BETTER CROPS WITH PLANT FOOD

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IN THIS ISSUE

Precision Agriculture – Using Traditional Tools and New Technology

BETTER CROPS WITH PLANT FOOD

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Our Cover: A crop consultant collects and stores scouting information in a soybean field.
Cover Photo: Debra L. Ferguson, Southern Images

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ABOUT THIS ISSUE:

Efficient nutrient management for crops includes use of tools and practices to monitor and diagnose growing problems in the field. This issue looks at key considerations of traditional methods as well as some promising new technology.

Proper use of time-tested techniques along with appropriate new technology, implemented with the skills of a diagnostician, can be valuable to profitable crop production.

Correction for Better Crops with Plant Food, *1997, Issue No. 2*

A graph which appeared on page 24 of *Better Crops with Plant Food*, issue No. 2, 1997, was presented incorrectly. The graph (**Figure 1**) was part of an article titled "Variability of Phosphorus Over Landscapes and Dryland Winter Wheat Yields."

Figure 1, shown here, compares variability of sodium bicarbonate ($NaHCO_3$) phosphorus (P) concentrations and yield of dryland winter wheat over a landscape at Sterling, Colorado. In the earlier presentation, the key for the graph line for wheat yield with no (0) P_2O_5/A was switched with the key for the line showing yield at 29 lb P_2O_5/A.

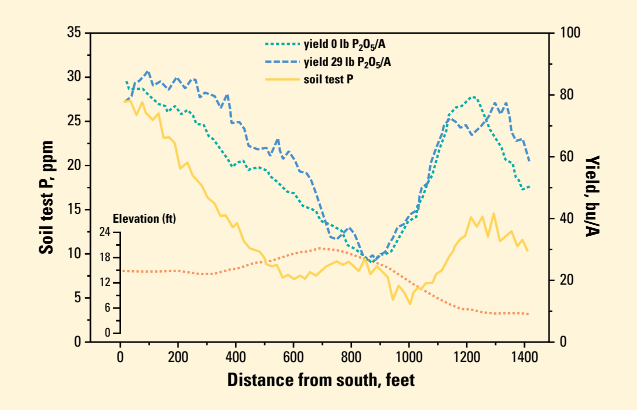


Figure 1. The variability in $NaHCO_3$-P and yield of dryland winter wheat over the Sterling landscape. Lines represent kriged values.

Dryland winter wheat yields varied from 14 to 97 bu/A, depending on landscape position and P rate at Sterling. The 29 lb P_2O_5/A rate is actually an average of the 23 and 34 lb P_2O_5/A rates used in the study.

Phosphorus soil test did not always accurately predict response to P fertilizer. Dryland winter wheat grain yields were limited by factors such as low soil organic matter and low residual soil nitrogen (N) in some areas. BC

Traditional Tools and New Technology Play Key Roles in Site-Specific Management

By A.E. Ludwick

The goal of any diagnostic program should be to evaluate and correct potential deficiencies before they actually occur and cause yield losses. The photos on pages 8 through 15 present symptoms expressed by crops when they are seriously deficient. Since significant production losses can occur even when plants express little or no obvious visual symptoms, growers should hope to never see these symptoms in their fields.

Soil testing and plant analysis are traditional diagnostic tools that continue to be important in site-specific nutrient management. Both are being refined to better plan fertilizer programs. New tools such as portable specific ion electrodes hold promise in speeding diagnosis and implementing corrective actions. All these and other tools that are being developed and perfected will contribute to higher, more efficient crop yields and improved environmental conditions.

In-season diagnosis offers the opportunity to fine-tune fertilizer recommendations, adjusting rates according to changes in yield potential and in environmental conditions as the season progresses. It has been most widely used over the years for nitrogen (N) fertilization where multiple applications are made in an attempt to enhance plant uptake efficiency and to minimize nitrate loss below the root zone. In-season diagnosis is also used for a spectrum of other nutrients, especially in irrigated and high cash value systems.

The pre-sidedressing soil nitrate test (PSNT) is proving to be a valuable research tool and holds promise for on-farm production systems as diverse as field corn in the Midwest and vegetables in the Salinas Valley of California. "Quick tests" make PSNT useful by eliminating costly time delays in obtaining and implementing the results. Samples may be run in the field or collected and run at the end of the day back at a central location. Quantitative procedures utilizing the portable nitrate specific ion electrode are enhancing the utility of this test.

Diagnostic procedures for plant tissue analysis and interpretation of the results are traditional tools that support site-specific management. Plant samples taken early can assist with in-season fertilizer decisions, and those taken later can guide plans for next season. The desire for greater production efficiency has led researchers to evaluate nutrient demand of crops on a per day basis throughout the growing season. These nutrient uptake patterns provide valuable information as to critical periods when nutrients are most in demand. Such information is essential to planning effective in-season fertilization.

Once limited to N, fertigation and foliar applications of various nutrients are proving beneficial in many cropping systems. Again, portable specific ion electrodes are being utilized for quantitative analysis via extraction of plant sap in the field. The nitrate specific ion electrode is most widely used. The K specific ion electrode is reliable up to about 2,000 ppm, the approximate critical level for some crops. This can be useful for diagnosing deficiency, but not for monitoring uptake over typically encountered ranges of K. Values from fresh plant sap must be correlated to those of dried tissue or new calibration data (critical values) obtained.

Improving Accuracy and Precision

Much has been written over the years about collecting reliable soil samples from the field. Traditionally, recommendations call for something on the order of 20 to 25 individual cores (subsamples) to be taken from each "uniform" area and composited into a single sample for analysis.

Site-specific management requires very accurate information. Soil sample intensity could be a seriously limiting factor. Sampling fields on a grid pattern offers some interesting questions. How many cores per grid point are sufficient...are practical? And what about a grid size of 1 acre...2.5 acres...5 acres? A fairly common recommendation seems to be five cores per grid point in fields of 2.5-acre grids. If the variability of nutrients is spatially independent across fields, then five cores would be a very small number to identify true variability.

Accurate sampling of plant tissue is also important to support the goals of site specific management. A recent refinement in plant tissue sampling and fertilizer management involves boron (B). Boron is generally considered to be an immobile or only slightly mobile nutrient. As such, growing tips should exhibit deficiency first since B would not be re-translocated in the phloem from more mature tissue.

Recent research at the University of California shows the mobility of B is species dependent. Those plant species in which sorbitol is a major sugar readily translocate B (e.g., almond, apple, nectarines, cherry, pear, and peach). Sorbitol-poor species that do not readily translocate B include walnut, fig and pistachio. Translocation is apparently accomplished through the formation of mobile B-sorbitol complexes. Nutrient mobility is an important factor in selecting which plant part to sample and in timing foliar sprays for greatest effectiveness.

Precision and accuracy of analyses are also issues in the laboratory. Past studies have demonstrated surprising variability in some cases. There are programs available to assist laboratories with a wide range of analyses for a nominal fee. One such program is the Western States Proficiency Testing Program which has been directed cooperatively by researchers at the University of California and Utah State University. In 1996, 104 laboratories from 26 states, Canadian provinces and foreign countries participated in this program. Based on the past three years, the program has demonstrated an overall improvement in both the precision of individual analyses and the number of laboratories providing acceptable values within prescribed limits.

Looking to the Future

Chloride (Cl) was declared an essential plant nutrient in the mid-1950s. However, it was believed at the time that this was primarily of academic interest and that actual deficiencies of Cl in the field would rarely, if ever, occur. During the next few decades researchers in the Great Plains observed many responses by wheat to K, applied as potassium chloride (KCl), on soils testing high in available K.

Initially it was thought that the K soil test was unreliable. However, it was ultimately determined that many of these soils did, in fact, contain adequate K for

(continued on page 7)

Up-to-date Calibration Research Is Vital to Site-Specific Nutrient Management

By A.E. Ludwick

Moving to higher yield levels through introduction of new varieties and implementation of new or modified management systems requires a continuing program of field calibration research to ensure accurate fertilizer recommendations. This is a formidable task considering how rapidly production agriculture is advancing.

Calibration research requires multiple sites and site-years spanning a range of soil and environmental conditions. The work is labor intensive and is frequently difficult to publish in scientific journals because of its applied nature. As a result, years or even decades pass between calibrations of many cropping systems. Frequently, a new calibration study will result in substantial increases in fertilizer recommendations since the previous calibration was done at a much lower production level.

Potassium (K) fertilization of cotton is a case in point. New guidelines from the University of California recommend up to 400 lb of K_2O/A with the soil test interpretation adjusted according to a K fixation test. Additional in-season foliar or water run K is suggested at first bloom when yield potential is good, regardless of soil test values or earlier K fertilization. Previously, state-wide K guidelines for cotton were not available. Because of a lack of in-depth research information, some questioned whether any K at all should be applied. It is now recognized that up to half of the cotton acreage in the San Joaquin Valley is K deficient.

> Precision farming has attracted a lot of attention over the past few years. More sophisticated hardware and software are seemingly available with each passing day. Envisioned benefits are higher yields and more efficient use of inputs leading to more profit and enhanced environmental protection.
>
> In the rush to grid fields and develop brilliant color overlays, the role traditional agronomic tools play in this process should not be forgotten. Updated soil test calibration data are essential to support the dynamic move toward precision farming.

The Cooperative Fertilizer Evaluation Program (CFEP) was initiated in 1993 through efforts of the University of Idaho and the fertilizer industry with the primary goal being to increase the scientific database from which nutrient recommendations are made. New phosphorus (P) recommendations for potatoes have been published. The recommendations have been substantially increased utilizing data generated through this program. The soil P sufficiency level has been raised from 15 to 20 parts per million (ppm) sodium bicarbonate ($NaHCO_3$)-extractable P. An adjustment in rate of P fertilization is made for each percent free lime rather than the previous increments of 5 percent, a starter of 80 to 100 lb P_2O_5 is recommended below 31 ppm, and P rates are adjusted according to yield goal. Changes under consideration for K on potatoes include increasing the K sufficiency level from 150 to 175 ppm and more than doubling recommended K_2O rates for comparable soil test values.

Researchers at Utah State University are presently re-evaluating calibration data for P and K for irrigated alfalfa production. Initial results suggest that current recommendations are too low. Soil test sufficiency levels and corresponding rates of P fertilizer should be raised. Also, recommended rates of K fertilization may be too low and should be increased. These observations are based on only one year of research. Calibration will continue for at least another three years to build a sufficiently reliable database.

A 10-year P calibration study by Montana State University researchers completed in 1995 for spring wheat indicated that the previously established sufficiency level of 16 ppm $NaHCO_3$-extractable P is still valid. However, recommendations for rates of P fertilizer should be increased and a starter P application should be applied regardless of soil test. Researchers cite advances in spring wheat varieties and production technology for prompting this study and the resultant new recommendations.

These are just a few examples to

MID-SEASON K deficiency is shown in this cotton field in the San Joaquin Valley.

illustrate the value of calibration research. Soil testing continues to be widely recognized as a diagnostic tool, but the point to be made is that soil testing programs based on outdated calibration data (or no data at all) can be counter productive. In each of the examples cited above, new research produced higher recommendations. Previous recommendations were obviously too low for optimum production. Site-specific management will best be served by current calibration information that accurately reflects the nutrient needs of today's production systems. BC

Dr. Ludwick is Western Director, PPI, Bodega Bay, California.

Traditional Tools... *(continued from page 5)*

optimum wheat production and that the responses were to the Cl component of the KCl fertilizer. Chloride deficiencies have since been documented in many of the Plains states and in several provinces of Canada. Both available soil test and tissue analysis procedures are calibrated for wheat, the crop most affected by Cl deficiency in North America.

There is ample opportunity to expand our understanding of fundamental agronomy and to improve the utilization of diagnostic tools. It is important that this knowledge base continues to grow in support of all new innovations, including site-specific management. BC

Dr. Ludwick is Western Director, PPI, Bodega Bay, California.

A Closer Look at Deficiency Symptoms in Major Crops

Nutrient deficiency symptoms are not commonly found in modern crops under good production agriculture practices. The classic signs of major nutrient deficiencies (or toxicities) do not normally appear in well-managed fields. However, knowledge of those symptoms and the conditions that cause them can be an important diagnostic tool.

In general, if deficiency symptoms do appear on crops during the growing season, significant yield loss has already occurred. Crops are more likely to suffer from "hidden hunger" or conditions which tend to limit yields or quality without apparent symptoms. More than one nutrient deficiency may occur at the same time.

Nutrient deficiencies can be prevented with intensive soil testing programs, followed by plant tissue testing. Tissue testing is an under-used tool that could help identify problems in time to take corrective action during the growing season.

The following photographs show symptoms of deficiencies in four major crops: corn, soybeans, wheat, and cotton. For each crop, deficiency symptoms are described for these nutrients: nitrogen (N), phosphorus (P), potassium (K), and sulfur (S).

Marginal purpling of corn leaves is a well known symptom of P deficiency. However, P deficiency can slow growth and delay maturity without purpling. The purpling may also be due to some restriction of root growth, rather than a shortage of P in the soil.

Nitrogen deficiency symptoms appear on this corn leaf.

Potassium-deficient corn ages too fast, cells die, and tissues deteriorate, inviting stalk rot. Potassium builds strong stalks and more brace roots and helps prevent decaying stalks.

Sulfur deficiency on corn may be confused with effects of low N.

Corn

Nitrogen deficiency in young corn causes the entire plant to be pale and yellowish green, with spindly stalks. Later, V-shaped yellowing may appear on the tips of leaves. Nitrogen is a mobile nutrient in the plant. Thus, yellowing begins at the leaf tip, along the midrib on the lower, older leaves and progresses up the plant if the deficiency persists.

Phosphorus-deficient corn plants may be dark green with reddish purple tips and leaf margins. The deficiency is usually identified on young plants. Phosphorus is readily mobilized and translocated in the plant. Deficient plants may be smaller and grow more slowly than plants with adequate P. Some corn hybrids at early stages of growth tend to show purple colors similar to P deficiency when soil P is adequate. Some hybrids do not become purple even though P is severely limiting.

Potassium deficiency on corn may appear as yellowing and necrosis of the leaf margins, beginning on the lower leaves. If the deficiency persists, the leaf symptoms will progress up the plant. Potassium is a mobile nutrient in the plant and is translocated from old to young leaves. Under severe K deficiency, lower leaves will turn yellow while the upper leaves may remain green.

Sulfur deficiency on small corn plants may appear as a general yellowing of the foliage, similar to N deficiency. Yellowing of the younger leaves is more pronounced with S deficiency than with N deficiency because S is not easily translocated in the plant. Other symptoms may include interveinal chlorosis, stunting of plants, or delayed maturity. Sulfur deficiency is more likely on acid, sandy soils, on soils low in organic matter, or on cold, wet soils.

Soybeans

Nitrogen-deficient soybean plants become pale green and leaves may later turn distinctly and uniformly yellow. Symptoms appear first on the basal leaves and quickly spread to upper parts. Soybean plants eventually defoliate and are spindly and stunted. The deficiency can be diagnosed by analyzing leaves for N, inspecting plant roots for nodule formation, and analyzing soil to determine pH and calcium (Ca) content. Soybeans do not normally need N fertilization, but it may be beneficial in high yield environments or in other special conditions.

Phosphorus deficiency symptoms in soybeans may not be well defined. Soybeans require large amounts of P, especially at pod set. It is required for normal N fixation. Phosphorus deficient soybean plants are spindly, with small leaflets and retarded growth. Leaves may appear dark green or bluish green. Leaf analysis for P content is the best way to diagnose deficiency.

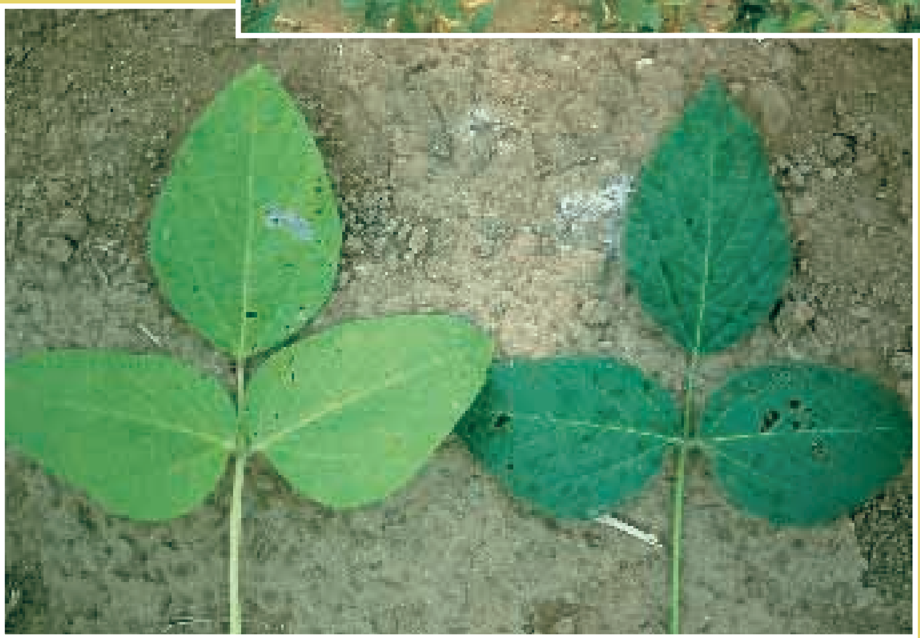
Potassium deficiency symptoms of soybeans are well defined. Soybeans require large amounts of K...it is important for all aspects of plant growth and influences the plant's nutritional balance. It is also involved in the uptake of Ca and magnesium (Mg). Potassium deficiency symptoms appear first on older leaves. In early stages of growth, an irregular yellow mottling appears around leaflet margins. The yellow areas may coalesce to form an irregular yellow border.

Sulfur deficient soybean plants will be pale green with the youngest leaves often appearing more yellow. Stems are thin, hard, and elongated, with small, yellow-green leaves at the top of the plant. Sulfur deficiency may lead to reduction of protein synthesis. Availability of S depends on the rate at which it is released from organic matter, influenced by plant residues, soil moisture, temperature, and soil pH.

Potassium-deficient soybean plants show symptoms first on older leaves.

Sulfur-deficient soybean plants (left pot) have pale-green leaves, especially at the top of the plant.

Phosphorus-deficient soybean plants.



Nitrogen-deficient soybean plants (left) appear pale green...leaves may turn uniformly yellow.

Wheat

Nitrogen deficiency in wheat and other small grains may first appear as yellowing and then as stunted growth. Chlorosis usually begins on older tissues such as lower leaves. Cell growth and division as well as protein synthesis may be slowed. Wheat and other small grains and grasses are generally sensitive to insufficient N and responsive to supplemental N applications.

Wheat and other small grains deficient in P may be more subject to stress and diseases. **Phosphorus-deficient** plants maintain their green color and may be darker green than plants with sufficient P. However, they are also slow growing and slow to mature. Tillering is often reduced or lacking completely. Leaf tips die back when shortages are severe and foliage of some varieties may show shades of purple or red. Older leaves and other tissues are the first to show P deficiency symptoms.

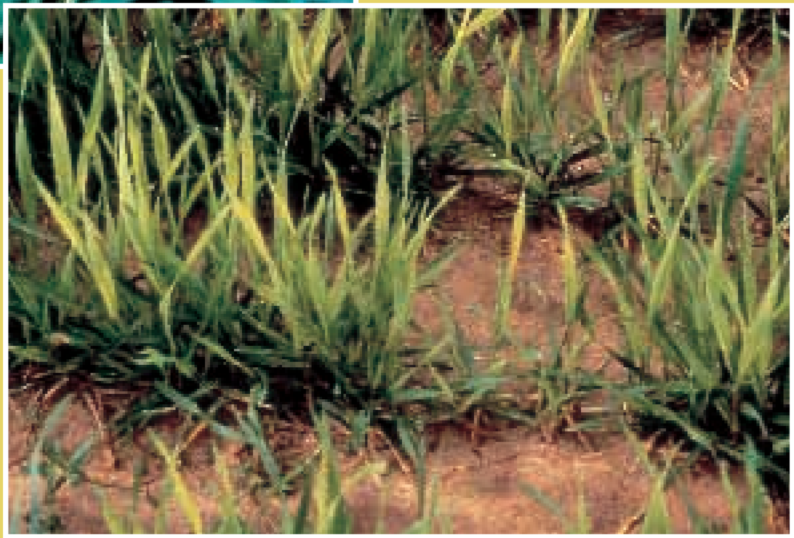
Potassium deficiency more commonly occurs where straw and grain are both harvested from small grain fields. Sandy, coarse-textured, intensively cropped soils are most likely to provide insufficient K. Chlorosis due to K deficiency may appear uniformly at first on older plant parts. Leaves may eventually become streaked with yellow. Certain plant diseases are more common when K is deficient.

Symptoms of S deficiency in wheat and other small grains are similar to those of N deficiency. Sulfur deficiency is more common in mineral soils that are well drained, coarse textured, and low in organic matter. Sulfur deficiency in wheat typically appears first on younger tissues, but eventually causes the entire plant to take on a pale green appearance.

Nitrogen-deficient wheat and other small grains show yellowing or chlorosis on older leaves first.

Adequate P fertility in plot at left above improved growth, tillering and yield potential of wheat.

Potassium-deficient wheat.



Sulfur deficiency of wheat occurs where soils are acid, well drained, and low in organic matter.

Cotton

Nitrogen deficiency symptoms on cotton early in the season include yellowish green leaf color, first appearing on older leaves. Younger leaves may be reduced in size. Plant height is also reduced, few vegetative branches develop, fruiting branches are short and bolls may be shed soon after flowering. When N deficiency occurs later in the season on plants with a moderate load of maturing bolls, foliar symptoms appear as reddening in the middle of the canopy. Few bolls are retained at late fruiting positions.

Symptoms of phosphorus deficiency in cotton rarely occur during early growth and are not distinct. Plants may be stunted, leaves darker green than normal, flowering delayed, and boll retention poor. Later in the season, leaves on P-deficient plants undergo premature senescence.

Foliar symptoms of K deficiency on

Phosphorus-deficient cotton may undergo premature senescence.

Nitrogen deficiency in cotton may occur early or late in the season.

cotton that occur before peak bloom may include interveinal light green to gold mottling first on older leaves, with yellowing and necrosis developing at leaf margins under severe deficiency. Late-season K deficiency results in foliar symptoms that differ from early season deficiency. After peak bloom, K deficiency symptoms first appear on the younger mature leaves in the upper third of the canopy. Potassium deficiency symptoms are sometimes confused with plant diseases such as Verticillium wilt.

Sulfur is not mobile in the cotton plant (unlike N), and thus S deficiency symptoms occur on younger leaves in the upper canopy. Older leaves retain a normal green color. Sulfur-deficient leaves turn pale green, then a yellowish green similar to N-deficient leaves, but leaf veins tend to remain somewhat greener than interveinal tissue. Plants deficient in S are short and have few vegetative branches and small bolls. BC

Sulfur-deficient cotton may show symptoms on younger leaves.

Potassium deficiency in cotton is more widely recognized in recent years.

Electronic Tools for Field Scouting

By Mike Thurow

Growing conditions are seldom stable or consistent from year to year, and that makes it challenging to know what factors really contributed to in-field yield variations. New, practical and affordable technologies exist that can tell you more. These new electronic field diagnostic tools fall into the following categories: nutrient management tools; weather instruments; and soil quality tools.

New electronic field diagnostic tools are being developed for use in nutrient management, weather monitoring, and gauging soil quality. But they will not eliminate the importance of someone walking crop fields to scout conditions.

Nutrient Management Tools

The lack of on-the-go soil sensors for nutrient management remains an important void in precision or site-specific agriculture. While research and development continue, it is doubtful that soil nutrient sensors for the field will be commercialized before the turn of the century. What's taking so long? It is difficult to achieve accurate and consistent soil analysis from a laboratory at zero miles per hour, so how can we expect to do accurate nutrient analysis with a soil sensor moving through the field at 5 miles an hour? However, there are practical and affordable tools that can provide valuable feedback on key soil nutrient parameters.

No other soil chemical property has such a profound effect on fertilizer efficiency or soil nutrient availability as soil pH. On-farm soil pH testing can be performed easily and accurately. Meters are affordable (about $150.00), reliable, and approach laboratory accuracy. The typical process itself involves mixing soil and distilled water in a cup, allowing the sample to equilibrate for 5 to 10 minutes and immersing the sensor into the soil slurry and waiting a few seconds for the meter reading to stabilize.

Several tools for infield nitrogen (N) soil and tissue analysis are available today. The Minolta Chlorophyll Meter is an example. Minolta developed this technology in the early 1980s as an N management tool for rice growers. The current model (SPAD 502) was introduced in 1987. University research shows a strong correlation between the meter's leaf chlorophyll measurement and leaf N content. Furthermore, University of Illinois researchers found a strong correlation between corn leaf chlorophyll readings at the reproductive stage and final yield. The higher the SPAD meter reading, the higher the yield.

Creating adequately fertilized reference or check strips within the field is important to fully utilize this technology and monitor the N status of corn. Meter readings from the reference strips are compared to the bulk field to identify the need for additional N. The benefit of the reference strip approach is that corn hybrid and growth stage factors are eliminated. And

Use of a chlorophyll meter with GPS may help monitor N needs or yield as related to management.

additional N can be applied beyond the usual side-dress time with high clearance equipment or through pivot irrigation if necessary.

The value of this technology is now greatly enhanced with the optional RS 232 (a serial 25-pin connection for data transfer) port on the SPAD meter and the Star-WALKER field data logger. This new wrist logger combines the SPAD chlorophyll measurement and differential global positioning system (DGPS) coordinates and stores the information in the robust data recorder for subsequent data transfer to a computer. This new technology is currently being beta tested.

Weather Monitoring Technology

Weather, particularly temperature and rainfall, directly impacts crop growth, quality and yield. Rainfall can vary from farm to farm and field to field, but to measure is to know. Rain data loggers can record daily rainfall and log detailed rainfall activity year round. If more weather information is needed, weather stations can measure solar radiation, wind speed and direction, temperature and humidity, soil temperature, and leaf wetness. Software can calculate degree-days, evapotranspiration, and create your own weather database for year-to-year comparisons and analysis.

Weather parameters can be tracked on a site-specific basis with data loggers for air and soil temperature, humidity, and light intensity. This affordable technology replaces expensive strip-chart recorders and interfaces with PCs for data analysis and storage.

Degree-day counters can electronically measure temperature and calculate heat units. They are ideal for growers that don't have a personal computer.

An essential integrated pest management (IPM) tool is an electronic leaf wetness/temperature logger which tracks leaf wetness duration and temperature as an aid in predicting gray leaf spot.

Soil Quality Tools

Just how beneficial is rainfall information if you can't measure what's in the soil? Soil moisture impacts plant growth and yield. Soil quality tools can shed more light on quantifying soil moisture and its variability by soil type and throughout a field. They are more useful when measurements are geo-referenced and analyzed in mapping software or even correlated with yield maps.

Soil compaction is an undisputed yield robber. But how much compaction is bad and how can it be measured more accurately? An electronic compaction meter is available with ultrasonic depth sensing technology. It measures probe insertion speed and warns the user if the speed is too fast. It also measures and logs compaction throughout the soil profile. The penetrometer has an RS 232 output and could be geo-referenced for mapping purposes.

Perhaps the greatest value of electronic field scouting tools is that someone is walking the fields. We use our own powerful resources: our eyes, knowledge and experience for observing and noting crop conditions. BC

Mr. Thurow is President of Spectrum Technologies, Inc., Plainfield, Illinois.

Analysis and Practical Use of Information from On-Farm Strip Trials

By D.R. Hicks, R.M. Vanden Heuvel and Z.Q. Fore

New practices and products that growers evaluate on their farms should ideally have previously met the rigors of research testing on small plot, replicated trials where all variables are well controlled and the treatments have shown that they are statistically repeatable. Therefore, the primary purpose of on-farm strip tests is to give the grower an opportunity to try a new practice or product and to find response areas (both negative and positive) within a field. This information will help the grower determine management zones where the practice should be used to maximize the return from the input investment. Following are guidelines on how to conduct on-farm strip tests and how to best use the information from them.

On-farm trials are useful in helping growers become familiar with new products and management practices and in deciding whether they want to adopt the practice on whole fields or their entire farm. Combine yield monitors now make it possible and easy to collect yield information from any part of a new field. Thus, growers may use yield monitors to evaluate new agronomic practices that they have placed in strips or parts of fields. It will be important to collect good information if growers want to use it to make decisions. Profitability depends upon making sound management decisions.

Planning is important to the success of an on-farm trial. What is the objective? Where will it be located? What treatments should be included? What data will be recorded? Who will plant, record information, harvest? These matters should be determined to make the results of the trial most useful.

The objective of on-farm trials may be to evaluate a new product or practice. Growers may adopt a practice or product on part or all of their acreage after they have more experience with it. They may need on-farm experience to gain confidence in the new technology.

Choose a representative area of a field for an on-farm trial. Soil type, slope, tillage, and fertility should be as uniform as possible (unless they are considered to be variables) so that yield differences observed are likely due to treatments rather than soil and field characteristics or natural variability. Record all information in a field book (or a computerized system) and store in a place convenient to continue entries throughout the growing season.

The choice of a treatment is determined by the objective of the trial, such as the evaluation of a new product or practice. The effect obtained from the treatment will be compared to other areas where the treatment was not applied. Yield and moisture at harvest are usually determined. Other effects that might be of interest are traits such as plant height, percent of weeds controlled, plant injury, maturity date, and lodging. A treatment could be a new herbicide, a different rate of the same herbicide, a change in plant population, changes in varieties or hybrids, etc. While all other practices are held constant, any one factor that is changed becomes a "treatment" and can affect yield and other characteristics.

On-farm trials should be kept as simple as possible. For example, two treatments...the new practice or product (treated) and the normal practice (check)...would be ideal. There can be more treatments, but the trial becomes more complicated and more difficult to properly manage as the number of treatments increase. Variety trials are a good example of where there are usually more than two treatments in a strip trial.

One can code with numbers or letters the strips where the treatment and check are laid out in the field to prevent introducing bias to the results. After all field notes are taken and the strips are harvested, the results can be uncoded to study the possible treatment effects. This prevents any bias in the results that might occur due to notions about what results are expected because of the treatment.

The simplest trial is one with only two strips–the treated and the check. There is no replication with this layout and, therefore, there is no estimate of error. As a result, one cannot judge statistically whether or not there is a real treatment difference. There will be a number of combine yields within each of the two strips, but these are not replications because the assignment of treatments along each strip is not re-randomized for each of the areas within the strip where combine yields will be taken. However, combine yields do represent samples within each strip and are valuable information to show variation within the strips.

Three replications of the treated and check strips in each field or farm allow for a statistical analysis, if one wants to do so, and provide a better estimate of the treatment effect by having three estimates rather than one. One replication of the treated and check strips on three or more farms is equally good for statistical analysis, providing all growers do an equally good job of taking care of the trial. The best reason for increasing the number replications of the strips is to provide a better estimate of the treatment effect.

Figure 1 presents the field layout for the simplest situation-two strips (treated and check) in one field. There is no replication with this layout, so conclusions that one can draw from the results are limited. However, results from similar layouts on three or more farms will allow for proper statistical analyses and a broader basis for making decisions regarding the treatment effect.

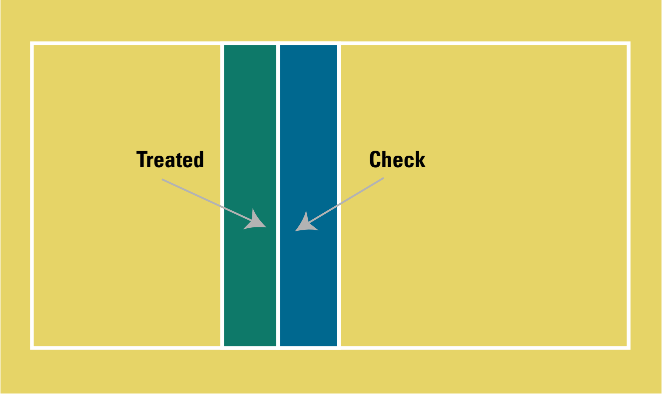


Figure 1. A field layout of an on-farm strip test with two treatments and one replication.

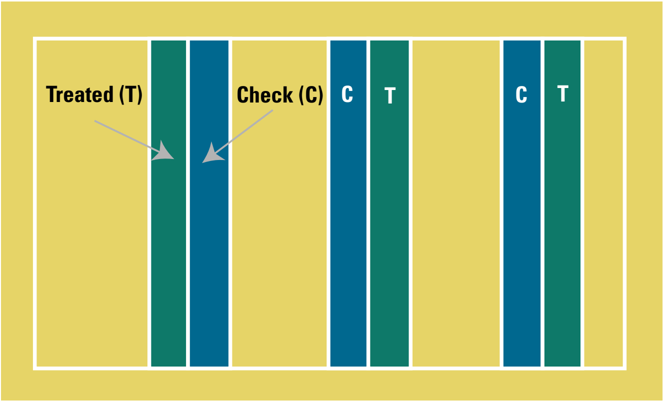


Figure 2. A field layout of an on-farm strip test with two treatments and three replications.

Figure 2 gives a field layout for two strips (treated and check) with three replications in the same field (there could be more replications, but we believe three are sufficient and push the limit of time and space that a grower should spend with an on-farm trial). When assigning the treatment and check to the strips, one should randomly assign the treatment and check to each of the strips. The layouts in **Figures 1** and **2** can be repeated on two or more fields or farms and the results combined to increase the number of replications of the treated and check strips. This will improve the estimate of the treatment effect.

Keep detailed records of the field where on-farm strip trials are located. Use Global Positioning System (GPS) equipment to locate the strips in the field and label them on a GPS generated field map. One could mark the strips with flags in the field such that they are easily found during the growing season to observe crop conditions. Record all events during the growing season that may help to explain the yields that are recorded later. This includes planting date, rainfall, unique weather conditions, fertility applied, pesticide use (kind, amount, and date applied), harvest date, and other pertinent data.

Results of replicated on-farm trials can be statistically analyzed. The purpose of a statistical analysis is to determine whether the treatment effect is repeatable (which may be known from previous research in small plot, replicated trials). Results from non-replicated on-farm trials can also be statistically analyzed if there are two or more farms (or locations) where farms are used as replicates in the statistical analysis.

Statistical analyses of on-farm data will likely show the treatment effect to be statistically significant at a very high level of confidence, even when very small differences occur between the treated and check strips. This will be especially true when large numbers of combine yield data are used as replicates in a statistical analysis.

A statistical analysis of data from on-farm trials may not be very important to a grower if the treatment has been thoroughly evaluated in small plot, replicated trials (normally including more than one location and year). If so, a grower can expect the treatment effect to be real and testing on that farm is not necessary except to become familiar with and gain confidence in the treatment technology.

In addition to the statistical analysis, one should determine if the treatment is profitable. A statistically significant effect does not mean that a practice or product will be economically significant or feasible. On the other hand, a treatment that does not give a statistically significant effect does not mean that the effect is not economically significant. Economic significance occurs when the value of the

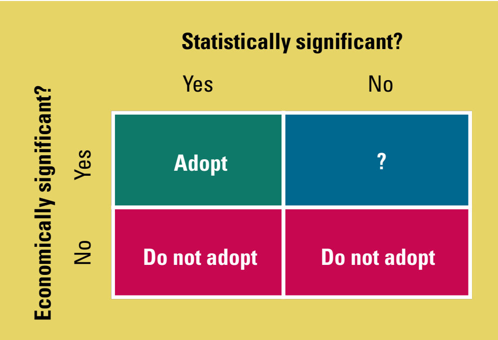


Figure 3. Matrix to evaluate the adoptability of an agronomic practice based on statistical and economic significance.

average treatment effect is greater than the cost of the treatment. To evaluate economic significance, one needs to know the average treatment response, expected crop price, and the cost of the treatment. These parameters are necessary to evaluate the average return on investment for the treatment.

Figure 3 graphically presents the decision options regarding adoption of a practice considering statistical and economic significances. Technologies should be adopted to improve profitability when the practice is both statistically and economically significant and not adopted when the practice is not economically significant, even though it may be statistically significant. The combination of economically significant and not statistically significant in the upper right quadrant in **Figure 3** represents a more difficult decision.

Both the cost of the treatment and the probability of a treatment response are important components of the decision to adopt new technologies. The relationship is shown conceptually in **Figure 4**. Ideally, the probability of a real response to a new technology should be very high or close to 1.0, especially when the cost of the technology (treatment) is high. But when the cost of the treatment is low, one might accept a lower required probability of a real treatment response when considering whether or not to adopt the new technology.

On-farm trials help growers become familiar with new products and management practices and should be helpful when determining whether they want to adopt the practice on whole fields or their entire farm. Combine yield monitors make it possible and easy to collect yield information from any part of a field. Growers may use yield monitors to evaluate new agronomic practices that they have placed in strips or parts of fields. Combine yield monitors also help growers to fine tune management practices that improve their profitability and efficiency in crop production. BC

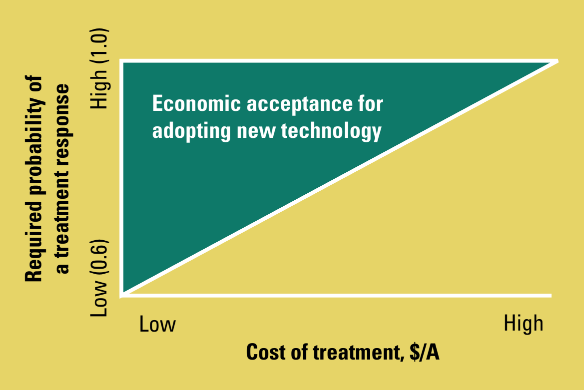


Figure 4. The conceptual relationship between the cost of a treatment and the required probability of a response.

Dr. Hicks is Extension Specialist, Corn Production, University of Minnesota, St. Paul. Dr. Vanden Heuvel and Mr. Fore are with Cenex/Land O'Lakes.

Satellite Imagery: An Advanced Diagnostic Tool for Crop Scouts using GPS

By Chuck Nichols

At ground level, it is often difficult for crop scouts to see crop health variations in a field much beyond the immediate area where they are standing. This is especially so in tall crops such as corn. Crop scouts can also use up a lot of time monitoring healthy areas that do not require as much attention.

> Infrared satellite images act as a "thermometer" of field health, helping dealerships and crop scouts locate the problem areas in customers' fields. The images won't tell **what** the crop problem is, but they can identify **where** the problem areas are, and the **size** of those areas.

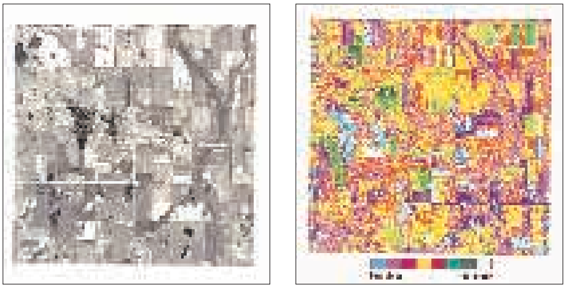
A satellite image is a natural aid for diagnosing crop problems in conjunction with crop scouting. A crop scout can locate, then go directly to the problem area of the field using the satellite image as a guide. Since every pixel in the image has its own latitude/longitude coordinates, crop scouts can more efficiently pinpoint their efforts to the problem areas with global positioning system (GPS) guidance and devote less time to healthy areas.

The satellite system detects in-field variability in fine detail. A near-infrared band measures the reflection from the photosynthetic material of the crop canopy on each one-tenth acre. It records a different signature when the plants are under stress, which is often caused by disease, lack of (or too much) moisture, soil compaction, inadequate nutrients, or a multitude of other reasons. It is up to the crop scout and the grower to determine the reason for the stress in that area.

Images can also be merged with geo-referenced data collected throughout the season by the crop scout for further analysis and correlation, such as the locations and types of weed, disease, and insect infestations, nutrient and pesticide applications, seed populations, irrigation water management, weather data, etc.

Crop scouts can use the technology to tally the number of acres affected, enabling them to determine the economic impact of their findings. Digital satellite images can be downloaded from a compact disk (CD) with any geographic

(continued on page 24)



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At left, a black and white image from SPOT satellite shows field boundaries, drainage patterns, buildings and roads in a township in North Dakota. **At right,** near-infrared imagery is used to distinguish patterns of vegetation vigor and stress. Colors represent relative levels of crop or vegetation vigor.

I L L I N O I S

Field Monitoring of Crop Photosynthesis and Respiration

By Steven E. Hollinger

Plants use the sun's energy to fix C through photosynthesis, the process essential to the production of economic crop yield. At the same time plants are fixing C, they are transpiring and losing water through their open stomata. The water lost by transpiration results in drying of the soil. When the soil becomes too dry to maintain the transpiration required to meet evaporative demand of the atmosphere, the stomata close and the rate of photosynthesis decreases.

Recent advances in technology should allow simultaneous measurement of factors such as weather, carbon (C), water and energy fluxes which will aid the understanding of effects of various management practices on crop growth and yield.

Much effort has been put into research to determine when canopy photosynthesis begins to shut down due to a water shortage. Researchers in the past have placed shelters over several corn plants to measure the rate of photosynthesis during the day. However, these shelters could stay over the plants only a short period of time before the environment in the shelter would become unfavorable for photosynthesis and the plants would stop fixing C. High labor requirements limited the number of measurements that could be taken, and the experiments were limited to short time periods when canopies were fully developed.

Recent technology advances have provided the tools needed to continuously monitor carbon dioxide (CO_2), water vapor, and energy exchange in plant canopies. The new tools include a three-dimensional sonic anemometer and an open path infrared gas analyzer. The three-dimensional sonic anemometer measures the vertical and horizontal components of the wind, and the infrared gas analyzer measures the concentration of the C and water vapor in the air.

Infrared light from a regulated light source is detected by sensors that measure the light from the source after it has passed through a column of air with a known path length. If the vertical wind direction is away from the surface of the canopy and the CO_2 concentration is lower than when the vertical wind direction is toward the canopy, then CO_2 is moving toward the canopy from the atmosphere. This would indicate that the canopy is removing CO_2 from the air...photosynthesis is occurring. If the CO_2 concentrations in air parcels moving away from the canopy are higher than air parcels moving towards the canopy, then the canopy is releasing C to the air by respiration.

The advantage of these new instruments is that they are designed for continuous measurements of CO_2, water and energy fluxes in the field.

In addition to the sonic anemometer and the infrared gas analyzer, instruments are available which measure global radiation, net radiation, incoming and outgoing photosynthetic radiation, air temperature, humidity, soil temperature, soil moisture, and soil evaporation at the site. These instruments provide the additional weather data needed to analyze the response of CO_2 and water vapor fluxes to temperature and water stresses.

While the main purpose of the observations is to understand the effects of crops on the weather, we are able to use the same instruments to monitor the response of the crops to weather.

For example, daily total photosynthesis and respiration were measured for a no-till corn field in Illinois in 1997. The measurements showed that from June 20 to July 31, photosynthesis was closely coupled with net radiation (sunlight). Prior to this period, the canopy was not developed to the point of making leaves compete with one another for light. After this period, soil moisture appeared to be more limiting than net radiation, even though the crop showed no visible signs of moisture stress. These measurements can increase understanding of yield limiting factors and have exciting potential for guiding the development of higher yielding cropping systems.

Farming is the art and science of managing the soil and crops to optimize photosynthesis and conversion of sugars to produce an economic yield. While each individual plant contributes to yield, photosynthesis occurs in a community of plants. The new technology described here allows the simultaneous measurement of weather and C, water and energy fluxes which will aid in the understanding of how different management practices affect crop growth and yield.

Instruments installed in fields with different soil fertility levels or treatments will demonstrate how fertility contributes to photosynthesis and respiration, and ultimately final yield, in different weather environments. BC

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Acknowledgements: The author thanks Dr. Tilden Meyers for supplying data and Mr. John Reifsteck for the use of his field.

Satellite Imagery... *(continued from page 22)*

information system (GIS) or desktop mapping program that has a high graphical interface.

The frequency of satellite shots depends on the crop type and how intensely the crop needs to be monitored. For high value, sensitive crops such as potatoes, weekly monitoring may be required. Otherwise, once or twice a season may be adequate. The cost of satellite image maps can range from 10 to 60 cents per acre depending on the number of fields in the image. Township sized images (6 miles x 6 miles) are available from SPOT.

Satellites are capable of photographing the same area every 1 to 6 days. Turnaround time from the date the shot was taken to when it is in the crop scout's hands can be about three days. Without time constraints, it will be 7 to 10 days.

Satellite imagery at a glance:

- Map field boundaries
- Identify crop stress
- Merge with other geo-referenced data to create a spatial database
- Latitude and longitude provide in-field accuracy. BC

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Fertilizer Placement Affects Rate of Nutrient Uptake by Grain Sorghum in Conservation Tillage Systems

By Dan Sweeney

Public awareness of the environment, farm programs, and economic concerns have increased the amount of U.S. land planted in conservation tillage. With less soil mixing, placement of fertilizer becomes more important. Research has shown that fertilizer placement can affect yields in conservation tillage systems. Surface or subsurface banding often has resulted in greater nutrient use efficiency than broadcast applications. The objective of this study was to determine the effect of broadcast, surface band (dribble), and subsurface band (knife) placements of N-P-K suspensions on dry matter production and N, P and K uptake by grain sorghum in conservation tillage systems.

Knife (subsurface band) placement increased uptake of nitrogen (N), phosphorus (P) and potassium (K) by grain sorghum early in the season. Knife placement of N-P-K suspensions may also improve yield potential.

Procedure

The experiment was conducted for two years on a Parsons silt loam, a typical claypan soil of southeastern Kansas. The soil was low in available P and K with a relatively high organic matter content. Fertilizer treatments included combinations of placement methods and timing of N applications, in addition to a no-fertilizer control. Preplant fertilizer application methods were broadcast, dribble and knife. Dribble and knife spacings were 30 inches, and knife depth was 4 inches. Nitrogen timings were all N applied preplant and split N (50 percent of N applied preplant and 50 percent applied at the nine-leaf stage as a dribbled sidedress). Preplant N plus all P and K were applied as a suspension. Later N applications used a urea-ammonium nitrate (UAN) solution. Total fertilization rate was 150-100-150 (lb/A of N-P_2O_5-K_2O).

Fertilizer treatments were applied in each of three conservation tillage systems: reduced tillage - disk and field cultivate; ridge tillage; and no tillage. Aboveground parts of four whole plants were collected at random from each plot at the nine-leaf, boot and soft dough growth stages, then weighed, and analyzed for N, P and K. Values were corrected by plant stands to calculate dry matter production and nutrient uptake on a per-acre basis. Dry matter accumulation and nutrient uptake were regressed against days after planting (DAP) for each placement method using cubic functions that maximized R^2 values for every variable. The first derivatives of these cubic functions then were taken to obtain uptake rates. The day of maximum uptake was determined by solving the equation obtained by setting the second derivative equal to zero.

Data were analyzed across years with

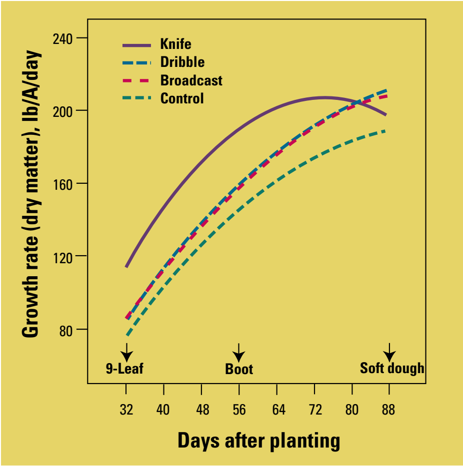

Figure 1. Rate of dry matter accumulation for broadcast, dribble, and knife placement methods and the control as obtained from the first derivative of dry matter accumulation functions.

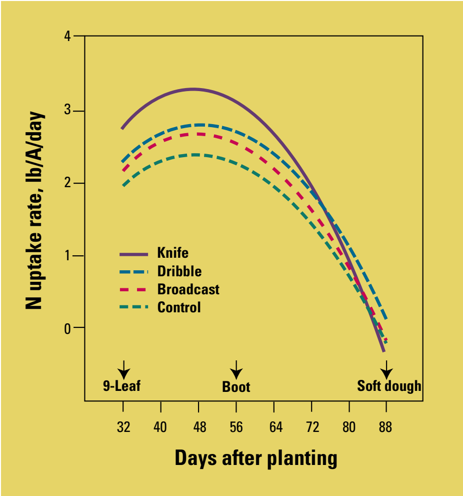

Figure 2. Rate of N uptake for broadcast, dribble, and knife placement methods and the control as obtained from the first derivative of N uptake functions.

minimal year by treatment interactions. Because none of the few year by treatment interactions for any variable occurred at more than one growth stage sampling, analyses of data were pooled across years to emphasize effects that were significant through all samplings.

Results and Discussion

Although no-tillage resulted in nearly a 30 percent decrease in dry matter accumulation and N, P, and K uptake at the nine-leaf growth stage when compared with either reduced or ridge tillage, further reductions at later growth stages were generally not significant (data not shown). In addition, split N applications or the interactions between tillage, placement method, and split N application had minimal effects on any of the parameters measured at the three growth stages.

The highly significant and uniformly consistent response to fertilizer treatments was due to placement method and to fertilization in general. The dry matter accumulation from the nine-leaf to the soft dough stage of growth suggested that the plants grew slowly at first and then more rapidly to soft dough (data not shown). At the nine-leaf stage, knife placement of the N-P-K suspension resulted in greater dry matter production than either surface placement or the control. This difference became more pronounced during the season. The growth rates with surface placement methods did not appear to reach a maximum until after 88 DAP (**Figure 1**). However, knife placement appeared to result in maximum growth rate by 74 DAP.

Cumulative N, P and K uptake by grain sorghum followed a general sigmoid pattern with time (data not shown). The maximum rate of N uptake with knifing was approximately 1 lb/A/day more than uptake for the control and 0.5 lb/A/day more than uptake for the two surface placement methods (**Figure 2**). The maximum N uptake rate occurred near 49 DAP for all placement treatments. The maximum rate of P uptake with knifing was approximately 15 percent greater than that with either broadcast or dribble

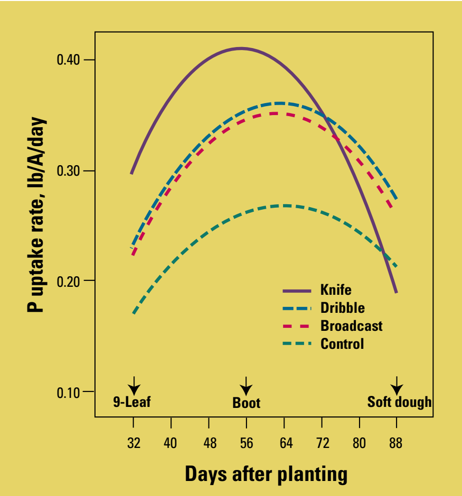

Figure 3. Rate of P uptake for broadcast, dribble, and knife placement methods and the control as obtained from the first derivative of P uptake functions.

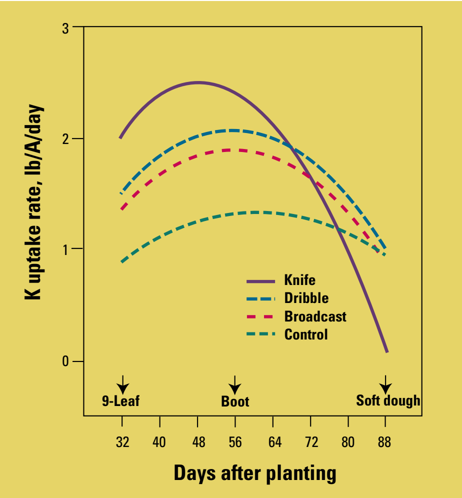

Figure 4. Rate of K uptake for broadcast, dribble, and knife placement methods and the control as obtained from the first derivative of K uptake functions.

placement methods and 50 percent greater than that for the control (**Figure 3**).

The maximum P uptake rate occurred at 56 DAP for knifing but approximately one week later for the control and the surface placement methods. This shift may be explained partially by differences in maturity.

Potassium uptake followed the same sigmoid patterns as N and P uptake (data not shown). Maximum K uptake rate with knife placement was nearly double the maximum rate for the unfertilized control (**Figure 4**). Even though uptake was less than with knifed placement, surface applications increased the maximum K uptake rate by 50 percent above that of the control. The date of maximum uptake with knifing was approximately 49 DAP, which was one week earlier than that for either surface placement method and two weeks earlier than that for the control. This effect of placement on the date of maximum K uptake cannot be explained entirely by a shift in maturity.

Summary

For each placement method and the control, the times of maximum rates of N, P and K uptake preceded the time of maximum rate for dry matter accumulation. The often-observed dilution of plant nutrient concentrations with time was demonstrated in this study by reduced nutrient uptake rates at later growth stages compared with the rate of dry matter accumulation. Knife placement increased the amounts and rates of N, P, and K uptake early in the season and appeared to shorten the time to reach maximum plant growth and P and K uptakes. The positional availability of knifed plant nutrients, especially P and K, early in the growing season may improve nutrient uptake by grain sorghum and also affect the kernel potential that is determined shortly after growing point differentiation and, consequently, yield. BC

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MONTANA

How to Profit from Phosphorus Fertilizer Use

By J.W. Bauder and B.E. Schaff

Montana farmers applied nearly 66,500 tons of P as fertilizer in 1996. That amounts to approximately 15 lb of P for every acre of cropland in the state, representing a significant cost to growers of small grain. Yet most admit that the rate they apply is routine; oftentimes, they never even take a soil sample to determine what that rate should be.

Recent Montana research sheds new light on significance of phosphorus (P) soil tests and periodic P fertilizer additions, even on some soils testing high in Olsen-extractable soil P. The greenhouse study tested response of sordan to P applied to calcareous soils.

Current findings show that the specific properties of the soil along with the soil test P level can have a dramatic effect on crop responses to fertilizer P. Past research has shown that some soils initially high in P still show good yield responses to P fertilizer. The study reported here found that soil test P level may have a greater effect on yield than the amount of fertilizer applied.

To determine just how important soil testing is with regard to P fertilizer rates, researchers at Montana State University conducted a study in cooperation with farmers and ranchers along the Powder River in southeast Montana. The purpose of the investigation was to determine how a crop (sordan, a sorghum-sudan hybrid) would respond to various P fertilizer rates when applied to soils with increasing soil test P levels. Three different soils, each with a relatively low soil test level, were collected from cropped fields: Gay Ranch in Powder River County, Griffin Ranch in Custer County, and Foulger Ranch in Prairie County (**Table 1**).

Typical Montana soil test levels range from 1 or 2 parts per million (ppm) to 20 or more ppm. Researchers currently recommend P additions when Olsen extractable levels are less than 18 ppm (approximately 36 to 40 lb/A). Recommended P_2O_5 rates generally range from 10 to 60 lb/A.

TABLE 1. Description of test soils and pre-experiment test levels.

Source	Soil series	Olsen P level, ppm	pH	EC, mmhos/cm	OM %	$CaCO_3$ %
Foulger Ranch	Glendive fsl[1]	2.4	8.3	1.04	1.2	2.5
Griffin Ranch	Havre l	7.2	8.3	2.61	2.3	3.6
Gay Ranch	Heldt sic	3.0	8.1	0.78	2.5	6.1

[1]fsl = fine sandy loam; l = loam; sic = silty clay

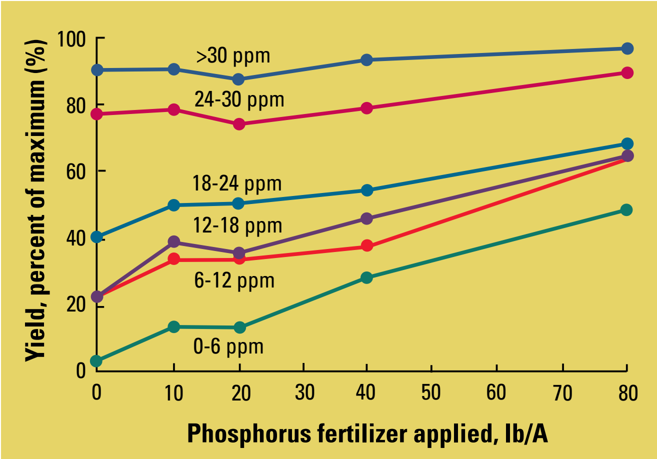

Figure 1. Composite response of sordan to P fertilizer additions when Olsen soil test P level was in the range of 0-6, 6-12, 12-18, 18-24, 24-30, and over 30 ppm.

After initially testing the soil, each of the original soils in the study was divided into five samples. The P soil test level of each sample was adjusted to create five levels (from very low to very high) for each soil. This procedure also provided an opportunity to see how the P soil test level would change with different P additions.

After the five soil test levels were created for each soil, P was added at rates equivalent to 0, 10, 20, 40 and 80 lb/A. Three crops of sordan were then grown on each soil. Sordan was used as the test crop partly because of its similarity in behavior to small grains, and partly because three successive crops could be grown and harvested without the need to replant between crops. Total yield from each harvest was recorded, and measurements were made of the soil test P level after all fertilizer additions.

Researchers hoped to determine the maximum fertilizer rate that still generated crop responses. To that end, they found that the pattern of yield response to P was similar across all three soils. If the soil test level was relatively low, yield response kept increasing with each additional P rate. The yield continued to increase each time more P was added, as long as the soil test P level was less than 30 to 40 ppm.

Current P fertilizer recommendations imply that responses will be minimal at soil test P levels above 18 ppm. The results of this study indicate that for a forage crop such as sordan, yield increases are nearly linear in response to the P applied, up to a soil test P level of approximately 30 ppm, at least on some soils. However, the greatest responses for each unit of fertilizer applied occurred when the soil test level was at its lowest. Response on the Gay site indicated that yield response decreases as the intial soil test P level increases. At a soil test level of 3.2 ppm, the yield increased steeply with each increment of P added. The same was true at an initial soil test P level of 13.2 ppm. However, by the time the soil test level increased to 29.0 ppm, there was almost no change in yield among the various P fertilizer rates.

When everything else is uniform, specific properties of the soil and the soil test P level can have a dramatic effect on crop responses to fertilizer P. On the Glendive soil, the research team observed no response to P additions at rates less than about 40 lb/A when soil test P level was greater than approximately 18 ppm. At the higher levels of soil test P (about 40 ppm or above), there was little or no response to each additional P rate. For example, with the Heldt soil at the highest soil test P level, yield did not increase at all between the point where no P was applied and where 80 lb/A rate of P_2O_5

was applied. Similarly, the yield increases on the Glendive and Havre soils were only 7 and 2 percent, respectively, at the high soil test levels.

To show just how important the soil test level is for determining the benefits of adding P, researchers adjusted and combined the yield data from all three soils to come up with one figure. **Figure 1** shows the yield (as a percent of the maximum yield) after applying increasing amounts of P to each soil at various soil test levels.

In general, yield responses were similar for all soils testing up to 18 to 24 ppm (similar slopes for response curves). There was less response to any additional P when soils tested higher than this. These results provide additional evidence that a soil test is a good index to determine if the soil has adequate P for cereal production. An important result is that soils which had low soil tests never did yield as much, even at 80 lb/A of applied P, as those testing above 24 ppm and with no additional P. **Results suggest that it may be a good soil management strategy to gradually build up P soil test level, rather than applying small annual applications which are barely adequate for each year's crop.**

It was interesting to note that the way yield increased with each increase in P rate was slightly different for each of the soils. In all three, however, yield continued to increase up to a P rate as high as 80 lb/A.

TABLE 2. Olsen P soil test levels of each soil following P fertilization.

P added, lb/A	Olsen P level after fertilizing, ppm Glendive fsl	Havre l	Heldt sic
0	3.0	7.2	2.4
10	4.0	7.7	3.7
20	6.1	8.9	6.5
30	6.0	15.4	9.1
40	8.9	13.0	8.9
60	9.9	14.5	11.3
80	18.0	18.3	19.3
120	32.3	31.8	26.3
240	61.5	56.0	51.9

Table 2 and **Figure 2** show soil test P levels after fertilizer was applied to each of the soils. Soil test P levels continued to increase, up to almost 60 ppm, when an equivalent of 240 lb/A of P was applied. In general, about 4 lb/A of P (10 lb/A P_2O_5) was needed to raise the soil test P level 1 ppm. Regardless of whether the initial soil test P level was low or high, it still took about 4 lb P/A to raise the soil test level 1 ppm.

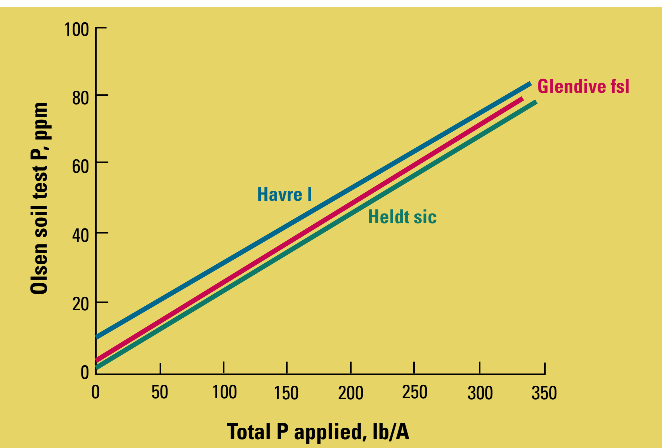

Figure 2. Change in soil test P level of three eastern Montana soils receiving increasing rates of P fertilizer (source was 0-45-0).

The study revealed that if a soil tested at 8 ppm (Olsen method) to start with, and a farmer wanted to raise the level to 18 ppm, he would calculate: [18 ppm (desired level) minus 8 ppm (starting level) x 4] = 40 lb of additional P needed per acre. Since fertilizer such as 18-46-0 is 46 percent P_2O_5 and P_2O_5 is 43 percent P, it would take the equivalent of about 200 lb of actual fertilizer material to raise the soil test level from 8 to 18 ppm.

Researchers only looked at short-term effects; it is likely that over a longer period, greater amounts of P would be "fixed" by the soil and more P would be needed to raise test levels. Data do not show what happens to soil tests over long periods of wetting and drying, freezing and thawing. Other research results indicate that the newly established soil test level would probably decrease somewhat for a few weeks or months.

In summary, keep in mind that all of the soils used in this study were from eastern Montana; the pH of each soil was greater than 8.0 (alkaline), and the lime (calcium carbonate level) ranged from 2.5 to 6.1 percent. Also remember that this study was conducted in the greenhouse under ideal conditions: plenty of water and all other nutrients were supplied abundantly. Under actual field conditions, other factors such as available water and temperature would probably limit yields so that a continued response to P at very high rates would probably not occur.

Observations:

- There does not seem to be any one soil test level at which response to fertilizer stops. However, when the soil test P level was above 30 ppm, the crops showed nearly no response to additional P additions.
- Two different approaches to P fertilization strategy can be seen here. They are: 1) build the soil test level and then supply only low amounts of P annually; or 2) maximize the return on each dollar spent on P fertilizer on your farm by applying higher rates of fertilizer on fields with low testing soils, and lower rates of fertilizer on fields with high testing soils.
- Finally, the value of a soil test for helping make wise P fertilizer decisions cannot be overemphasized.

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Information Agriculture Conference

The 1997 InfoAg Conference at the University of Illinois-Urbana attracted about 800 participants August 6-8. The three days of educational sessions and workshops featured more than 80 speakers and presenters. Over 50 exhibits displayed products and services related to precision agriculture. The 1997 event, organized by PPI and the Foundation for Agronomic Research, was the third Information Agriculture Conference.

Labor's Rewards

Itching for what you want doesn't help;

you've got to scratch for it.

What is fair pay for an honest day's work?

As an engineering graduate at the time of the Great Depression, my pay was $2.25 for a 12 hour day, and I felt lucky to get it. In charge of major construction, it was probably the most responsible job I ever had.

Today, a professional athlete's income often exceeds a million dollars a year. Pay of executives in the Fortune 500 companies runs into the millions. A sign in my auto shop says labor costs are $49 an hour. Professors, always considered poorly paid, now may receive $100,000 or more annually. Engineers, construction tradesmen, autoworkers, accountants...take a look at almost any profession today, and you might be surprised at how the income levels have escalated.

Someone asked me, "What about those rich farmers who get 70 cents for one tomato?" How badly misinformed is the public! It's difficult to find accurate figures on rate of earnings per hour for farmers...men and women. Their work hours are long—and with no paid vacation, no sick leave, no health insurance provided, and no retirement program.

Yet the hard work and dedication of farmers and their families go largely unnoticed and unappreciated in our society today. While most farmers...men and women...don't draw a regular paycheck, they probably face a more demanding work schedule and considerably more financial risk than almost any of their non-farm neighbors.

When I drive past row after row of expensive new houses in the suburbs, I sometimes think of farmers' net incomes and their vital place in our economy. I wonder...how long until we recognize the real value of their contribution?

J. Fielding Reed

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