The Analysis

Agronomic Information From

Spectrum Analytic Inc.

Summer 2013

Spring planting was another fast and furious pace again this year. Side dressing, post emergent herbicides along with other applications continues to be the norm for summer tasks. Over all as I talk with customers the crops seem to be progressing nicely and looking good.

You will also find an article about plant tissue analysis. This part of our business continues to grow each year. The most information things to keep in mind are to send us enough material to make a good representative sample, send the correct plant parts for the stage of growth. And if you want an agronomist interpretation, the more information we have the more we can help you with diagnostics.

Speaking of plant analysis, sulfur seems to be an element that we continue to see shortages of or marginal levels in the plants. We have taken a great article from IPNI to help you better understand sulfur and how it works in the plants.

Mike will soon be starting his summer visits. All soil sampling is just around the corner. If you are need of supplies, please let us know and we see that he brings all or at least part of your order with him.

Have a safe and enjoyable summer.

High Tunnel Production Practices

By Bill Urbanowicz

Over the past few years we have been receiving soil samples, plant tissue sample and phone calls in regard to high tunnel vegetable production. Most of these have been related to tomatoes with a few other vegetables. In the beginning there were two practices of vegetable production, plants grown in the field and plants grown in a greenhouse. Field production is planted in the soil with the addition of fertilizer and some other crop protection products applied during the growing season. Greenhouse tomatoes are grown in a media or hydroponically and under the protective cover of a greenhouse. The greenhouse allows for control of nutrients applied, some control over insects and diseases, water application, etc. Greenhouse has more control over environmental effects than field grown vegetables. Field grown has relatively low capital expenditures while a greenhouse can be a huge investment

Who To Contact...

Agronomy .... Bill Urbanowicz, Amanda Martin, Scott Anderson
Computer .... Wayland Reid
Chief Chemist .... Vernon Pabst
Sales/Marketing .... Mike Hall
Billing .... Donna Scott
Fertilizer & Feed .... Vernon Pabst
Lab Technicians .... Randy Johnson, Jim Armstrong, Wayne Jinks, Cynthia Cook, Justin Stich, Sue Sunderhaus

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High Tunnel Production Practices

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that may be beyond what a field grower may want to invest. Around 2007 growers started to do some experimenting in putting temporary plastic covered structures over vegetables planted in the soil, they had some resemblance to the more expensive glass greenhouses. Thus was born high tunnel vegetable production.

High tunnel structure comes with many of the advantages of a greenhouse, with less capital investment. A longer growing season due to the coverage of the plants with no chance of frost damage and protection from the elements like hail and other severe conditions. No expense in media because the soil is used. The high tunnel grower will need to invest and install an irrigation system to provide adequate moisture to the plants for the growing season. There is also the maintance of the high tunnel structure. The biggest challenge for most is going to be learning how to care for plants as they adapt to moving outside plants into a controlled structure.

A major investment it going to be an irrigation system and learning how to manage the moisture needs of the crop. Another part of the learning curve is what occurs in the soil without natural rainfall. Some of the fertilizers that are applied to the soil contain salts, with natural rainfall these salts are leached out of the rooting zone of the plants. After a couple of years in high tunnel production and not physically moving the structure, these salts can begin to accumulate in the rooting zone of the plants. The salts can cause damage to the root system of the plants, uptake competition with other cations such as potassium, and continuing buildup can cause death to the plants. This can lead to soil conditions that are seen in the southwest where high rates of gypsum are applied along with high amounts of water to flush the salts out of the rooting zone of the plants. To monitor the salt levels in high tunnel production growers should request a soluble salts test be run by the soil testing laboratory. Another thing to keep in mind is that with higher soil temperatures under the high tunnel there is going to be faster N and P mineralization rates in both chemical and non-chemical amendments. With nitrates there is also going to be less leaching and/or denitrification since there is no rainfall water entering the high tunnel and irrigation rates are not going to be as high as natural rainfall. Both of these conditions will lead to potential nitrate carryover from one crop to the next crop when compared to field grown crops. Soil nitrate levels can also be tested, this is an optional test with many soil testing labs.

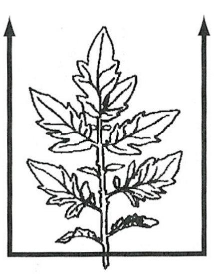
Monitoring High Tunnel Soils and Plants

When plants are grown in the field, conventional soil analyzes are used and calibrated based on soil test level and yield goals to make recommendations. When plants are grown in a greenhouse media, a saturated paste extraction is used. Soil is a highly buffered environment with complex chemical and mineral release system that supplies plants with nutrients for the entire growing season (with the exception of sands). With a greenhouse media there is not a highly buffered environment and nutrients must be supplied to the growing crop the entire growing season normally through slow release fertilizer materials or materials applied through an irrigation system.

The first year of production a conventional soil analysis will work fine in the high tunnel system. Primary, secondary and micronutrients as well as soil pH and organic matter should be tested. Since structures are going to be put over the soil and high yields will be harvested it is important that soil test levels be built to the upper end of the good range. However as time goes on as described earlier, there will be changes that occur. For tunnels that are less than 3 years old or are regularly uncovered and flushed it is suggested that total water soluble salts and available nitrogen (NO_3-N and NH_4-N) be added to the standard soil analysis package. High levels of salts can cause problems to plants and excessive nitrate levels can also lead to problems. Because of the reduced rainfall that is occurring within the high tunnel structure and the use of irrigation these levels will begin to change and need to be monitored.

Through the use of soil testing and plant tissue analysis we have started to see some additional changes occurring to the plants within the high tunnel. Current soil tests taken along with plant tissue analysis have found situations of high potassium (K) levels in the soil and yet the plant tissue samples are reporting low potassium levels. What is going on to cause this condition? If sodium levels start to build in the soil, there can be an interference with other cation uptake such as potassium and magnesium. Another thing that may be occurring is due to the high buffering capacity of the soils and the lack of natural water working in the soil since the plants are in a high tunnel the conventional soil extractant may be overestimating the actual amount of K that is available to the plants during the growing season. Therefore a different type of soil testing needed for monitoring levels called saturated media extraction. Two test packages are available from Spectrum Analytic as G1 and G2.

Soil analysis is used to monitor the nutrient levels in the soil and make fertilizer recommendations. A plant tissue analysis monitors the amount of nutrients taken up by the plant. With plant tissue analysis it is important to take the correct part of the plant for the stage of growth and be sure to submit a sufficient amount of plant material. For high tunnel tomatoes it has been found that at the seedling stage the entire above ground portion of the plant be submitted and in the vegetative, bloom and fruiting stages submit the youngest mature leaf on the main stem (see photo) rather than just the leaf tip or terminal leaflet that is normally submitted with media grown type tomatoes.



Tomatoes

Sample uppermost mature leaf or main stem

Reference: Hoskins, Bruce. 2013. Soil Testing Options for High Tunnel Production. The Soil ~ Plant Analyst. Spring, 2013.

Plant Analysis: A Good Plant Sample Goes a Long Way

by Amanda Martin

Plant tissue analysis is a useful tool to assess the fertility status within a plant and identify hidden hunger to prevent potential yield loss. While soil testing approximates nutrient availability during the growing season, plant tissue analysis tells us what nutrients the plant is taking up when compared to a standard range. Both are used to monitor a fertility program, and adjust fertilizer recommendations. Using comparative plant samples, this form of testing, allows a grower and dealer to monitor crop growth and identify variability within a field. Plant analysis, although, has been researched is often underutilized; therefore, questions often come up addressing "How many plants do I need to collect?" or "How much plant material is needed?"

Conveniently, the same general rule for taking a "good soil sample" applies to plant sampling; and that is take a representative sample. Therefore, when sampling a field collect enough leaves over enough area that is random and represents the entire field while avoiding the areas of the field that may interfere with the analysis. For a comparative test, if there is a section or spot in the field where there are injured or dying plants avoid sampling directly in that section and sample on the outside of that area and submit a separate sample of plants that are healthy for comparison.

One of the challenges at any testing facility is having enough material to complete the analysis. For example, we advise customers to provide 1-1 ½ cups of soil. Plant analysis requires a pint (or two fistfuls or a softball size) amount of plant material. The reason is to ensure that once the sample is dried and ground there is enough sample that is not only representative, but there enough to weigh out and process during the lab analysis.

Depending on the growth stage and plant type growing it is best to sample the entire plant above the soil if the crop is at seedling stage. For plants that are at a vegetative stage (or bloom stage) the uppermost mature leaf will suffice. Note: It is important to sample and indicate the correct growth stage, plant part, and history. This information helps us provide accurate recommendations for that specific crop (See Illustrated Guide to Sampling for Plant Analysis for specific crops: http://www.spectrumanalytic.com/services/analysis/plantguide.pdf). The guide provides additional information not only about specific crops but also additional sampling "Do's" and "Don'ts" that guarantee a better assessment of plant nutritional status.

Plant sampling is not too different from soil sampling. One critical difference is in the quantity of the plant material needed. A softball size sample will guarantee better results than a few leaves (below 20). Other factors include the appearance of the plant such as healthy leaves versus leaves with heavy insect damage. A good sample with enough details provided is another way to guarantee that nutrients supplied are meeting the demands of the crop and its highest yield potential. Additional information is provided on Spectrum Analytic's website or feel free to give us at a call at the lab.

Sulfur for Plant Nutrition

By Rob Norton, Robert Mikkelsen and Tom Jensen

Sulfur (S) is essential for plant nutrition, but its concentration in plants is the lowest of all the macronutrients. Plants are able to assimilate sulfate and reduce it to essential amino acids, where S is involved in a range of metabolic functions, including protein synthesis. Greater attention needs to be paid to the role of S in balanced crop nutrition in many global regions.

Sulfur is an essential macronutrient for plants and animals,and is required for many important metabolic functions. Plants are able to convert sulfate (SO_4^{2-}) into organic compounds, but animals must consume S-containing amino acids (methionine and cysteine) for their dietary requirement.

The need for S in crops has taken a higher profile in recent years as many farming systems have fewer S inputs than previously. Higher crop yields, slower organic matter turnover, reduced use of S-containing crop inputs, and changing crop patterns have also contributed to the need for additional S fertilization.

While most S in soils is present in organic matter, soluble sulfate is present in most soils and is the primary source of S nutrition for plants. It is actively transported into the root, especially in the root hair region, and moves into plant cells through a variety of sulfate transporters. Within the plant, sulfate moves in the transpiration stream until it is stored in cell vacuoles or participates in a variety of biochemical reactions. Leaves are also able to assimilate sulfur dioxide (SO_2) from the atmosphere, but this amount is usually no more than 1 kg S/ ha/yr. Plant leaves can also emit hydrogen sulfide (H_2S) gas, which is assumed to be a type of detoxifying mechanism after exposure to high SO_2.

Most of the sulfate taken up by roots is converted to cysteine in leaf chloroplasts. Cysteine is the primary starting point from which most other organic S compounds in plants are formed. This synthesis process begins with sulfate reduction to adenosine phosphosulfate and ultimately to various S-containing organic compounds (Figure 1). Sulfate reduction requires considerable plant energy. Other important S amino acids include the amino acids cystine (a linkage of two cysteine molecules), and methionine (Figure 2). Smaller amounts of S are incorporated into important molecules such as coenzyme A, biotin, thiamine, glutathione, and sulfolipids.

Sulfur deficiency in wheat. The inset image compares a normal leaf (right) to a deficient leaf (left). (Sharma and Kumar, 2011).

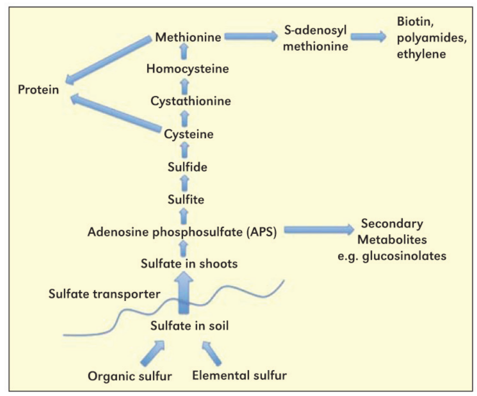


Figure 1. The general process of sulfate reduction and assimilation in plants. (Adapted from Hawkesford, 2012)

Once sulfate is converted to organic compounds, they are exported through the phloem to the sites of active protein synthesis (esp. root and shoot tips, fruits and grains) and then become largely immobile within the plant. The symptoms of S deficiency occur first in the younger tissues and are seen as leaves and veins turning pale green to yellow. These chlorosis symptoms look similar to those that occur with N deficiency, but because of its higher internal mobility a low N supply becomes first visible in the older leaves. When S deficiencies are first observed, some crops may not entirely recover the lost growth following S fertilization.

There are a large number of secondary S compounds that provide biochemical benefit to specific plant species. Some crops (e.g. brassicas such as canola and mustard) have a relatively high S requirement and produce glucosinolate compounds. Members of the Allium species (e.g. garlic and onions) produce alliin compounds that may contain >80% of the total plant S. The characteristic flavor and smell of onions and garlic related to these volatile S compounds are enhanced when plants are grown in high S soil. These and other S-containing compounds are linked with resistance to various pests and environmental stress.

Crop Sulfur Requirement

Crops differ widely in their S requirement with plant matter concentrations typically between 0.1 and 1% S. The S requirement is typically greatest for brassicas (such as cabbage, broccoli and rapeseed), followed by legumes, and then by cereal grasses.

The S demand will vary during the growing season. For example, S demand for canola is greatest during flowering and seed set. Uptake of S by maize is fairly constant throughout the growing season, with grain accounting for >50% of the total S accumulation. Wheat may lose up to half of the total plant S between flowering and maturity. Each crop species needs to be examined for its specific nutrient requirement (Figure 3).

Removal of S during crop harvest is typically in the range of 10 to 30 kg S/ha depending on the crop and yield, but total plant uptake can be as high as 70 kg S/ha for some brassica species (Table 1).

Crop Quality

Crops grown in S-deficient soils can suffer reduced yields as well as poor product quality. An adequate S supply is a major factor in supporting plant protein quality, where it plays a major factor in the structure and function of enzymes and proteins in leafy tissues and seeds. For example, an adequate supply of cysteine plays a central role in giving cereal proteins their shape and functional properties. Because of this, bread baked with low-S wheat will not rise, and results in dense and poorly shaped loaves.

Sulfur Interactions

Because of the importance of both S and N in protein synthesis, these nutrients are intimately linked and are often considered to be co-limiting. It has been established that for every 15 parts of N in protein, there is approximately 1 part of S (i.e., 15:1 ratio of N:S). However this general guide will vary for different crops. For example, wheat grain has an N:S ratio of around 16:1, while the N:S ratio for canola seed is around 6:1.

Other crops such as wheat, sugar beet and peanut are generally considered to have a low S demand. There are many examples of how an adequate supply of both S and N are required to achieve desired yields (Figure 4). Sulfur deficiencies in legumes also decrease proper N utilization, since the number of root nodules and the effectiveness of atmospheric N fixation are reduced with low S.

An over-reliance on the N:S ratio for diagnostic purposes can be misleading because this ratio can be maintained even when both N and S are both low. Also, an excess of either N or S can be falsely misinterpreted as a deficiency of the other.

An inadequate S supply will not only reduce yield and crop quality, but it will decrease N use efficiency and enhance the risk of N loss to the environment. Studies have

Table 1. Sulfur removal in the harvest portion[1] of some typical crops. Grain values are at 10% moisture content.

Cereals	kg S/t	lb S/unit[2]	Oilseed	kg S/t	lb S/unit
Wheat	1.4	0.084 (bu)	Canola	5.0	0.25 (bu)
Barley	1.2	0.058 (bu)	Sunflower	1.7	0.17 (cwt)
Corn	1.1	0.062 (bu)	Cottonseed	2.9	0.29 (cwt)
Rice	0.9	0.041 (bu)	Flaxseed	2.0	0.11 (bu)
Pulses	**kg S/t**	**lb S/unit**	**Other Crops**	**kg S/t**	**lb S/unit**
Soybean	3.5	0.21 (bu)	Sugarcane (fresh wt.)	0.26	0.52 (ton)
Chickpea	1.8	0.11 (bu)	Alfalfa Hay (13% moist)	2.6	5.2 (ton)
Field Pea	2.1	0.12 (bu)	Grass silage (fresh wt.)	2.2	4.4 (ton)
Lentil	1.4	0.08 (bu)	Hops (dry)	3.6	7.2 (ton)

[1]The unharvested portion of the plant may contain as much or more S than the harvested crop.
[2]Unit of yield shown in parentheses.
Source: National Land and Water Resources Audit, 2001.

Cysteine: HOOC–CH–CH2––SH
(NH2 on CH)

Cystine: HOOC–CH–CH2–S–S–CH2–CH––COOH
(NH2 on each CH)

Methionine: CH3–S–CH2–CH2–CH––COOH
(NH2 on CH)

Figure 2. Three essential S-containing amino acids.

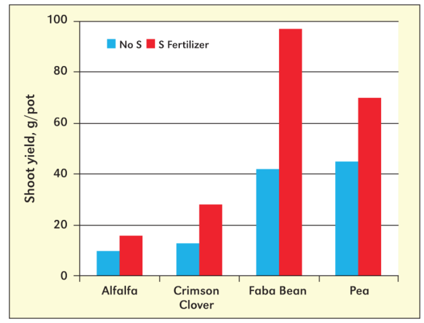


Figure 3. An adequate S supply improves the yield of alfalfa, crimson clover, faba bean, and pea. (Adapted from Lange, 1998).

demonstrated that supplying S to deficient pastures increased yields, N use efficiency, and lowered N losses from the soil. Due to the close linkage between S and N, Schnug and Haneklaus (2005) estimated that one unit of S deficit to meet plant demand can result in 15 units of N that are potentially lost to the environment. They calculated that S deficiencies in Germany may be contributing to an annual loss of 300 million kg of N (or 10% of the total N fertilizer consumption of the country).

Sulfur fertilization is known to induce Mo deficiency at high application rates. This is due to antagonism between sulfate and molybdate (MoO_4^{2-}) during root uptake as they compete for root membrane transporters. Coincidently, Mo is an essential component of an enzyme that regulates the formation of organic S. Sulfur and Se (especially selenate, SeO_4^{2-}) are also antagonistic for essentially the same reason. Sulfur fertilization on soils with normally sufficient Se can reduce the pasture Se concentration, with consequences

Sulfur for Plant Nutrition

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for grazing animals requiring adequate dietary Se. Sulfate additions have been shown to be an effective method of reducing the uptake by plants of other elements in contaminated soil. However, fertilization with elemental S can stimulate the uptake of metal micronutrients (i.e., Cu, Mn, Zn, Fe, and Ni) due to rhizosphere acidification as S oxidation occurs.

Sulfur Management using the 4R Nutrient Stewardship Principles

The 4R Nutrient Stewardship principles (Right Source of nutrient applied at the Right Rate, Right Time, and Right Place) apply to all plant nutrients. Since S can be supplied from many different sources, including animal manures, the 4R principles help with efficient nutrient delivery. As an example of these 4R concepts, ammonium sulfate [Source] is commonly used in the seed-row [Place] of small-seeded crops at planting [Time], but fertilizer additions [Rate] must be low to reduce the risk of ammonia (NH3) damage, especially with wide rows and when grown in dry and sandy soils. The following are considerations in applying the 4R Nutrient Stewardship principles to properly supply S for crop nutrition.

SOURCE: Sulfur fertilizers contain either soluble sulfate or a form of S that will be converted to sulfate. An estimate must be made of the time that will be required for conversion of insoluble S to plant-available sulfate. A variety of excellent dry and fluid fertilizers that contain various forms of S are available for blending or direct application. A combination of soluble sulfate and elemental S may be useful to provide both an immediate and a prolonged source of plant nutrition. The particle size of elemental S can be a key property for making this estimate, as smaller S particles tend to oxidize to sulfate more quickly than large particles.

TIME: Sulfate sources of fertilizer can be applied to match the time of crop demand since they are readily available. However elemental S must be applied far enough in advance of the crop need to allow microbial oxidation. In areas with cold winter temperatures, application may need to precede plant uptake by many months. The release of sulfate from soil organic matter and crop residues will proceed more quickly in warm soils and can supply significant amounts of S during the growing season. A constant supply of soluble sulfate is required by most plants.

PLACE: Placement of sulfate fertilizers in a band near the seed row of annual crops can be quite effective. However, avoid large amounts of sulfate in direct contact with seedlings to avoid osmotic damage to roots. Since sulfate is fairly mobile in soil, it will tend to move with water through the root zone. Elemental S is most effective when broadcast onto the soil and tilled into the ground. In flooded soils, elemental S is best left at the surface so it can be converted to sulfate in the thin aerobic zone at the soil-water interface.

RATE: Sulfur application rates should be adjusted for the crop demand, soil conditions (such as soil texture and organic matter content), and environmental factors (such as temperature and rainfall). Sulfur applications are commonly adjusted to account for multi-year crop rotations. For example in a canola-barley-wheat rotation in Western Canada, the high S demand by canola can be met with a single S application to supply nutrition over the three-year cycle.

An adequate supply of S is required for sustaining crop yields and quality. Inadequate S will reduce protein synthesis and will result in poor utilization of applied N and reduced N2 fixation by legumes. Application of the 4R Nutrient Stewardship principles will identify the need for supplemental S to overcome potential limitations to plant nutrition.

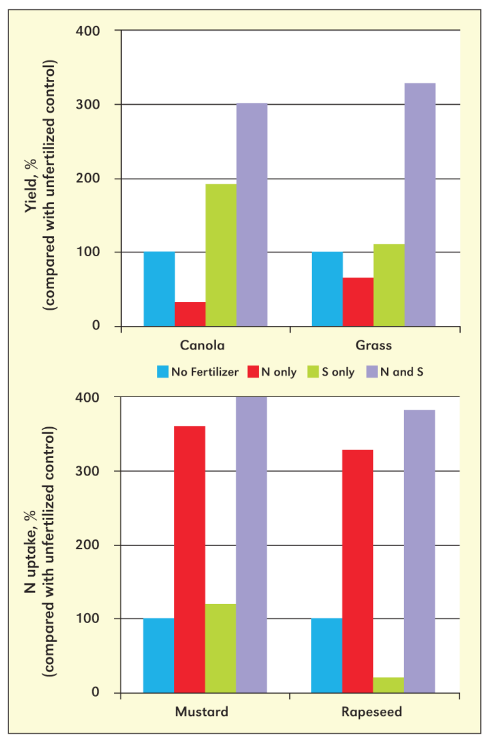

Figure 4. The influence of fertilization with N or S alone, or their combined benefit, on crop yield (top) and plant N uptake (bottom). (Aulakh and Malhi, 2004).

The Future Of 4R Nutrient Stewardship

by Dr. T. Scott Murrell, Northcentral Director, IPNI,

The 4Rs of nutrient stewardship – right source, right rate, right time, and right place – are factors that have been investigated by crop and soil scientists for decades. With such a rich history, does agriculture really have anything new to bring to these management practices?

Right source. Rather than producing only bulk commodities like MAP, DAP, urea, and anhydrous ammonia, fertilizer manufacturers are investing more and more resources into developing new technologies that improve the synchrony between nutrient release and crop uptake. Such advances may significantly increase future nutrient use efficiencies, reducing the risk of nutrient movement to unwanted places in the environment.

Right rate. The standard for past rate recommendations has been static look-up tables. The future is looking very different. Crop growth models are being integrated into nutrient rate algorithms, making it possible to estimate crop nutrient needs during the season as weather changes. Crop sensors also provide valuable in-season assessments of nutritional status, making it possible to alter rates within the season. Ongoing advances in GPS and GIS are making it easier and simpler to design and deploy on-farm nutrient rate experiments. Additionally, freely-available software tools can get rid of "bad" yield monitor data and statistically analyze studies to identify optimum rates. Models that estimate nutrient losses through a variety of pathways continue to develop and some of those algorithms are already finding their way into nutrient rate recommendation tools. All of these advances continue to make scientific methods and knowledge more accessible to farmers and advisers, allowing them to determine what rates work best under local conditions, not only to increase production but also to meet an ever expanding set of ecosystem services.

Right time. Changing weather patterns are making it difficult to rely on some past application timings to achieve the same results. The suite of tools available for on-farm research allows farmers and advisers to test different application timings to determine which ones produce the highest yields as well as have the best logistics. Equipment is constantly changing as well, increasing the time window in which applications can be made. Improved fertilizer technologies may also provide more options in the future.

Right place. Real-time kinematic (RTK) guidance systems have created unprecedented records of where bands are placed in the field, making it possible to create, over time, customized networks and configurations of sub-surface bands. In the future, these bands could be arranged to be in the best position for each crop in the rotation. Research continues as well into where to place nutrients in the landscape and how to combine that placement with other management practices, such as buffer strips, tillage, and cover crops, to reduce nutrient losses.

While the 4Rs have a rich history, they also have a promising and bright future. Improvements in nutrient management have always been a process rather than an end point. The journey ahead will bring many innovations that can improve our ability to achieve not only production and economic goals, but social and environmental targets as well.

The Analysis is published as a service to agricultural dealers and crop consultants by Spectrum Analytic Inc.

If you have any questions or comments, please call 800-321-1562 or 740-335-1562 or Fax us at 740-335-1104.

Bill Urbanowicz
Editor

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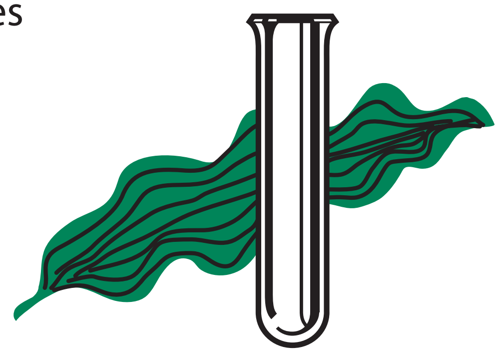

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Spectrum Analytic Inc.
1087 Jamison Road NW
Washington Court House, OH 43160

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