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MANAGING NITROGEN WITH CROP SENSORS

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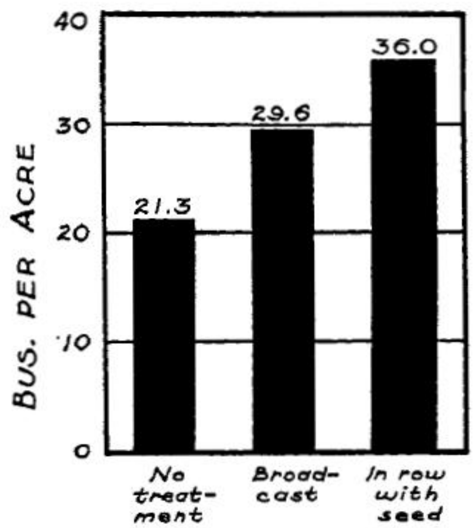
For most people the objective of a N fertilization program is to provide adequate nutrients to support the growth and development of a high yielding crop, as simply and as cheaply as possible. That is a reasonable objective for most farmers, but like everything else in crop production, especially in drier regions such as Kansas, the devil is in the details. The focus of this paper will be wheat, but it will also discuss sensor use with corn and grain sorghum. The specific objectives of this paper are to:

- Discuss the relationship between key growth stages of wheat, corn and sorghum and yield;
- Describe how fertilization and nutrient availability can impact the relationships;
- Define some of the important aspects of a timely and efficient fertilization program;
- Discuss how crop sensors can help add efficiency to a fertilization program.

When planning a fertilization program, it's important to consider how nutrient availability or application will interact with other important management decisions such as seeding rate, planting date and row spacing etc, and influence the major components of yield. In wheat those are: number of heads, seeds per head, and seed size/test weight. Also remember that we can over do a good thing, and reduce yield by over fertilizing, especially with nitrogen. Many farmers in SE Kansas learned that the hard way in 2012 as the result of large quantities of carry-over N from a failed 2011 corn crop, combined with high rates of fertilizer N. The result was excess vegetation, high levels of plant disease (even with fungicide application) and lodging which combined to slow harvest, reduce test weight and reduce yield. So, how do we put all this together into a simple system which can be applied over a lot of acres in a reasonable amount of time, at a reasonable cost?

First, let's keep in mind that when we use current crop sensors to guide fertilizer application rates, we are measuring the amount of vegetation and pigment content or color, in growing plant materials. This will likely mean that topdressing of wheat, or N application of corn will be pushed back later into the growing season than normal. For wheat, we find good sensor performance really doesn't start until the Feekes 4 growth stage, and in corn it can be as late as V-8 or 9. As a result, our planting time fertilizer practices, may also need to change. In the case of wheat, rather than applying a little N at planting, and topdressing in December in combination with herbicides, we may need to apply 15-30 pounds of N at planting to ensure we have enough N to support fall tillering and prevent early spring tiller abortion due to N stress before we topdress in March or April. Tillering is a key to determining the potential number of heads per foot of row. Ideally, we would like to see as many as 3-4 tillers per plant in a high yielding wheat field, depending on row spacing, seeding rate and planting date. We also would like to see most of those tillers produced in the fall, since research shows early tillers yield more. Two key nutrients that influence the number of fall tillers are nitrogen (N) and phosphorus (P). The wheat plant is very responsive to both nutrients, and we have good, well calibrated soil tests which can help us determine the potential need for fertilization of both N and P. Generally, the first nutrient we think about with fall fertilizer is P. Many farmers in Kansas have traditionally applied P at planting with their drill (or now air seeder) at rates near the amount removed by a "good" crop. Early work in Kansas and other states showed that row application of P, at low soil test P levels and low rates of fertilizer, was superior to broadcasting. That hasn't changed. We still have a high percentage of the soils used for wheat production, especially dryland wheat production, which test low for P, and drill row application of 11-52-0 (MAP) or 18-46-0 (DAP) is an excellent way to apply that fertilizer. One of the key reasons we see that response to planting time P applications is the positive impact it has on tillering. P placed close to the wheat seed enhances early growth and tillering, and in many cases results in more heads per foot of row.



KS, 1932

FIG. 18.—Graphs showing effect on yield of wheat of applying superphosphate broadcast and in the row with the seed.

Figure 1. Effect of P placement on wheat yield, KSU research, 1932. P applied was 100 pounds 0-20-0 per acre.

In corn and sorghum, as soil test P goes up, the response to starter P goes down. But in wheat, that's not as true, since wheat produces the majority of its tillers, and future heads, in the fall or early spring under cool conditions. The current KSU P fertilizer application rates based on soil test level and yield potential are given below in Table 1.

Nitrogen can have a similar effect on tillering, but in many of our wheat production systems we have enough N available, naturally or as carry-over fertilizer, in the system to support early growth. The one key place where this is usually not true is where wheat is planted following sorghum. Sorghum is a terrific scavenger of nutrients, especially late in the season as it produces "sucker heads". Most sorghum residue also has a very wide C:N ratio. This creates a demand for N by soil organisms responsible for the decomposition of that residue. As a result, wheat planted in sorghum stubble really responds to preplant or at planting N. As a minimum, 30 pounds of N per acre should be applied in the fall prior to or at planting. Total N applications for wheat after sorghum should also be a minimum of 30 pounds per acre higher than for wheat following corn, wheat or soybeans.

Soil test ppm		Yield Potential, bushels per acre 30	40	50	60	70
		pounds P_2O_5 per acre				
0-5	Deficient	50	55	60	60	65
6-10	Deficient	35	40	40	45	45
11-15	Deficient	20	25	25	25	30
16-20	Deficient	15	15	15	15	15
21-30	Adequate	0	0	0	0	0
31+	Adequate plus	0	0	0	0	0
Crop Removal		15	20	25	30	35

Table 1. P application rates for wheat: Nutrient Sufficiency Approach

Picture 1 - Feekes 2/3 wheat in the fall, with tillers.

Images from "Growth stages of wheat" TAMU publication SCS-1999-16 by Travis Miller

The second key growth stage where nutrients can be critical is when the wheat head is being formed. This occurs early in the spring at approximately Feekes 5. A similar situation occurs with ear formation around V-6 in corn. It is important to have adequate N and P present to ensure optimum head or ear size, and the potential for enough seeds per head. While we can add enough N topdressing to overcome any shortage slightly before this point, it is not really possible to fully correct deficiencies of P at this point. Partial correction is possible but not full correction. So this reinforces the importance of providing adequate P at planting time.

There are several options available to farmers to ensure that they have adequate N in the soil prior to head formation. These would include: Soil testing to determine the N soil supply before planting and applying additional N if needed; Applying all the N prior to planting, for example applying all the N as ammonia prior to planting on medium or heavier textured soils; Applying a significant amount of N, 30-40 pounds per acre in the fall for wheat, and topdressing at Feekes 4 or 5 if additional N is needed; or Topdressing N during the winter or early spring before or at greenup. All of these systems work, but the potential for N loss can increase as N is exposed to the environment for extended periods of time before uptake in high rainfall environments, while under dry conditions, there is some risk of the N not being moved into the root zone with precipitation, if topdressing is done just prior to Feekes 5, or head differentiation. My personal preferred choices to ensure adequate N for head formation is applying 80% of the recommended N as ammonia preplant on medium textured soils, planning to topdress any additional N needed late (at or shortly after jointing), or applying 30-40 pounds of N at planting or by broadcasting with P prior to planting or with the drill, and topdressing the balance at Feekes 4/5. I don't personally like winter topdressing due to the potential for high N loss, and the fact I can't make adjustments in N rate based on winter survival and spring moisture conditions.

Picture 2 - Feekes 4 stage wheat, tillering complete and head differentiation beginning (assumes adequate vernalization)

One of the problems with all preplant or early topdress decisions is that the amount of N available from mineralization of soil organic matter and crop residue is a guess at best, even when a person takes a profile N test prior to planting. In some soils and climates the potential for N loss over winter is fairly significant some years, but difficult to guess in advance. The amount of N mineralized is impacted by soil temperature and soil moisture. Again, this is difficult to estimate in advance. For this reason, I am very high on making topdress N applications late, Feekes 5 or 6, jointing, and using crop sensors such as the Green Seeker or Crop Circle and a fertilized reference strip to estimate the actual available N.

So, how does this system work? The sensor sends out a beam of light in two wavelengths, one in the red wavelengths, absorbed by the pigments responsible for photosynthesis, and one in the near infrared which is not absorbed by plants. A photocell measures the relative amount of each wavelength reflected back off the target plant/soil. This then can tell us how much biomass is present, the amount of growth on the crop, and how much photosynthetic capacity that biomass has. These two pieces of information, together with the growth stage of the crop, can be used to estimate the yield potential at that point in time,and the need of the crop for additional N, particularly when compared to a well fertilized reference strip in the same field of the same variety.

Examples of the relationship between the NDVI index readings from the sensor and measured yield at Feekes 4 and Feekes 6/7 are given in Figures 2 and 3 respectively. Note the big range in NDVI values across the range of yield values obtained at both vegetative growth stages. Also note that the later the measurements are made, the tighter the relationship between NDVI and yield. This simply reflects the shorter period of time for things to go wrong in the field. If the measurements are made even later, at boot for example, the relationship is even tighter, less variable.

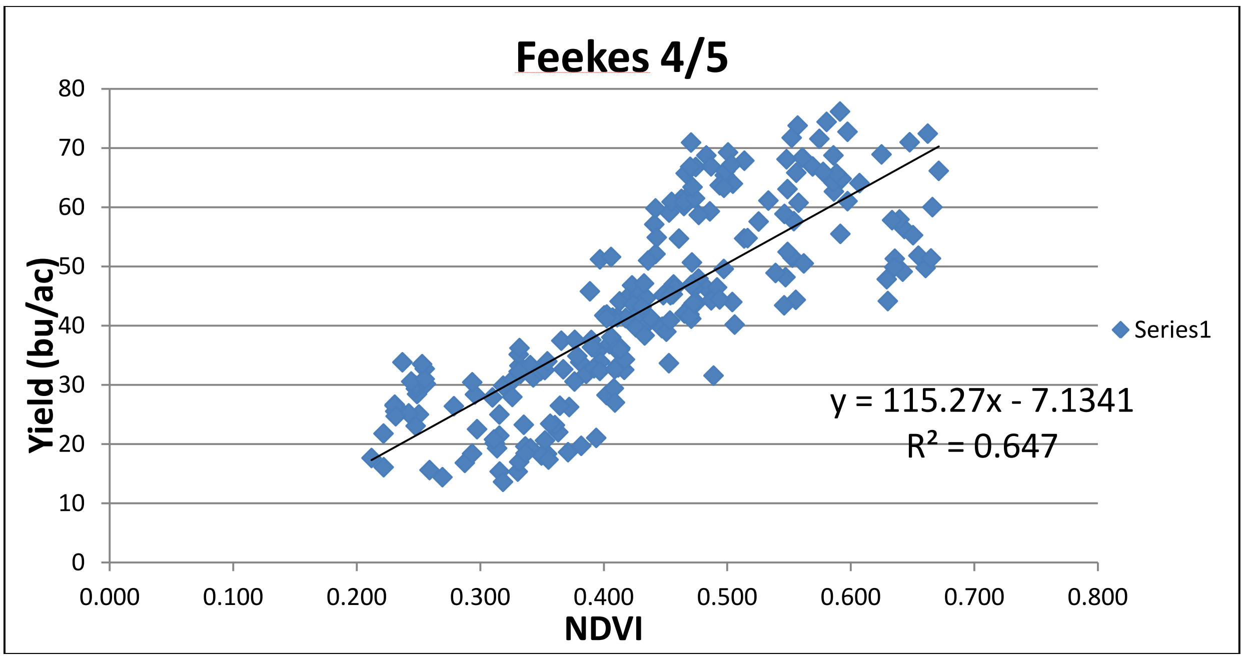


Figure 2. Relation between NDVI and yield of wheat in Kansas, 2007 to 2012.

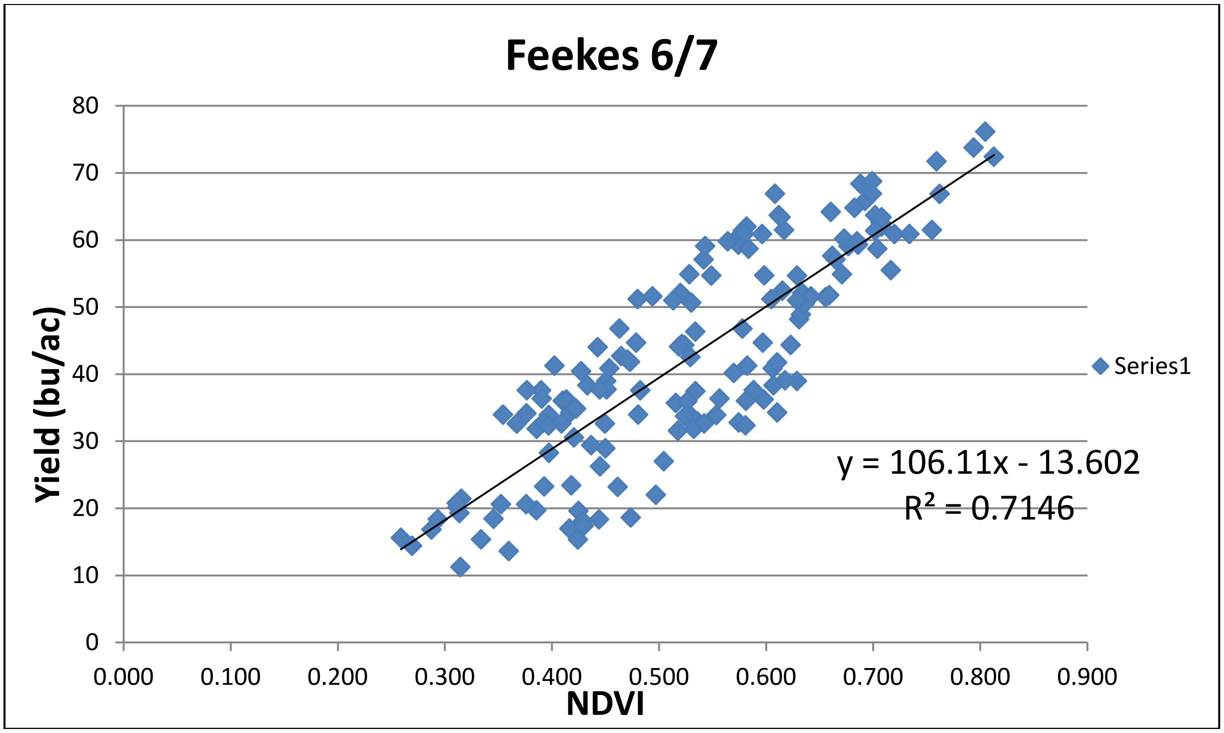


Figure 3. Relationship between NDVI and wheat yield in Kansas, 2007 to 2012.

One of the concepts we are incorporating in our newer algorithms is “Recoverable yield”. We are finding that by keeping N stress to a minimum prior to topdressing allows near full yield recovery as compared to preplant application systems. However if the plant becomes significantly stressed, recovery of 100% of unstressed yield potential isn’t possible. Figure 4 shows the relationship between N stress as measured by a response index, simply the ndvi of a well fertilized reference strip divided by the ndvi of the target area, and the resulting yield obtained from topdressing at the Feekes 4-5 growth stages.

What about situations where too much N is applied, either as a result of large amounts of unaccounted for carryover N, or just too high of N application? Can this reduce yield? Yes! That is one of the reasons for the high level of variation in the relationship between NDVI and yield shown in Figures 2 and 3. Several things can happen when too much N is available. These include excess canopy development stimulating disease development, lodging, or simply utilizing the available soil water to produce straw and not having adequate amounts left to produce grain. This creates a potential advantage to using sensor guided N recommendations.

This idea was tested in 2012 in SE Kansas on a number of farmer fields. Working with a crop consultant, reference strips were established in late 2011 on a number of fields where wheat was planted after failed corn crops. Sensor readings were made in spring 2012 at around Feekes 5/6, or at or near jointing. In only 1 field was any N recommended by the sensor using our current algorithm. The farmers decided if they trusted the sensor or wanted to put on additional N. About half the fields received N and half did not. Those fields which did not receive N yielded in the 70 to 80 bushel range with minimal lodging, while those that did receive N lodged and yielded from 60 to 70 bushel per acre.

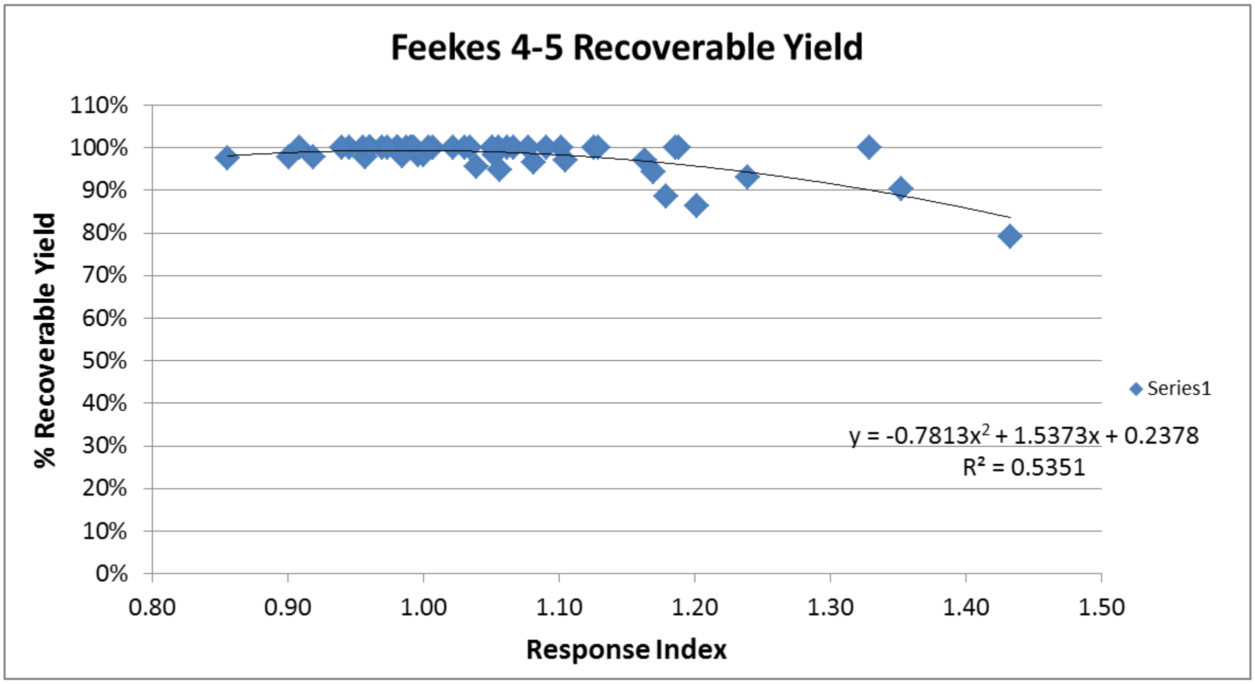


Figure 4. Percent of potential yield which can be recovered by topdressing at Feekes 4-5 growth stage, as impacted by previous nitrogen stress.

What about other crops? KState has had a very good algorithm or rate calculator available for grain sorghum since 2009. This can be found on the KSU Agronomy Soil Testing Lab website, www.agronomy.ksu.ed/SoilTesting/ and is available in a downloadable form. It is designed for use in constant rate, whole field or management zone systems. NTech/Trimble (GreenSeeker) has included a version of that algorithm on their control units identified as Kansas grain Sorghum, so a farmer can use it for variable rate application also. The sorghum system is designed for use at GS3, or approximately the 7-8 leaf stage in sorghum, which occurs at roughly 30-40 days after emergence. The N can normally be applied on most varieties at that time with standard ground equipment commonly used for side-dressing. However, sorghum grows very quickly and by 45-50 days will require high clearance equipment. The data in Figure 5 demonstrates that little difference in yield results in these early growth stages between the 30-40 day applications. A 50 day treatment was planned, but the sorghum was so tall by that point about half the plants were snapped off by the tool bar.

At this time we do not have a rate calculator for corn, but hope to in 2014. A beta test version will be available by May 2013 at the Soil Testing lab web site. At this time we think it will be for use primarily between the 8-9 leaf stage and tasseling. It will be similar in design and function to the others.

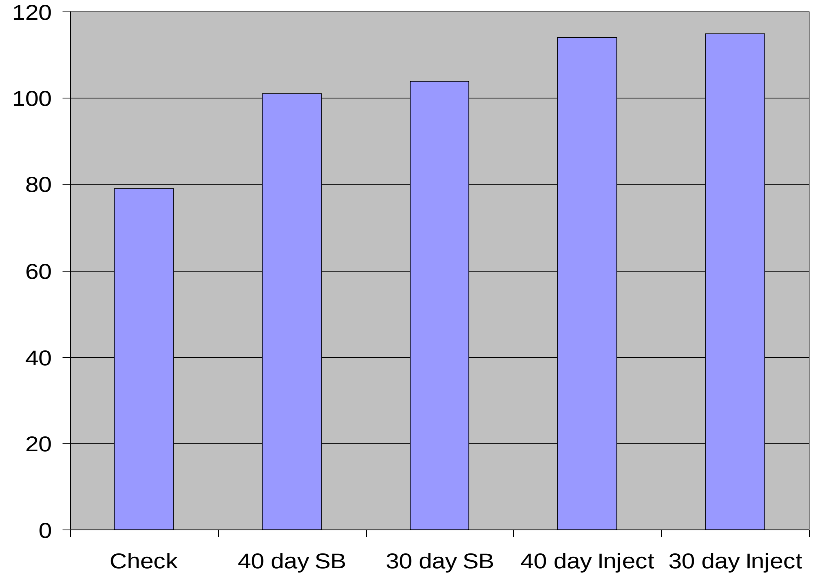


Figure 5. Response of grain sorghum to N applied 30 or 40 days after planting by surface banding or coulter injecting UAN.

So in summary, providing adequate, but not excess, N at key growth stages is important for crop production. Crop sensors can help manage this process and potential improve yield and reduce risk. In most cases, the will not result in huge yield increases compared to our current practices, unless used to replace N lost through in-season leaching or denitrification. But, sensor guided recommendations should reduce the total N applied, reduce N loss and reduce N costs. With wheat and sorghum we have consistently reduced N use by 15 to 30 pounds per acre.

SOIL SAMPLING RECOMMENDATIONS AS INFLUENCED BY FERTILIZER PLACEMENT

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Abbreviations: BR, in between the crop row; IR, in the crop row; NTBC, no-till broadcast; STBC, strip-till broadcast; STDB, strip-till deep band.

No-till corn and soybean production has become more widely accepted over the last 20 years because, among other factors, it can represent savings in operation cost and may conserve soil and water resources to a greater extent than conventional tillage systems. However, new technologies that increase corn plant densities and reduce pest damage to plant materials have resulted in larger amounts of undecomposed crop residue remaining by springtime on the soil surface of no-till systems. Besides the mechanical interference with planting operations, soils covered with crop residue tend to stay wetter and cooler longer. These conditions can delay planting, germination, and early crop growth compared with conventional tillage systems. In recent years, strip-till has emerged as an alternative system as it incorporates the benefits of soil and water conservation of no-till and the improved seedbed conditions of conventional tillage. Improved seedbed conditions with strip-till have resulted in enhanced crop growth and yield.

Strip-till allows for simultaneous deep banding of fertilizers. While deep banding of slowly mobile nutrients, such as P and K, has been proposed as an alternative to improve nutrient availability, fertilizer use efficiency, and yield, there is no universal agreement since some studies have shown no or small benefit to deep-banding relative to broadcast applications. Nonetheless, when repeated broadcast applications of P have caused high levels of this nutrient in the soil surface, deep banding may help reduce such levels and lower the potential for environmental degradation associated with P runoff from fields. Conversely, a potential drawback is that the soil disturbance created with strip-till during deep banding of P could actually increase the potential for P loss by soil erosion compared with no-till systems. Regardless of whether or not deep-banding P and K fertilizer is beneficial, there is consensus that deep banding creates a challenge when soil sampling to try to accurately represent soil P and K test levels of a field.

Since crops do not usually take up all of the P and K applied in a band, the residual fertilizer creates a zone of concentrated nutrients. While succeeding crop removal and chemical transformations that render P and K less available to plants can reduce the amount of residual fertilizer, soil P and K normally remain high for a prolonged period of time. Perpetuation of a horizontal pattern of high and low levels across the field is most likely to occur with strip-till because this system is designed to maintain strips in the same location and provide a controlled-traffic system. In recent years, the use of RTK satellite navigation technology makes it possible to plant and band fertilizers always in the same location, which can also intensify the formation of fertilizer patterns in the field. When nutrients are banded, representing the fertility of the field can be difficult even when the location of the fertilizer band is known. Despite the fact that the challenge of obtaining a sample that accurately represents the fertility of a field with banded fertilizer is generally recognized, the best way to collect such samples is poorly understood, especially for strip-till fields where the fertilizer band is typically maintained at a constant location.

In a recent study published in the Soil Science Society of America Journal, we set out to determine the distribution of soil P and K after repeated applications of various P and K rates and develop soil-sampling procedures to improve estimation of soil P and K for three systems: no-till broadcast (NTBC), strip-till broadcast (STBC), and strip-till deep band (STDB) where the fertilizer was applied 6 inches below the surface at the row position.

Materials and methods

Site description

The study was conducted in commercial fields during 2007 to 2010 at three locations near Pesotum, IL (east-central Illinois). Soils in all three sites were a combination of Drummer silty clay-loam soil (fine-silty, mixed, mesic Typic Endoaquoll) and Flanagan silt loam (fine, smectitic, mesic Aquic Argiudolls). Each of these sites had no prior history of banded fertilizer placement, and fields were chisel-plowed after corn and field cultivated after soybean in years before the study. Soil analysis of composite samples collected from the top 7-inch layer showed organic matter ranged from 3.0 to 3.5% across sites, cation exchange capacity (CEC) ranged from 17 to 30 meq of charge/100 g, and pH ranged from 5.1 to 6.3. Except for tillage and P and K fertilization, the crops were managed as recommended for the region.

Treatments

The study was conducted on a corn–soybean rotation with 30-inch row spacing in all sites and for both crops. All three sites had soybeans during the 2007 growing season before the start of the study, and thus corn was the first crop planted after treatment establishment. Plot size was 20 by 500 ft, and treatments remained in the same plot for the duration of the study. The study was set up as a split-plot arrangement in a randomized complete-block design with two replications. The main (whole) plot included three tillage/fertilizer placement treatments: NTBC, STBC, and STDB. The split-plot treatments were blends of P2O5 and K2O made to create seven P-K fertilizer treatments with a control receiving no P or K (0-0 or check). The six additional rates were established in 23 lb P2O5 and K2O/ac increments starting with a blend of 46 lb P2O5/ac and 46 lb K2O/ac. We established these rates to ensure a distribution of fertilizer rates above and below P and K removal levels. Three consecutive corn–soybean cropping years before our study (2002–2007; mean corn yield of 159 bu/ac and mean soybean yield of 49 bu/ac) and recommended removal rates were used to estimate P and K removal levels.

Strip-till operations were done always in the fall, and corn was planted on the location of the strips the following spring. The soybean crop was also planted on the same crop-row position as corn, but no tillage operations were performed for soybean. The location of the tillage and the banded fertilizer was maintained constant by using RTK satellite navigation technology (+/–1-inch accuracy; Trimble Field Manager Software) with two GPS receivers, one mounted on the tractor and the other mounted on the tillage bar. Strip-till was performed on 30-inch row spacing using a strip-till toolbar (DMI, Model 4300) that formed a residue-free berm approximately 2 to 3 inches tall and 10 inches wide and disturbed the soil approximately 7 to 7.5 inches deep. There was no soil disturbance before planting in the NTBC treatment.

Fertilizer treatments were also applied every two years in the fall before corn planting starting in fall 2007. Broadcast applications were done with a drop spreader (10T Series, Gandy, Owatonna, MN). For the STBC treatment, broadcast applications were performed after the strip-till operation. For the STDB treatment, the fertilizer was banded 6 inches below the soil surface during the tillage operation using a Gandy Orbit Air applicator (Model 6212C, Gandy, Owatonna, MN). Fertilizer sources were diammonium phosphate (DAP) (18–46–0) in 2007 and triple superphosphate (TSP) (0–45–0) in 2009 as the P source and KCl (0–0–60) as the K source. For the 2008 corn crop, corrective nitrogen (N) rates were applied to offset the N content of DAP fertilizer. All corn plots received a total of 180 lb N/ac. To minimize variability, the same equipment and operator were employed to perform strip-tillage and nutrient placement at all three locations.

Measurements

Soil samples for P and K analysis were collected from each plot every fall after crop harvest except in 2009 when soil samples were collected in the spring because wet soil conditions in the fall prevented access to the field before the soils froze. A composite of 12 soil cores (0.75-inch diameter each) was made for each of four sampling positions with respect to the crop row: in the crop row (IR) and in between the crop rows (BR) 7.5, 15, and 22.5 inches from IR. (From this point forward, these BR positions will be referred to as BR-7.5, BR-15, and BR-22.5.) Each sample was partitioned into 0- to 4-, 4- to 8-, and 8- to 12-inch depth increments. The composite 12 soil-core samples were collected three per each of the positions with respect to the crop row within a four-row geo-referenced 10- by 10-ft area in the center of each treatment. To ensure consistency in the sampling position, a board with pre-drilled holes at the designated distances was used. Soil samples were air dried, ground to pass through a 2-mm diameter sieve, and analyzed for P and K.

Most P and K fertilizer recommendations in the U.S. Midwest are based on no more than 8 inches of soil depth. Following this approach, we created a soil P and K test-weighted average for the top 8 inches of the soil for the different tillage/fertilizer placement and fertilizer rate treatments. In order to determine whole-field test levels, the top 8-inch soil P and K test levels were then used to calculate soil test levels for different sampling scenarios created by various ratios of IR to BR cores: 1:3, 1:2, 1:1, 1:0, and 0:3. The 1:2 and 1:1 ratios were calculated from the average of all possible combinations of IR, and the appropriate number of BR samples were drawn from a population of three BR samples. All of these calculated test levels were compared with the calculated "true" mean soil test levels for each fertilizer rate treatment. The "true" mean soil test level for the top 8 inches of soil was defined as the value obtained when averaging across the test values from one sample collected at IR and three samples collected at BR (1:3 ratio of IR/BR cores) for the NTBC system. This approach to calculate the “true” mean was deemed appropriate because pre-treatment (starting conditions) soil P and K test levels in 2007 were similar for the different treatments. Also, since the effect of broadcast P and K applications in no-till systems is already well documented, this system would represent an appropriate standard on which to compare other less-defined systems. The 1:3 sampling rate for the “true” mean represents the most complete set of cores collected. Since banding creates the same pattern across the field and one of the objectives of soil sampling is to use a sampling area to represent a larger area, it follows that using a systematic approach that accounts for one complete pattern or multiples of it should fulfill this objective. In our study, the sampling approach systematically divided the 30-inch banding pattern into four 7.5-inch-wide quarters.

Results and discussion

General background

While seed yield response to treatment was not the focus of this study, we briefly present this information as it relates to nutrient removal, which can influence changes in soil P and K levels. Corn seed yield (two-year mean) was 182 bu/ac for the NTBC treatment and lower than 191 bu/ac for STBC and 188 bu/ac for STDB. Mean soybean yield was 45 bu/ac, and there were no treatment differences. Similarly, there were no treatment effects on seed P and K concentrations, and mean nutrient concentrations in corn seed were 0.23% P and 0.35% K, while nutrient concentrations in soybean seed were 0.65% P and 2.00% K. Removal of P and K in seed over the three-year period of this study (two years of corn and one of soybean) were not affected by tillage/fertilizer placement treatment, but there was a linear increase in nutrient removal in seed with P and K fertilizer rate. We calculated mean annual removal rates of 43 lb P2O5/ac (range = 39 to 45 lb P2O5/ac) and 43 lb K2O/ac (range = 41 to 44 lb K2O/ac). Since these values were nearly equivalent to the biennial fertilizer rate of 92-92 lb P2O5-K2O, we selected this rate to represent the maintenance fertilizer rate for our study.

Averaged across location and treatments, starting soil test levels in 2007 were 60, 26, and 16 lb P/ac and 378, 246, and 232 lb K/ac for the 0- to 4-, 4- to 8-, and 8- to 12-inch depth increments, respectively. The degree of vertical stratification in soil test levels was greater for P than K. For P, the ratio of surface (0 to 4 inch) to subsurface test levels was 2.2:1 for the 4- to 8-inch depth increment and 4.0:1 for the 8- to 12-inch depth increment. For K, the ratio of surface (0 to 4 inch) to subsurface test levels was 1.5:1 for the 4- to 8-inch depth increment and 1.6:1 for the 8- to 12-inch depth increment. This large degree of vertical stratification was likely the result of broadcast applications with minimal disturbance of the soil by tillage before this study. Even with chisel-plow (the most aggressive soil-mixing tillage implement used before the study) it would be expected that broadcast P and K fertilizers would become stratified in the soil.

Change in soil P and K test levels

The statistical analysis of soil P and K as affected by treatment and treatment interactions can be more easily understood when presented as the change in soil P and K over time. For simplicity, we only show three fertility levels representing the check (0-0 P2O5-K2O lb/ac), a maintenance rate (92-92 P2O5-K2O lb/ac), and a buildup rate (highest fertility rate) (161-161 P2O5-K2O lb/ac) following state recommendations. Similar decline in soil P and K at the top 4 inches of the soil occurred for the unfertilized check for all sampling positions and the different tillage/fertilizer placement treatments; but no change occurred in the 4- to 8- and 8- to 12-inch depth increments (Fig. 1A and 2A). The decline of P and K in the soil surface is likely related to crop removal of these nutrients.

At the maintenance P fertilizer rate (92 lb P2O5/ac), there was no change in soil P for the broadcast treatments (NTBC and STBC) across all sampling positions for the top 12 inches of the soil (Fig. 1B). These results agree with P removal rates measured in seed and illustrate that the current P maintenance rate recommendations, developed under conventional tillage systems, are adequate for broadcast applications under conservation tillage systems. For the STDB treatment, there was an increase of 160 lb P/ac at the IR position within the 4- to 8-inch depth increment. This increase was the result of localizing a maintenance rate on a small portion of the soil volume. Just as with the unfertilized check, soil P in STDB decreased at the surface layer for all BR positions and illustrates that despite placement technique, corn and soybean crops take most of their P from the surface layer. These data further indicate that continuous band application of P in the same location can result in a substantial localized increase in soil P and depletion in the rest of the root zone. We observed this increase even at the lowest P rate of 46 lb P2O5/ac where soil P at IR in the 4- to 8-inch layer of STDB increased 38 lb P/ac between the start of the study in fall 2007 and fall 2010.

At the highest P fertilizer rate (161 lb P2O5/ac), soil P increased at the soil surface of the broadcast treatments at most sampling positions (Fig. 1C). This increase was expected as fertilization exceeded the measured annual 43 lb P2O5/ac removal rate in seed. Averaged across sampling position, the highest fertilizer rate increased soil surface P for the NTBC treatment by 22 lb P/ac and for the STBC treatment by 30 lb P/ac, whereas soil surface P decreased by 22 lb P/ac for the STDB treatment. Similar to the maintenance rate, P levels increased by 146 lb P/ac in STDB at IR in the 10- to 20-cm depth increment as result of the band application of 161 lb P2O5/ac. However, with the highest P rate, we observed an increase in soil P below the application band in the 8- to 12-inch depth increment. It is likely that the increase in soil P in this location is the result of downward movement of P with the highest fertilization rate. Another possibility for the increase in test levels at the 8- to 12-inch depth at IR for STDB is deeper-than-expected fertilizer applications. However, this is unlikely because as with the maintenance rate (92 lb P2O5/ac), the 8- to 12-inch depth increment had no significant changes in P levels for the 46, 69, and 115 lb P2O5/ac rates (data now shown). On the other hand, as with the 161 lb P2O5/ac rate, there was a significant 44 lb P/ac increase in the 8- to 12-inch depth increment with the 138 lb P2O5/ac rate; further indicating that downward P movement in STDB was the result of high P application rates.

Change in soil K at IR for STDB treatments receiving K fertilizer (Fig 2B and C) showed similar results to those of P. Application of K fertilizer in a concentrated band produced a large increase in soil K at the 8- to 12-inch depth increment. For the maintenance rate (92 lb K2O/ac), the increase was 86 lb K/ac while for the highest rate (161 lb K2O/ac), the increase was 170 lb K/ac. The highest fertilizer rate also increased soil K in the 8- to 12-inch depth increment below the location of the band, but no difference was observed for the maintenance rate. The increase in soil K at 8- to 12-inch for the highest K rate was likely the result of K leaching and may indicate that this rate was too high at the point of application to be retained by the soil. In contrast to P, soil surface K declined, or at least showed a declining trend, for the broadcast treatments at BR for the maintenance rate (Fig. 2B), and no buildup of soil K occurred for the highest K fertilizer rate (Fig. 2C). These results were surprising since the biennial maintenance fertilizer rate was nearly equivalent to the actual annual K removal rates in seed of 43 lb K2O/ac, and the highest fertilizer rate exceeded the amount of K removed in seed. On the other hand, the 0- to 4-inch soil layer at the IR position of broadcast treatments showed an increase in soil K for NTBC and an increasing trend for STBC at the maintenance rate (Fig. 2B) and an increase of 120 lb K/ac for NTBC and 146 lb K/ac for STBC at the highest K fertilizer rate (Fig. 2C). We speculate that greater K in the soil surface at IR than BR positions for the broadcast treatments is the result of K leaching out of mature plants before harvest. This leaching would not occur for P since this nutrient becomes part of the plant tissues and P is released to the soil after tissues are decomposed. Another possible explanation as to why soil K increased at the IR position of broadcast treatments is by mixing of soil and fertilizer during strip-till operation or by coulters during planting. However, this is not likely since it would be expected to influence soil P as well, and we did not observe such effect for P (Fig. 1B, 1C).

Soil-sampling fields with banded fertilizer applications

It is obvious from our study that the use of RTK satellite navigation technology, which allows for maintenance of crop rows and band applications of immobile nutrients always in the same location, can intensify the formation of patterns of varying fertility levels in the field. These patterns can have important implications for soil sampling. It is clear that within treatments, the three BR sampling positions were similar to each other but differed substantially relative to the IR position for soil P and K (Fig. 1 and 2). The effect of fertilizer placement and rate on soil P and K for the strip-till treatments (STBC and STDB) was calculated using different ratios of IR/BR sampling (Table 1). Those levels were compared with a “true” mean, defined as the value calculated from the average of test values from one sample collected at IR and three samples collected at BR (1:3 ratio of IR/BR cores) for the NTBC system. Because a shallow sample that does not include the subsurface fertilizer band can result in inaccurate soil fertility estimates, these calculations were made based on the top eight inches of soil to include the subsurface fertilizer band.

For STBC, soil P was not different than the “true” mean regardless of the sampling ratio used or the fertilizer rate (Table 1). This indicates that for soil P measurements when fertilizer is broadcast, the sampling strategy in strip-till can be the same as for no-till broadcast systems, and samples could be collected with no regard to the location of the crop row. On the other hand, always sampling in the location of the tilled strip (IR position) overestimated soil K. Averaged across all fertilizer rates, the 1:0 sampling ratio overestimated soil K by 56 lb K/ac relative to the “true” mean. However, for soil K, the comparison to the “true” mean needs to be considered with caution because K accumulation occurred at IR for the NTBC system as well (Fig. 2C). As previously discussed, K accumulation at IR for broadcast treatments is likely caused by K leaching out of standing plants during senescence. The fact that K accumulation occurs at IR when successive planting is done in the location of the previous crop row indicates that for broadcast applications in no-till and strip-till, sampling position is an important consideration when determining K fertility. For instance, the 46, 69, and 92 lb K2O/ac rates had “true” mean levels recommending fertilization to increase soil K to at least the critical level of 300 lb K/ac needed to maximize corn and soybean production. Those same K rates in the strip-till treatments showed no need to apply additional fertilizer to increase soil K when using a 1:0 sampling ratio. Although not statistically different than the “true” mean, increasing the ratio of IR/BR samples to 1:1 resulted in numerically greater soil K test levels, and collecting samples that do not account for the higher soil K at IR (0:3 ratio) resulted in numerically smaller soil K test levels. Our data indicate that the 1:3 or 1:2 sampling ratio would be most appropriate to measure soil K in fields where the planting band remains constant from year to year.

For STDB, using a 1:3 or 1:2 sampling ratio was adequate regardless of the fertilizer rate (Table 1). The 92-92 lb P2O5-K2O/ac rate showed an increase for these sampling ratios, but it was likely the result of a lower-than-expected soil test level for the “true” mean, for which there is no apparent explanation. We also observed that for low P-K rates (46-46 and 69-69 lb P2O5-K2O/ac), it may be possible to soil sample at an IR/BR ratio of 1:1 without over-estimating soil P or K relative to the “true” mean. This would indicate that in fields with adequate fertility where P and K fertilizers are applied only in small quantities or as a starter application, the fertilizer band should not pose a substantial challenge for accurate soil sampling. On the other hand, for maintenance P and K fertilizer rates (92-92 lb P2O5-K2O/ac or greater), the IR/BR ratio of 1:1 or 1:0 will cause over-estimation of soil P and K relative to the “true” mean. For instance, the “true” mean soil P and K of the higher P and K fertilizer rates would indicate the need to apply a fertilizer rate equal to what the crop removes in order to maintain fertility levels. However, soil test results from the 1:0 sampling ratio were above 66 lb P/ac and 400 lb K/ac where additional fertilization is not recommended because there is no expectation of a yield response to additional fertilizer. Similarly, avoiding sampling at the IR is not recommended since it would cause substantial under-estimation of the “true” fertility. This is because banding all the P and K fertilizer, as shown in Fig. 1B and C and Fig. 2B and C, respectively, caused a depletion of soil P and K at BR similar to when no P or K fertilizers were applied (Fig. 1A and Fig. 2A, respectively). Our results indicate that avoiding the fertilizer band would result in over application of fertilizer. While this over-application is highly unlikely to result in a negative impact on seed yield, it can result in lower short-term financial return on the fertilizer investment.

In fall 2007, starting soil P test levels were 44 lb P/ac for NTBC and STBC and 42 lb P/ac for STDB. Examining test levels in fall 2010 using the 1:3 ratio for each of the tillage/fertilizer placement treatments showed maintenance or a slight buildup with the 92 lb P2O5/ac rate, except for the NTBC that started at the 115 lb P2O5/ac rate (Table 1). Though as mentioned earlier, we suspect that the soil test level for the 92 lb P2O5/ac rate for NTBC was lower than expected, this fertilizer rate was likely sufficient to maintain or slightly build up soil P and agrees with measured P removal in seed. On the other hand, starting soil K levels were 320, 300, and 316 lb K/ac for NTBC, STBC, and STDB, respectively. Except for STBC where the highest K rate (161 lb K2O/ac) increased soil K test levels, rates considered sufficient to maintain or build up soil K by current recommendations and based on actual removal rates for this study failed to do so (Table 1). This may reflect either a need to evaluate current K recommendations for Illinois or that the soils in our study fail to build up with the fertilizer rates used. Finally the 1:3 sampling ratio showed no change in soil P and K for different tillage/fertilizer placement treatments and indicate that fertilizer rate should not be adjusted based on tillage or fertilizer application method.

Conclusions

Soil P and K were highly related to the placement method but not to tillage since both NTBC and STBC showed similar results. Within treatment, the different sampling positions for BR were always similar to each other. Deep banding the fertilizer reduced the surface to subsurface P and K stratification ratio by increasing test levels in the subsurface with the fertilizer application, and by decreasing soil test levels in the surface as crops likely continued to remove nutrients from that layer. Deep banding the fertilizer created a pattern of high soil P and K test levels at IR and lower levels at BR. Movement of P and K below the fertilizer band occurred with the highest fertilizer rate. Also, maintaining the crop row always in the same position increased soil K test levels, but no soil P test levels, at the 0- to 4-inch depth increment at IR compared with BR positions in all tillage/fertilizer placement treatments. This increase in soil K at IR was likely the result of greater K leaching from plant materials before harvest compared with P. Changes in soil P averaged across sampling position followed closely what was expected in terms of incline, decline, or maintenance of soil P levels by current recommendations and as measured by actual P removal rates in seed. On the other hand, soil K was not maintained or increased as expected by current recommendations or measured K removal rates in seed, possibly indicating a need to re-evaluate the current recommendation system at least for the soils in the study. Nonetheless, the fact that changes in soil P and K were similar across the different treatments indicated that fertilizer rate need not be adjusted based on the tillage/fertilizer placement conditions of this study.

In general, this study clearly showed that when the fertilizer band and the planting row are maintained in the same location from year to year, sampling location is an important consideration. Underestimation of soil test levels can occur if the band is deeper than the recommended sampling depth or the location of the band (for P and K) or the planting row (for K) is avoided during sampling. On the contrary, if soil samples are collected only from the location of the fertilizer band, this would result in overestimation of soil P and K test levels. This study showed that this can be a substantial mistake when the overestimation of soil fertility indicates no need for fertilizer application when actual soil test levels may be yield limiting. In systems where RTK satellite navigation technology is used and the location of the fertilizer band or planting row is maintained constant, a ratio of 1:3 IR/BR sampling procedure appears to be adequate to estimate soil fertility across a wide range of P and K fertilizer rates and soil test levels. While this approach appears to be adequate for both P and K, the fact that K accumulation occurred at IR in the NTBC system may not allow an accurate representation for soil K test.

Adapted from the Soil Science Society of America article, "Assessment of Soil Phosphorus and Potassium following Real Time Kinematic-Guided Broadcast and Deep-Band Placement in Strip-Till and No-Till" by Fabián G. Fernández and Daniel Schaefer. 2012. SSSAJ 76:1090–1099.

Table 1. Calculated mean soil P and K test level in fall 2010 for the top eight inches of soil for different P and K fertilizer rates with various ratios of samples collected in the crop row (IR) to between the crop rows (BR) for strip-till broadcast (STBC) and strip-till deep-band (STDB) compared with the "true" mean calculated for no-till broadcast (NTBC).

P-K rate	NTBC "true" mean	STBC					STDB				
	1:3	1:3	1:2	1:1	1:0	0:3	1:3	1:2	1:1	1:0	0:3
lb/ac	lb P / acre										
0-0	24	34	34	32	30	36	24	24	22	20	26
46-46	42	38	38	38	36	40	30	32	38	52	22**
69-69	40	42	40	38	32	46	38	42	50	70†	28*
92-92	32	44	42	40	36	46	50*	58**	74**	124**	24
115-115	52	48	48	46	42	50	50	58	76*	128**	24**
138-138	48	60	58	56	48	64	52	60	78**	132**	26**
161-161	52	66	66	64	60	68	46	52	68	112**	24**
	lb K / acre										
0-0	256	250	254	262	286	238	240	242	250	268	230†
46-46	278	264	272	286	328†	244	262	270	288	340*	236**
69-69	286	296	304	322†	374**	270	276	286	306	366**	246*
92-92	270	272	276	286	314†	256	296†	310**	334**	412**	258
115-115	302	294	300	314	352*	274	292	306	336*	422**	248**
138-138	314	300	308	326	374*	276	324	342†	382**	498**	264**
161-161	310	322	330	344	386**	298	306	322	358**	460**	254**

*Significant differences at $P < 0.05$.

** Significant differences at $P < 0.01$.

† Significant differences at $P < 0.1$.

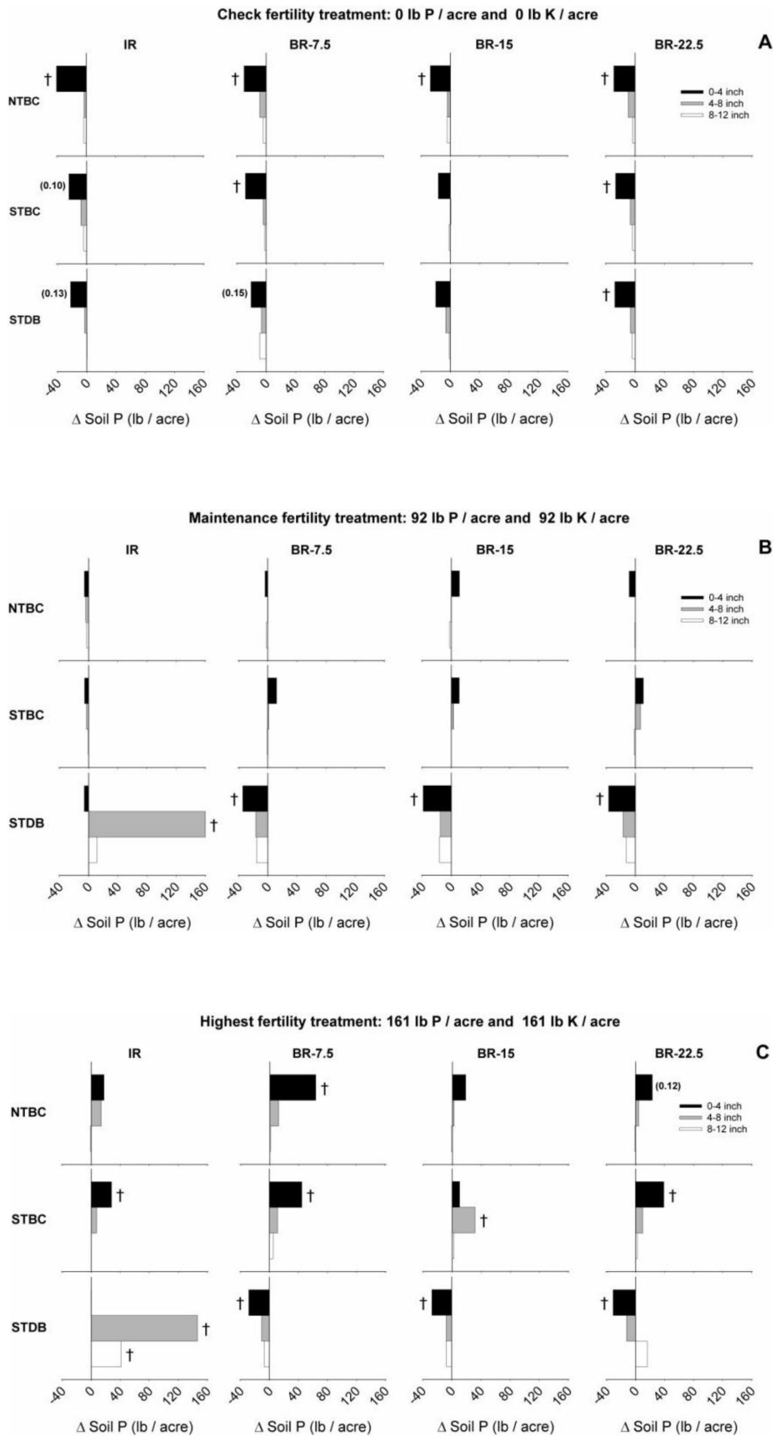

Fig. 1. Change in mean soil P test level from pre-treatment levels in 2007 to fall 2010 at various soil depth increments for different positions with respect to the crop row [in the crop row (IR) and between the crop-rows (BR) 7.5, 15, and 22.5 inches from IR] for no-till broadcast (NTBC), strip-till broadcast (STBC), and strip-till deep-band (STDB) tillage/fertilizer placement treatments and three fertilizer rates (graphs A, B, C). **†** Indicate significant differences at P <0.1; actual probability indicated between parenthesis for $0.15 \geq P \geq 0.1$.

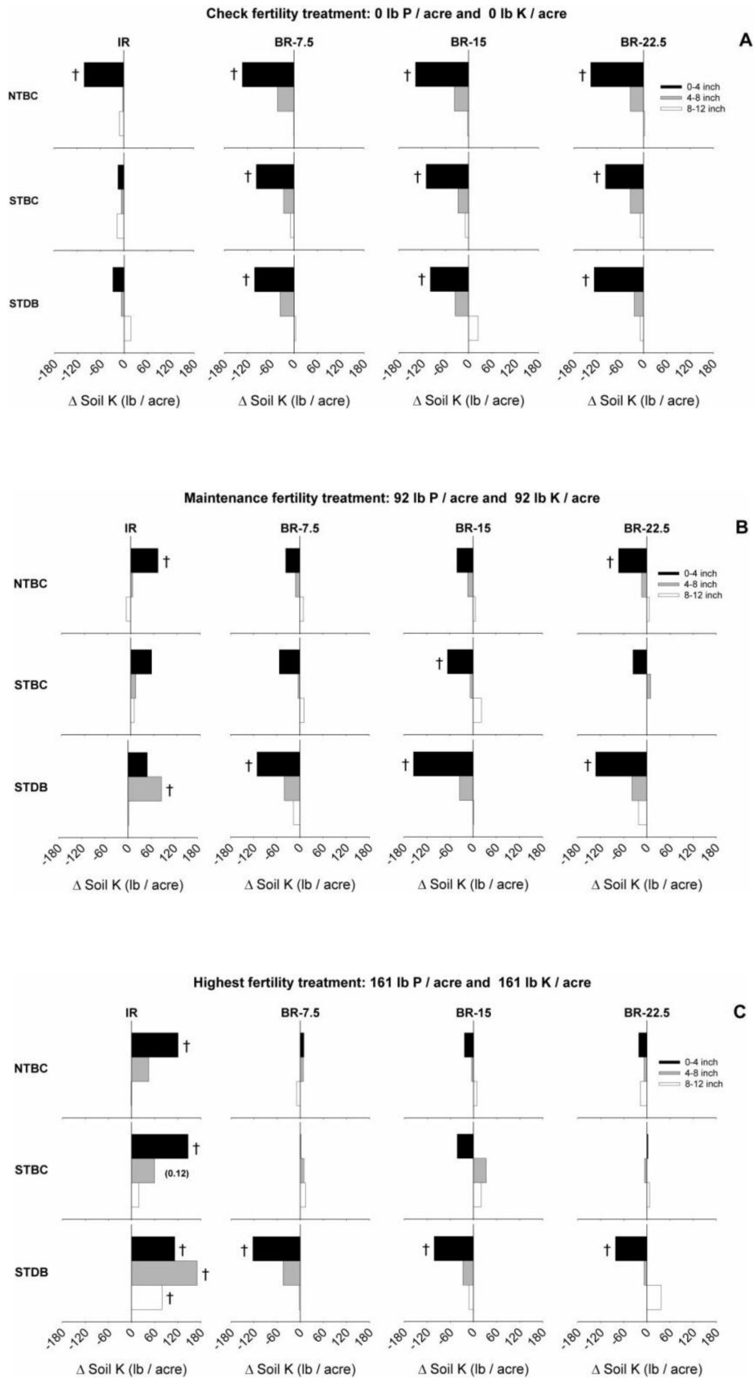

Fig. 2. Change in mean soil K test level from pre-treatment levels in 2007 to fall 2010 at various soil depth increments for different positions with respect to the crop-row [in the crop row (IR) and between the crop rows (BR) 7.5, 15, and 22.5 inches from IR] for no-till broadcast (NTBC), strip-till broadcast (STBC), and strip-till deep-band (STDB) tillage/fertilizer placement treatments and three fertilizer rates (graphs A, B, C). † Indicate significant differences at $P < 0.1$; actual probability indicated between parenthesis for $0.15 \geq P \geq 0.1$.

Update on the NCERA-13 Recommended Chemical Soil Test Procedure Manual and NCERA-13 web site

Manjula V. Nathan
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Abstract

The North Central Extension Research Activity -13 group on Soil and Plant Analysis has recently developed a website to post the activities of the group and the publications. It was decided the group will update the "Recommended Chemical Soil Test Procedure Manual" for the North Central Region on a chapter by chapter basis with development of new procedures and the manual will be an online publication and will be posted on the NCERA-13 website. At this time, we have completed revisions of chapters on soil sample preparations, soil pH and lime requirement, greenhouse root media and laboratory quality assurance program. Additional chapter revisions are in the process and will be updated online when completed.

For additional information visit the North Central Extension and Research Activity group's website at URL: http://ncera-13.missouri.edu/

DEVELOPMENT OF LOSS ON IGNITION PROCEDURE FOR KANSAS AND COMPARISON TO OTHER ORGANIC MATTER TESTS

Robert Florence and Dave Mengel

Abstract

Accurate and precise organic matter (OM) measurements are important to farmers as each one percent soil organic matter (SOM) is credited to supply 11.2 or 22.4 Kg N ha -1, for winter and summer crops, respectively. Soil quality researchers also rely on dependable SOM measurements. Kansas State University Soil Testing lab currently uses Walkley-Black (WB) for farmers' samples and offers dry-combustion (DC) as an alternative for researchers in SOM measurements. Analysis by WB produces hazardous waste, has much interference, and is based on two assumptions regarding the C content of SOM and C recovered by the procedure. Disadvantages of DC are its cost and time required, making it not commercially viable for farmer samples. Loss-on-ignition (LOI) is an alternate method for farmers that does not produce hazardous waste, and is inexpensive. Organic matter is measured as the weight difference from a sample oven dried and then ignited. The objective of this study is to develop a LOI procedure for farmers to replace WB that is reliable, commercially possible, and well correlated to WB and DC. Appropriateness of either a 105 or 150oC oven drying temperature was determined with NAPT samples, mineral water loss, and a calibration curve. The preferred method is a 1 g sample dried for 2 hr at 150oC, weighed after sitting 15 min, ignited at 400oC for 3 hr, cooled to 150oC for 1 hr, and final weight recorded after sitting for 15 min. To correlate the three methods, three replicates of one hundred samples were analyzed using WB - scooped, DC, and LOI - weighed. Using soils with a pH < 7.1, a regression equation of DC = 0.57 (LOI) - 0.18 with a R2 of 0.98, was produced. Comparison of WB to LOI produced an equation of WB = 0.55 (LOI) + 0.17 with a R2 of 0.88. Mean values and standard deviations of WB and LOI both scooped and weighed, along with DC, were analyzed with twenty samples. Measured SOM for LOI weighed, DC as OM, and WB weighed were 3.44, 3.15, and 2.89 %, respectively. Standard deviation was lowest for DC as OM with 0.07. Weighed LOI and WB samples were 0.11 and 0.09, respectively. Scooped LOI and WB samples were 0.14 and 0.17, respectively.

RE-IMPLEMENTATION OF MOIST SOIL TESTING TO IMPROVE THE ASSESSMENT OF CROP-AVAILABLE POTASSIUM IN IOWA SOILS

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Potassium Soil Testing Issues

Since 1989 and until the summer of 2012 all soil testing laboratories in Iowa and the USA dried soil samples at 35 to 40 ºC (95 to 104 ºF) before soil analysis for potassium (K), phosphorus (P), and other nutrients. Since last fall, however, a laboratory that began operations in Iowa is using testing procedures that involve no soil sample drying, and another laboratory is offering moist soil testing in addition to the commonly used test based on dried samples. These laboratories are using a moist soil sample handling procedure that the Iowa State University (ISU) Soil and Plant Analysis Laboratory used from 1963 to 1988, and which was among methods recommended by the North-Central Regional Committee for Soil Testing and Plant Analysis (NCERA-13) committee during the 1980s (Eik et al., 1980; Eik and Gelderman, 1988). The re-implementation of the moist test by these laboratories and last fall update of the NCERA-13 sample preparation chapter to again include the moist sample handling procedure (Gelderman and Mallarino, 2012) have generated many questions.

Most soil-test K (STK) methods used in the USA estimate crop-available soil K by measuring exchangeable K and K in the soil solution because these forms are readily available or quickly become available. The ammonium-acetate and Mehlich-3 methods are the two K tests used in Iowa and most other states. They provide comparable results, and are suggested methods by ISU (Sawyer et al., 2002) and the NCERA-13 committee (Warncke and Brown, 1998). In spite of extensive field K research in Iowa and the north-central region, predicting crop-available K by soil testing has proven to be a difficult task, and the reliability of soil testing for K has been shown to be much less than for P or pH. This is due to complex and largely unpredictable reactions between several soil K pools, interactions with many site factors that influence crop-available K levels, and plant K uptake.

Research with soils of the north-central region during the 1960s, mainly in the greenhouse, showed that K extracted from undried soil samples was better correlated with crop K uptake and yield than from dried samples. Therefore, a procedure for extracting K from homogenized moist samples or from a soil-water slurry was implemented by the ISU laboratory in 1963. Comparisons at the time comparing these two versions of the moist test gave similar results (unpublished), but for fine-textured soils the slurry facilitated sample handling and improved the repeatability of the analysis. Detailed sample handling procedures for both versions of the moist test were included among procedures suggested by the NCERA-13 committee during the 1980s.

In spite of demonstrated better performance of K testing of undried soil samples, no other laboratory adopted the test, citing impractical handling procedures. Therefore, in 1988 the ISU laboratory discontinued its use. As a consequence, in 1998 the NCERA-13 committee also dropped this procedure from its sample preparation chapter of the updated recommended methods publication (Gelderman and Mallarino, 1998).

Iowa field calibration with the dry K test with both corn and soybean conducted from the middle 1990s to 2001, which were to update interpretations and recommendations in 2002 (Sawyer et al., 2002), continued showing a poor prediction of crop response to K fertilization. Therefore, new research began in 2001 to re-evaluate the moist K test as a way of improving the assessment of soil K availability for crops.

Comparison of Nutrient Amounts Extracted by Dry and Moist Tests

Soil samples (6-inch depth) were collected from many field K trials from 2001 through 2006 were sieved, mixed, and divided in two sub-samples. One subsample was prepared for K analysis with the oven-dried sample handling procedure (35 to 40 ºC) and the other with the direct version of the field-moist K analysis (no soil/water slurry preparation). Soil moisture was determined immediately after sieving by drying a small subsample to constant weight, which ranged from 6 to 31% across samples (20% on average). The K extraction and measurement procedures by the ammonium-acetate and Mehlich-3 methods were similar for the dry and moist sample handling procedures. Grain yield data was expressed as relative responses to K fertilization by dividing the average yield of non-fertilized soil across replications at each site by the average of the highest K rate and multiplying result by 100.

In 2011 soil samples again were collected from many Iowa field trials, and this time were analyzed by P, K, calcium (Ca), and magnesium (Mg) in either moist or dried samples. The sample handling for the dry testing was similar to that described for the earlier study. For the moist test, however, this time the soil-water slurry version of the method was used. Moist soil was sieved through a 1/4-inch screen and an amount of soil equivalent to 100 g of oven-dry soil was mixed with 200 mL water and stirred to prepare a homogenous slurry. A subsample of the slurry was extracted with the same ammonium-acetate and Mehlich-3 procedures as used for the dry and direct-sieving moist tests, being careful to use the same dry soil/solution ratio and molarity recommended for the dry tests. The P in the extracts was measured colorimetrically, whereas K, Ca, and Mg were measured by inductively-coupled plasma (ICP).

Comparisons for potassium

The amount of K extracted from dried soil usually was much higher than for moist soil for most samples collected and analyzed. The relative difference between dry and moist K tests decreased with increasing STK levels, however, and varied greatly among years. Only results for the ammonium-acetate test are shown because results for the Mehlich-3 K method showed similar differences between dry and moist tests.

Figure 1 shows K test results for the study conducted in the 2000s. The dry K test results averaged 145 ppm and ranged from 56 to 388 ppm. Results for the moist test (using the direct version of the method) averaged 76 ppm and ranged from 30 to 356 ppm. Therefore, on average the dry K was 1.92 times higher than the moist test. The difference and ratio between dry and moist K values decreased with increasing STK levels, although the relationship was very weak for the difference but strong for the ratio. The amounts of K extracted from dried and moist samples tended to be the same for the few values greater than about 200 ppm by the moist test (only six samples tested between 200 and 360 ppm, the highest observed value).

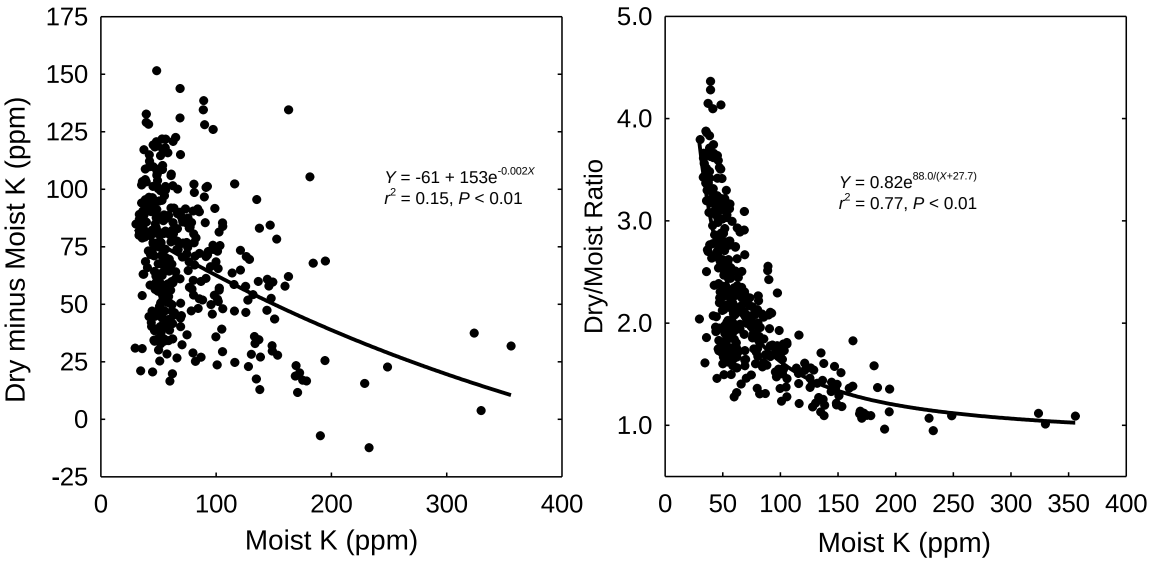

Fig. 1. Relationship between the difference or the ratio of K extracted from dried or field-moist soil samples collected and analyzed from 2001 through 2006.

Figure 2 shows comparisons for soil samples collected in 2011, for which the slurry version of the moist test was used. Potassium for the dry test averaged 161 ppm and ranged from 73 to 373 ppm and results for the moist test averaged 112 ppm and ranged from 25 to 567 ppm. Therefore, on average the dry K test was 1.44 times higher than the moist K. As with the 2000s data, the difference and ratio between dry and moist K values decreased with increasing STK levels. The highest STK levels observed for this sample set were much higher than for the sample set from the 2000s, however. Therefore, this data set showed that for values higher than about 350 ppm by the moist test the difference between dry and moist tests reversed, and K extracted from dried samples was less than for moist samples. This inverse relationship at extremely high STK values also was observed in studies conducted during the 1960s.

Therefore, the amounts of K extracted from dried and moist samples indicate that no simple factor can be used to relate or “correct” dry and moist K test results. Furthermore, laboratory studies during the 1960s with soils from several states of the north-central region showed that the difference between dry and moist K tests tended to be larger for the western states of the region than for the eastern states. It is relevant to note that the ratio of dry/moist K tests for both sets of samples increased linearly (not shown) with soil clay, organic matter, cation exchange capacity (CEC), and (Ca+Mg)/K ratio, but the strength of the relationships was poor ($r^2 < 0.35$). The ratio of dry/moist K increased with increasing sample moisture content for both sets, but the relationship was very poor ($r^2 < 0.10$). This research and other NCERA-13 committee research (not shown) have demonstrated that the effect of soil drying on STK increases with increasing temperature, but the effect can vary greatly across soil series.

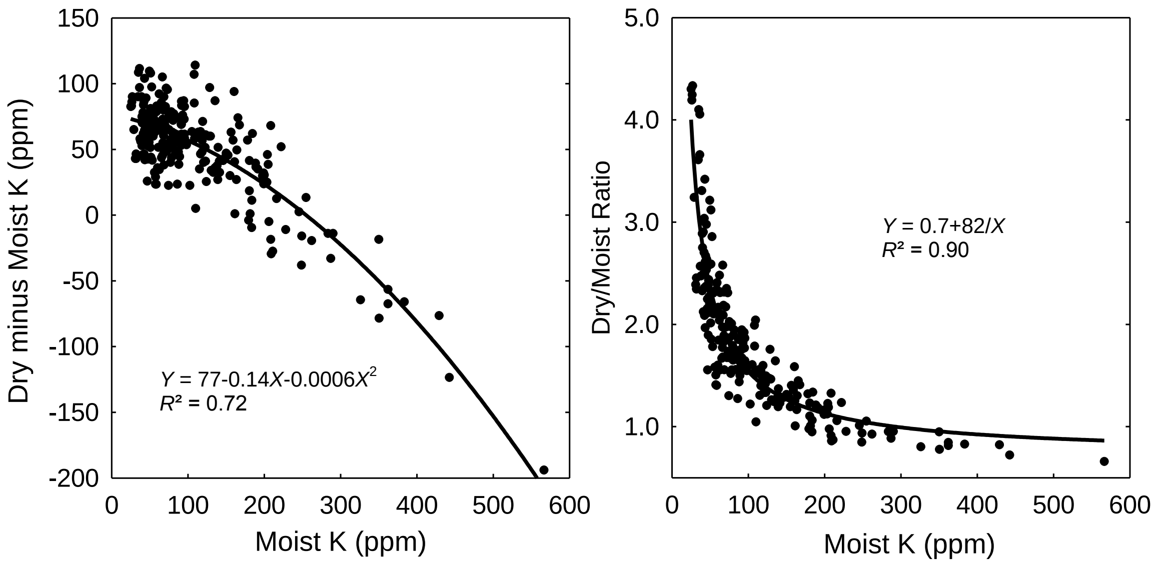

Fig. 2. Relationship between the difference or the ratio of K extracted from dried or field-moist soil samples collected and analyzed in 2011.

Comparisons for phosphorus, calcium, and magnesium

Unpublished results of laboratory research in Iowa during the 1960s showed no significant differences for soil P measured by the Bray-1 method on dried or field-moist samples, as long as the ratio of the extracting solutions to equivalent dry soil was kept the same. Data from samples collected in 2011 (shown in Fig. 3) confirm this result, and show a similar result for the Mehlich-3 method. Small deviations from an intercept of zero and a slope of 1.0 were not statistically significant or important given the usual variability due to soil sampling or analytical error.

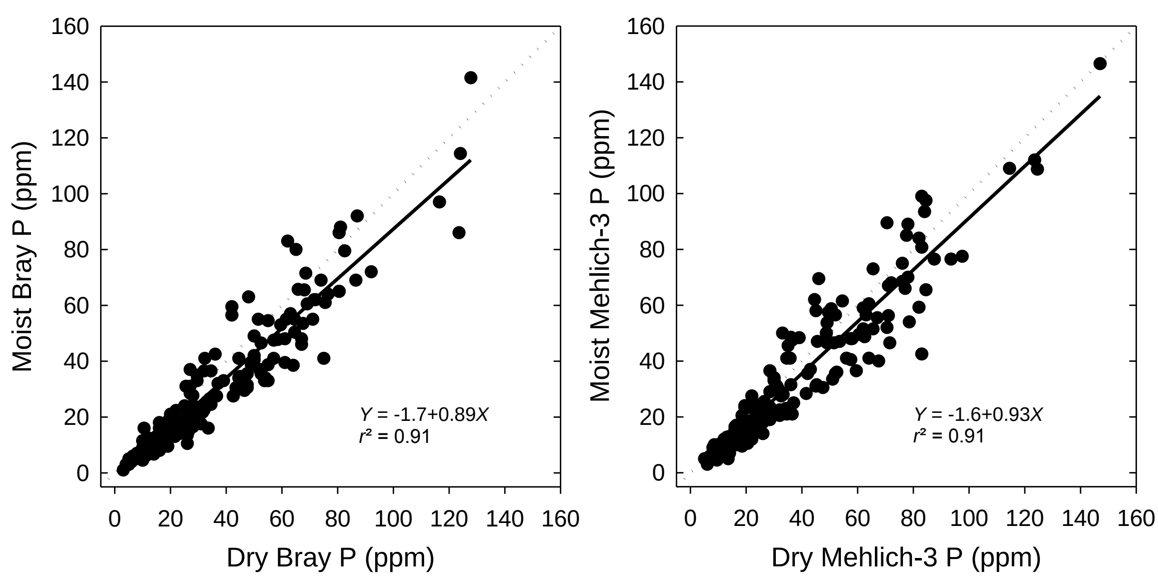

Fig. 3. Relationship between P measured on moist or dried samples using the Bray-1 and Mehlich-3 methods (extracted P was measured colorimetrically for both methods).

Relationships between Ca and Mg measured from dried and moist soil samples by the ammonium-acetate or Mehlich-3 methods did not deviate from a 1:1 ratio (not shown). There were small deviations, but the slopes of the regressions between dry and moist tests for both the ammonium-acetate and Mehlich-3 methods were statistically similar to 1.0. The relationships had more random variability than for P and K, however, and the variability for the difference between dry and moist tests was higher for the ammonium-acetate method than for the Mehlich-3 method. The reasons for a higher variation for the ammonium-acetate method are not clear.

Field Correlation between Crop Response to Potassium Fertilizer and Dry or Moist Tests

Iowa field correlations for the moist K test during the 1980s

Iowa interpretations for the moist K test were last published by Voss (1982). As an example, Fig. 4 shows correlations between moist K test results and yield response of corn and soybean published by Mallarino et al., (1991), which summarized data from two Iowa long-term experiments conducted from 1976 until 1989. At the time there was no comparison with the dry K test, and the slurry version of the moist test was used by the ISU soil testing laboratory following the standard handling procedures used by the lab and which were included among recommended procedures by the NCERA-13 committee during the 1980s. The categories very low, low, optimum, high, and very high shown in the figure for the moist test were the ones recommended in Iowa at the time. The interpretation classes' border values were 0-36, 37-67, 68-100, 101-149, and > 150 ppm, respectively.

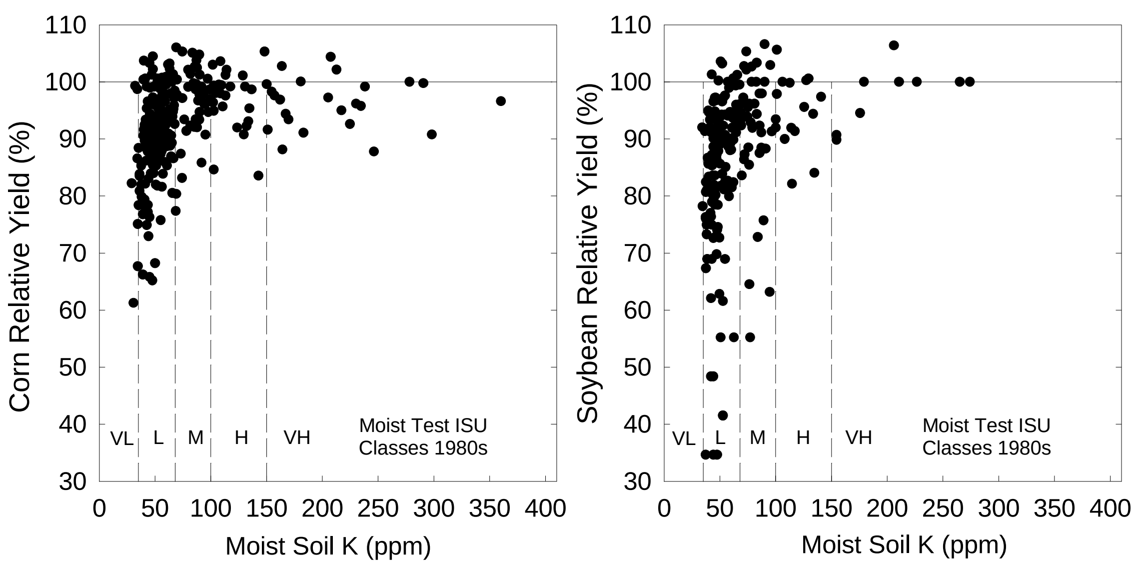

Fig. 4. Relationship between relative corn and soybean yield response to K and soil-test K measured on moist samples for data collected from 1976 until 1989 (Mallarino et al., 1991). VL, L, M, H, and VH identify the 1982 ISU very low, low, medium, high, and very high interpretation classes for the moist test.

New field correlations shown here are from a field study that was conducted in Iowa from 2001 through 2006 with corn and soybean to compare K testing of dried and moist soil samples by the ammonium-acetate and Mehlich-3 methods. Field response trials with either crop were conducted across 20 counties and 32 soil series. There were 200 corn site-years and 162 soybean site-years. Crops and soils were managed with chisel-plow/disk tillage for 120 trials and with no-till for 42 trials. Each trial included several K fertilizer rates (granulated 0-62-0) applied in the fall. The fertilizer was broadcast at most sites, except 30 trials where broadcast and planter-band K placement methods were evaluated. Averages across K placement methods were used for the correlations since they seldom differed. The soil samples were analyzed as described above for this study, by the dry K test following recommended NCERA-13 procedures and by the moist testing using the direct testing of moist soil as recommended until the late 1980s and again since 2012 by the NCERA-13 committee.

Figure 5 shows relationships between relative corn and soybean yield response to K fertilizer and dry K test results using the ammonium-acetate extractant for the field response trials conducted from 2001 until 2006. Results for the Mehlich-3 method were similar to that with ammonium acetate, and are not shown. The graphs also show the current ISU STK interpretations for the dry K test (Sawyer et al., 2002). Only fertilization based on crop K removal is recommended for the Optimum class. When applying the boundaries of the optimum category, then the optimum category encompasses mean relative yields of 93% for corn and 95% for soybean. The different symbol colors indicate the drainage class for each soil series. The graphs for both crops show that according to the dry test, crops grown on the best drained soils needed a lower STK level than crops grown on soils with poor drainage, and crops grown on soils with moderate drainage were distributed between these two extremes. The different STK values for the different groups of soils and the number of site-years for each group do not allow for determining reasonable separate relationships by drainage group. A classification of soil samples based on clay, CEC, K saturation, cation ratios, and other properties (not shown) did not indicate as clear of a grouping as that shown for soil drainage. Several, but not all, soils with poor drainage also had deep profiles and higher CEC, extractable Ca, and organic matter compared with the other soils.

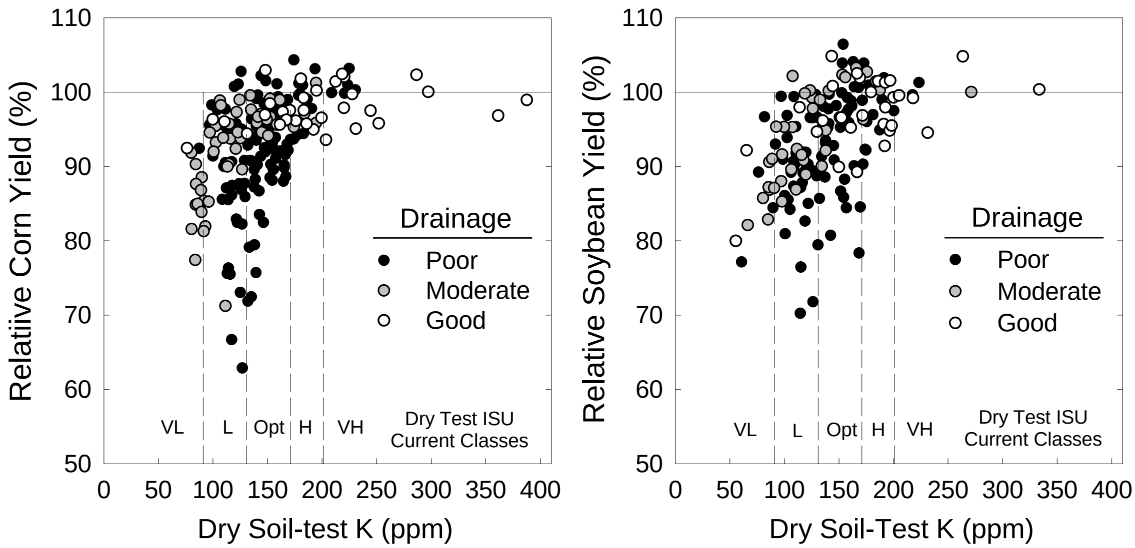

Fig. 5. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried samples. Symbols identify data for soil series with different drainage. VL, L, Opt, H, and VH identify current ISU very low, low, optimum, high, and very high interpretation classes for the dry test.

Figure 6 shows relationships between relative corn and soybean yield responses to K fertilizer and the moist K test results, using the ammonium-acetate extractant. There was a much better relationship for the moist test than for the dry test. This result indicates a better capacity to identify different soil K sufficiency levels for corn and soybean than the dry test, and better prediction of yield response to K fertilization. Moreover, with few exceptions, the data points representing contrasting soil drainage blend into the same general trend for the moist test without the obvious differences shown for the dry test.

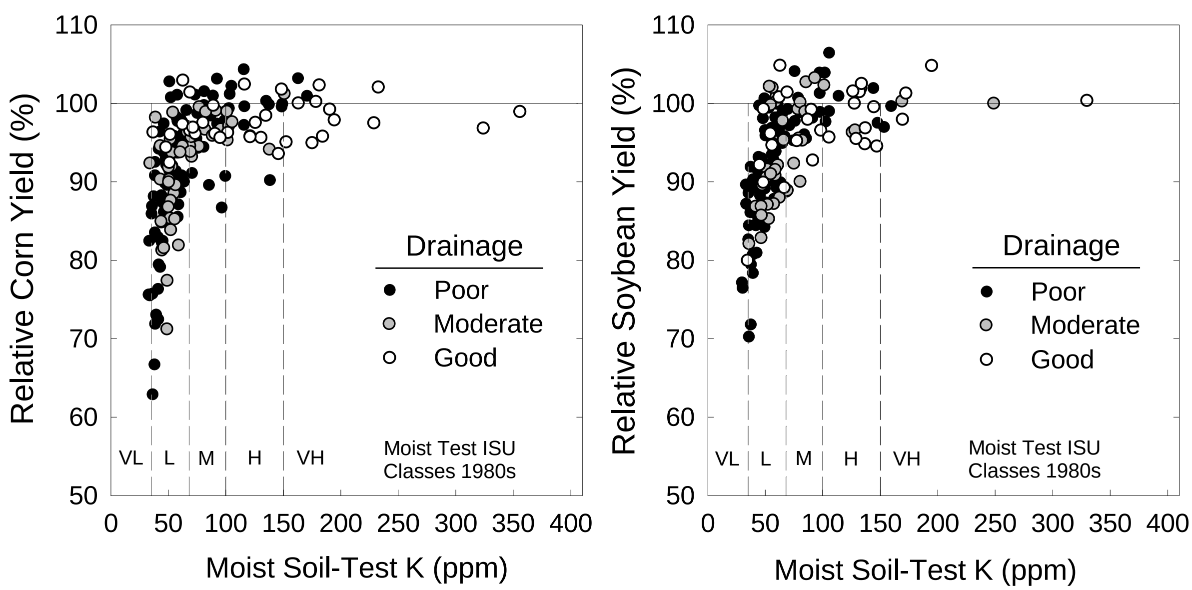

Fig. 6. Relationship between relative corn and soybean yield response to K and soil-test K measured on moist samples. Symbols identify data for soil series with different drainage. VL, L, M, H, and VH identify the 1982 ISU very low, low, medium, high, and very high interpretation classes for the moist test.

The Iowa interpretation category for the moist K test used until 1988 for which maintenance fertilization was recommended (named medium at the time) was 68 to 100 ppm for both corn and soybean. For the old moist K and yield correlation data set (Fig. 4), the boundaries of the old medium category encompass mean relative yields of 96% for corn and 92% for soybean. For the new data set (Fig. 6), the boundaries of the old medium category encompass mean relative yields of 97% for corn and 98% for soybean. The approximately similar fit of the old ISU moist test interpretation classes to both the old dataset and the new dataset is remarkable, since in the 1970s and 1980s crop yields were much lower (especially for corn), hybrids or varieties were different, and only two soil series were included in the old research (many years of two long-term experiments), however, 32 soil series and six years were included in the new research.

Therefore, if criteria for establishing the moist test interpretation categories were the same as in the 1980s, approximately similar interpretations could be used today. New field calibration research for the moist test with corn and soybean are being conducted since 2011 using the slurry version of the moist test. Therefore, results summarized in this study together with results of the ongoing research will be merged during 2013 to establish updated interpretations for the moist K test and fertilizer recommendations.

Summary

Results of the summarized studies strongly suggest that re-implementation of the moist K test in Iowa would significantly improve the assessment of crop-available K and the prediction of crop yield response to K fertilization. Based on old and new research results, and because at least two private laboratories already are offering the moist test for P, K, and other nutrients, in the fall of 2012 the NCERA-13 regional committee re-introduced the moist sample handling procedure to the Sample Preparation chapter of its publication with recommended soil testing procedures.

New ISU interpretations for the moist test will be developed during 2013, as results of ongoing field and laboratory research become available and can be merged with results of previous research summarized in this article. The interpretations for the moist test for K may be approximately similar to those suggested by ISU in the 1980s. Moist test interpretations for P using Bray, Olsen, and Mehlich-3 methods (using colorimetric or ICP procedures) should be similar to those for the dry tests, since data already showed similar test results.

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TESTING MOIST SOILS IN SOUTH DAKOTA

Ron Gelderman
South Dakota State University

Abstract

Renewed interest in the wet soil test has occurred since potassium response was better correlated with the moist soil test than with the dry test in recent studies with Iowa soils. Handling wet soils is challenging. Automated preparation techniques are being developed by commercial laboratories to handle wet samples more efficiently. Analyzing variance and repeatability of wet soil handling procedures is needed both within and among laboratories. This paper will look at potential sources of variation in both the direct and slurry methods of the moist test and indicate potential problems. Several loam and silt loam South Dakota soils were use to calibrate the pipette method by extracting various volumes of soil slurry, air drying and weighing the soil. A 5 mL volume of slurry produced a 2.0 gram equivalent dry weight with excellent precision using these medium textured soils. A coarse textured soil had about 7% less weight (1.86 g) when using the 5 mL volume. Other data and possible studies and soil sample exchanges will be discussed.

FIELD MOIST PROCESSING: RESULTS FROM SOLUM

Morgan Mager, Nick Koshnick, and Michael Preiner
Solum, Inc., Mountain View, CA

Abstract

There is a large body of literature documenting that standard soil processing (in particular, drying and grinding the soil) prior to chemical extraction can affect soil fertility measurements in a significant but unpredictable manner. However, processing soil in its “field moist” state is technically challenging. Because of these difficulties, the field moist process was not widely adopted, and the only large-scale laboratory to use a field-moist procedure (Iowa State University) dropped the method in 1988. Recent work has highlighted the benefits of using a field moist process to predict crop response, fueling renewed interest in the process. At the same time, Solum has developed a viable commercial-scale process to perform field moist measurements. Here we present results showing: 1) Solum’s field moist process gives very similar results as the methods used at Iowa State in their recent large-scale field trials, and 2) Solum’s automated process has a high degree of precision and repeatability, making it well suited for commercial testing.

MOIST SOIL K TESTING AT AGSOURCE LABORATORIES

Jim Fredericks
AgSource Laboratory, Ellsworth, IA

Abstract

In response to our client's interest, and after reviewing Iowa State's historical testing method, AgSource Laboratories implemented a moist soil test for potassium in the fall of 2012. This Wet K test is provided as an additional K test to supplement routine Mehlich 3 determinations. Subsamples are removed from the soil sample during log-in and handled according to the NCR-13 Direct Method in preparation for Mehlich 3 extraction and analysis. Both 'dry' K and Wet K results are reported to clients. Results of samples from the fall 2012 testing season followed trends consistent with Iowa State research results. Comparison of results between Wet and dry K test methods indicate that 40% of samples moved into a lower Soil Test Category when applying the ISU categories used in the 1980s for moist soil testing. But 18% of the samples moved into a higher category as well. These changes diminished as the season progressed either because of changes in the K fractions in the soil or differences within the population sampled.

HISTORY OF PLANT ANALYSIS: SOYBEAN NUTRIENT SUFFICIENCY RANGES

Nathan Mueller
South Dakota State University

Abstract

Soybean trifoliolate (leaf) analysis for essential plant nutrient concentrations is not a new tool for agronomist in managing for maximum yield and diagnosing deficiencies. A comprehensive set of nutrient guidelines by spectrochemical methods dates back to the 1960s by J.B. Jones at the Ohio Agricultural Experimental Station. These nutrient sufficiency ranges (N, P, K, Ca, Mg, Mn, Fe, B, Cu, Zn, and Mo) were determined for the youngest mature uppermost trifoliolate at full bloom w/o the petiole. However, S.W. Melsted and others at the University of Illinois also derived lower limits for nutrient sufficiency ranges from studies done from 1952 to 1967 including the petiole with the trifoliolate. Authors carefully worded that the lower limit of the sufficiency ranges can seldom be derived from one experiment, but rather numerous studies are needed across varieties, seasons, fertility levels, etc. The authors emit that there is some level of personal judgment involved in deriving nutrient sufficiency ranges (regression analysis, probability or response, etc.). The lower limit of the nutrient sufficiency range generally had been set at the initiation of maximum plant growth or seed yield. As of today, most guidelines still suggest to take the youngest uppermost mature trifoliolate (w/o petiole) during flowering prior to pod set (R1-R2). There is some evidence that the composition of this particular trifoliolate at the R1-R2 stage provides the most superior index for the nutritional status of the plant related to seed yield potential. We know that including petioles with the trifoliolate will lower the nutrient concentrations, i.e., Mn and Zn. Older trifoliolates can have a different nutrient composition than newer ones. New trifoliolates sampled during R3-R4 generally have lower K concentrations than prior growth stages due to remobilization. It is probably overly hopeful that one sampling time a year and one particular plant part will provide a perfect index for all the plant nutrients related to potential seed yield. Given our current knowledge, I still propose that the youngest uppermost mature trifoliolate (w/o petiole) prior to pod set be used as nutritional index of seed yield potential. Yields have increased and varieties have changed dramatically over the last four decades since the initial development the soybean nutrient sufficiency ranges that bring into question their robustness. There are many new suggested sets of nutrient sufficiency ranges by various entities with significant differences amongst them. Additional research and educational efforts are needed to address this disparity and create a standard set of soybean nutrient sufficiency ranges for growers.

INTERPRETATION OF PLANT TISSUE TEST RESULTS FOR PHOSPHORUS AND POTASSIUM IN CORN AND SOYBEAN

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Introduction

Crop producers often ask questions about plant tissue testing to assess phosphorus (P) and potassium (K) sufficiency in corn and soybean and if it is useful to help make decisions for in-season foliar fertilization. Since adequate P and K supplies are needed early for crop growth most fertilizer recommendations recommend pre-plant P and K application, and this is the practice most producers use. In some cases this pre-plant fertilization may have not been sufficient to meet crop needs due to error in management or soil sampling and testing, however. Farmers and crop consultants have used soil sampling and testing of visually affected and seemingly unaffected field areas to help determine if there is a nutrient deficiency. Tissue testing is a diagnostic tool that could be used as the basis for remedial action for the current crop or future crops.

Interpretation of Tissue Test Results

Early research for a corn ear-leaf test for K reviewed by Jones et al. (1990) suggested a sufficiency range of 1.3 to 3.0% K. More recently suggested ranges were 1.7 to 3.0% K by Mills and Jones (1996) and 1.8 to 3.0% K by Campbell and Plank (2011) for the southern region. Based on 28 Iowa field trials with corn conducted during 1989 and 1990, Mallarino and Higashi (2009) reported an ear-leaf critical concentration (CC) of 1.23% K. Early research for a K test based on mature trifoliate soybean leaves sampled before pod set was summarized by Small and Ohlrogge (1973), who suggested a sufficiency range of 1.7 to 2.5% K. More recently, Mills and Jones (1996) suggested a sufficiency range of 1.7 to 2.5% K, and Sabbe et al. (2011) suggested a range 1.5 to 2.25% K for soybean in the southern region of the USA.

Research with tissue P testing conducted mainly before the 1980s suggested a sufficiency range from 0.25 to 0.40% P for the corn ear-leaf P test and 0.26 to 0.50% P for mature soybean leaves sampled prior to pod set (Small and Ohlrogge, 1973; Jones et al., 1990). These sufficiency ranges continued to be suggested until the middle 1990s (Mills and Jones, 1996). Iowa field correlations for the corn ear-leaf P test conducted during the 1970s and 1980s (Mallarino, 1995) showed that this test identified severe P deficiencies but did not evaluate appropriately near-optimum and above-optimum supplies. The coefficient of determination was low (R^2 0.32), but a CC range of 0.23 to 0.25% P was identified, which was in the lower portion of values reported earlier. In a study conducted during 1989 and 1990 in Iowa (Mallarino, 1996) the CC reported for corn ear leaves was 0.24% P, but the coefficient of determination was very low (R^2 0.14).

Studies in the north-central region during the early 1970s suggested that the P and K concentration of whole young corn plants (about the V5 or V6 stage) also is a good indicator of P and K supply. Although many published studies have analyzed the P or K concentration of young soybean plants at the V5 to V6 growth stage, no generally accepted sufficiency ranges have been suggested. Sufficiency ranges suggested for young corn plants from the 1970s to the middle 1990s were 2.5 to 4.0% K and 0.30 to 0.50% P (Jones et al., 1990; Mills and Jones, 1996). In their study for data collected during 1989 and 1990, however, Mallarino and Higashi (2009) did not find a significant correlation between the K concentrations of corn young plants and yield response, even though the K concentrations ranged from 0.76 to 4.6% K. In an Iowa study conducted during 1989 and 1990 (Mallarino, 1996), the CC reported for corn small plants (V6 growth stage) was 0.34% P but there was a very low R^2 of 0.18.

New Field Correlations of Tissue Tests for Corn and Soybean

Numerous tissue samples were collected during the last decade from many Iowa field trials that evaluated the corn and soybean response to P and K fertilization. The tissues samples collected were the aboveground plant portions at the V5 to V6 growth stage, corn ear leaf blades at the R1 stage (silking), and top mature trifoliate soybean leaves at the R2 to R3 stage. Therefore, we sampled tissue at two growth stages for corn and soybean. It is important to note, however, that not always both small plant and mature leaves were collected in all trials for either the P or K trials. Therefore, direct comparisons of nutrient concentrations in small plants and leaves, if made, should be interpreted with caution. Data presented are the relationships (means of replications) between relative grain yield response and the P or K concentrations in the tissues. The relative yield values give a good idea of the frequency and magnitude of the observed yield responses to P and K fertilization. The criterion for establishing CC ranges was to use the CC values identified by the two best-fitting models. Depending on the crop, nutrient, and tissue, these values were those determining a 95% of the maximum estimated relative yield for asymptotic models and values corresponding to the intersection of the two portions of linear-plateau or quadratic-plateau models.

Figures 1 and 2 show that there was a relationship between the P or K concentration in corn or soybean plant tissue and grain yield response, but the strength of the relationship always was very poor. Given the obvious poor relationships and very low correlations shown by the figures, no reliable CC ranges could be established for the P concentration of soybean small plants, soybean mature leaves, and corn ear leaves (R^2 0.02 to 0.11). For the same reason, no reliable K CC range could be established for the K concentration of soybean small plants (R^2 0.09), although the distribution of points (Fig. 2) suggest it would be lower than about 1.2% K. The strength of the other relationships (R^2 0.21 to 0.34), although still poor, allowed for tentative determination of CC ranges.

The P CC range identified for corn small plants was 0.35 to 0.40% P, and the curve for the best fitting model (asymptotic) is shown in Fig. 1. This P concentration range coincides almost exactly with CCs determined before for corn small plants by Mallarino (1996) for data collected during 1989 and 1990, and is in the middle of the sufficiency range suggested by Mills and Jones (1996).

The K CC range identified for soybean mature leaves was 1.99 to 2.22% K, and the fit line for the best model (quadratic-plateau) is shown in Fig. 2. This range is in the middle of sufficiency ranges suggested many years ago by Small and Ohlrogge (1973) and more recently by Mills and Jones (1996) and Sabbe et al. (2011). The K CC range identified for corn young plants was 2.49 to 2.99% K (Fig. 2 shows the fit by an asymptotic model). This range is in the lower portion of sufficiency ranges suggested by Jones et al. (1990) and Mills and Jones, 1996). It is noteworthy that in an Iowa study with data collected during 1989 and 1990, Mallarino and Higashi (2009) did not find a significant correlation between the K concentrations of corn young plants and yield response.

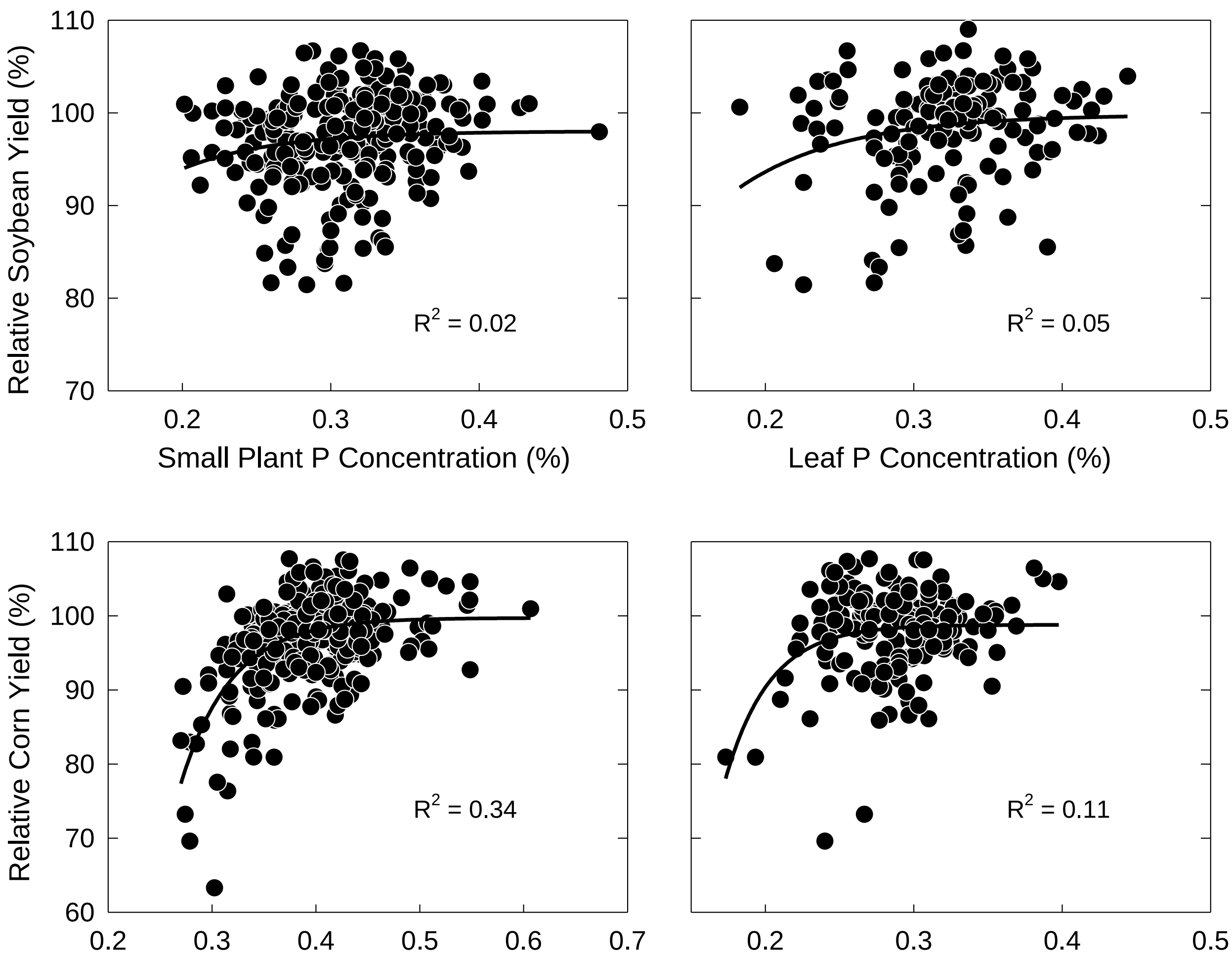

Figure 1. Relationship between the relative yield response of corn and soybean to P fertilization and the P concentration of small plants or mature leaves (V5-V6, and R1 or R2-R3 for corn or soybean) across several trials and years. All relationships were statistically significant at $P \leq 0.05$.

For corn ear leaves, the identified K CC range was 0.89 to 1.02% K (Fig. 2 shows the fit of a quadratic-plateau model, which was he one which fit the data best. This range is much lower than sufficiency ranges suggested by Jones et al. (1990) and Mills and Jones (1996) or by Campbell and Plank (2011) for the southern region. On the other hand, the upper value of the range is slightly lower than the ear-leaf K CC reported by Mallarino and Higashi (2009) for Iowa field trials conducted during 1989 and 1990.

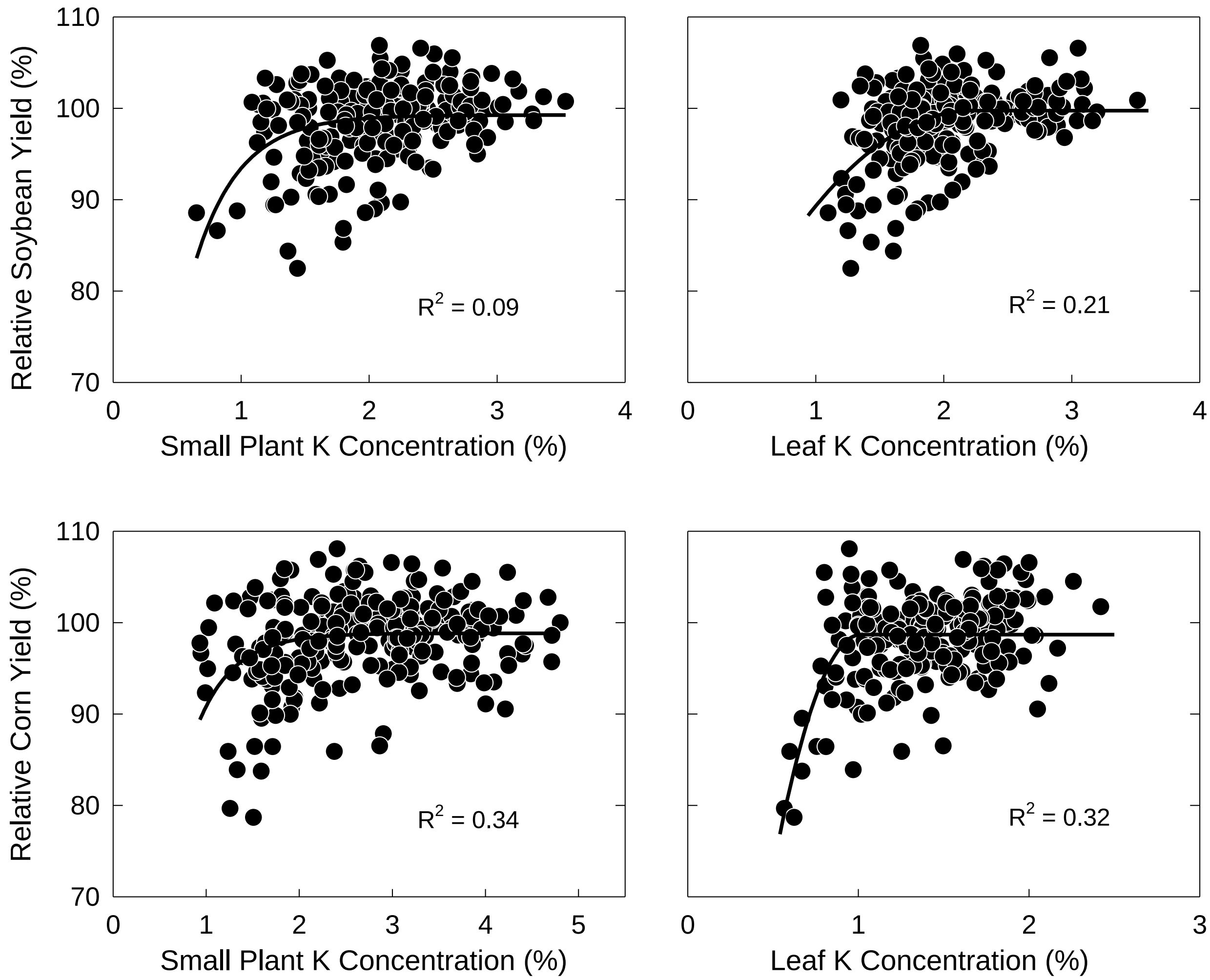

Figure 2. Relationship between the relative yield response of corn and soybean to P fertilization and the P concentration of small plants or mature leaves (V5-V6, and R1 or R2-R3 for corn or soybean) across several trials and years. All relationships were statistically significant at $P \leq 0.05$.

The tissue P and K concentrations reflected better nutrient supply and P or K fertilization treatments in a specific site and year (not shown). However, results showed that tissue testing is a poor diagnostic tool across fields and years. The reason is that many factors other than nutrient supply affect plant growth and the tissue nutrient concentrations due to nutrient uptake and dilution or concentration of nutrients in the dry matter. Attempts to overcome this problem by using systems based nutrient ratios (such a DRIS) have not been successful and often suggest higher fertilizer rates than needed.

Summary and Conclusions

Relationships between crop yield response to P and K fertilization and the concentration of P and K in plant tissue were statistically significant, but the strength of the relationships was very poor. Very poor relationships for P concentration of soybean small plants and leaves and of corn small plant did not allow for establishing CC ranges, but a range of 0.34 to 0.40% P was identified for corn small plants. The relationship between soybean yield response and small plants K concentration also was very poor, and no reliable CC range could be identified. The K CCs identified for soybean mature leaves, corn small plants, and corn ear leaves were 1.99 to 2.22, 2.49 to 2.99, and 0.89 to 1.02% K, respectively. All these ranges were in the middle of published sufficiency ranges or lower.

The observed poor relationships between yield response and the nutrient concentration in plant tissue are not surprising, and similar results abound in the literature. Use of the CCs identified in this study or sufficiency ranges suggested in the literature to make decisions about P and K status of corn and soybean in production agriculture could result in serious error. In addition to the uncertainty arising from poor relationships, no tissue test evaluated appropriately near-optimum and above-optimum nutrient supply. An appropriate evaluation of near-optimum and above-optimum nutrient supply is justified, because use of safe (high enough) tissue concentrations would lead to application of unneeded fertilizer.

Use of soil testing and fertilization before planting is the most effective way of assuring adequate P and K supply for corn and soybean. A practical and useful way of using tissue testing is to use it in conjunction with pre-plant or in-season soil testing to compare field areas with apparent deficiency symptoms or poor growth with nearby seemingly unaffected areas. This strategy may not solve the problem for this years' crop, but will provide clues to improve fertilizer or soil management for next year.

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MID-SEASON PLANT ANALYSIS SURVEYS FOR CORN, SOYBEANS, AND WHEAT

Daniel Kaiser, University of Minnesota

Abstract

Plant sampling has increased in popularity as a method for determining in-season if nutrient deficiencies exist. Sampling is done early in the season with the intention to make corrective applications of nutrients. However, sampling later in the season typically has been more of diagnostic measure since higher percentages of the total nutrients are taken up at that time. When this type of sampling is done, the database behind the numbers was developed over a number of locations irrespective of hybrids and varieties. In Minnesota, wheat variety and corn hybrid trials were sampled to determine the amount of variability of tissue nutrient concentration between varieties and hybrids within and across locations. Fourteen wheat varieties were sampled by taking flag leafs at heading at seventeen locations in 2011 and 2012. For the corn locations, 34 hybrids were sampled across six locations in southern Minnesota and 25 at three northern locations. Ear leaf samples were collected from plants at approximately the R2 growth stage. Nutrient concentration varied by variety and location. The analysis indicated an interaction between variety and location. For the wheat study, the interaction meant some difference in the ranking of varieties, high to low, in tissue nutrient concentration based on location. For the corn study, the interaction generally meant there that some of the hybrids did not differ across the locations. In general, varieties and hybrids with low and high concentrations tended to always be low or high regardless of location. Depending on the nutrient, the variability in variety tissue concentration provides some evidence of potential differences in critical nutrient concentration based on variety. For most location, soil test levels were high enough that nutrient should not have been limiting. However, as significant amount of variability existed between locations means which is likely a result of environmental conditions within a given location. Overall, the data from the variety and location differences indicate a significant amount of variability in tissue concentration is due to environmental and variety factors within a given location. In addition to the hybrid and variety trials, mid-season samples were taken from corn studies focusing on nitrogen (N), phosphorus (P), potassium (K), or sulfur (S) concentration in the leaf tissue. Critical plant tissue concentrations for corn were 2.9% for N, 0.37% for P, 1.44% for K, and 0.15% for S. Nitrogen, P and S critical levels were all within the sufficiency ranges currently suggested by the University of Minnesota. However, the critical level for K was below the current accepted level. It is not known if dry weather conditions affected the low levels. Future research is planned for additional years to determine if K levels are trending lower. Overall, mid-season tissue testing can be used for determining nutrient sufficiency. However, research needs to be continued to update tissue databases to ensure numbers being used are accurate based on new hybrids and varieties and for current growing conditions.

WHAT DO RECENT PLANT TISSUE ANALYSIS SURVEYS IN SOYBEAN AND ALFALFA TELL US?

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Abstract

Plant tissue analysis surveys were conducted for soybean in 2011 and 2012 and alfalfa in 2010 and 2011. Seventy-three random alfalfa fields throughout Wisconsin were sampled at bud to first flower prior to first or second cutting. For alfalfa, 49% of samples were low in potassium (K) based on sufficiency levels, and results were related to soil test K level and amount of K applied. Sulfur (S) was low in 62% of all alfalfa samples. This result was surprising, as only 18% of the fields were considered abnormal in appearance and no specific nutrient deficiency symptoms were observed. Reduced atmospheric deposition of S in the Upper Midwest may be the cause of low tissue S levels. These results suggest that alfalfa growers should pay more attention to K and S management as they try to improve alfalfa yield. The soybean survey was conducted by sampling the upper fully most developed trifoliate and petiole at R1 and R3 from five varieties at 10 locations in the Wisconsin Soybean Variety Trials. When possible, the same five varieties were sampled at different locations. Soil samples were also collected at each location at R1. Results revealed that variability in nutrient content existed among varieties grown at a given location. In addition, when the same variety was grown at multiple locations the nutrient content varied between locations and was often related to variability in soil test levels. At all locations, every variety had an R1 S concentration that was less than the sufficiency level of 0.38% S that is currently used in Wisconsin. There were no nutrient deficiency symptoms present at any location and yields were generally very good. These data suggest that research is needed on correlating plant analysis results to yield response in modern hybrids for plant analysis to be a reliable tool in diagnosing yield-limiting factors.

AGRICULTURAL NUTRIENT MANAGEMENT REGULATIONS: CAN WE LEVEL THE PLAYING FIELD FOR PHOSPHORUS AND NITROGEN?

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Abstract

Nitrogen (N) and phosphorus (P) losses from agricultural fields to freshwater ecosystems is of increasing concern due to our lack of ability to predict optimum N application rates and elevated soil P levels brought on by long term applications of manures and commercial fertilizers. Indiana's P fertilizer recommendations and P application rate limits were originally developed using colorimetric Bray P1 soil testing procedures. However, both Bray P1 and Mehlich-3 P (PM3) soil tests are now used in Indiana to make fertilizer recommendations and to limit manure application rates, and most soil extracts are analyzed using ICP. The Mehlich-3 P Saturation Ratio (PSRM3) has been proposed as an alternative to Bray P1 and PM3 for assessing the soil source component of more comprehensive P risk tools like P indexes. We assessed the correlations among agronomic soil test methods (PM3 and Bray P1), environmental soil test methods (soluble P: deionized water, DW; artificial rainwater, ARW; dilute salt extractable P, DSEP), ammonium oxalate P (POX), total P (TP), and P saturation methods for 565 Indiana surface soil samples. Significant correlations were found among the various soil test P methods evaluated, and the potential impacts of these relationships on fertilizer recommendations and P application rate limits will be discussed. For N, optimum application rates are dependent on soil properties, topography and other terrain attributes, the source, timing, and method of N application, and weather. Most fertilizer recommendations are based on average yield response from long term rate studies conducted on only a few soils with near optimum N application methods. This leaves most producers with only general guidelines for optimum N management for their specific location. We are developing software tools to bring some light to this challenging issue and we would like your input on how to improve the process.

Manure Analysis Proficiency (MAP) Program Update

Minnesota Department of Agriculture
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Overview

- Types of Minnesota Department of Agriculture (MDA) Laboratory Programs
- Manure testing manuals
- Changes in the 2012 manure laboratory evaluation for accuracy
- Encourage you to submit client reports
- Additional reference samples
- Using the MAP reports

Three MDA Laboratory Programs

- Manure Analysis Proficiency (MAP) Program
- Certified Manure Testing Laboratory Program -- Laboratories must have acceptable performance in the MAP Program to become eligible for manure testing certification.
- Certified Soil Testing Laboratory Program -- Laboratories must have acceptable performance in the ALP or NAPT soil proficiency programs to become eligible for soil testing certification. Laboratories completing an ALP or NAPT release form will receive a report from MDA in November or December.

Manure Testing Manuals (download at no charge)

- *Recommended Methods of Manure Analysis*, edited by John Peters, 2003
  http://uwlab.soils.wisc.edu/pubs/a3769.pdf
- *California Analytical Methods Manual*, 2010
  http://anlab.ucdavis.edu/docs/uc_analytical_methods.pdf

Evaluating Accuracy in 2012

- Bob Miller's Method -- Run the data two times. Identify results exceeding ±4.0 MAD units from the median and remove those results as outliers. On the second run, flag results for accuracy exceeding ±2.9 MAD units from the median after removing outliers.
- MDA Method -- In previous years, MDA only ran the data one time and flagged laboratory results that exceeded ±2.5 MAD units from the median. In 2012, MDA combined our normal method with Bob Miller's method. MDA flagged laboratories for accuracy only if the mean of their three results exceeded ±2.5 MAD units from the median on the full data set, and the replicate mean exceeded ±2.9 MAD units from the median after removing outliers.

Evaluating Precision

- MDA and Bob Miller use the same method to evaluate precision, and there were no changes in the precision evaluation.
- The coefficient of variation for each laboratory's three replicates is calculated and designated as Rp. Then the median value for Rp is calculated for each test and sample and is designated as Rd. We flag labs for precision if their Rp value exceeds three times the Rd.

Scoring Results for Certification

- For certification, laboratories must have acceptable results for both nitrogen (TKN or N-C) and phosphorus.
- MDA evaluates all other tests individually, and does not penalize labs doing poorly on a particular test.
- Five points are deducted for each accuracy flag, and three points are deducted for each precision flag.
- Each test is worth 48 points (6 manure samples times 8 points for accuracy and precision).
- Labs are given a score and ranked from highest scoring the lowest scoring. The top 80% have passing results.

Reference sample provided in 2012

- Dried to approximately 90% total solids -- has to be quite dry to use the Retsch rotary mill
- Milled first through a 1.0 mm screen and then through a 0.5 mm screen
- Provided in a 250 ml bottle
- Next step is to encapsulate a similar (or the same) sample
- I would appreciate some feedback on if this additional sample is useful

Customer or Client Reports (only applies to the MAP Program -- not the soil testing program)

- I encourage labs to run the MAP samples as if a client submitted them and generate the normal client report as you would for any sample.
- Use the client report to complete the MAP Excel spreadsheet.
- Submit both the Excel spreadsheet and all nine client reports.

Why submit client reports?

- If a lab makes a mistake completing the official Excel spreadsheet, I can use their client reports to correct the mistake. Some typical examples of mistakes corrected with client reports are the following:
  - Reporting phosphate (P2O5) or potash (K20) instead of elemental phosphorus or potassium.
  - Reporting Percent Moisture instead of Total Solids.
  - Entering results on the wrong row.
  - Sending in the wrong spreadsheet.
  - Reporting results on a dry matter basis instead of an as received basis.
  - Misplacing a decimal point or transposing the digits.

MDA will correct these errors if a client report shows the lab's intent. We do not want to penalize labs for errors made in completing the Excel spreadsheet. However, MDA cannot make changes for certification if no client reports are submitted with the regular Excel spreadsheet.

Using Reports from the MAP Program

- Bob Miller and Jerry Floren evaluate the results individually. If there are significant differences in these reports, contact Jerry Floren.

Bob Miller's Reports

- Generic 4 page report
- Your lab report on 8 1/2" X 11" paper.

Jerry Floren's Printed Reports

- The large size detailed report (11" X 17") -- The flags on this report should be similar to those on Bob's report. MDA uses the flags on this report to certify laboratories for manure testing.
- A summary sheet showing if your lab is eligible for certification the next year and the status (pass or fail) for each analysis your lab attempted.

Jerry's PDF reports emailed to you (new in second exchange for 2012)

- These are individual scatterplot graphs for each lab showing how your lab compared with other labs in the MAP Program.
- Your laboratory results are printed in black, and the other lab’s results are printed in light gray. You can easily see how your lab compares to other labs in the MAP Program.
- Unlike the tabular reports that are edited using Excel, these graphs are generated in R. There is less chance of an error on the scatterplot graphs than on the Excel tabular reports. Therefore, if you have a flag on the Excel report that does not show on the graphs, I probably made a mistake.

Conclusion

- The Minnesota Department of Agriculture provides three laboratory programs:
- There are two manure methods manuals available on the Internet at no cost.
- There was a change in 2012 method for determining accuracy flags that combined Bob Miller’s method of removing outliers with the traditional method.
- Laboratories wanting to become certified for manure testing are encouraged to submit client reports along with the standard Excel spreadsheet.
- Please let me know if the more finely ground and dried reference samples are helpful.
- You may find the PDF graphs emailed to you helpful.

TISSUE ANALYSIS
ALP RESULTS AND MIDWEST RESEARCH

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The Agricultural Laboratory Proficiency (ALP) Program conducts a tissue analysis proficiency program tri-annually, utilizing three plant materials per cycle. Plant materials represent a range of botanical tissue materials which include: row crops leaves, vegetable leaves, tree leaves, vine crop petioles and blades and forage materials. Each round statistics are compiled on twenty-three nutrient parameters and seven trace elements / heavy metals. Laboratory bias is assessed based on the 95% Confidence Limit (CL) of the population median for each analysis parameter for each plant sample material. Laboratory participants results exceeding CL are flagged for bias (as designated by Inter-Lab CL). In addition laboratory precision is assessed based on a statistical comparison of the within lab precision to the consensus precision of the all participants, for each analysis (as designated by inter-lab). Individual Proficiency reports are provided to each ALP participants each cycle listing lab results for each test performed, noting bias and precision values that exceed industry norms.

Results of a composite corn leaf sample, ALP SRB-1106 evaluated in cycle 15 of 2011, indicate that confidence limits (Inter-lab 95% CL), for N are 3.10 ± 0.19 %; P 0.302 ± 0.056 %; K 2.40 ± 0.38; and for S 0.24 ± 0.038 % (see Table 1). Generally, macro nutrient confidence limits of the median for row crop leaves are 15-20% for P, K, S, Ca, and Mg, with that for N using the automated combustion averages 5-8%. For micro nutrients; Zn and Cu confidence limits average 18% of the median while that of B was 26%. For ALP SRB-1106 of 2011, two labs were noted for bias for N and K; and one lab each for P, Ca, S, Zn and B.

Intra-lab precision for corn sample SRB-1106 indicates that intra-lab uncertainty (based on three replications) across thirty participating labs for N was 3.10 ± 0.085 %; P 0.302 ± 0.018 %; K 2.40 ± 0.09; and for S 0.24 ± 0.017 %. For micro nutrients was: Zn are 40.4 ± 4.2 ppm; and B 15.0 ± 2.2. Generally macro nutrient intra-lab uncertainty for row crop leaves is 4 - 6% for P, K, S, and Ca, with that for N using the automated combustion at 2.7%. For ALP SRB-1106, two lab participants were flagged for a lack of precision for K, and one lab each for P, Ca, Mg, S, Zn and B. None of the participating labs were flagged for precision for N. It is worth noting that intra-lab precision for N and K for 2/5ths of the participating were less than ± 0.065 % for N and ± 0.05 % for K of median elemental content.

Table 1. ALP elemental analysis results for SRB-1106 corn leaf, Cycle 15, 2011.

Analysis	Median	Inter- Lab 95% CL	Intra-Lab Std	Intra-Lab Uncertainty
N %	3.10	± 0.19	0.040	± 0.085
P %	0.302	± 0.056	0.008	± 0.018
K %	2.40	± 0.38	0.036	± 0.09
S %	0.24	± 0.038	0.008	± 0.017
Ca %	0.78	± 0.15	0.022	± 0.046
Mg %	0.24	± 0.05	0.011	± 0.024
Zn (ppm)	40.9	± 7.4	1.96	± 4.2
B (ppm)	15.0	± 4.1	1.0	± 2.2
Cu (ppM)	11.6	± 2.3	0.53	± 1.1

Midwest Research

Increasingly corn leaf tissue analysis has been used to diagnose nutrient deficiencies in the Midwest. In 2011a study was conducted to sample corn ear leaves at growth stage VT-R1 were sampled from 434 fields in western Indiana over a range of corn varieties, plant populations soil types and management systems. Leaves were analyzed for N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B and Mo nutrient constituents. The study was continued in 2012 in Indiana and in Iowa across more than 300 fields.

Based on published nutrient sufficiency levels for corn ear leaves at VT (Purdue University) results indicate results for Indiana 2011, show 2.8% of sites having less than adequate N, while 30.4% sites exceed the adequate range, with 6 sites greater than 6.0% N (See Table 2). Ninety-eight percent of sites had leaf P concentration within the adequate range. Potassium and Mg was designated as less than adequate approximately 8% of sites, where as Mg exceeded the adequate range at 7.4% of sites. Corn ear leaf Ca was found to exceed the adequate range at 77% of sites, and based on international published guidelines of Rueter et al 1997, 16% of sites were considered to be toxic. Only two sites were less than adequate in corn ear leaf S and 3.2% for Zn. Six percent of sites were observed to be less than adequate B and 7.6% exceeded the adequate range.

Table 2. Corn ear leaf nutrient adequacy and nutrient analysis for 434 sites Indiana 2011.

Analysis	Adequate Range 1	% Sites Sub-Optimal	% of Sites Supra-optimal
N %	2. 76 - 3.75	2.8	30.4
P %	0.25 - 0.50	0.2	1.4
K %	1.75 - 2.75	7.8	2.5
S %	0.16 - 0.40	8.5	7.4
Ca %	0.30 - 0.60	0.0	77.6
Mg %	0.16 - 0.50	0.2	0.0
Zn (ppm)	19 - 75	3.2	1.4
B (ppm)	5 - 40	6.0	7.6

1 http://www.extension.purdue.edu/extmedia/nch/nch-46.html

Elwali et al in 1985, published corn ear leaf nutrient Diagnosis and Recommendation Integrated System (DRIS) norms for corn grown in Georgia. Utilizing lab analysis uncertainty information, the Indiana 2011 data was parsed in 0.10% K ranges and data was evaluated. Observations indicate significant nutrient ratio relationships for N:K, Ca:K, Mg:K and Mg:N ratios all which increase with decreasing leaf K content. These results were in agreement with published nutrient ratios for corn ear leaves published by the Southern Extension Regional in 2000 (www.ncagr.gov/agronomi/saaesd/scsb394.pdf). Additional analysis is being performed and will be published in 2014.

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