact. Nitrogen recommendations determined using a linear-plateau will potentially have the least environmental impact, but may increase the risk of being short of N. It should be pointed out that the response observed from one year to the next can change dramatically. This elucidates the need for in-season N decision tools to improve N management.

Introduction

Cropping history can play a pivotal when determining corn (*Zea mays* L.) response to applied N. Bundy et al. (1999) reported that of 301 sites only 56% were responsive to N when corn followed a legume crops. All locations that followed alfalfa (*Medicago sativa* L.) showed no response to applied N at all. Of the sites where corn followed soybeans (*Glycine max* L.) only 67% sites were considered responsive (Bundy et a., 1999). Thus crops that follow legume crops most likely have a decreased demand for supplemental N. Most states that generate N recommendations for corn recognize this and provide N credits for corn following leguminous crops. Inadequate N management can result in significant environmental impacts. Current estimates state that 50% of the N, which contributes to the hypoxic zone in the Gulf of Mexico, comes from agricultural inputs (Goolsby and Battaglin, 2000). Thus balancing N recommendations between profitability and environmental impacts is a significant decision (Cerrato and Blackmer, 1990).

To date, N recommendations generated by land-grant universities are, generally, based on historical data collected from multiple site-years. These data are averaged to reveal an N response function which is used to reveal a relationship between potential yield and N application rate. Typically, rules of thumb or linear function models are developed to provide an N rate recommendation based on yield goal or yield potential. Utilizing potential yield to determine the N rate is logical considering that the amount of N needed by a crop is directly related to the yield of the crop. This approach to N management has been profitable for production agriculture. Yields of corn over the last fifty years (since the advent of anhydrous ammonia production) have steadily increased as has N application.

Split applications of N have been documented to result in yield increases and improved NUE, specifically in agricultural systems which are susceptible to early season losses. Delaying N applications until plant need has been recognized as a method to improve nitrogen efficiency and avoid potential N loss mechanisms (Russelle et al., 1983; Jokela and Randall, 1997). Randall et al. (2003) reported that split application of N between planting (40%) and sidedress (60%) at V8 resulted in higher yields than when N was applied in the spring as a single event. Nitrogen recovery was also increased by split application of N compared to spring application. Scharf et al. (2002) reported that maximum yield could be achieved with N applications as late as V11, but applications delayed until silking resulted in a 15% yield loss. Split applications also allow for adjustment of N management based on environmental conditions encountered since planting. For example, if plant population has been affected by excess water, N rates can be adjusted accordingly to account for lower yield potential.

The objective of this study was to determine differences in the optimum N rate for corn following corn and corn following soybeans using three different response models.

Materials and Methods

The experiment was established at the Northwestern Experiment Station near Hoytville, OH on a Hoytville clay loam (fine, illitic, mesic, Mollic Epiqualf) in the spring of 1998. The study has been repeated each year at different locations on the station. A randomized complete block design with split plots (rate is the main plot, source is the subplot) was employed with four replications. Plot sizes were 4 rows wide by various plot lengths. The corn following soybean cropping system was not initiated until 2000 when two trials were established. Since, there has only been one corn following soybean trial per year. Starter N was applied 2 x 2 to all plots at a rate of 45 kg ha^{-1}. Sidedress N was applied at V6 (Ritchie et al., 1997) as either anhydrous ammonia or UAN at five rates (0, 22, 90, 157, and 224 kg N ha^{-1}). Anhydrous ammonia was subsurface injected using a knife applicator and UAN was applied with a coulter injection system. A nitrification inhibitor and urease inhibitor (Agrotain, Agrotain Internation LLC) was included with an application of 134 kg N ha^{-1} as anhydrous ammonia and UAN, respectively. Corn was planted each spring at a seeding rate of 69,160 plants ha^{-1} on a row spacing of 0.76 m. Corn grain yield and moisture were measured by harvesting the two center rows of each plot with a plot combine. Corn following corn was planted without tillage, while corn following soybeans was chisel-disked and field cultivated the fall prior to corn planting.

Daily climatic information was recorded at a site located within 1 km from the experimental location. Analysis of variance statistics and determination of quadratic equations were performed using the GLM procedure in SAS (SAS Inst., 2000). Linear plateau equations were determined using the NLIN procedure in SAS (SAS Inst., 2000). Economic return was determined assuming that the price of corn was \$0.07 kg^{-1} and the price of N was \$0.55 kg^{-1}. The N rate necessary to maximize yield and maximize return using the two quadratic equations was determined by setting the first derivative equal to zero.

Results and Discussion

Corn following corn

Inclusion of a N stabilizer with anhydrous ammonia application resulted in a 13% increase in yield in 2003, while other years revealed no significant response to inclusion of either N stabilizer (data not shown). Differences between sources of N were sporadic and were only significant at specific rates in 1998, 1999, and 2001 (data not shown). No response to N was observed in 2002 due to an extremely dry growing season. Comparison of the optimum N rates reveals that on average, the rate of N necessary to maximize economic return was 48 kg ha^{-1} lower than that necessary to maximize yield. The N recommendation generated using a linear-plateau model was slightly lower than the quadratic model used to identify the maximum economic return averaged over all years (Table 1). It should be pointed out that the N rate necessary to maximize either yield or economic return varies greatly from year to the next. There also appears to be no relationship between yields attainable at low N levels and those attainable with high N levels. Thus a high yielding growing environment does not necessarily indicate a large response to applied N. Obviously the model used to develop the quadratic relationship between N rate and return is a function of corn price and N cost. Thus alterations of these will result in a different optimum N rate.

Corn following soybeans

Inclusion of a N stabilizer did not result in increased yields in any year of the study (data not shown). No consistent differences between N sources were observed. Two application rates (67 and 269 kg N ha^{-1}) in 2001 did show significant differences between N sources (data not shown). Similar to corn following corn, there was no response to applied N in 2002. The N rate necessary to maximize economic return for corn following soybeans was 66 kg ha^{-1} lower than the rate necessary to maximize yield. As noted for corn following corn, the N recommendation generated using a linear-plateau model was slightly lower than the N recommendation from the maximum economic return model (Table 2). As pointed out by Cerrato and Blackmer (1990), deciding on which model to use should try to achieve a balance between profitability and potential environmental costs.

Conclusions

Nitrogen recommendations can and do vary dramatically depending upon the model chosen, thus care should be taken when selecting a model. Recommendations based on a maximum yield model may ensure that N is not limiting, but they may also increase the risk of environmental degradation. Recommendations based on a maximum economic return model decrease the potential environmental impacts of applied N, but may also increase the potential for N shortage. If application errors are to occur, under-application (compared to maximum yield models) should result in better profitability and present a lower risk to the environment. Nitrogen demand by a corn crop can change dramatically from one season to the next without any predictability. Thus in-season decision tools are important to improve N management.

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Table 1. Regression equations for quadratic relationship between N rate and yield and N rate and economic return for corn following corn, 1998-2003.

Year	Model	Regression equation	N rate for maximum (kg ha^{-1})
1998	Yield	$y = -0.20x^2 + 79.51x + 8282.90$	199
1998	Return	$y = -0.014x^2 + 5.02x + 579.80$	179
1999	Yield	$y = -0.086x^2 + 32.39x + 9060.09$	188
1999	Return	$y = -0.0060x^2 + 1.72x + 634.21$	143
2000	Yield	$y = -0.061x^2 + 23.55x + 9179.95$	193
2000	Return	$y = -0.0043x^2 + 1.10x + 642.60$	128
2001	Yield	$y = -0.10x^2 + 50.15x + 4639.40$	251
2001	Return	$y = -0.0072x^2 + 2.96x + 324.76$	206
2002		No response to N	
2003	Yield	$y = -0.18x^2 + 96.81x + 3333.53$	269
2003	Return	$y = -0.013x^2 + 6.23x + 233.35$	240
Average	Yield	$y = -0.10x^2 + 47.55x + 6615.05$	238
Average	Return	$y = -0.0073x^2 + 2.78x + 463.05$	190
Average	Linear-Plateau	$y = 26.77x + 6278.93$	Joint = 178 Plateau = 11.042

Table 2. Regression equations for quadratic relationship between N rate and yield and N rate and economic return for corn following soybeans, 2000-2003.

Year	Model	Regression equation	N rate for maximum (kg ha^{-1})
2000	Yield	$y = -0.042x^2 + 15.31x + 8909.80$	182
2000	Return	$y = -0.0029x^2 + 0.52x + 623.69$	90
2000	Yield	$y = -0.019x^2 + 10.04x + 9484.12$	264
2000	Return	$y = -0.0013x^2 + 0.15x + 663.89$	58
2001	Yield	$y = -0.055x^2 + 28.05x + 8875.14$	255
2001	Return	$y = -0.0039x^2 + 1.41x + 621.26$	181
2002		No response to N	
2003	Yield	$y = -0.15x^2 + 80.32x + 5588.14$	268
2003	Return	$y = -0.011x^2 + 5.07x + 391.17$	230
Average	Yield	$y = -0.061x^2 + 29.22x + 7544.62$	240
Average	Return	$y = -0.0043x^2 + 1.50x + 528.12$	174
Average	Linear-plateau	$y = 18.37x + 7941.87$	Joint = 164 Plateau = 10.962

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