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Revising Nitrogen Recommendations for Wheat in Response to the Need for Support of Variable-Rate Nitrogen Application

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Abstract: Sampling studies in North Dakota conducted from 1994 to 2003 showed that variable-rate N application could be practically directed with zone soil sampling. Results from variable-rate N studies using zone soil sampling were often less than rewarding due in part to the use of a whole-field predicted yield-based formula for developing the N recommendation in each zone. Nitrogen rate studies on spring wheat and durum were established in 2005 through 2009 with the objective to reexamine N recommendations and construct a new system if necessary. The results of the study and archived wheat N response data showed that the state should be divided into three separate N response regions. Within each region historic yields from low to high productivity were defined. The gross N rate was determined using the return-to-N concept developed in the US corn-belt states but with additional consideration for wheat protein value. The gross N rate is then modified by credits for previous crop, soil test N from zone soil sampling, tillage systems, excessive straw from the previous year, relative susceptibility to nitrate leaching or denitrification. Finally, the user is encouraged to use common sense and consider whether particular fields have characteristics that require more or less N fertilizer than suggested by the recommendation formulas.

Key words: Variable-rate fertilizer application, nitrogen fertilizer, fertilizer recommendations, spring wheat, durum wheat.

1. Introduction

Nitrogen recommendations for spring wheat and durum wheat in North Dakota were until recently based solely on grower yield goals and a simple formula, 2.5 × YG less credits; where YG was a grower yield goal, or yield prediction, and the credits included soil test nitrate from a 60-cm sample depth and previous crop N credits. The recommendation was the same for the entire state. Application to site-specific nitrogen management was quite simple; yield goals were established for different parts of the field based on previous yield maps and the formula was used to generate a rate. One problem with the system was it was not effective in maximizing the advantages of site-specific nutrient management. A study comparing nutrient management methods in North Dakota Montana and Minnesota, conducted from 2000-2004 found zone management of nitrogen was possible [1]. However, comparisons of variable-rate with uniform rate of N had profitability advantages particularly with sugar beet, but found little advantage in spring wheat,

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largely due to deficiencies in the N-rate recommendations [2]. Similar problems with N recommendations were recently addressed in US corn-belt states [3]. Nitrogen recommendations for corn in several US states not only consider the corn yield response to N, but also consider the return from added N towards additional corn yield. Return to N in North Dakota spring wheat and durum depends not only on yield increase, but protein increase. A study was initiated in 2005 to review N recommendations for spring wheat and durum in North Dakota to better serve growers in their nutrient management efforts in whole fields and with variable-rate N management.

2. Materials and Methods

Previously published and unpublished works from 1970-2005 were used to build an archive of about 50 site-years of data [4-13]. Data included in the archive required a location, wheat yield, protein content and beginning soil test nitrate analysis on a 60-cm soil sample. Many sites also included previous crop and tillage information. From 2005-2008, over 50 site-years of N-rate data were generated around North Dakota. These data also included location, wheat yield and protein content, beginning soil test nitrate analysis on a 60-cm soil sample, previous crop and tillage information.

The data were subjected to analysis using the "Return to N" model [3]. This model uses the N yield response regression equation to predict yield of grain from zero to some high N level. The cost of N is subtracted from the grain income, resulting in a net profit from using a certain level of N. Subjecting wheat to this model must include a protein economic component, because in many years discounts or premiums imposed on grain price results from lower than 14% protein or greater than 14% protein content grain. The economic considerations for protein in this model used a 50 cent/bushel premium for wheat between 14%-15% protein, and no additional premium for protein above 15%. A dockage of 50 cent/bushel was given grain for each 1% protein below 14%. Scaled discounts were used for each 0.1% protein discount or premium.

Considerations of spatial scale were made with the yield and protein response data. Analysis of the data was conducted separately on data representing the Langdon area, the rest of eastern North Dakota and western North Dakota (Fig. 1). Pre-anthesis wheat lodging was observed in the area around Langdon, ND, over a number of years. Pre-anthesis lodging is most commonly associated with high levels of available N, and is most often observed in fertilizer application overlap areas and areas of abandoned and recently

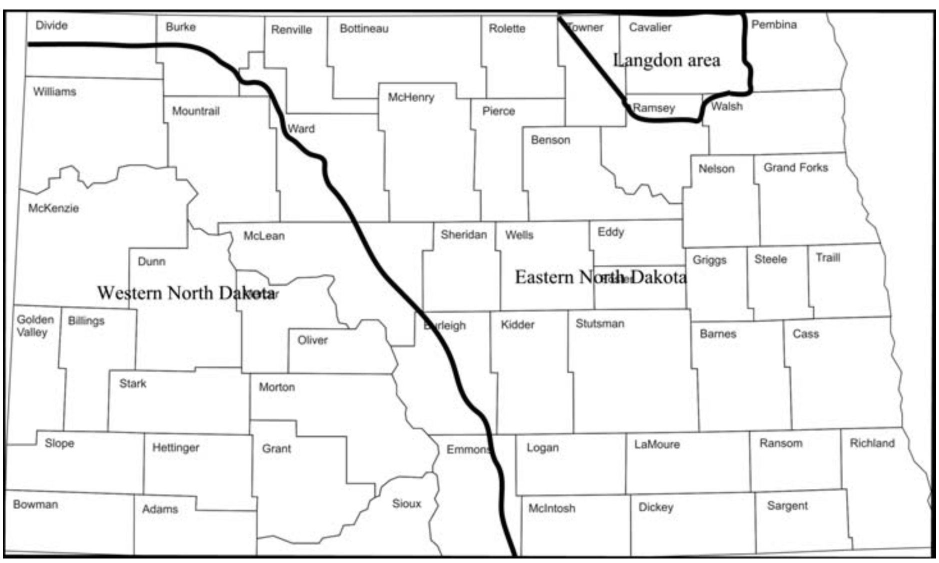


Fig. 1 Three regions for recommendation analysis defined in North Dakota.

farmed through feedlots. In the Langdon area, however, pre-anthesis lodging is observed in many areas not associated with these conditions. Over twenty site-years of data were generated from the Langdon region. These data were analyzed separate from the rest of the eastern North Dakota data.

Eastern and western North Dakota data were analyzed separately due to the soil and climate differences between the two regions. Soils in the east are usually deeper with higher organic matter than the west. The climate in the east is generally more humid than the west. If the response of wheat to nitrogen was different in these three regions from each other, then separate nitrogen recommendations for each region should be developed.

3. Results and Discussion

Regional analysis of the data resulted in three different N yield responses for spring wheat and durum (Figs. 2-4). The example Return-to-N curves in Fig. 2 for the Langdon area show an arc, where after maximum returns are achieved, profitability falls. The abrupt decrease in profitability may be due to the pre-anthesis lodging that results in lower yields in the region. The Langdon arc is in contrast to the rest of eastern North Dakota, where the Return-to-N relationship more closely resembles a straight line (Fig. 3). Both Langdon and eastern North Dakota differ from the curve in the western North Dakota example. Therefore, since all three are different, all three were analyzed separately and three different recommendations were developed. The Langdon area response curve may be different from the rest of the Eastern North Dakota region due to soil that is shallow to shale and contains significant shale fragments from the deposited glacial till parent material [14]. This shale contains significant mineralizable N [15] and may be the source of the unique N responses of spring wheat and durum in this area.

State data was analyzed without (Fig. 5) and with (Fig. 6) the nitrate soil test results from a 60 cm core

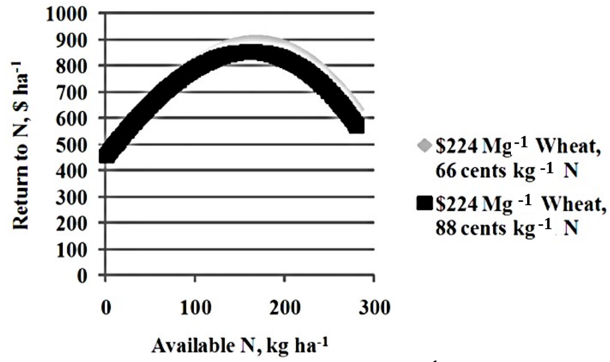


Fig. 2 Langdon return to N for \$224 Mg^{-1} wheat and 66-88 cents kg^{-1} N.

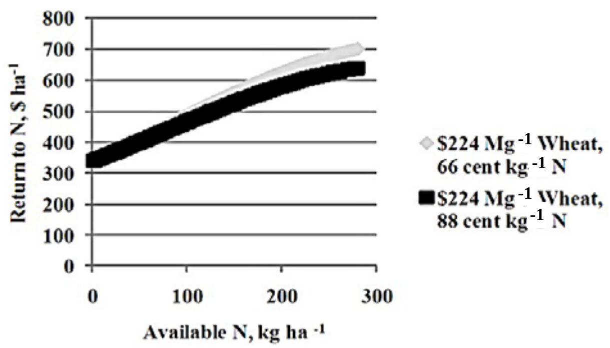


Fig. 3 Return to N for eastern North Dakota for \$6/bushel wheat and 30 to 40 cent/lb N.

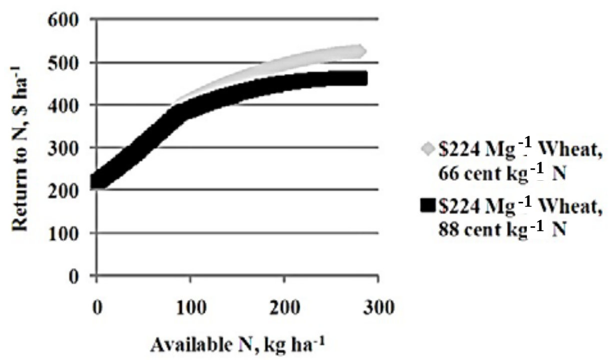


Fig. 4 Return to N for western North Dakota for \$224 Mg^{-1} wheat and 66 to 88 cent kg^{-1} N.

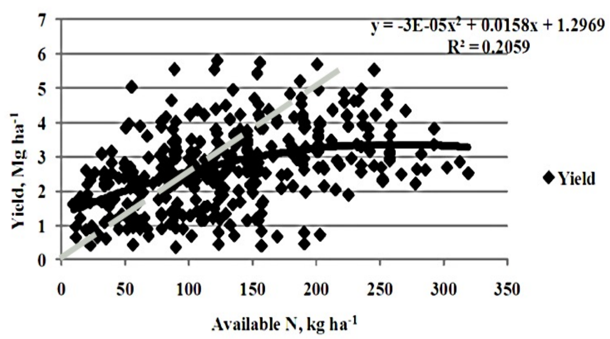


Fig. 5 Relationship of N rate, without consideration of residual soil nitrate, with yield.

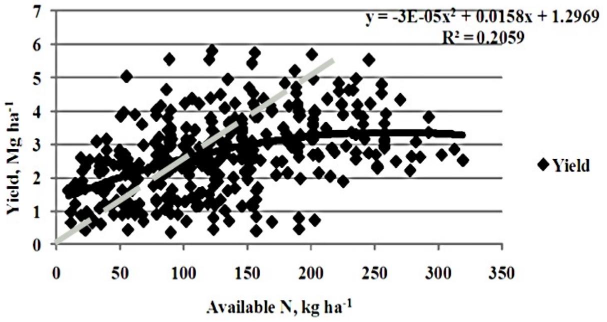


Fig. 6 Relationship of N rate, with soil nitrate included, with yield. The dashed line is the old recommendation formula.

composite sample. The results showed that the correlation coefficient was higher with the soil test added into the available N relationship with yield. Without the soil test, the relationship is a line, and not a typical "law of diminishing returns" curve. Also, the scatter around the zero N rate is very large. The relationship for available N that includes soil test N is a curve, and the scatter around the lowest N rates is not as large. The new recommendations therefore continue to include soil test nitrate.

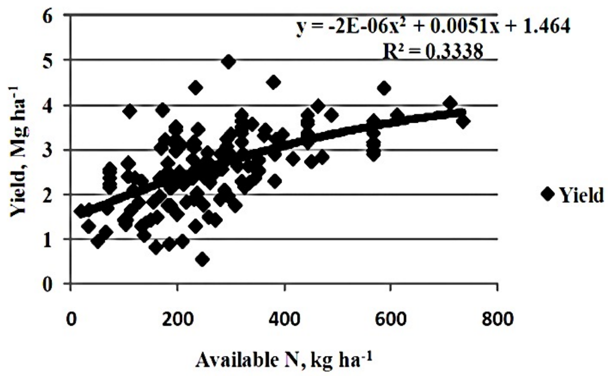
Previously, the nitrogen recommendation forced growers to predict a yield. From this prediction, the recommendation formula multiplied a factor. Then N credits from soil test and credit for N-supplying previous crops from the previous season were subtracted. The new recommendations push growers into putting their field or part of a field into one of three productivity zones- low, medium or high. A historical record of yields would be a much better indication of future performance than a yield prediction. Yield mapping and the use of yield frequency maps would be of great value in helping growers categorize productivity zones within a field.

The large range of data scatter suggests that trying to pinpoint an actual yield has little chance of success. However, categorizing yield productivity into three broad ranges allows for site-specific N applications. Certainly less N is required in areas of the field where less grain is likely. Recommendations for each region are categorized as low, medium or high. Tables were developed [16] for each regional productivity category. From these table values, the soil test nitrate is subtracted. The soil test requirement means that in the zone nitrogen management strategy utilized by nearly all of the site-specific providers in the state, zone soil testing must be used.

Another, more field-sized adjustment is the previous crop N credit. Although the credit for annual legumes is a constant across the field based on data available, the credit for sugarbeet tops is site-specific [17]. Credits for sugarbeet tops is made with a combination of satellite imagery to direct a ground-truth estimate of sugarbeet leaf color and a subsequent credit allotment.

An additional credit not considered in the past is the N credit for long-term (6 years or longer) no-till systems. Long-term no-till growers in western North Dakota have lowered their N rates over time. The large numbers of plots in both western and eastern North Dakota data sets that included tillage history information allowed partitioning of conventional till sites from no-till sites to determine whether the response to N was different. The data showed that in both western and eastern North Dakota, it required at least 50 pounds per acre less N to produce similar yield and protein with no-till compared to conventional tillage. Some of this difference may be due to release of previously applied N through delayed release from residue decomposition. However, some of the difference may also be due to increased N efficiencies caused by temporary early-season biological immobilization that keeps amounts of N lost through denitrification or leaching lower than in conventional tillage. Fig. 7 illustrates the difference in wheat yield in the east comparing conventional till with no-till sites.

The need for an organic matter adjustment to N rate was investigated in 2009. At five locations in the state, three N-rate studies were conducted within the same field using the same farmer cooperator and the same wheat variety within the field. A study was established in a low, medium and high organic matter area within each field. If the response to N differed between areas, that would suggest a need to develop an organic matter



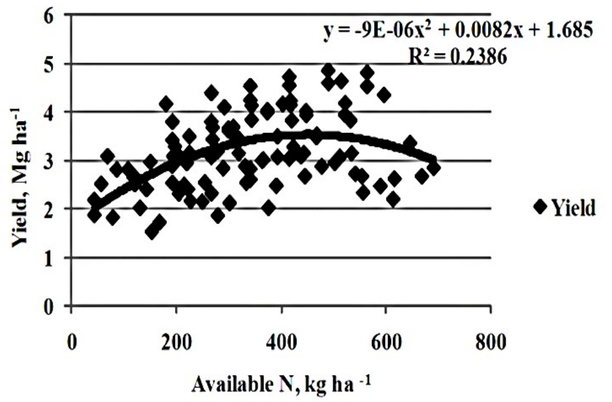


Fig. 7 Conventional till yield with available N (top) compared with no-till yield with available N (bottom).

To achieve 2.7 Mg ha^{-1} yield in conventional till required about 130 kg ha^{-1} N. In no-till Mg ha^{-1} was achieved with less than 80 kg ha^{-1} N.

adjustment. If the response was similar, no organic matter adjustment would be necessary. Fig. 8 shows each of the five locations. At each location, the organic matter determined the productivity of the plot; however, the relative response to N between organic matter levels was similar. Certainly organic matter is important in determining productivity levels within a field, but within the range of organic matter tested at these sites (1%-5.9%) there is no organic matter adjustment to N rate. Due to observations of pre-anthesis lodging in plots and fields where organic matter is 6% or greater, there is an organic matter adjustment of 50 lb N/% organic matter for each full percent organic matter greater than 5%.

After these adjustments, the recommendation user is left with a number. However, this number is not the final number. The recommendations allow for plus or minus 30 lb N/acre depending on several factors including wheat variety protein characteristics, N application method, soils susceptible to denitrification, excessive straw from the previous year and grower common sense. In terms of site-specific management, the excessive straw is most related. Recommendations assume about 2,000 lb straw per acre. This is about the amount of straw generated by a 40 bushel per acre wheat crop. However, sometimes the yields and the straw may be more than twice that amount. Work by Moraghan et al. [18] and current Montana N recommendations by Dinkins and Jones [19] suggested that for every 2,000 lb straw per acre above the current standard of 2,000 lb per acre, an additional 30 lb N per acre should be applied to compensate for additional immobilization by soil microorganisms and residue decomposition. A web-interactive worksheet for the new spring wheat and durum recommendations is available at the following URL: www.soilsci.ndsu.nodak.edu/franzen/franzen.html.

4. Conclusions

New wheat recommendations developed at North Dakota State University are yield and protein response based, economics based and also incorporate several characteristics that lend it to site-specific nitrogen management. These characteristics include the requirement for soil test nitrate, possible categorization of the field into low, medium and high productivity zones, consideration of sugar beet leaf color when appropriate, and consideration of excessive straw from the previous season.

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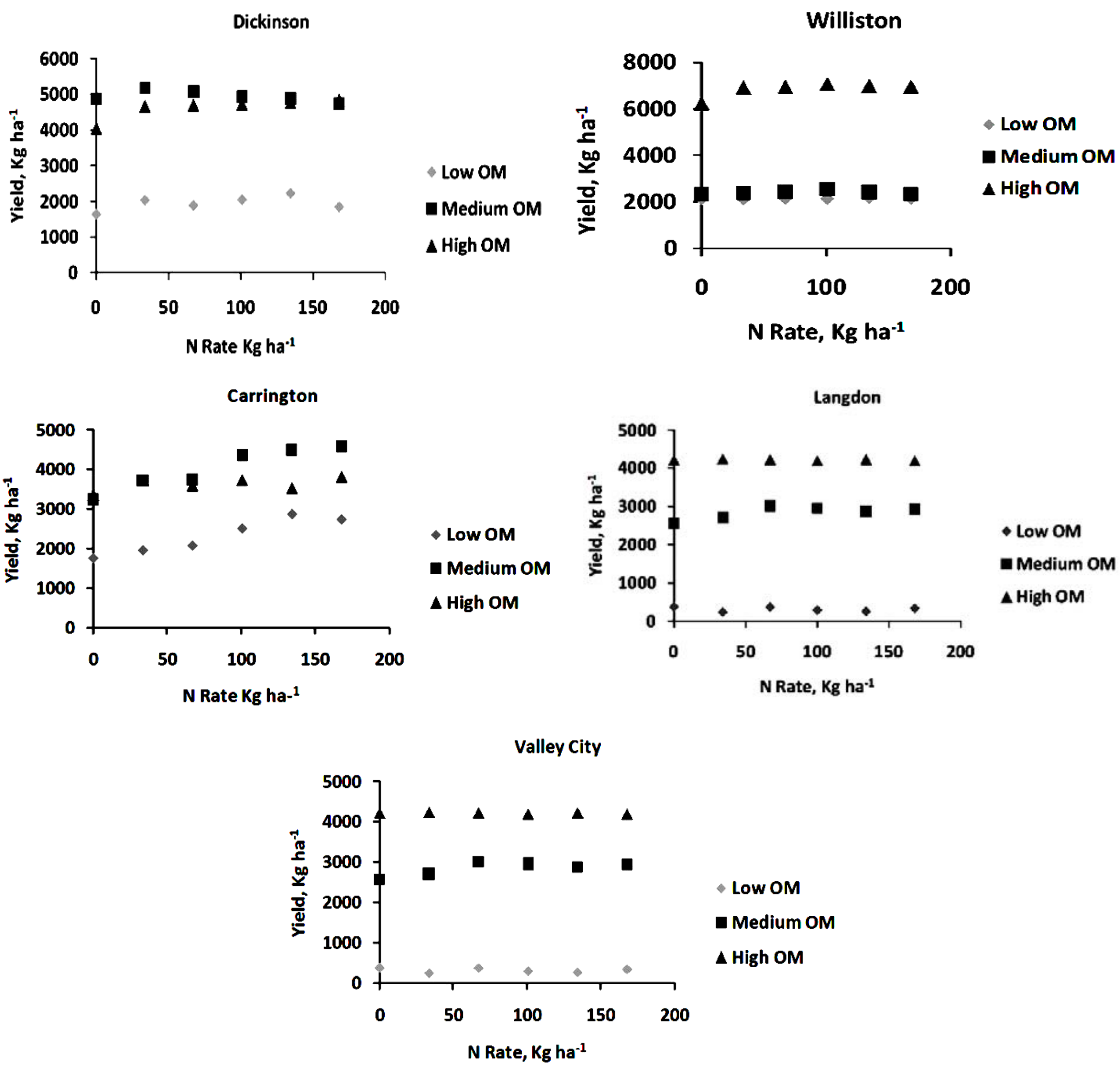

Fig. 8 Spring wheat yields from N rate trials in fields near Dickinson, Williston, Carrington, Langdon and Valley City in areas of low, medium and high organic matter (OM).

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