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Plant Nutrition TODAY
Better Crops, Better Environment...through Science

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Winter 2015/16, No. 1

FITTING THE 4Rs INTO NUTRIENT CYCLE STEWARDSHIP

The farm nutrient cycle is now a central focus of sustainable development discussions. It plays crucial roles in global issues including food security, climate change, biodiversity, and water quality. Thus it is important to understand where 4R Nutrient Stewardship fits into the stewardship of the cycle.

The flow of nutrients through a farm includes inputs from the atmosphere, internal turnover, and outputs in the form of crop removals and losses with soil erosion, in drainage water, and back to the atmosphere. The 4Rs directly address an important part of that cycle: the application of nutrients to the soil. Agricultural service providers have a large but not total influence on producer decisions regarding the right source, right rate, right time and right place for nutrient application. The 4R concept addresses everything included in those decisions, and its implementation requires stewardship of all important controls of nutrient flows into, within, and from the farm.

It's no surprise that the 4R concept has been widely embraced by agricultural service providers. It is the most appropriate place to start in any effort to reduce nutrient loss. While managing source, rate, time and place may not be enough, why put effort into controlling and trapping excess nutrients coming off the edge of the field, before doing what can be done to avoid loss at the point of application? From a grower's perspective, it's the most profitable way to reduce nutrient loss.

The 4Rs address the full decision cycle for choices of source, rate, time and place. Any technology relating these choices to the full farm nutrient cycle can be considered part of 4R Nutrient Stewardship. Enhanced efficiency fertilizers, soil testing, and variable rate application can't be considered technologies separate from the 4Rs. They are included, along with a list of traditional practices like plant analysis and scouting for symptoms, and precision tools like GPS, GIS, yield monitors, sensors, and weather-based computer models.

Nevertheless, the agricultural service provider's role in the stewardship of nutrient cycling need not be limited to nutrient applications. Crop, soil and pest management practices interact strongly with source, rate, time and place choices. Key performance indicators of nutrient stewardship—crop productivity, soil health, and nutrient use efficiency—can be influenced strongly by choices of crop genetics, pest control, and conservation tillage. Tillage and drainage systems also influence the amounts and forms of nutrients lost. Most service providers already provide service relating to these choices.

In many cases, reducing nutrient losses to societally acceptable levels will require going beyond agronomic practices. 'Control and trap' practices beyond the edge of field may be necessary because, face it, to attain the productivity levels demanded for today and tomorrow, crops need nourishment beyond natural levels. Agricultural service providers are considering how to provide services addressed at nutrient losses beyond the edge of the field. It is challenging, but efforts are being made. Possibilities for making it profitable include environmental credit trading, food industry supply chain sustainability initiatives, and other collaborative actions.

Society increasingly expects agriculture and agri-business to improve its stewardship of the nutrient cycle. Agricultural service providers applying 4R Nutrient Stewardship embrace every opportunity to engage this challenge.

– TWB –

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Winter 2015/16, No. 2

CUSTOMIZING YOUR FERTILIZER APPLICATIONS IN RELATION TO WEATHER

Don't forget the weather experienced during a crop year has the greatest effect on crop yields. Crops need sunlight, warmth, moisture, and nutrients to grow. When crops are grown under rain fed conditions the only need we can supplement is nutrients by adding fertilizers and livestock manures as appropriate. Access to irrigation allows addition of water if moisture is in short supply, but we can't do much if rainfall is excessive. The reality is that farmers are at the mercy of the weather. Most of the time the weather is conducive to reasonably good crop production, but sometimes we receive insufficient moisture, and or warmth, and crop yields are poor. In contrast there are those extraordinary crop years when all the crop needs are supplied in just the right combination.

2013 was an example of one of those extraordinary crop years, as experienced in the Western Canadian Prairie provinces. For example, in Alberta the average yield of all wheat types was over 58 bu/A. This is the highest average wheat yield experienced from 1962 through to 2013. The average for the previous 9 crop years, 2004 through 2012, was just over 45 bu/A, so considering the past 10 years the 2013 crop year was 29% higher yielding than the average of the previous 9 years. The question can be asked—did farmers fertilize sufficiently for that above average crop?

We could always apply the most correct source, rate, time, and placement of fertilizer inputs if we knew what the crop year weather was going to do. The challenge is we don't know what the exact weather will be until after it happens. At the end of the crop year we can look back and see where adjustments could have been made to the fertilizer program. If we had cool and droughty conditions, lower fertilizer rates would have been adequate for the reduced crop potential. Also, in an ideally warm and sufficiently moist year, as in 2013, in many cases the above average crop yields could have been even higher if higher fertilizer rates were used.

In practical terms most farmers apply nutrients in anticipation of a slightly better than average crop year. But there are some nutrient management strategies that could be beneficial in those much better than average years. One is by soil testing regularly, e.g., every 3 years or so, for plant nutrients that can be gradually built up and maintained at optimum levels, like P. It is suggested that optimum levels of Olsen soil test P could be 20 ppm, not the normal soil test level of 14 for most western Canadian soils. Another strategy is to be capable and ready to supply additional nitrogen fertilizer as an in-crop application if much better than normal crop growth up to the stem elongation stage of crops is experienced. This would allow farmers to supply ample nutrients to optimize crop yields, when that much better than average weather is experienced.

– TLJ –

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Winter 2015/16, No. 3

YEAR OF SOILS: 4R NUTRIENT STEWARDSHIP AND SOIL MANAGEMENT

This year was designated as the International Year of Soil. This recognition gives us an extra opportunity to reflect on the importance of soil as the basis for plant growth, healthy animals, clean water, and maintaining life on earth.

In recent years, much of the fertilizer industry has embraced the principles of 4R Nutrient Stewardship as a way that farmers can maximize their yields, improve nutrient efficiency, and reduce environmental impacts. This involves selecting the right source of nutrient, added at the right rate, applied at the right time, and put in the right place. Adopting the correct set of 4R principles requires planning, management, and flexibility to meet local challenges.

It is important to remember that 4R Nutrient Stewardship is not a single set of practices that stand alone in achieving these economic, environmental, and social goals. Careful nutrient management must be accompanied by a package of other production and conservation techniques to be successful.

A sophisticated jet airplane cannot launch into flight if it lacks an engine or is missing the jet fuel. Similarly, successful modern crop production requires all the components to work together to be successful. Modern nutrient management practices must be accompanied by other locally appropriate conservation approaches.

The concept of "Soil Fertility" integrates many factors such as soil physical properties (e.g., soil texture, structure, water, and air), biological properties (microorganisms and organic matter), and chemical properties (nutrient availability, pH). Clearly the 14 essential plant nutrients supplied from the soil are a vital part of growing a healthy plant that produces high yields. Despite their irreplaceable nature, the presence of an adequate nutrient supply does not alone make a fertile soil.

4R practices are not confined to only inorganic fertilizer, but they are applicable for both inorganic and organic nutrient sources. Organic and mineral fertilizers complement each other and best results for both crops and soil commonly occur when they are used together. For example, there is plenty of evidence that proper fertilization will commonly increase soil organic matter or at least slow its loss in cultivated soils compared with using no fertilizer.

As the end of the International Year of Soil draws near, remember the essential role that plant nutrients play in sustaining soil productivity. Proper 4R-based nutrient stewardship clearly has a positive contribution in this effort. But nutrient management is only one piece of the solution to maintaining our precious and irreplaceable soil resource.

Let's make 4R Nutrient Stewardship more than a slogan. It needs to be implemented into a complex and continually changing conservation-based farming landscape that wisely preserves soil for generations to come. The conclusion of the International Year of Soil prompts a renewed reflection of the fundamental role of soil and the need for wise nutrient management.

– RLM –

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4R FUND SUPPORTS THE NEXT GENERATION OF CROP NUTRITION RESEARCH

The 4R Fund was established in 2013 by the fertilizer industry to measure and document the economic, social, and environmental impacts of 4R Nutrient Stewardship. The concept of 4R Nutrient Stewardship is to apply the right fertilizer source at the right rate, at the right time, and with the right placement. Moving "right" from a concept to something measurable requires a two-pronged approach: gleaning knowledge from previous studies and initiating new studies to fill knowledge gaps. The 4R Fund provides researchers with resources to do both. In 2013, a request for proposals was publicized and a total of twenty-three projects in the U.S. and Canada were funded.

Five of these projects are gleaning knowledge from previous studies. These aren't traditional reviews. The techniques being used are new to agriculture but are not new to science. They have been used extensively in the social sciences and in medicine. Meta-analyses, as they are called, leave the traditional narrative style of past reviews behind. Instead, they provide quantitative answers to the question, "Across all studies that can be analyzed, how much of an overall difference is there?" The 4R Fund meta-analysis projects are reviewing published research to find strategies most likely to reduce nutrient losses while securing needed supplies of food, feed, fuel, and fiber.

Seventeen of the 4R Fund studies are research and demonstration projects aimed at increasing our understanding of what practices constitute the next generation of nutrient stewardship. These studies examine not only productivity but also nutrient use efficiency and nutrient losses. Many sites are heavily instrumented and measure a variety of environmental variables.

A unique feature of the 4R Fund is the mandate for open access to data. This is the objective of the remaining project. Eventually, all data and meta-data from each experiment will be collected, described, and archived. This will preserve the data and make it available for answering new questions in the future. This is a unique offering for industry-funded research and sets a precedent for transparency.

The 4R Fund was established from contributions of members of The Fertilizer Institute and Fertilizer Canada (formerly the Canadian Fertilizer Institute) and has since grown to include contributions from additional agricultural stakeholders. For more information, visit http://www.nutrientstewardship.com/funding.

–TSM –

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Winter 2015/16, No. 5

GETTING MORE OUT OF 4R PERFORMANCE INDICATORS WITH PRECISION AGRICULTURE

One of the unique components of 4R Nutrient Stewardship that separates it from traditional nutrient management planning strategies is the inclusion of performance indicators. Performance indicators are parameters that can be used to objectively evaluate outcomes from a specific set of management practices selected for a specific cropping system. The performance indicators are chosen based on stakeholder input and will align with the sustainability goals for the crop production system. Precision agriculture (PA) technologies can improve the quality of information that performance indicators provide and subsequently increase the ability to properly evaluate chosen practices.

Yield mapping can greatly enhance the information gained from one of the most easily measured performance indicators. Yield is often used as an indicator of economic sustainability and to assess both productivity and profitability of chosen practices. However, spatial variability in yield is masked when considering the average yield for the entire field. While performance indicators are selected to evaluate fertilizer practices, it is important to note that they are also affected by several non-fertilizer factors. Locating and quantifying yield variability through mapping can help identify these factors (i.e., compaction, poor drainage, soil textural changes, etc), which might need to be managed differently leading to even greater sustainability.

Yield data can also be used to calculate nutrient balance by multiplying yield by a scientifically validated nutrient removal coefficient. Nutrient balance is a performance indicator that typically provides an accounting of total nutrient inputs and outputs. Calculating nutrient balance on a spatial scale can help evaluate the effectiveness of variable-rate (VR) fertilizer applications. It can also identify fields receiving uniform fertilizer rates that may respond favorably to VR applications. Nutrient balance also provides an indirect measure of nutrient surpluses, which can affect the environmental sustainability of the cropping system.

Nutrient use efficiency (NUE) is another performance indicator often tied to environmental and economic sustainability. Nutrient use efficiency is often mistaken as the most important indicator of sustainable fertilizer practices. However, nutrients are applied to improve the overall performance of the cropping system and NUE is only one aspect of that performance and can be defined many different ways. Various PA practices have been shown to improve NUE including VR nitrogen (N) fertilizer applications based on crop reflectance. Research conducted by Dr. Wade Thomason at Virginia Tech demonstrated that using GreenSeeker® crop sensors to determine in-season N rates for wheat and corn increased NUE (calculated as recovery efficiency) by 7% and 13%, respectively.

Automated equipment technologies also contribute to the value of performance indicators. Technologies like auto-guidance, section control, and variable-rate distribution significantly improve the precision of agricultural inputs. The ability to eliminate overlapped applications has economic implications as demonstrated by survey data collected by the Auburn University Precision Ag Extension Team, which show an average of 22% saving on input costs when utilizing the above-mentioned technologies. There are also environmental and social benefits to the ecosystem due to the precise application of inputs near conservation structures (i.e., grass waterways) and outdoor recreation areas.

Finally, on-farm data collection leads to more comprehensive outcome evaluation and continuous improvement in nutrient stewardship. Another unique characteristic of 4R stewardship is the dynamic feedback mechanism that is central to the evaluation process. There are cycles of action and evaluation at each level of the stakeholder group (farm, regional, and policy). The opportunity to use PA technologies to collect high-resolution, geo-referenced data (tabular and graphic) on nutrient prescriptions, applications, and removal greatly enhances the evaluation process, results in increased transparency and accountability of practices among stakeholder groups, which in turn lead to the adaptive management necessary to meet sustainability performance goals.

To learn more about these and other PA technologies, consider attending the next InfoAg Conference, which will be held August 2 – August 4, 2016 at the Union Station Hilton in downtown St. Louis, MO. In 2016, InfoAg and the International Conference on Precision Agriculture will be co-located, providing additional educational and networking opportunities. Stay informed by visiting www.infoag.org and following @InfoAg.

– SBP –

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NICKEL IS A PLANT NUTRIENT… REALLY?

Nickel was formally recognized as an essential nutrient in 1987, making it the most recent addition to the list. Compared to other plant nutrients, relatively little is know about Ni nutrition. In fact, it is sometimes referred to as "the forgotten essential trace element."

Ni in Plants: Nickel is taken up from soils as Ni^{2+}. It is readily mobile in plants, and in some species is preferentially translocated to developing seeds. The Ni concentration of most plant material normally ranges from about 0.1 to 5 ppm dry weight, but can be highly variable depending on its availability in soils, plant species, plant part, and season. Concentration greater than 10 ppm is considered toxic in sensitive species, and when greater than 50 ppm it becomes toxic in moderately tolerant species. Some plants can tolerate levels of Ni in tissue as high as 50,000 ppm dry weight. These are called "hyperaccumulators", and are defined as plants that can accumulate at least 1,000 ppm Ni without phytotoxicity.

Pecan is a species that has a relatively high Ni requirement due to its unique physiology. Deficiency in pecan occurs when tissue Ni concentrations fall below 1 ppm, with toxicity occurring when concentrations exceed 100 ppm. The adequate range is estimated to be between 2.5 and 30 ppm; however, these Ni threshold values depend on concentrations of competing cations such as zinc (Zn^{2+}), copper (Cu^{2+}), and iron (Fe^{2+}).

Nickel is known to be an irreplaceable constituent of the urease enzyme. Urease has a Ni metallo-center, making Ni essential for urease activity. The urease enzyme assists in the hydrolysis of urea to ammoniacal-N, which plants can utilize. Nickel is thus important in N nutrition of plants. Under certain conditions where Ni is insufficient and urea is the major source of N, urea can accumulate in leaves to the point of toxicity. This urea toxicity, often manifested as necrosis of leaf tips, is actually a symptom of Ni deficiency. Nickel nutrition has also been shown to play a role in protecting against plant diseases. For example, it is involved in the synthesis of chemicals (phytoalexins) that the plant produces to defend against pathogens.

Ni in Soils: Nickel is present in nearly all agricultural soils, which commonly have Ni concentrations of 20 to 30 ppm and seldom exceed 50 ppm. The most important single soil factor affecting Ni availability is pH—as soil pH increases Ni plant availability decreases. Therefore plants grown in high pH soils may be vulnerable to Ni deficiency. Also, high concentrations of divalent cations such as Zn^{2+}, Cu^{2+}, and Fe^{2+} in soil solution can inhibit uptake of Ni. Soil testing for Ni as a plant nutrient is not an established practice since there has been little research in the area of Ni nutrition of most crops.

Soil application of Ni is rarely needed since most plants are adequately supplied. Also, trace amounts of Ni are contained in some commonly applied fertilizers. Where Ni fertilizer is needed to address a deficiency, it is most often applied as a foliar spray. Nickel salts (e.g., sulfates and nitrate) and organic Ni ligands (lignosulfonates, heptogluconates) are effective foliar fertilizers. The Ni-lignosulfonate form is preferred for field use due to potential safety concerns with other sources.

Although it is unlikely that Ni input will be needed in the production of major crops, it is nevertheless a recognized micronutrient, and therefore warrants a brief review. For more on Ni nutrition see IPNI's *Nutri-Facts* series (https://www.ipni.net/nutrifacts-northamerican), or a recent and comprehensive chapter by Wood (Wood, B.W. 2015. Nickel. p. 511-536. In A.V. Baker and D.J. Pilbeam (ed.) Handbook of plant nutrition. CRC Press, Boca Raton, FL).

– WMS –

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Winter 2015/16, No. 7

FANTASY FERTILITY - NOT SUSTAINABLE

Higher crop yields place increased nutrient-supplying pressures on the soil. It is well known that crop roots absorb nutrients from the soil solution through **root interception** *(as roots explore new soil volumes),* **mass flow** *(as water moves through soil pores)*, and **diffusion** *(as nutrients move in the soil solution from a zone of higher concentration to a lower concentration)* processes. Soils with higher fertility levels are better able to supply plant nutrients during times of environmental stress and also during peak crop uptake demands.

Wise, economic additions of fertilizer and/or manure help replace the available nutrients removed from the soil by crop harvests, erosion, leaching, and other losses. Neglecting such nutrient replenishment leads to declines in: 1) soil fertility, 2) crop productivity, 3) cropping system resilience, and 4) indices of soil health; which threaten sustainability. Soil testing is a very important tool in assessing current levels of soil fertility, and in monitoring changes over time; an essential sustainability practice. However, soil testing is not a perfect tool …. and experienced agronomists know that they should also use complementary plant tissue analyses, as well as estimates of crop harvest nutrient removal, to assess and manage optimum plant nutrition in each field and sub-field area.

Many farmers and their crop advisers currently face difficult economic decisions because of undesirable crop prices and lower-than-expected crop yields; due in part to unfavorable weather in 2015. **As management plans are developed for the 2016 cropping season, it may be helpful to be reminded of some fundamental facts:**

- Soils do contain significant amounts of total nutrients, but those amounts are not necessarily reflective of *available plant nutrient levels.*
- Release of plant available nutrients from soil clay minerals and soil organic matter can often be slower than plant uptake demand; especially during rapid crop growth.
- Cover crops can help capture residual soil nitrate, but they do not magically produce new nutrients from the soil, and they may not cycle nutrients to successive field crops at rates that match those crop needs.
- Manure nutrients are often not a balanced crop nutrient supply:
  - manure *"book values"* for plant available nutrients may not represent actual variable contents,
  - release of nutrients in plant available inorganic forms is less predictable than from fertilizers, and
  - based on 2012 data, use of all the recoverable manure resources, that are capable of collection and application to fields in the U.S., could provide less than 10% of crop nitrogen needs, less than 35% of crop phosphorus needs, and less than 25% of crop potassium needs in the U.S.
- Shallow soil sampling, especially in no-till or reduced till systems, can lead to a false sense of true root-zone fertility levels (i.e., an over-estimate of root zone soil test levels).
- Neglect of nutrient replacement does impact soil fertility and does show up on soil test results; provided that soil samples are representative, have consistent sampling quality (e.g., right depth, consider fertilizer bands, etc.) and are collected from the same field location from year to year to enable head-to-head soil fertility comparisons and trend evaluations.
- "Miracle" products that provide a few ounces of plant available nutrients can not, and do not, replace typical levels of nutrients removed from fields in crop harvests:
  - if a product claim seems too good to be true, then it probably is just that,
  - rely on advice from an experienced agronomist or crop adviser on new products and technologies,
  - consider your own appropriately-designed on-farm evaluations.

We all aspire to a better and more productive future, and we admire optimistic dreamers and those with a clear vision of that future. But as we tell our children and grand-children, dreaming does not make it so. A practical, implemented plan of action is necessary to achieve one's goals and dreams. Consider the facts above in your 2016 plans. Base your nutrient management and input decisions on solid agronomic advice and research-based evidence. Avoid being fooled by the fantasy of adequate soil fertility, that may rob your productivity and economic sustainability.

– CSS –

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