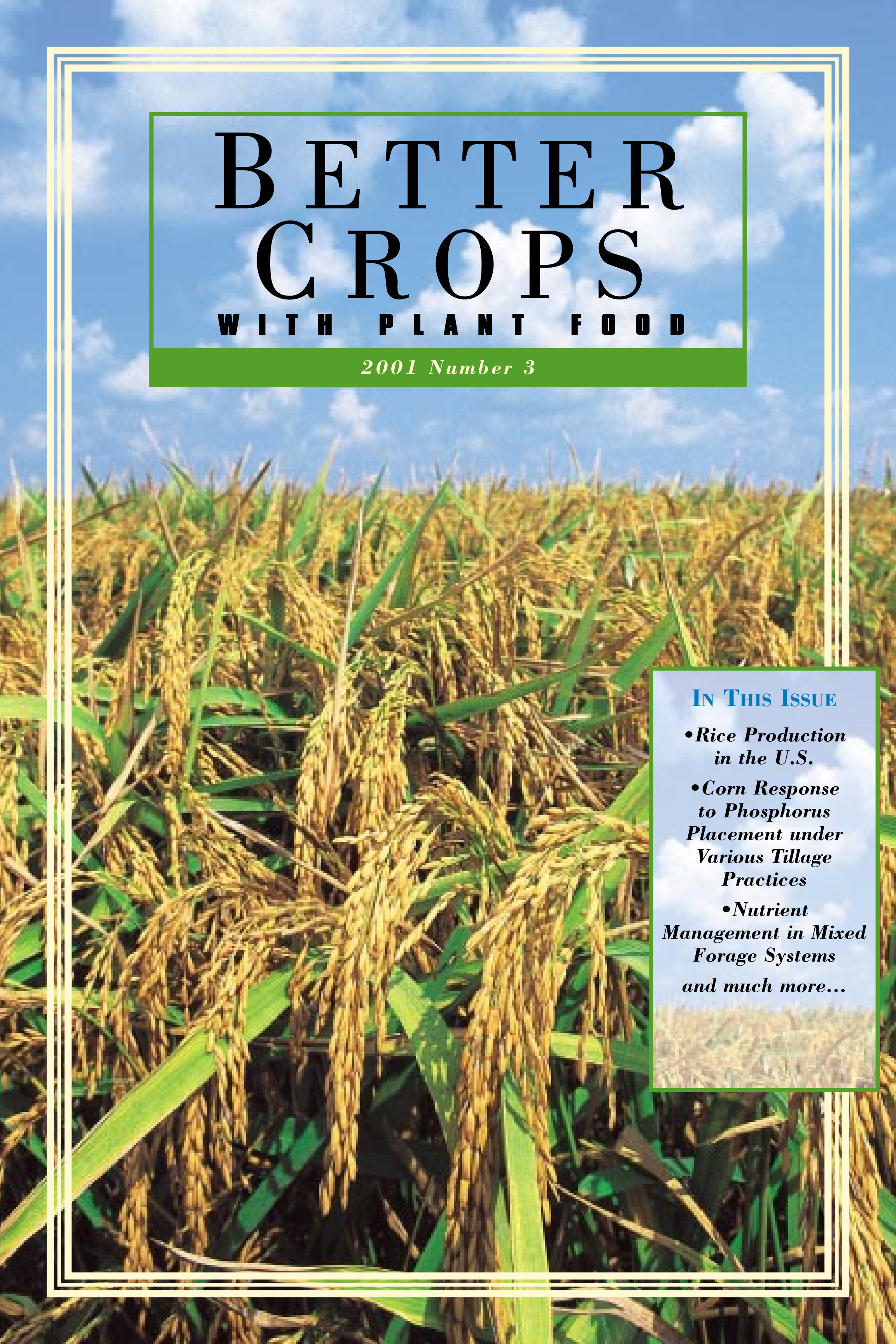

BETTER CROPS

WITH PLANT FOOD

2001 Number 3

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- ***Corn Response to Phosphorus Placement under Various Tillage Practices***
- ***Nutrient Management in Mixed Forage Systems***

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BETTER CROPS
WITH PLANT FOOD

Vol. LXXXV (85) 2001, No. 3

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UNITED STATES

Rice Production in the United States – an Overview

By C.S. Snyder and N.A. Slaton

Rice is the staple food of more than one-half of the world's population. Archeologists suggest that rice cultivation began in China more than 5,000 years ago. Rice culture in the U.S. began in the Carolinas and Georgia about 300 years ago and is one of the nation's oldest agri-businesses. After the Civil War, cultivation shifted westward to the lowlands of Louisiana and Texas.

Modern rice production in the U.S. has concentrated in Arkansas, California, Louisiana, Mississippi, Missouri, and Texas, using different cultural production practices. The first U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) records for rice indicate 292,000 acres were harvested in 1895 with a yield of 1,140 lb/A. Harvested area increased to more than 1 million acres in 1919, 2 million in 1959, and 3 million in 1980. The greatest harvested acreage to date was 3.79 million acres in 1981, with an average yield of 4,820 lb/A.

> The combined effects of higher-yielding varieties, better fertility management, threshold-based pest management, and intensive irrigation management have enabled rice producers in the U.S. to continuously increase national average rice yields since the early 1980s.

State and national rice yields are shown in **Figure 1**, for 1950 and every five years since. The highest national average yield was reported in 2000 at 6,240 lb/A for 3.08 million acres. Seventy-three percent of the rice acreage grown in 2000 was long grain, 26 percent was medium grain, and about 1 percent was short grain rice. California has the highest average yields (**Figure 1**), while Arkansas has the greatest acreage (**Figure 2**). A single crop is harvested from most U.S. rice fields each year. In Texas and southwest Louisiana, a second or ratoon crop may be harvested from a single planting because of the longer growing season.

U.S. rice acreage has shifted from year to

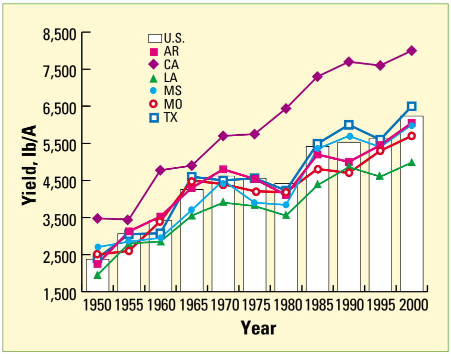

Figure 1. U.S. and state average rice yields – 1950 to current. Source: USDA-NASS

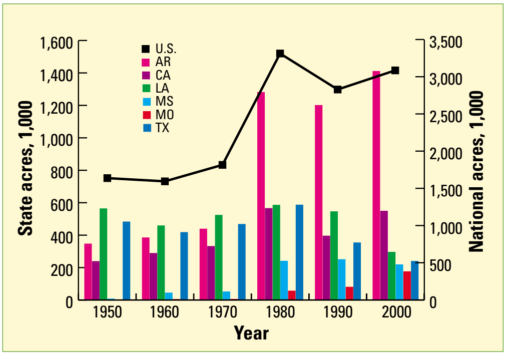

Figure 2. State and U.S. rice acreage harvested – selected years. Source: USDA-NASS

year depending on many factors: marketing quotas, government acreage allotments, export demand, production deficiency payments, acreage reduction programs, water availability, and the ‘freedom-to-farm’ government policy. Production costs vary among the rice producing states and are influenced by factors such as seeding method, soil type, and variety-dependent nitrogen (N) rate. Average U.S. price per hundred weight (cwt) ranged from $2.00 in the early 1920s to a high of over $12.80 in 1980. It is currently around $6.00/cwt (**Figure 3**). Total direct production costs (excluding fixed expenses: tractors, implements, self-propelled equipment, and irrigation systems) have varied from about $290 to $388/A/year. Fertilizer costs have ranged from about $44/A for N-only programs to $66/A for N, phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) programs in the Midsouth to $86/A for N and P programs in California. Fertilization costs account for about 13 to 26 percent of the annual direct production costs.

Fertilization

Nitrogen is the fertilizer nutrient required in the greatest amount for maximizing rice yields. Fertilizer N use efficiency (NUE) is usually greatest in dry-seeded production systems when it is applied to dry soil, just prior to permanent flood establishment. Urea is the most common N source because of its high analysis and relatively low cost per pound of N. Only ammonium-N (NH_4-N) fertilizer sources are recommended because the NH_4 is stable under flooded soil conditions. Nitrate-N (NO_3-N) sources are subject to denitrification losses after flooding and are not recommended for use. Nitrogen is often applied up to three times during the season. Approximately 50 to 70 percent of the total N rate is applied at preflood, 15 to 25 percent at $^1/_2$-in. internode elongation (IE), and 15 to 25 percent at 10 to 14 days after $^1/_2$-in. IE. Isotopic N studies have shown that plant recovery of urea-N fertilizer can approach 70 to 75 percent when applied in a three-way split.

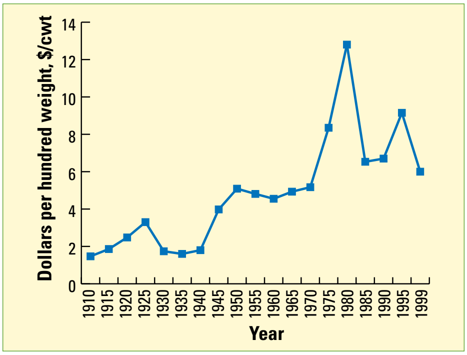

Figure 3. Average U.S. rice price.
Source: USDA-NASS

Grain yield and NUE are reduced when: flood establishment is delayed after the preflood fertilizer N application; fertilizer N is applied to a wet soil; and/or N fertilizer is applied into the floodwater for seedling rice uptake. The goal with the preflood application is to incorporate fertilizer N into the soil with the floodwater. This positions N in the root zone, below the oxygenated soil-water interface, limiting nitrification and potential for subsequent denitrification. According to research and monitoring of water quality in Texas and Arkansas, N and P concentrations in surface runoff from flooded commercial rice fields are frequently lower than groundwater pumped onto the fields. The rapid nutrient uptake and filtering effects of rice make runoff N and P losses negligible under recommended fertilizer and irrigation management practices.

The appropriate agronomic N rates and best times of application are determined by each state based on variety and cultural management-specific research. Prior to 1995, a three-way split application of N fertilizer was common in the Midsouth. A two-way split (preflood and at IE) has recently replaced the three-way split in the Midsouth states because of more precise irrigation management and increased planting of short-season, stiff-strawed cultivars.

Recent legislation in California is phasing out the common practice of rice straw burning. Straw must either be incorporated or removed from fields. Many rice farmers in California and the Midsouth reflood fields in the winter months to create a more favorable habitat for waterfowl. The impact of these practices on nutrient cycling, especially N, K, and carbon (C), and management of pre- and post-plant nutrients is currently being studied.

Research suggests that maximum rice yields can be obtained using less total seasonal fertilizer N when the majority of N is applied immediately before flooding during vegetative growth. Thus, recommendations are shifting towards the use of a single, large preflood N rate with fertilizer NUE monitored at midseason growth stages. Where it is difficult to establish or maintain a permanent flood in a timely manner, many farmers continue to use a two-way split: 60 to 120 lb N/A (depending on variety) preflood with the remainder (about 60 lb N/A) applied at midseason, beginning at IE to $^1/_2$-in. IE. The N rate on clay soils is generally 20 to 30 lb N/A greater than that recommended for silt loam soils. The need for a midseason N application in the Midsouth is increasingly based on plant biomass estimates of total N uptake using a plant area reference board, calibrated and specific for the variety and growing degree unit [DD-50 (degrees Fahrenheit)] accumulation. The DD-50 program is used extensively in Arkansas and some adjacent states to assist growers in making up to 26 management decisions. In Texas, and other areas, midseason N requirements are sometimes based on chlorophyll meter readings from recently matured leaves. In California and other states, laboratory N analysis of sampled flag leaf or Y-leaf tissue determines the need for midseason N. Midseason fertilizer applications are typically made by airplane or helicopter.

In an effort to reduce weed pressure from red rice, water-seeded systems are sometimes used, especially in Louisiana. In water-seeded, permanently flooded systems, the maximum response to N is achieved by NH_4-N preplant incorporated 2- to 4-in. deep into a dry seedbed before flooding. Additional N is applied at midseason as needed. It is sometimes beneficial to broadcast some of the N during the pin-point drain (after water seeding to ensure anchoring of roots) and prior to reflooding.

Balanced fertilization with P, K, S, and Zn in many rice fields is essential for production of high yielding rice and to attain maximum NUE. These nutrients are usually applied to silt and sandy loam soils based on soil test recommendations. Rice farmers commonly use 30 to 60 lb P_2O_5/A, 60 to 90 lb K_2O/A, and from 10 to 20 lb S/A. Although infrequent, silty clay and clay soils may also receive P, K, and S fertilizers. Zinc is often applied on many alkaline silt loam soils (pH > 7.0) and occasionally to clays at rates from 1 to 10 lb Zn/A, depending on the Zn source and time/method of application. Deficiencies of these nutrients can reduce plant growth, encourage disease development, interfere with normal plant maturity, and limit yield.

Historically, P and K fertilizers were seldom applied directly to rice. Rice relied on residual P and K from fertilizer applied to other crops in the rotation. Early research indicated that rice yield responses to P fertilization were infrequent because P was released from iron (Fe) and aluminum (Al) compounds in the soil upon flooding. Now, many rice fields have a long history of irrigation with well water (groundwater), and significant amounts of calcium bicarbonate have been deposited. Soil pH has risen to the alkaline range, and forms of soil P have shifted to include calcium phosphates, which are not as affected by reduction upon flooding. Recent research suggests that economic rice yield responses to P fertilization are most likely to occur on alkaline soils or where land-forming has removed topsoil. Soil test summaries from several Midsouth states reveal that soils used for rice production generally have some of the lowest P and K soil test levels compared to those used for the production of other major field crops (**Figures 4** and **5**). Most of the

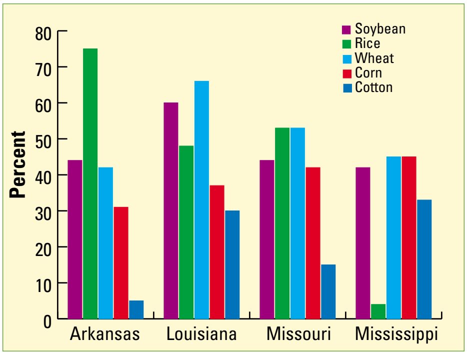

Figure 4. Crop acreage (%) with medium or lower soil test P in selected states (1995-96).

soils used for rice production in Texas and Mississippi are acid to strongly alkaline silty clays and clays that do not test as low in P and K as the silt loam soils in other states. Soil test P levels for these clayey soils in Mississippi and Texas range from low to high, and K levels often test in the high range. In Arkansas, the responses to recommended rates of P have ranged from 10 to 50 bu/A on alkaline silt loams testing medium or lower in Mehlich 3 P [<15 to 25 parts per million (ppm)]. Responses to K typically range from 10 to 30 bu/A on soils testing medium or lower in Mehlich 3 K (<88 ppm). In response to the increased frequency of P and K deficiencies in rice, university research efforts and industry and Extension educational programs concerning crop nutritional requirements have intensified. More Midsouth farmers have begun to apply maintenance rates of P and K to silt loam soils, equivalent to the rate of harvest removal (0.29 lb P_2O_5/bu and 0.18 lb K_2O/bu). Failure to increase or at least maintain soil test P and K levels on soils used for rice production has been blamed for compromising Midsouth soil fertility management and lowering the yield potential of rotational crops such as wheat, soybeans, corn, and grain sorghum.

Land Preparation, Planting, Irrigation

The majority of U.S. rice has typically been planted with seed drills on prepared seedbeds following several tillage and smoothing operations. Seed are usually drilled at about 40 seed/ft^2 under ideal conditions, to provide a uniform stand of about 15 to 20 plants/ft^2. Adjustments from the standard seeding rate are made for different varieties, tillage systems, seeding methods, and environmental conditions.

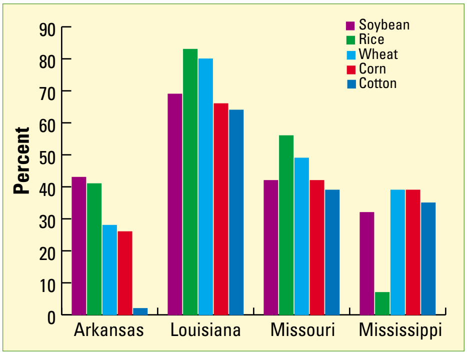

Figure 5. Crop acreage (%) with medium or lower soil test K in selected states (1995-96).

Many fields are shaped to a uniform grade to facilitate efficient flood irrigation and field drainage prior to harvest. Either before or after planting, levee locations are laser surveyed and marked. After planting in dry-seeded systems, levees (soil burms) are established at 0.1- to 0.2-ft. elevation intervals using levee discs or squeezers. The levees are established on the contour, except where precision leveling has been conducted to facilitate straight levees. Rice seeds are usually broadcast on the levees and incorporated during the last trip(s) over the levee in the forming process.

Levee gates, or spills, are established in each levee using metal and/or vinyl frames, to permit maintenance of a shallow 2- to 4-in. flood depth in each paddy throughout the growing season. Desirable irrigation pumping capacities from wells, surface reservoirs, and streams enable farmers to flush water across an entire field (40 to 160 acres) in three to four days and to flood a field in three to five days. Precise flood irrigation management is one of the most important factors affecting NUE and integrated pest management practices. Irrigation is stopped, and fields are drained about 14 and 25 days after heading, respectively.

Pest Management

Field scouting is used to detect weed, disease, and insect infestations and to time pest management practices. Plant protectants are applied in-season based on research-based treatment thresholds in integrated pest management programs. Plant nutritional status, as affected by nutrient management, may impact rice response to pests and pest management strategies. The relative level of soil fertility most dramatically affects disease reaction. Inadequate or excessive fertilization, especially with N, may increase the frequency and severity of many rice diseases. Ensuring adequate K nutrition has reduced the incidence of brown leaf spot, stem rot, and some other diseases. Sheath blight (*Rhizoctonia solani*), blast (*Pyricularia oryzae*), straighthead (physiological disorder), stem rot (*Sclerotium oryzae*), kernel smut (*Neovossia barclayana*), black sheath rot (*Gaeumannomyces graminis* var. *graminis*), brown spot (*Cochliobolus miyabeanus*), brown leaf spot, (*Bipolaris oryzae*), scab (*Fusarium graninearum*), Fusarium sheath rot (*Fusarium proliferatum*), and other diseases are managed/controlled through selection of tolerant/resistant varieties, balanced fertilization, rice stubble management, and rotation to non-host crops.

Summary

Rice grower support of public breeding and management research programs has led to the release of high-yielding short-statured and semi-dwarf varieties. The combined effects of higher-yielding varieties, better fertility management, threshold-based pest management, and intensive irrigation management have enabled U.S. rice producers to continuously increase the national average rice yields since the early 1980s. The adoption and use of site-specific management technologies such as global positioning system (GPS)-referenced yield monitoring, variable rate or management-zone application of nutrients and soil amendments, remote sensing, etc. are increasing, especially where significant precision land leveling has been performed to improve irrigation water use efficiency. The trend toward improved management and higher U.S. rice yields is likely to continue as the world demand for rice grows.

Dr. Snyder is PPI Midsouth Director, located at Conway, Arkansas; e-mail: csnyder@ppi-far.org. Dr. Slaton is former Extension Agronomist-Rice, University of Arkansas, previously located at the Rice Research and Extension Center at Stuttgart, Arkansas. He is currently Assistant Professor and Director of Soil Testing and Plant Analysis programs at the University of Arkansas in Fayetteville; e-mail: nslaton@uark.edu.

New Handbook on Rice Nutrient Management Now Available

The International Rice Research Institute (IRRI) in the Philippines has forecast that rice yields must increase by 30 percent by 2020 to keep pace with growing demand due to population increases.

A new handbook published by IRRI and PPI/PPIC describes site-specific nutrient management methods and provides a reference to assist with the identification and management of nutrient disorders. Titled *Rice: Nutrient Disorders & Nutrient Management*, the 191 page book is authored by Dr. Achim Dobermann, formerly with IRRI and now with the University of Nebraska, and Dr. Thomas H. Fairhurst, Deputy Director, PPI/PPIC East and Southeast Asia Program, Singapore.

Oriented to production in tropical and subtropical regions, topics include rice ecosystems, nutrient management, nutrient deficiencies, and mineral toxicities. Estimates of nutrient removal in grain and straw are included to help researchers and extension workers calculate the amount of nutrients lost from the field under various management systems. The publication will improve understanding of new approaches to nutrient management at the farm level.

The book with CD-ROM is available for purchase. The price (including shipping/ handling) is US$32.00 in less developed countries and US$77.00 in highly developed countries. For more details, check the website at **www.eseap.org**, or contact Doris Tan, PPI/PPIC (ESEAP), 126 Watten Estate Road, Singapore 287599. E-mail: dtan@ppi-ppic.org, phone: 65 468 1143, or fax: 65 467 0416.

ALBERTA

Mapping Soil-Available Phosphorus: Considering Changes in Crop Yield and Fertilizer Sales

By Paolo Manunta, Len Kryzanowski, and Doug Keyes

In recent years, there has been increased interest in agricultural practices associated with the application and movement of soil P. The use of fertilizer has increased almost every year since 1945 in western Canada. Phosphorus is removed from the soil by plant uptake or lost by soil erosion and runoff. Crops remove varying amounts of P from the soil. With the changes in agricultural practices occurring across the Canadian prairies, it is timely to assess how the use of fertilizer is reflected in the amount of plant-available soil P measured by soil test.

In most areas of Alberta, soil phosphorus (P) has stayed the same or decreased by up to 40 percent over a 30-year period.

A data set that included more than 150,000 soil test records collected between 1963 and 1967 was obtained from Alberta Agriculture Food and Rural Development (AAFRD). It was compared with a 1993 to 1997 data set provided by Norwest Labs and containing about 130,000 samples. Data recorded over the 1963 to 1967 time period were obtained using the Miller and Axley extraction method (0.03N NH_4F + 0.03N H_2SO_4), while the data recorded during the 1993 to 1997 time period were obtained using the Norwest Labs modified Kelowna method (0.015N NH_4F + 0.5N HOAc + 1N NH_4OAc). In order to reconcile the discrepancy in the measuring protocol, we performed a simple regression analysis using

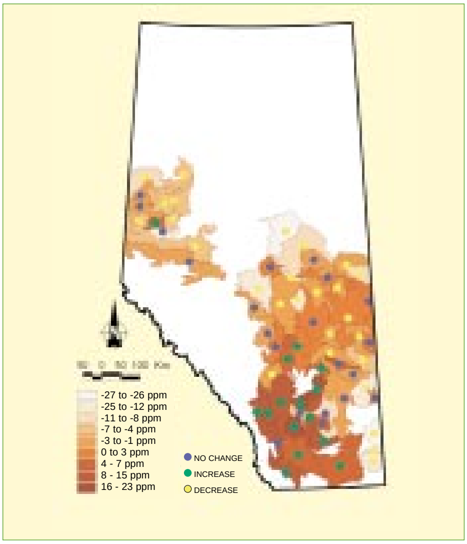

Figure 1. Changes in available P for rainfed annual crops, 1963-67 vs. 1993-97.

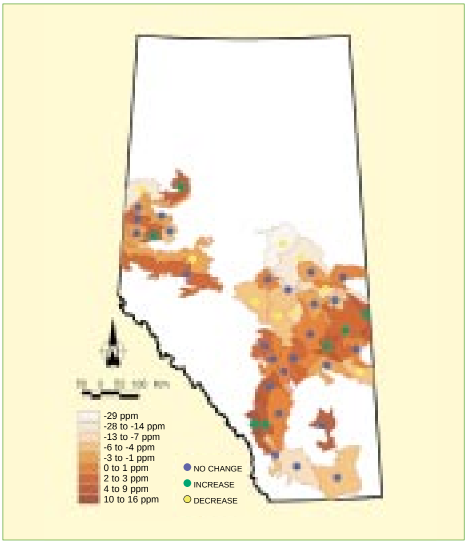

Figure 2. Changes in available P for rainfed perennial crops, 1963-67 vs. 1993-97.

data previously published elsewhere for Alberta. The data used for analysis were for the 0- to 6-in. soil depth, divided into two cropping classes, annuals and perennials. In this summary, data from only rainfed fields are included, with irrigated fields excluded. Crops such as wheat, barley and canola were grouped in the annual crop class, as was fallow. Grassland, alfalfa and clover are typical examples of the crops included as perennials.

Data were grouped on the basis of ecodistricts for analysis. Ecodistricts are part of a Canadian nationwide system of categorizing areas with similar land, climate and vegetation characteristics. There are 94 ecodistricts in Alberta, spanning over 50 million acres of land. Student's *t* test was used to identify statistically significant trends in soil available P that occurred over time in 62 ecodistricts for rainfed annual crops and 40 ecodistricts for rainfed perennials.

After 30 years of cropping, the comparison revealed that soil-available P for rainfed annual crops did not change in 20 ecodistricts, increased in 15, and decreased in 27 (**Figure 1**). For rainfed perennial crops, soil-available P from the 1960s compared to the 1990s remained unchanged in 24, increased in 7, and decreased in 9 ecodistricts (**Figure 2**). Although there are some ecodistricts with a high proportion of fields with excess or optimum soil P for crop production, most soils in Alberta are deficient or marginal in soil P. For the recent 1993 to 1997 time period, 46 out of 62 (74 percent) ecodistricts for the rainfed annual crops (**Figure 3**) and 35 out of 40 (87 percent) for the rainfed perennial crops (**Figure 4**) had a soil P concentration equal to or lower than the 25 parts per million (ppm) level used to designate a crop response to P amendment.

The use of commercial fertilizer in both the U.S. and Canada has increased steadily since the 1950s, primarily as a result of higher application rates. An analysis of the fertilizer sales data for Canada reveals that the P sales in Alberta have increased at a slower rate than nitrogen (N) sales. In particular, while P sales doubled from 1968 to 1998, N sales increased five-fold over the same period. Although a number of concurrent factors should be considered, it is generally accepted that higher use of N fertilizer results in a higher biomass production. Therefore, if the amount of applied P fertilizer is not increased proportionally, the net uptake of P per volume of soil increases with the higher yields. This may result in a decrease in plant-available soil P.

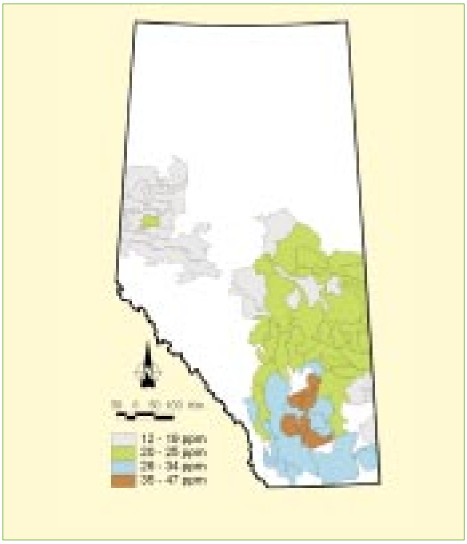

Figure 3. Available P for rainfed annual crops, 1993 to 1997.

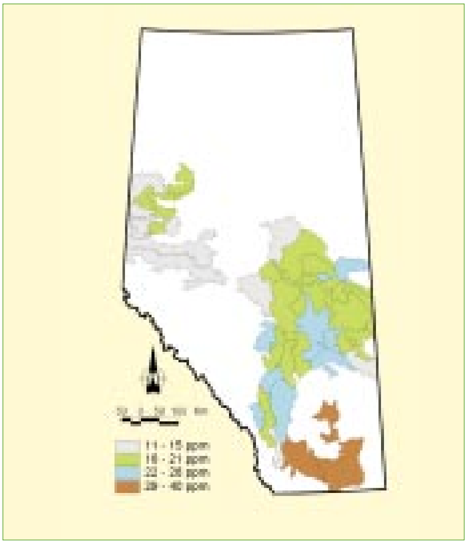

Figure 4. Available P for perennial annual crops, 1993 to 1997.

The progressive increase in yields for annual crops since the 1960s is illustrated in **Figure 5**. Annual crop values were obtained by averaging the yields across major crop types. An increase in perennial yields was also found between 1963 through to the early 1990s, after which perennial yields are characterized by a decreasing trend.

The changes in soil P recorded over the 30-year period were found to be more numerous on those soils cultivated with annual crops than those with perennials. A possible reason for soils with perennial crops being less affected by changes in soil P over time could be related to changes in management practices. Although a specific investigation is needed, we hypothesize that changes in the use of fertilizer have been more widely adopted in the production of annual than with perennial crops.

The practice of fertilizer band application with annual crops has resulted in more efficient and economical use of P by placing the fertilizer close to the plant roots. Traditionally, the P fertilizer has been seed-row applied for cereal crops and top-dressed for forage crops. During the 1980s, the widespread adoption of deep (3- to 4-inch) banding of N fertilizer, often in combination with P, was also effective in reducing immobilization of P on these dominantly alkaline soils. Good crop responses obtained with banded or seed-row application of P fertilizer on annual crops have been the key factor in changing fertilizer practices toward a more efficient and economical use of P.

Major technological advancements in the way P fertilizer is applied to perennial crops, such as low disturbance banding or injection of P, have not been widely adopted. Therefore, we could speculate that the lack of major changes in technology could be another cause for the higher number of ecodistricts that show no changes in the soil P level over time on perennial crops.

In summary, available soil P did not increase consistently from the 1960s to the 1990s despite increased fertilizer application rates. Although there are some ecodistricts with a high proportion of fields with excess or optimum soil P for crop production, most soils in Alberta are deficient or marginal in soil P. Soil P levels and soil testing are required to develop a nutrient management plan to encourage optimum economic crop production.

Dr. Manunta is a resource data analyst (e-mail: paolo.manunta@gov.ab.ca) and Mr. Kryzanowski is a crop nutrition agronomist with Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada. Mr. Keyes is a soil scientist with Norwest Labs, Edmonton, Alberta, Canada.

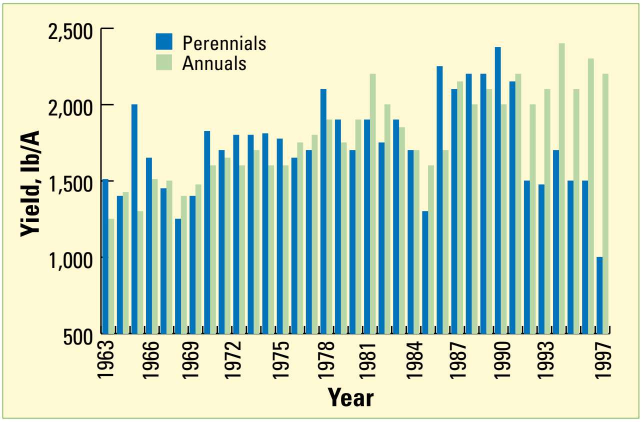

Figure 5. Provincial yield averages grouped by annual and perennial crop classes. Original source of data: Agriculture Division, Statistics Canada.

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A copy of the full report on this research is available from the senior author at the e-mail address above.

Dr. Keith A. Kelling Receives Robert E. Wagner Award

Dr. Keith A. Kelling of the University of Wisconsin-Madison has been selected as the 2000-2001 recipient of the Robert E. Wagner Award (Senior Scientist) by the Potash & Phosphate Institute (PPI). The annual recognition, which encourages worldwide candidate nominations, includes a plaque and an award of $5,000.


Dr. Keith A. Kelling

Dr. Kelling who has been with the Department of Soil Science at the University of Wisconsin since 1977, is now Professor and Extension Soil Scientist. He is widely recognized as an innovative leader in Extension and applied research programs in nutrient management. His efforts have effectively increased productivity, efficiency, and profitability on Wisconsin farms while maintaining or improving environmental quality. Dr. Kelling is also well-respected regionally and nationally. He has contributed to numerous professional publications.

The Robert E. Wagner Award recognizes distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The award honors Dr. Wagner, President (retired) of PPI, for his many achievements and in recognition of the MEY concept...for profitable, efficient agriculture.

"We congratulate Dr. Kelling for notable achievements in his profession," said Dr. David W. Dibb, President of PPI. "The standards for this award are high, and those chosen are truly deserving of recognition." Nominations were received from North America and other regions of the world. No award was presented this year in the Young Scientist division.

A basic component in Dr. Kelling's programs is the integration of economic considerations into nutrient management decisions. He developed a well-received Extension program entitled 'Getting the most from your fertilizer dollar' that emphasized improved efficiency of purchased nutrients, complete crediting of on-farm nutrient sources, and innovative ideas for improved profitability.

Dr. Kelling has made important contributions to development and implementation of research-based soil testing and plant analysis programs. His research on alfalfa responses to potassium (K) rates, sources and timing has created a comprehensive database for determining crop K needs based on soil test results.

Soil fertility management in vegetable crops, especially potato and vegetables grown on organic soils, is also a major component of his program. Dr. Kelling has determined K rates and sources for optimum potato yield, quality, and disease control.

Dr. Kelling's work on manure management addresses a critical need in Wisconsin, where appropriate use of manure in livestock and crop farming systems has important agronomic and environmental implications.

Involving agrichemical dealers in helping farmers make informed nutrient management decisions is one of the priorities of Dr. Kelling's program. He has vigorously promoted implementation of the Certified Crop Adviser (CCA) program in Wisconsin. For the past 22 years, Dr. Kelling has coordinated the Wisconsin Fertilizer, Aglime and Pest Management Conference.

A native of Edgerton, Wisconsin, Dr. Kelling completed his B.S. degree in 1966, M.S. in 1972, and Ph.D. in 1974, all at the University of Wisconsin-Madison. He is a member of the Soil Science Society of America and a member and Fellow of the American Society of Agronomy. He has been recognized with numerous other honors and awards and holds membership in several other professional and honorary organizations. BC

Corn Response to Phosphorus Placement under Various Tillage Practices

By G.W. Randall, J.A. Vetsch, and T.S. Murrell

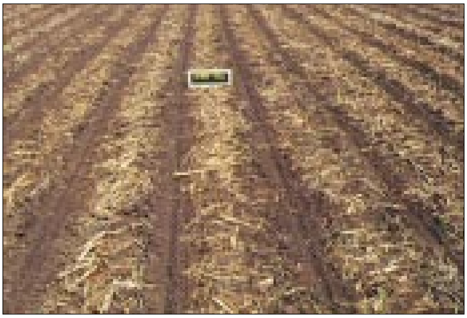
Under very low soil test phosphorus (P) levels, large responses to P were observed for all placements. Banded applications at half the recommended broadcast rate were not sufficient to optimize corn grain yield.

Row-crop agriculture in the Mississippi River Basin is under intense pressure to reduce sediment and nutrient losses by practicing less tillage and more precise application and placement of nutrients, especially nitrogen (N) and P. By keeping more crop residue at the soil surface, no-till can reduce sediment losses. However, no-till corn production has provided serious challenges to corn growers in the northern portions of the Corn Belt and has not been economically competitive with conventional tillage systems. This is especially true on the highly productive but poorly drained clay loam soils of northern Iowa and southern Minnesota where approximately 8 million acres are in corn production annually. In these northern climates, where soils are cold at the time of planting and are slow to warm, alternatives to no-till are being examined.

Conservation tillage alternatives currently used are strip tillage and one-pass secondary tillage. Strip tillage (strip-till), or zone tillage, disturbs the soil to a depth of 7 to 8 in. and creates a 4 to 6 in. wide by 1 to 2 in. high mound of soil that is free of residue (see photo). Corn can be planted early and directly into the strip area that is warmer and drier. One-pass secondary tillage consists of no primary tillage in the fall and either field cultivation or a disking operation in the spring. This system is now quite popular for corn following soybeans in the Corn Belt.

In conservation tillage systems, placement of P is an important management consideration. Less soil disturbance limits the opportunity for incorporation of P fertilizers that are broadcast on the soil surface. Banded applications of P, as with starters or deep banding, serve as viable alternatives to broadcast applications. Application of P below the soil in bands serves two purposes: 1) It places P in the soil volume where it is easily accessed by roots and 2) concentrated zones of P can decrease P fixation, making it more readily available for plant uptake. For these reasons, the University of Minnesota recommends that rates of banded P be reduced to half the recommended broadcast rate at Bray P-1 levels of greater than 5 parts per million (ppm). We tested this recommendation to understand how best to manage P for the various tillage practices currently being used.

A study was begun in the fall of 1996 on a tile-drained Nicollet-Webster clay loam soil complex located at the Southern Research and Outreach Center, Waseca, Minnesota. The study utilized a corn-



Distribution of residue is shown in a field where strip tillage has been performed.

soybean rotation and several P and tillage management practices on two adjacent sites. The high P site had been previously maintained at approximately 19 ppm Bray P-1 with periodic P fertilizer applications while in a corn-corn-corn-soybean rotation. The low P site had previously been in continuous corn and received no P for 15 years, resulting in very low levels (3 to 4 ppm Bray P-1). Tillage practices were no-till, one pass of a field cultivator in the spring (one-pass), fall strip-till, and conventional tillage (conventional) utilizing a chisel in the fall plus a field cultivator in the spring.

Phosphorus application methods for all tillage practices included a check (no P) and a band application in the seed furrow at planting (starter). Broadcast applications (bdcst.) with subsequent incorporation were made for the one-pass and conventional systems. The starter and broadcast P rates applied prior to corn every other year were 40 and 80 lb P_2O_5/A, respectively, for the high testing site and 50 and 100 lb P_2O_5/A, respectively, for the low testing site. For the strip-till and one-pass tillage practices, deep band P applications were made in the fall, prior to the next season's corn crop, at rates of 40 lb P_2O_5/A for the high testing site and 50 lb P_2O_5/A for the low testing site. In the strip-till system, two types of band positions were tested. In the fixed band treatment [deep band (f)], the band was placed about 5 in. deep with the strip tiller in approximately the same place prior to each corn year. In the random band treatment [deep band (r)], the placements were offset by 8 in. between the two years when they were applied. In the one-pass system, the fall band treatment was placed about 5 in. deep in a band that ran at about a 2° angle to where the corn row was planted. This assured that the fertilizer band was not located continuously under the corn row, but varied from directly under the row to as much as 15 in. from the row.

Corn (Pioneer 36R10) was planted in 30 in. rows at a population of 32,000 seeds/A. Banded applications of P also contained a small amount of N. It was applied in the bands at rates of 15 to 20 and 11 to 16 lb/A at the low and high P sites, respectively. Small amounts of supplemental N, applied as a surface dribble, were added near the rows of plots not receiving banded P applications. This allowed the effects of P placement to be isolated and evaluated separately from the effects of N placement. Additional N to meet the season-long need was broadcast as urea + Agrotain on all plots two weeks after planting.

Tillage Effects

The low P site had no significant difference among tillage practices; yields were 121, 129, 128, and 128 bu/A for the no-till, one-pass, strip-till, and conventional systems, respectively, averaged over the four years. On the high P site, the one-pass, strip-till, and conventional systems produced similar yields of 169, 167, and 171 bu/A, respectively. The no-till system produced significantly lower yields than the others, averaging 160 bu/A.

In **Table 1** and the following tables, the high P site exhibited higher overall yields

TABLE 1. Corn grain yield response to starter fertilizer under no-till, one-pass, strip till, and conventional tillage practices on sites testing high and low in soil test P.

Tillage	P application method	P_2O_5 applied, lb/A High P site	P_2O_5 applied, lb/A Low P site	Grain yield, bu/A (1997-2000 avg.) High P site	Grain yield, bu/A (1997-2000 avg.) Low P site
No-till	none	0	0	160	102
	starter	40	50	159	141
One-pass	none	0	0	168	104
	starter	40	50	171	153
Strip-till	none	0	0	164	103
	starter	40	50	169	151
Conventional	none	0	0	171	103
	starter	40	50	172	154
Average	none			166	103
	starter			168	150

than the low P site. Although a statistical comparison between the two sites is beyond the scope of this study, the higher yields associated with the high P site are suspected to be largely due to better P soil fertility.

Corn grain yield response to starter fertilizer applications are shown in **Table 1**. At the high P site, no significant response to starter was observed for any tillage practice. At the low P site, significant responses to starter occurred for all tillage systems. Yield increases were 39, 49, 48, and 51 bu/A for the no-till, one-pass, strip-till, and conventional tillage practices, respectively. Corn grain yield responses behaved similarly for each tillage practice. The overall response to starter, averaged across all tillage systems, was 47 bu/A.

TABLE 2. Corn grain yield response to starter and broadcast applications for one-pass and conventional tillage practices on sites testing high and low in soil test P.

Tillage	P application method	P_2O_5 applied, lb/A		Grain yield, bu/A (1997-2000 avg.)	
		High P site	Low P site	High P site	Low P site
One-pass	none	0	0	168	104
	starter	40	50	171	153
	spring bdcst.	80	100	174	164
Conventional	none	0	0	171	103
	starter	40	50	172	154
	fall bdcst.	80	100	176	166
Average	none			170	104
	starter			172	154
	bdcst.			175	165

TABLE 3. Corn grain yield response to starter and deep band P applications for one-pass and strip tillage practices on sites testing high and low in soil test P.

Tillage	P application method	P_2O_5 applied, lb/A		Grain yield, bu/A (1997-2000 avg.)	
		High P site	Low P site	High P site	Low P site
One-pass	none	0	0	168	104
	starter	40	50	171	153
	fall band	40	50	164	144
Strip till	none	0	0	164	103
	starter	40	50	169	151
	fall band (f)	40	50	164	147
	fall band (r)	40	50	169	139

Testing the Efficiency of Banded P

The effects on corn grain yield of reducing banded rates to half the recommended broadcast rates are shown in **Table 2**. At the high P site, there was no response to either broadcast or banded P applications. However, at the low P site, corn grain yield was increased significantly by both application methods. Broadcast applications produced an average of 11 and 12 bu/A more than banded applications for the one-pass and conventional tillage practices, respectively. Broadcasting P in the spring followed by field cultivation (one-pass) produced similar yields to fall-applied P incorporated by a chisel. Reducing banded applications to half the recommended broadcast rate on very low testing soils was not sufficient to optimize corn yields in this study and reduced yields by an average of 12 bu/A.

Evaluating Different Band Placements

Corn grain yield responses to various band placements are shown in **Table 3**. At both the high and low P sites in the one-pass tillage system, yields were significantly lower when P was deep-banded in the fall compared to applying P in starter at planting. Significantly lower yields than those attained with starter P were also seen in the strip-till system on the low P site when fall band locations were offset from year to year [fall band (r)]. No yield reductions were detected when P was placed in the same position from year to year in the strip-till system [fall band (f)].

The lower yields for the fall, deep band P treatments described above were largely due to 12 to 21 bu/A reductions found in 2000 for these treatments. These reductions

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were surprising and are not easily understood. One possible explanation is the distance between the banded P and the seed which could have been an issue in the 2000 year when the seedbed conditions were very dry at planting. Seventeen days later and about one week after seedling emergence, frost occurred one day and temperatures were in the 30s for three days. This was followed by more than 5 in. of rain and saturated soils for the next two weeks. Therefore, reduced rates of root development could have been a factor.

Summary

Soil test P level is an important factor for understanding corn grain yield responses to various P placements and tillage practices. Placement is less of a consideration when soil tests are high. However, when soil tests are low, substantial yield increases may be seen when P is applied either broadcast or banded. Reducing banded rates to half the rate recommended for broadcast applications did not optimize yields and overestimated the efficiency of P banding in this study.

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Nutrient Management in Mixed Forage Systems

By Tim Griffin, Mary Wiedenhoeft, and Tom Bruulsema

A six-year study in Maine reveals that mixed forage stands respond well to nutrients applied in either manure or fertilizer form. Management of nutrients in these stands can improve forage yield and quality and is essential for maintenance of soil fertility.

Across eastern Canada and the northeastern U.S., more than 5 million acres of land produces hay from mixed forage stands. Many of these stands are not managed to their full potential. Producers and crop advisers tend to undervalue their role in nutrient management, both in terms of the increased forage that could be produced and the capacity to utilize surplus manure nutrients. We conducted this study to determine the capacity of a mixed-species hayfield to respond to nitrogen (N), phosphorus (P) and potassium (K) in liquid dairy manure and commercial fertilizer and to examine the associated effects on soil test levels.

The mixed hayfield chosen for this study had produced hay for more than 30 years. Located in Stillwater, Maine, it comprised a mixture of species dominated by Kentucky bluegrass, timothy, and quackgrass, with smaller amounts of orchardgrass, reed canarygrass, white clover, and dandelion. The soil was a Lamoine silt loam with less than 2 percent slope, a soil type broadly distributed in Maine and often used for forage production. Soil pH was 5.9.

Over a six-year period from 1995 to 2000, we applied nutrients each year except 1997 and 2000, using four treatments:

1. control with no nutrients applied
2. N fertilizer only [ammonium nitrate (34-0-0)]
3. blended NPK fertilizer [34-0-0, triple superphosphate (0-46-0), and muriate of potash (0-0-60)]
4. liquid dairy manure (LD manure)

The rate of LD manure was chosen to supply 75 lb/A of N to the first cutting and 50 lb/A to the second cut, based on manure analysis and assuming 75 percent of the ammonium-N and 10 percent of the organic N were available. Total rates of liquid ranged from 3,600 to 8,700 gal/A. Rates of the two fertilizer treatments matched the rates of the respective nutrients in the manure treatment and were applied with the same timing. In some years, treatments 2, 3, and 4 also received an additional 50 lb/A of N as 34-0-0 following the second cut. In the four years when nutrients were applied, the rates averaged 150 lb N/A, 125 lb P_2O_5/A, and 280 lb K_2O/A.

While yields varied greatly from year to year, plots fertilized in any way yielded 37 percent more than the control (**Table 1**).

A balanced supply of nutrients is essential for sustainable forage production, even on marginal soils.

The NPK fertilizer treatment produced yields 11 percent higher than either the manure or the N only treatment. Manure nutrients may have been less available than anticipated, and over the course of the experiment, there appears to have been a benefit to the P and K.

Forage nutrient concentrations were also affected by treatments (**Table 1**). Nitrogen, and therefore crude protein, was higher in fertilized treatments than in the control. Phosphorus concentration was higher in the two treatments supplying P than in the N only treatment. Treatments supplying K increased forage K concentrations substantially, but did not raise the levels to where there might be concerns of excess for use in dry cow rations.

TABLE 1. Yield and nutrient concentration in mixed forage, six-year average, 1995-2000.

Nutrient treatment	Hay yield, ton/A	Nutrient concentration, % N	P	K
Control	2.8	1.7	0.29	1.5
N fertilizer	3.7	1.9	0.27	1.3
NPK fertilizer	4.1	1.9	0.30	2.0
LD manure	3.7	1.9	0.31	2.1

TABLE 2. Nutrient balance over six years and final soil test levels.

Nutrient	Nutrient balance[1], lb/A		Final soil test[2], lb/A	
treatment	P_2O_5	K_2O	P	K
Control	-217	-543	10	92
N fertilizer	-264	-622	9	88
NPK fertilizer	184	-16	13	116
LD manure	209	84	12	124

[1] Sum of nutrients applied in fertilizer and manure minus those removed in forage harvest.

[2] Modified Morgan soil test level in 2000. Initial soil test levels in 1995 were 15 lb/A for P and 134 lb/A for K.

Comparing nutrients supplied to those removed in harvested forage over the six years, both NPK fertilizer and LD manure supplied more P than was removed (see **Table 2**). However, in both cases soil test P did not increase. And where no P was added, soil test P declined. Fixation processes appear to be retaining P in the soil. To supply optimum P levels to crops in this soil and to maintain the soil test at its current level, additions may need to be higher than removals.

The LD manure resulted in a small excess of K supplied relative to that removed, while treatments supplying no K had very large deficits (**Table 2**). Changes in soil test K reflected the differences in nutrient balance.

The use of N, averaged over the six years, was highly profitable. Assuming a forage value of $60 per ton, N cost of $0.22 per pound, and application costs of $12 per acre per year, the net return was over $24 per acre, a 70 percent return on investment. While the incremental benefit in treatment 3 did not pay for the high rates of P and K used, NPK fertilizer was profitable compared to the zero input treatment. Obviously, where manure is available locally, it is the most economical source of nutrients, and P and K could be applied at these rates in a sustainable manner. If more expensive fertilizer sources were used for P and K, optimum rates would likely be lower, but some input would be essential for sustainable production. A study on a similar forage stand in New Brunswick found that an annual rate of 140-90-120 lb/A of N, P_2O_5 and K_2O was most profitable over a 26-year period, using commercial fertilizers exclusively.

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Fertility of Oklahoma Agricultural Soils

By Hailin Zhang

The soil fertility summary of 65,656 Oklahoma cropland samples tested from 1994 to 1999 is presented in **Table 1**. All the identifiable lawn, garden, and research samples were excluded in the summary since most of those samples are not representative of typical agricultural fields. Soil samples were analyzed for pH, buffer index (BI, SMP method) if pH was less than 6.5, nitrate-nitrogen (NO_3-N), soil test phosphorus (P; STP) index, and soil test potassium (K; STK) index. Samples were generally collected from the surface 6 inches (plow layer). Medians are given because most of the data are not normally distributed. In non-normal distributions, averages can sometimes give a false impression of where the center of the distribution lies.

An accurate evaluation of soil fertility levels for an individual county or a whole state is necessary for generally estimating nutrient needs, tracking changes in soil pH and nutrient levels, and guiding manure nutrient redistribution. The Oklahoma Cooperative Extension Service Soil, Water and Forage Analytical Laboratory analyzes soil samples and archives test results for most Oklahoma counties.

Soil pH and Lime Requirement

The pH of Oklahoma soils tends to be acidic, with a median of 5.9. Soil pH was divided into four groups, as shown in **Figure 1**. Twenty-eight percent of the samples had pH values less than 5.5. Below pH 5.5, there is a potential for production loss due to soil acidity. Low soil pH has become a crop production problem of increasing concern in many parts of Oklahoma, especially in the central wheat growing region where up to 39 percent of the fields had pH values less than 5.5.

The median values of soil pH for each of the 76 counties included in the study are shown in **Figure 2**. In general, soil pH is neutral to calcareous in the west and southwest part of the state, but acidic in east and north central Oklahoma. Strong soil acidity not only lowers the availability of P, but also increases the level of toxic elements such as aluminum (Al) and manganese (Mn). Banding P fertilizer and using Al-tolerant wheat varieties have shown some benefits on acid soils, but eventually lime must be applied to neutralize the acidity and sustain crop production.

TABLE 1. Median, average and ranges of test results for 65,656 Oklahoma agricultural soil samples tested from 1994 to 1999 (0- to 6-in. depth).

	pH	NO_3-N, lb/A	STP index	STK index
Median	5.9	12	57	342
Average	6.1	21	100	399
Maximum	10.8	988	1,990	2,000
Minimum	3.6	1.0	1.0	11

Soil NO_3-N

The majority of the surface soil samples had less than 20 lb/A residual NO_3-N (**Table 1**). Only 12.4 percent of the fields sampled had levels greater than 40 lb/A, 3.3 percent greater than 80 lb/A. This indicates that most farmers

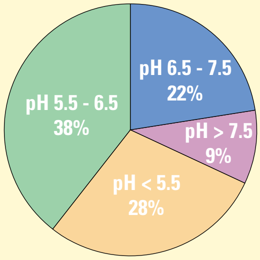

Figure 1. Distribution of soil pH across 65,656 Oklahoma samples tested between 1994 and 1999.

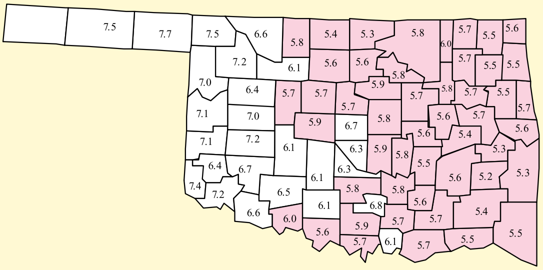

Figure 2. Median values of soil pH for 76 counties in Oklahoma. Shaded counties are pH 6.0 or less.

need to apply N fertilizer for crop production based on surface soil tests alone. Since very few farmers submitted subsoil samples, subsoil NO_3-N results were not included. However, subsoil samples (6 to 24 in.) can contain significant amounts of NO_3-N.

Deep-rooted crops, such as winter wheat, can access and utilize subsoil N. Results from another program demonstrated the importance of taking subsoil samples for estimating residual N. Farmers can better manage N fertility and minimize NO_3-N leaching if they take into consideration available N in the subsoil and follow soil test recommendations.

Soil Test P Index

The P soil test estimates the availability of soil P to the crop throughout the growing season. The Mehlich 3 extraction method is used in Oklahoma and many other central and eastern states for plant available P and K analysis. The estimated availability is reported in Oklahoma as an index and percent sufficiency in the soil. Phosphorus fertilizer should be applied if the STP index is less than 65 (100 percent sufficient).

The statewide distribution of STP is shown in **Figure 3**. About 57 percent of the soil samples had STP index values less than 65, or less than 100 percent sufficiency. Therefore, the majority of Oklahoma agricultural soils need P fertilizer to achieve optimum crop yields. A quarter of the samples had STP index values between 65 and 120. In this range, the probability of an economic response to P fertilizer is low. However, some crops may benefit from additional P fertilizer, particularly where environmental conditions such as cool soil temperature and/or compaction exist. Only 18 percent of the fields statewide had STP values over

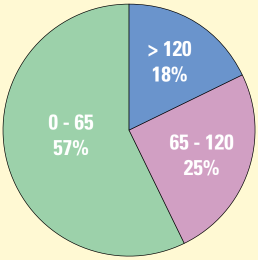

Figure 3. Distribution of soil test P index across 65,656 Oklahoma samples tested between 1994 and 1999.

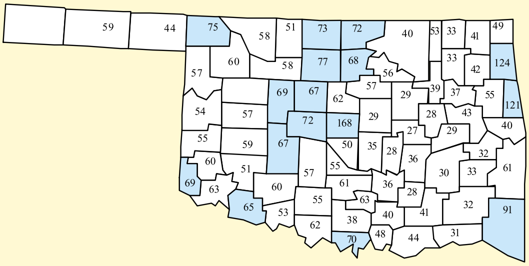

Figure 4. Median values of soil test P index for 76 counties in Oklahoma. Shaded counties are 65 and above (65 considered adequate).

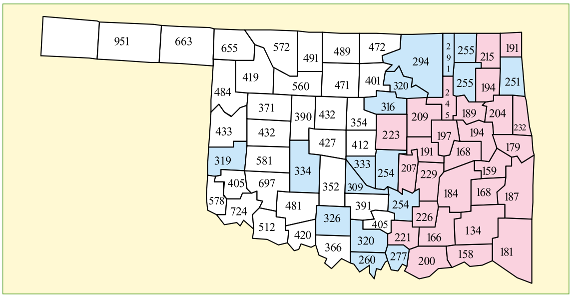

Figure 5. Median values of soil test K index for 76 counties in Oklahoma. Pink shaded areas are 250 and above (250 considered adequate for most crops). Grey shaded areas are between 250 and 350 (350 considered adequate for alfalfa).

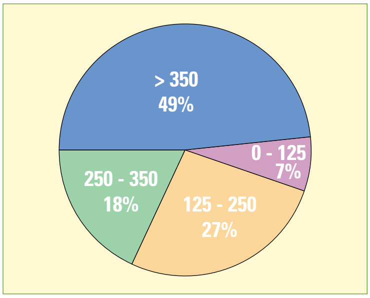

Figure 6. Distribution of soil test K index across 65,656 Oklahoma samples tested between 1994 and 1999.

120, although some parts of the state had a much higher percentage of this category due to heavy application of animal manure. The median STP index of Oklahoma counties is presented in **Figure 4**. While there is no obvious pattern of STP distribution, three counties had STP index values over 100 for specific reasons. Oklahoma County (central Oklahoma) includes the Oklahoma City area. The samples collected from this county probably included some mislabeled lawn and garden samples that inflated the median STP value. Adair and Delaware Counties (northeastern Oklahoma) also had high STP values. These counties have a high concentration of poultry operations. Therefore, the high STP values are probably due to a history of poultry litter application.

Soil Test K Index

Most soils in western Oklahoma are high in K (**Figure 5**). The relatively high K level in this part of the state is probably due to the parent materials and low rainfall under which these soils were developed. Most soils in eastern Oklahoma are low in K. The soils in this region are exposed to higher rainfall and more intensive weathering. Basic cations such as K tend to be removed through leaching under these conditions. Statewide, about 34 percent of the fields had STK index values less than 250 (**Figure 6**), or less than 100 percent sufficiency for all crops except alfalfa. Alfalfa needs additional K to meet crop requirements. The 100 percent sufficiency value for alfalfa is 350. About 51 percent of samples had STK values less than 350. Potassium fertilization is especially important in optimizing forage and other crop yields and profitability in eastern Oklahoma and may be beneficial statewide for specific crops such as alfalfa.

Conclusion

This summary provides a valuable indicator of the soil fertility status of Oklahoma farmland. Nevertheless, soil samples should be collected from individual fields to better manage soil fertility and correct soil acidity problems. The individual county data may be used as a general guide to improve the distribution of nutrients in animal manure to avoid over application and the associated environmental consequences.

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Almond Productivity as Related to Tissue Potassium

By Edwin J. Reidel, Patrick H. Brown, Roger A. Duncan, and Steven A. Weinbaum

Heavy crop removal and inadequate soil potassium (K) availability could limit almond production in California. This research suggests that K deficiency is associated with higher mortality rates for fruiting spurs. Leaf K concentration from samples taken in July were found to be moderately correlated with yields in the following year. Leaf K concentration below 0.8 percent in July was associated with K deficiency. No yield benefit associated with leaf K concentrations greater than 1.4 percent was observed. Almond fruit (kernel, shell and hull) is a major K sink, containing the equivalent of about 55 lb K_2O/1,000 lb of harvested kernels.

Almond yield is the product of fruit number and fruit size, but fruit number is arguably the most important yield determinant. There is evidence, from other fleshy *Prunus* species, that K deficiency limits fruit size. Almond flowers are differentiated during the summer prior to anthesis, and almost all fruit is borne laterally on relatively long-lived spurs. Therefore, a nutrient deficiency may conceivably reduce potential future yields (in terms of flower/fruit number) by limiting growth of new shoots and spurs, by reducing the productivity of existing spurs, and by reducing the quality or quantity of floral differentiation.

Potassium fertilizer was applied to drip irrigated 'Nonpareil' almond trees in a Modesto, California, orchard at rates of 0, 240, 600, and 960 lb K_2O/A/year as potassium sulfate (K_2SO_4), beginning in 1998. The fertilizer was applied directly beneath six drip emitters per tree, split three times (May 23, June 17, and July 3) in 1998 and two times (February 26 and April 29) in 1999 and 2000 (February 2 and May 4). Forty individual branch units from trees in the control (0 K) and 960 lb K_2O/A rates ('low-K' and 'high-K', respectively) were selected to monitor yield determinants and individual spur longevity over several years. Yield and leaf K concentrations were also measured.

Differential K application rates were initiated during the summer of 1998 (year 1), July leaf K concentrations indicative of K deficiency were established during year 1999, and a statistically significant yield response to K fertilizer occurred in 2000 (**Table 1**). Our data indicate there is a time lag between establishment of K deficiency and yield reduction, that yield is a multi-component process, and these components vary both in sensitivity to K deficiency and the time frame over which they contribute to the yield reduction.

There was no yield reduction in 1999, despite K deficiency as determined by leaf K concentration. This indicates that some of the parameters influencing yield...namely percentage fruit set, the number of fruit, fruit growth, and total crop weight...are relatively insensitive to limited soil K availability. The insensitivity of percentage fruit set and fruit growth to low K availability was demonstrated in both 1999 and 2000 (**Table 2**).

Although overall percentage fruit set was not different among low-K and high-K trees in 2000, the return bloom (flower number in 2000 divided by flower number in 1999) was markedly lower on unfertilized trees (**Table 2**). The lower return bloom in low-K trees might have been caused by the death of existing

TABLE 1. Effects of K applications on leaf K concentrations and yields.

Treatment, lb K_2O/A	Leaf K, % dry wt.[1] 1998	1999	2000	Nut yield, meats, lb/A 1998	1999	2000
0	1.1	0.7	0.7	780	3,930	2,410
240	1.3	1.3	1.2	890	3,840	2,860
600	1.3	1.6	1.4	830	4,380	2,860
960	1.3	1.7	1.7	1,070	4,020	2,770
	**	**	**	ns	ns	*

*, **Significant differences among treatment means at $p < 0.05$ and $p < 0.01$, respectively. Not significant = ns.

[1] Samples taken in the last week of July.

spurs, decreased initiation of new spurs within the canopy, and/or a reduced number of flowers per spur. Our data from monitoring individual spurs from the low- and high-K trees suggest that the 27 percent increase in mortality of spurs that fruited in 1999 (**Table 3**) was a major factor in the lower return bloom and reduced yields of low-K trees in 2000. Tree K status did not influence the mortality of spurs that were non-fruiting in 1999 (**Table 3**), meaning that this effect of K-deficiency was localized to fruiting spurs.

Leaf K Critical Value. The concept of a leaf K critical value implies the existence of a relationship between leaf K concentration and yield. As noted above, we believe that the lower yields for untreated trees in 2000 were due to the persisting or carryover effects of K deficiency in 1999, while we expect that tree K status in 2000 would have no relationship to the crop harvested in 2000. Therefore, we correlated the 2000 yields with the 1999 leaf K concentration. This analysis indicated a moderate (60 percent), but significant relationship between leaf K concentration and future productivity. The relatively low variability in leaf K concentration and yield for untreated trees suggests leaf K concentrations are diagnostic for K deficiency (**Figure 1**). The highest yields among plots receiving fertilizer had leaf K concentrations ranging from 1.4 to 1.7 percent (**Figure 1**). There were also, however, plots within the latter leaf K concentration range that yielded no better than the controls. This suggests that factors other than K were limiting yield when K concentration in leaves exceeded 1.4 percent.

TABLE 2. Effect of tree K status on yield determinants measured on individual branches, beginning eight months after differential K fertilization was initiated.[1]

Treatment, lb K_2O/A	Fruit set, % 1999	2000	Nodes/shoot 1999	Weight, 1999, g Embryo	Whole fruit	Return bloom, % 2000
0	27 ± 2.4	21 ± 2.2	11.1 ± 0.86	0.95 ± 0.04	2.76 ± 0.05	23 ± 3.2
960	26 ± 1.8	25 ± 2.2	11.6 ± 0.43	1.01 ± 0.01	2.78 ± 0.09	33 ± 4.6
						*

[1] means ± Standard Error (SE).

*Denotes means which differ at $p < 0.10$.

Almond production requires substantial amounts of K, and deficiency can reduce future yield potential.

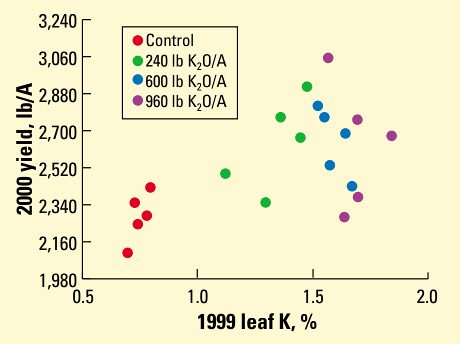

Figure 1. Almond yields as measured in August 2000 versus their leaf K concentration measured in July 1999.

TABLE 3. Effect of tree K status on subsequent productivity of spurs tagged in 1999.

Treatment, lb K_2O/A	1999 status	Number of samples	Spur status in 2000, % of total sample Vegetative	Fruiting	Dead
0	Fruiting	133	26	18	56
960	Fruiting	172	31	27	42
					*
0	Vegetative	113	21	77	2
960	Vegetative	138	16	77	7

*Denotes means which differ at $p < 0.05$.

TABLE 4. Total fruit K removed in 1999 per 1,000 lb of 'Nonpareil' almond kernels (meats)[1].

		Low K		High K	
Fraction	Weight, lb[2]	K conc., %	K removed, lb K_2O	K conc., %	K removed, lb K_2O
Kernel	1,000	0.7	8.4	0.7	8.4
Shell	400	1.5	7.2	2.0	9.6
Hull	1,200	1.7	24.0	2.6	37.2
Total			39.6		55.2

[1] Includes the mesocarp plus exocarp.

[2] There were no yield differences among treatments in 1999 (data not presented).

We also determined the quantity of K removed per acre in the almond crop so that growers and consultants can better estimate the amount of K fertilizer required to avoid deficiency (**Table 4**). Based on 1999 data, the kernel contains the equivalent of about 8 lb K_2O/ 1,000 lb. The shell contains slightly more than the kernel, and the largest K sink is the hull, containing the equivalent of about 37 lb K_2O (high-K treatment). Since kernel, shell and hull are all removed from the field at harvest, the equivalent of approximately 55 lb K_2O was removed/ 1,000 lb of harvested kernels. Thus, a 3,000 lb crop would remove about 165 lb K_2O.

Conclusions

July leaf K concentration is moderately associated with future productivity. Maximum yields were correlated with leaf K values equal to or greater than 1.4 percent, but due to the lack of data points between 0.9 percent and 1.4 percent, we cannot clearly delineate the zone of sufficiency from that of deficiency.

Potassium deficiency will not affect yield in the year it is indicated by leaf testing, since percentage fruit set and fruit size are not influenced by K status in the current year. Very low July leaf K concentrations in a heavy-cropping year (below 0.7 to 0.8 percent for non-fruiting spurs) are associated with a K limitation to tree productivity. This will reduce yields in subsequent years as a result of decreased overall flower number due to increased spur mortality.

The effects of K application on leaf K concentrations observed in this study are site- and cultivar-specific and may vary according to soil type, application technique, and irrigation method. However, since most of the fruit K is contained in the hull and because 'Nonpareil' almond has a relatively large hull compared to other cultivars, it should be possible to match K fertilizer application to the predicted crop size. Also, growers and consultants should consider whether the soils in their area are likely to fix significant quantities of applied K and adjust fertilizer recommendations accordingly.

Although the data are not presented here, early spring is likely to be the most critical period for K availability because this is the period of rapid vegetative growth and fruit development. It makes sense to apply K so that it will be available at this time.

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ENVIRONMENTALISM

According to an editorial I was reading the other day, a recent Gallup public opinion poll showed that about 90 percent of all Americans consider themselves to be environmentalists. The results of another poll, commissioned by The Nature Conservancy, found that 54 percent of the nation's 104 million households were 'extremely' or 'very' concerned about the environment; another 31 percent were 'somewhat' concerned.

America's fascination with the environment and its protection is reflected in the fact that in 1999 individuals, companies and foundations gave an average of nearly $10 million a day to environmental groups (National Center for Charitable Statistics). One organization, The Nature Conservancy, received $403 million in 1999...as much as its six nearest rivals combined.

While I consider myself an environmentalist and am supportive of those who organize and campaign to protect endangered species, water, soil, and air, I am also struck by the fact that something is missing from the picture. With all the lip service and financial commitment, why aren't we doing a better job of keeping our roadsides, recreational lakes, parks, and beaches clean?

Don't tell me I'm being negative. Each morning I drive to work, through a well-to-do area of metropolitan Atlanta, and see the trash and garbage and cigarette butts littering the rights of way and intersections. My wife and I have a home in Amelia Island, Florida, soon to be our retirement residence. When we are there, we walk the beach daily. Our path takes us along luxury beachfront hotel and public beach areas. We both spend considerable time picking up debris left by hotel guests and other beach visitors.

I'm sure most of the roadside and beach waste I see is strewn by those who consider themselves environmentalists. It could be that 90 percent of us are not true environmentalists after all, or perhaps the other 10 percent are awfully messy. **The truth is, we all should do our part to protect our air, water, soil, and wildlife.**

That's real environmentalism, and it starts with each of us properly disposing of the garbage we make.

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