# Pro-VRF Variable Rate Nitrogen Management

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## INTRODUCTION

The dominant concern in small grains production systems in Western Canada can be described in two words — profit margin. Prices of grains are beyond the control of individual producers and economies of scale have not provided adequate relief from fleeting margins. Government initiatives directed at improving the efficiency of small grains production have been progressively scaled back. Consequently grain producers, although surrounded by a myriad of high tech products, have in a way been taken back to pioneer days where they survived by virtue of their own resourcefulness and ingenuity.

The quest for the elusive profit margin takes us back to basics. What is typically the largest single input cost in grain production? For most producers the answer is nitrogen fertilizer. Crop yields are generally considered to be most responsive to nitrogen of all the major crop nutrients. It follows directly that there is a compelling need for farmers to improve their management of nitrogen fertilizers and nitrogen fertilizer costs.

The Pro-VRF method of variable rate nitrogen fertilizer management was developed at Melfort, Saskatchewan in response to these crop production challenges. Pro-VRF management has substantially improved profit

margins in long term field scale trials at Melfort. Ongoing work is targeted at improving the integrity of the procedure and making it more easily implemented on other farms.

## NITROGEN FERTILIZER RECOMMENDATIONS

### *1. Recommendations From Soil Nitrate Measurements*

Nitrogen recommendations in North America frequently show a common shortcoming whether they apply to Canadian or American locations. They are often too high and as a result create serious production issues. This has been verified through on-farm trials in many jurisdictions.

Soil fertility is a moving target, a target whose movements have been exaggerated by farming practices over the last 100 years. Since nitrogen recommendations are generally based on soil nitrate levels that reflect only part of the nitrogen supplying power of the soil, it is clear these recommendation methods may be open to question. These questions have been explored by comparing the recommendations of 6 different soil test laboratories on exactly the same soil samples1. As an example, the nitrogen recommendations for wheat on a soil sample from Irricana, AB ranged from 55 to 129 pounds per acre. Similarly, recommendations for canola at Fort Saskatchewan, AB ranged from 0 to 72 pounds using the same soil sample. These discrepancies are even more alarming in view of the fact that there was no consistent high/low pattern in the recommendations from the different laboratories.

### *2. Advanced Soil Testing Methods*

Numerous tests have been published to predict the nitrogen release from soil organic matter (OM), commonly referred to as potentially mineralizable nitrogen tests. These predicative N mineralization tests rely on environmental assumptions, factors that are in fact variables on a year-to-year basis. Furthermore, our

investigations at the Saskatchewan VRT project indicate these analytical procedures may require regional or local calibration as absolute values of the tests are not consistent with other data obtained from zero nitrogen yield strip trials.

Three N mineralization tests are being examined by the Saskatchewn VRT Project. A fourth method has been abandoned due to the unreliable nature of the potential yield predictions associated with this method. A combustion OM method is also being evaluated. The 2003 nitrogen soil test program at the Saskatchewan VRT Project is extensive including more than 4,200 tests performed on samples drawn from 13 fields. Developing N recommendations from these newer testing methods is a work in progress and few conclusive endpoints have been reached at this stage.

## SPATIAL VARIABILITY

Measurements of potentially mineralizable nitrogen at 42 Alberta locations suggest the variability of mineralizable N across individual fields is nearly equal to the average rate of nitrogen fertilizers that farmers apply in a given region2. Indirect measurements of N mineralization using zero nitrogen strip trials at Melfort suggest even greater variability in soil mineralized N than the values reported in the Alberta study.

At Melfort localized barley yields of more than 100 bushels per acre have been observed without nitrogen fertilizer in testament to the very high levels of mineralized N in specific field locations. Wheat yields over 60 bushels per acre have been observed under the same conditions. Fields under fixed rate nitrogen management typically have higher overall variability in nitrogen fertility than what is reflected by the mineralizable N test alone as high fertility parts of these fields sometimes show very high residual nitrate and ammonium levels as well. These relationships are likely the result of chronic over-fertilization of the high fertility parts of the fields.

## INDIRECT ESTIMATES OF NITROGEN FERTILITY

### *1. The Gold Standard — On-Farm Strip Trials*

The validity of field scale strip trial data compared to traditional small plot trials has been adequately described elsewhere2. Bringing yield mapping procedures and surface interpolation techniques into the strip trial methods creates large data sets useful for the comparison of different layers of site specific information such as fertilizer rate and yield. At the VRT Project fields are divided into 50 Logical Management Units (LMUs) per acre3. Collecting data of this dimension with small plot methods is clearly unaffordable and impractical.

Since nitrogen fertility has been demonstrated to be highly variable within fields, and between fields, farms and soil types it is inconceivable that a small number of widely dispersed fertilizer response trials will provide the detail necessary to establish reliable fertilizer recommendations. These limited fertilizer response trials are the basis of most nitrogen fertilizer recommendation systems currently available to producers.

It is useful to note that on-farm variety strip trials are commonplace in some jurisdictions where the trial results are used to promote the sales of costly proprietary seed varieties. The on-farm strip trial approach to nitrogen fertility testing is scarcely used in Western Canada and not visibly supported or encouraged by the fertilizer industry.

It is essential to introduce on-farm strip trial methods on our farms to reach higher levels of fertilizer use efficiency, particularly when all the fertilizer is applied either pre-plant or during planting.

### *2. The Silver Bullet — In-Crop NDVI*

In-crop Normalized Difference Vegetative Index (NDVI)) measurements can be used to assess plant biomass. Plant biomass may be viewed as an indication of nitrogen sufficiency and, when referenced to long term yield data, as a predictor of potential crop yield. NDVI estimates from satellite imagery have been promoted by NASA and others for many years but with the inherent weakness associated with satellite data, have never received mainstream billing in the agricultural sector.

Oklahoma State University has, over a 9 year period, developed a method to more precisely measure NDVI values and associate these values with crop nitrogen sufficiency. Algorithms are applied to the NDVI data to estimate the potential for profitable in-crop nitrogen applications. This system is highly innovative and unequalled by any other known method of crop NDVI measurement. While $25 million has done into these developments it is still early days.

In collaboration with Oklahoma State University this NDVI technique underwent extensive field evaluation at Melfort during 2003. But is it truly a silver bullet? 2003 data indicate the technique has a remarkable ability to predict relative yields of spring wheat across individual fields. Unfortunately no fields were found where the system predicted a yield response from an in-drop nitrogen application, again a reflection of chronic over-fertilization practices. Experimental in-crop nitrogen applications were made to verify the NDVI interpretations. Crop yield results were consistent with the predicted yield responses – there was no significant yield response from the in-crop nitrogen applications although some of the fields had received only 15 pounds per acre of pre-plant nitrogen.

## NITROGEN CYCLING

### *1. Fate of Nitrogen Fertilizer*

Complex nitrogen interactions take place between the soil, plant material, soil microbes and the atmosphere. Despite spirited attempts to trace the disposition of nitrogen fertilizer in cropping systems about 30 % of the nitrogen can not be accounted for. Of greater significance to efficient crop production, it has been estimated that the average nitrogen use efficiency (NUE) of nitrogen fertilizer in cereal crop production worldwide is only 35 %. From a profitability point of view only 35 cents of every dollar that farmers spend on nitrogen fertilizers actually ends up in the crop. Improving the global NUE of nitrogen fertilizers by only 1 % would amount to a savings of $325,000,000 annually on nitrogen fertilizer expenditures.

### *2. Soil/Plant Nitrogen Buffering*

For discussion it is useful to view soil and plant materials as sponges with a limited ability to store nitrogen for future crop production. Mineral forms of nitrogen are both mobile and highly reactive and therefore prone to losses through denitrification and soil leaching mechanisms. However, more stable nitrogen reserves in the form of organic matter (OM) can be rebuilt over time with appropriate crop and fertility management programs. Soil fertility has gradually been compromised by farming practices over the last 100 years or so. The rebuilding process must be viewed as a long term undertaking when using inorganic fertilizers. Attempts to fast track the process will result in abysmal nitrogen use efficiencies and excessive nitrogen greenhouse gas emissions.

## NITROGEN FERTILIZER APPLICTION METHODS

### *1. Shotgun Method*

This approach applies fertilizer at a fixed rate over entire fields without regard for spatial variability in soil fertility. Assuming an optimum fixed rate is selected about 1/3 of the field is fertilized optimally, 1/3 is under fertilized and 1/3 is over fertilized. It is impossible to achieve high nitrogen fertilizer use efficiencies in this scenario as soil nitrogen fertility has been demonstrated to vary in units as small as 1 square meter.

### *2. Grid Based Methods*

Nitrate soil tests performed on about 2.5 acre grids have been promoted by some as means of establishing variable rate fertilizer (VRF) recommendations. With the inherent limitation of the nitrate soil test and recommendation system, and the 2.5 acre sampling interval, it is highly unlikely this recommendation method will provide an effective outcome for VRF applications. Perhaps this method of fertilizer management should be more appropriately referred to as “delusional VRF”.

*3. Macro VRF Methods*

The Pro-VRF solution to variable rate nitrogen management uses 8,000 Logical Management Units (LMUs) per 160 acres or 50 LMUs per acre and is therefore referred to as a macro management method. Existing soil testing and recommendation methods provide neither the accuracy nor the level of detail required to implement a Pro-VRF management program. The unique feature of this VRF management technique lies in the fact that the farmer's understanding of spatial variability within individual fields is used to build base data layers from which variable rate prescriptions can be derived.

*4. Micro VRF Management*

Late breaking technology has made it possible to apply variable rate nitrogen fertilizer with a spatial resolution of 4 square feet or about 1.8 million management units per 160 acres — true micro management. And this operation is performed in-crop, in real time, after it has been determined there will likely be a profitable yield response from an additional nitrogen application. The VRF applicator senses crop nitrogen needs by measuring NDVI at two foot intervals across the width of the applicator. Oklahoma State University has also been the lead developer in this fertilizer application system.

Field scale winter wheat trials on 7 Oklahoma farms in 2003 showed an average net financial benefit of $5.33 per acre while using 55 % less fertilizer than the amount recommended by the Oklahoma State soil test and recommendation system. Recalculating the outcome using prevailing Canadian prices for nitrogen fertilizers the net benefit would be $7.76 per acre and of course this value will continue to rise as nitrogen prices spiral upward.

Perhaps the greatest benefit to micro VRF management lies in its potential for reducing the financial risk associated with crop production — the 2003 Oklahoma results translate into a reduction in fertilizer investment of $3,400 per 160 acre field while at the same time increasing the net profit by $850.

## Pro-VRF NITROGEN MANAGEMENT

*1. Early VRF Trials*

Basic, perhaps even primitive, field scale VRF management began 8 years ago at the central research site of the Saskatchewan VRT Project. Next, prescription VR nitrogen applications were made based on an experimental method devised by Dr. Dan Pennock of the University of Saskatchewan and secondly, based on a prescription provided by a commercial service provider. While both methods relied on aerial photograph interpretations to arrive at field management zones, their technical approaches were substantially different. Yield mapping techniques were used to assess the profitability of the procedures. Neither VRF method resulted in a profitable outcome owing to interpretive errors in the management zoning procedures.

*2. Pro-VRF Method*

Early results indicated there was a remarkable opportunity to improve profitability with VR nitrogen management. Although not a hot topic at the time, one of the clear financial benefits was associated with eliminating yield depression in areas of the fields of high natural fertility that had previously been subjected to over fertilization.

When the VR prescriptions from the aerial photographs failed to make a passing grade it was back to ground zero where the operator controlled the variable rate application manually as he motored across the fields. A site specific application map was recorded by an onboard task controller during the application and with some software manipulations this map served as the base prescription template for future years. Once a useful field prescription template is created it can be used for many years as soil doesn't readily migrate from one field location to another when conservation methods of farming are followed. Prescription nitrogen rates applied in

the different field management areas can easily be changed on an annual basis by using a GIS software program such as SSToolbox.

It was evident that nitrogen recommendations obtained through site specific nitrate soil test procedures were well off the mark. These findings were confirmed with fertilizer strip trials and yield map information. Farmer estimates of appropriate site specific nitrogen rates were more effective than those obtained from normal soil nitrate tests. With additional data from multiple crop years the prescription application rates can be improved upon by reviewing the nitrogen yield responses observed in the strip trials.

## LONG TERM EFFECTS OF VRF MANAGEMENT

Field results over an 8 year period suggest the benefits of VR nitrogen management are cumulative, that is starting with fields of average nitrogen status, the profitability effects attributable to the VRF nitrogen applications tend to increase over time. It appears the soil nitrogen buffering and mineralization characteristics are altered in a fashion that enables the soil to support higher yields under certain growing conditions. While moisture remains the dominant factor limiting yields in dryland crop production, the VRF managed fields appear to perform notably better than fixed rate nitrogen fields during growing seasons where crops are subjected to intermittent stress conditions. While we commonly refer to the breakdown of soil OM by microbial and chemical activity as nitrogen mineralization other nutrients of interest including sulfur are also released in plant-available forms during this process and are likely contributing to improved yield results in long term VRF fields. Eventually a new soil fertility equilibrium will be reached under long term VRF management however it is unknown when this point will be approached.

## ECONOMIC BENEFITS OF Pro-VRF MANAGEMENT

Pro-VRF methods have shown an economic return of $5 to $46 per acre. The $45+ benefits were experienced after 5 or more years of continuous VR nitrogen applications.

Previous VRF investigations by Dr. Dan Pennock on thin black soils resulted in economic benefits of $4 to $28 per acre however these studies were short term in nature.4 Noteworthy, in Dr. Pennock's research there was one production year where even low rates of applied nitrogen, starting at 30 pounds per acre, actually reduced the yield of hard red spring wheat. These independent findings certainly support the notion that over-application of nitrogen fertilizers significantly depresses crop yields.

## Pro-VRF ENHANCEMENTS

### *1. Equipment Performance and Ergonomics*

It is important that GPS-enabled VRF products become more widely available so farmers can begin to incorporate these practices into their routine management practices whether they choose to use granular, liquid or anhydrous ammonia nitrogen sources. Engineering enhancements that will improve the performance of variable rate fertilizer application systems are currently under development.

Improved operator interfaces are also required to facilitate operator-controlled VRF applications and to generally simplify the process. Product engineering initiatives are presently underway to reach these objectives.

Although specific equipment enhancements are under development to streamline the farm implementation of the Pro-VRF method it should be remembered that the method was developed by a farmer with products that are commonly available off the shelf. And it is much easier to implement a known procedure that to develop it from scratch.

### *2. Soil Testing and Site Specific Nitrogen Recommendations*

A more predictable nitrogen recommendation system is required to facilitate VRF implementations over a broad range of soil types. Progress has been made on this front using more recent soil testing protocols however

further work is required to adequately characterize and calibrate these methods. Cost remains an important consideration in any soil testing solution.

***3. Expert Personnel***

The most important elements in a VRF management plan are the expert human resources. Equipment is readily available — expert human resources are in a word, scarce. Farmers may not always recognize their highly developed expertise but in fact this expertise is the most critical component in executing a successful VRF management system. Remember the number one objective is to improve the nitrogen use efficiency and profit on your farm. Simply stated, you will be using less fertilizer on your farm in the long term under VRF management. This may not be an appealing outcome for fertilizer retailers or manufacturers so agronomists associated with these businesses may be less than enthusiastic when approached regarding VRF implementation services for your farm — or they may simply lack the necessary skills and computer software.

## CONCLUSIONS

The Pro-VRF method of variable rate nitrogen fertilization has been demonstrated to be profitable and practical in black soils at Melfort, Saskatchewan. Fields under long term Pro-VRF management require less fertilizer than traditionally managed fields. Reduced nitrogen fertilizer usage inherently reduces greenhouse gas emissions in cropping systems and aids in meeting emerging regulatory pressures associated with environmental sustainability issues.

Pro-VRF methods in combination with crop NDVI measurements and in-crop nitrogen fertilizer applications show great promise for both reducing production risk factors and improving farm profitability. Variations of these potent fertility management methods can be readily tailored in very precise ways to the risk tolerance and crop production goals of individual farmers.

Without regard to the particular method of VR nitrogen management that is under implementation, on-farm strip trials are fundamental to the success of these management practices. Better yet, get the fertility strip trials started on your farm right now before you get on the VRF train.

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