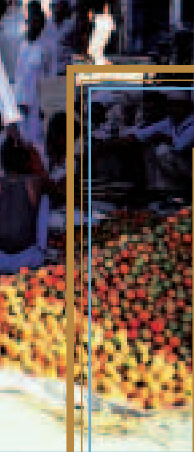
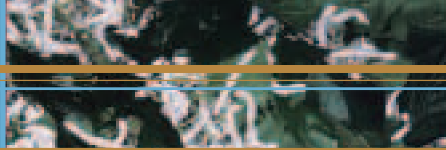
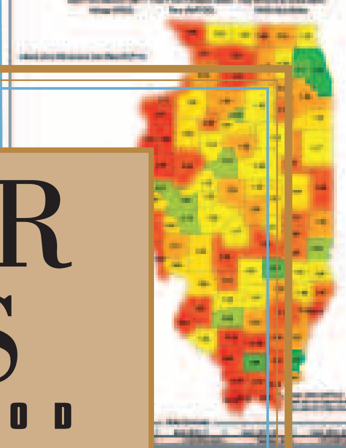




BETTER CROPS

WITH PLANT FOOD

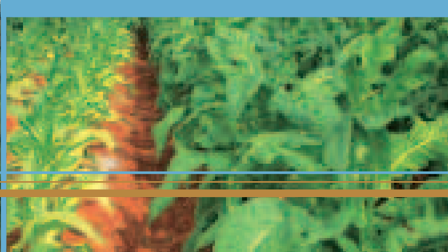
Now Including International Topics

2006 Number 4

In This Issue:

- U.S. Fertilizer Tonnage Reporting
- Fertilizing Mulberry for Silkworms
- Fertigation Boosts Optimum N for Tomatoes and Peppers

and much more…


BETTER CROPS
WITH PLANT FOOD

Vol. XC (90) 2006, No. 4

Our cover: Images from articles in this issue.

BETTER CROPS WITH PLANT FOOD
(ISSN:0006-0089) is published quarterly by the Potash & Phosphate Institute (PPI). Periodicals postage paid at Norcross, GA, and at additional mailing offices (USPS 012-713). Subscription free on request to qualified individuals; others $8.00 per year or $2.00 per issue. POSTMASTER: Send address changes to Better Crops with Plant Food, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Phone (770) 447-0335; fax (770) 448-0439. www.ppi-ppic.org.

The Government of Saskatchewan helps make the International Section of this publication possible through its resource tax funding. We thank them for their support of this important educational project.

CONTENTS

Predicting Phosphorus Runoff from Calcareous Soils

By R.A. Schierer, J.G. Davis, and J.R. Zimbrunnen

Soil calcium carbonate ($CaCO_3$) has a major impact on soil-phosphorus (P) interactions and can significantly influence levels of plant-available and soluble P in soils. This experiment investigated the effect of manure applications on soil test P (STP) and runoff of P from three soils with $CaCO_3$ contents ranging from 1 to 9%. The relationship between P added from manure and STP differed among soils, with the highest $CaCO_3$ soil showing the most resistance to changes in STP. Also, for any given STP level, surface runoff was reduced as soil $CaCO_3$ level increased. This work shows that soils with high levels of $CaCO_3$ are well suited as sinks for excess P in manure. Thus, soil $CaCO_3$ level should be considered in the P index in states with calcareous soils.

Few studies have investigated the effect of manure applications on P runoff from calcareous soils, where P sorption occurs primarily through binding and precipitation with Ca ions (Whalen and Chang, 2002). A link between STP and dissolved P in runoff in calcareous soils was demonstrated in previous work (Sharpley et al., 1989, 1994; Robbins et al., 2000). However, these relationships were established with laboratory-based rainfall simulation, and the work did not include field evaluations of manure-amended soils.

Our field study was designed and performed with the overall goal of characterizing STP and runoff P relationships for Great Plains soils with varying free $CaCO_3$ concentrations in the surface horizon. Three sites were selected, one each in Colorado, Nebraska, and Kansas. Three STP methods (Olsen, Mehlich-3 colorimetric, and water-soluble) were compared to find which was the most effective at estimating soluble P in runoff. The study was designed to meet the standards of and participate in the National Phosphorus Runoff Project which was developed by USDA Natural Resources Conservation Service (NRCS) and the Southern Extension and Research Activity (SERA-17) workgroup.

The specific objectives of this study were to determine soil series-specific relationships between STP and runoff P, to compare the use of different soil extractants for runoff P prediction, and to evaluate the impact of $CaCO_3$ levels on the STP/runoff P relationship.

Soil $CaCO_3$ contents of the sites ranged from 1 to 9% in the surface horizon (**Table 1**). Plots at each location were 15 ft. wide by 20 ft. long (4.6 by 6.1 m), with the long axis of each plot oriented parallel to the slope. Eight manure rate treatments were established with two replications in a randomized complete block design. The manure was roto-tilled into the soil, and

Table 1. Soil properties for three study sites.

Soil series	State	Texture	pH	Slope	Organic matter	Calcium carbonate
				%	%	%
Rosebud	Nebraska	Loam	7.9	2	1.07	1
Wagonbed	Kansas	Silt loam	7.8	2	1.97	4
Kim	Colorado	Clay loam	7.9	1	1.89	9

all residues were removed before simulating rainfall.

A portable rainfall simulator with constant intensity was used to compare measured parameters at each site. The use of a rainfall simulator allows comparison of different soils and management variables among locations (Humphry et al., 2002). The rain simulator was based on the design of Miller (1987). A runoff collector was installed at the down-slope edge of each plot to divert runoff to a collection point. A one liter bottle (autoclavable) was used to collect runoff at the collection point. The rainfall intensity was 3.3 in./hour. As runoff began in each plot, a stopwatch was started and run for 30 minutes. During this half-hour, approximately 1 quart (1 liter) of runoff was collected at 2.5-minute intervals (12 discrete samples/plot). Records were kept on sample volumes and time required for collection, to calculate mean runoff flow rates and total runoff volumes. Samples collected at 2.5, 7.5, 12.5, 17.5, 22.5, and 27.5 minutes were analyzed individually for their P content. A sub-sample was taken from each of these samples and filtered, then total dissolved P was measured by ICP. Samples collected at 0, 5, 10, 15, 20, and 25 minutes were analyzed for runoff and soil loss.

Prior to rainfall simulation, three soil samples were taken from the established plots from 0 to 2 in. (5 cm) deep and composited to measure antecedent soil water conditions and soil test P. Samples were analyzed using Olsen P, water-soluble P (0.01 M $CaCl_2$), and Mehlich-3 extractants.

Although there was no difference among the three soil extractants in their ability to predict runoff P from the Kim soil (the soil with the highest $CaCO_3$ level), the Mehlich-3 and Olsen STP measurements were more highly correlated with runoff P on both the Rosebud and Wagonbed soils. The Mehlich-3 extract consistently resulted in the highest r^2 values across all three soil types. Therefore, only the Mehlich-3 data is presented in this paper.

Increase in available soil P with manure addition was not consistent among soils (**Figure 1**). In particular, the slope of the line (change in Mehlich-3 per unit change in P added) was significantly lower for the Kim soil than for the other soils. Mehlich-3 STP in the Rosebud and Wagonbed soils on average increased 0.18 parts per million (ppm) for every lb P_2O_5/A of added P, while the Kim soil increased by only 0.0098 ppm Mehlich-3 STP. There was no difference in the intercepts of the lines. All of the different sites received the same manure application rates. However, the manures had different P concentrations resulting in different amounts of P added. Nonetheless, the high $CaCO_3$ soil (Kim) had lower Mehlich-3 levels at the same amount of P added, apparently due to the reaction between P and Ca and the consequent reversion to less available P

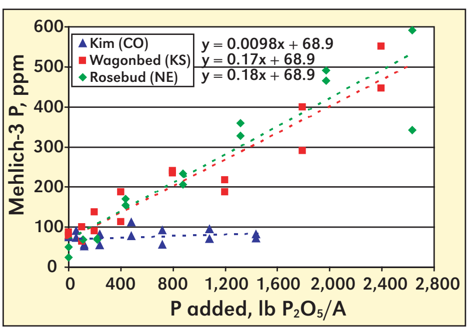


Figure 1. Mehlich-3 STP as a function of P added for three soils.

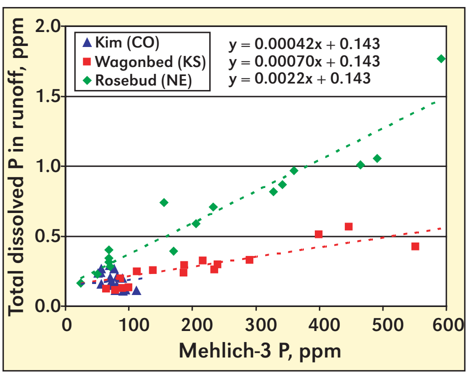


Figure 2. Total dissolved P in runoff as a function of Mehlich-3 STP for three soils.

There has been little previous study of P runoff from manure-amended calcareous soils in the Great Plains. Inset photo shows the rainfall simulator in action.

compounds.

The relationship between total dissolved P in runoff and Mehlich-3 STP also differed significantly by soil (**Figure 2**). Again, the slopes were different, but the intercepts of the lines were not. The slopes were in the order Kim soil (9% $CaCO_3$) < Wagonbed soil (4% $CaCO_3$) < Rosebud soil (1% $CaCO_3$). This means that at a given STP level as soil $CaCO_3$ level increased, the total dissolved P in runoff decreased.

A multiple regression equation was developed to predict the total dissolved P in runoff as a function of Mehlich-3 STP and $CaCO_3$. The equation is:

$$TDP = 0.071 + 0.003\,(M3) + 3.11\,(CaCO_3) - 0.059\,(CaCO_3)\,M3$$

TDP=total dissolved P in runoff, ppm
M3=Mehlich-3 soil test P, ppm
$CaCO_3$=$CaCO_3$ content in decimal form

The regression equation has an r^2 value of 0.92 and $p<0.0001$. A similar equation was developed using Olsen P, but the r^2 value was only 0.81. Therefore, we recommend the use of Mehlich-3 for the prediction of runoff P from calcareous soils.

Summing Up

In conclusion, the higher the percentage of $CaCO_3$ in the soil surface layer, the less dissolved P ran off the field at the same STP level. This research evaluated only three soils with many differences in their physical and chemical characteristics. Notable were differences in clay content. Therefore, clay content was inserted into the multiple regression equation with a subsequent increase in the r^2 value of only 0.01. $CaCO_3$ should be considered for integration into the P index, a planning tool used to evaluate the environmental hazard of applying organic P fertilizers to cropland. This research indicates that soils with high levels of $CaCO_3$ are well suited as sinks for excess P in manure. Accordingly, when producers are making decisions about where to apply manure, soil $CaCO_3$ level is an important consideration. BC

Mr. Schierer (e-mail: ron.schierer@co.usda.gov) is with USDA-NRCS at Greeley, Colorado. Dr. Davis (e-mail: jgdavis@lamar.colostate.edu) and Dr. Zimbrunnen are with Colorado State University, Fort Collins.

References

Humphry, B.J., T.C. Daniel, D.R. Edwards, and A.N. Sharpley. 2002. A portable rainfall simulator for plot-scale studies. Applied Engineering in Agriculture 18(2):199-204.

Miller, W.P. 1987. A solenoid-operated, variable intensity rainfall simulator. Soil Science Society of America Journal 51(3):832-834.

Robbins, C.W., L.L. Freeborn, and D.T. Westermann. 2000. Organic phosphorus source effects on calcareous soil phosphorus and organic carbon. J. Environ. Qual. 29:973-978.

SERA-17 Work Group. 2001. National Phosphorus Research Project Protocol.

Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for the protection of surface waters: issues and opinions. J. Environ. Qual. 23:437-451

Sharpley, A.N., U. Singh, G. Uehara, and J. Kimble. 1989. Modeling soil and plant phosphorus dynamics in calcareous and highly weathered soils. Soil Sci. Soc. Am. J. 53:153-158.

Whalen, J.K. and C. Chang. 2002. Phosphorus sorption capacities of calcareous soils receiving cattle manure applications for 25 years. Commun. in Soil Sci. and Plant Analysis 33:1011-1026.

Organic Crop Management and Soil Phosphorus

By C. Welsh, M. Tenuta, D. Flaten, C. Grant, and M. Entz

Long-term organic production systems show a deficiency of plant-available phosphorus (P), but not total P. High crop removal of P with alfalfa had the greatest impact on soil P.

The inability to add fertilizer P to an organic farming system, as currently defined, limits the ability of soils to balance other nutrients, such as nitrogen (N) and sulfur (S), and to achieve yield goals. While soils are well known to be able to supply some P to crops even after many years of production and no P additions, the amount supplied is often insufficient to optimize crop yields. Also, many organic growers are hard pressed to find an adequate supply of organic manure to supply P to their production fields.

Soil testing for P estimates the soil P supply available for plant uptake. However, these analytical methods do not take into account those less available forms of soil P which are known to be quite significant in many soils, especially clay soils. As a result, these questions are often asked:

Is the depletion of soil P in organic cropping systems a general depletion, or just a reduction in plant-available P?

What impact does annual crop removal of a nutrient like P have on the stable, recalcitrant fractions of soil P?

A cropping systems study initiated at the University of Manitoba in 1992 evaluated the impact of crop rotation and production inputs (herbicides and fertilizers) on crop yield, weed dynamics, energy use, and soil fertility. The project is located on a Rego Black Chernozem (Udic Boroll), with a textural analysis of 12% sand, 32% silt, and 55% clay. Soil organic matter content is 5.5%. The three cropping systems included wheat/dry pea/wheat/flax, wheat/alfalfa/alfalfa/flax (no manure), and wheat/alfalfa/alfalfa/flax (composted manure). A previously cropped area was also restored to native tall grass prairie with no crop removal.

The conventional production systems received fertilizer and herbicide treatments, while the organic production systems received no herbicide or fertilizer additions. The amount of P applied annually in conventional systems ranged from 0 to 27 lb P_2O_5/A. After 12 years (1993-2004), soil samples were collected and soil P (0 to 6 in.) was evaluated. Soils were evaluated using a modified Hedley fractionation procedure, including P removed with water, sodium bicarbonate, sodium hydroxide, and hydrochloric acid. Total P was also determined using inductively coupled plasma. The P balance was estimated using average P content of crops harvested (*Soil Fertility Guide for Manitoba*), measured crop yields, and annual fertilizer and manure additions.

The P balance calculated for the crop rotations showed a P deficit when no fertilizer P was added to the organic systems, and a surplus when fertilizer P was added to the conventional systems (**Figure 1**). The large P deficit for the organic forage-grain production systems reflects the high level of nutrient removal with alfalfa production and harvest. This P deficit was much larger than the organic grain production system, where only grain was removed

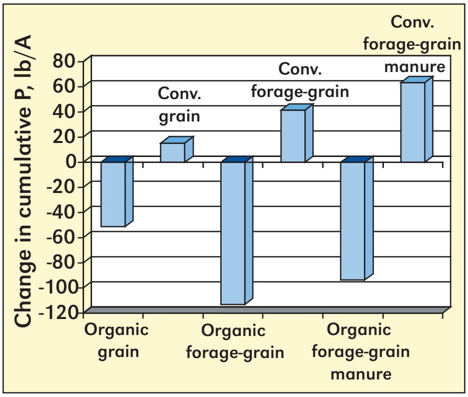


Figure 1. Expected P balance for 1993-2004.

from the cropping system and all straw returned. The P surplus recorded for the conventional forage-grain systems reflects P fertilizer additions in excess of estimated crop removal at this location.

The soil P analysis revealed that the management system used in the study had a much greater impact on soil P levels than the cropping system (**Figure 2**). The levels of plant-available P in the soil sample fractions (water, sodium bicarbonate and sodium hydroxide) were significantly ($p<0.05$) lower for the organic management. The more plant-unavailable (recalcitrant) hydrochloric acid fraction was not different between cropping systems or

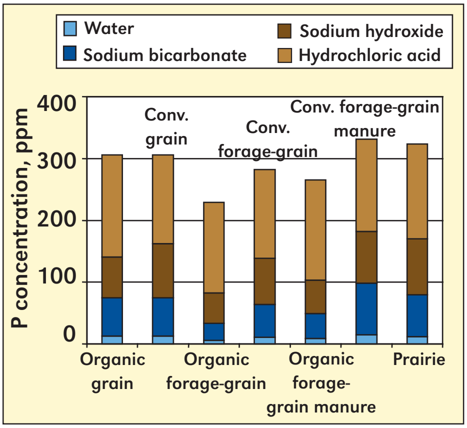


Figure 2. Total P concentrations in organic and conventional systems under different crop rotations.

management. This indicates that during the 12-year period of this study, it was the plant-available forms of soil P which were selectively altered most by management.

It is important to note that while the calculated P balance (**Figure 1**) showed a P deficit for the organic grain rotation, soil fractionation of P indicated that it had similar soil P levels as the conventional production system (**Figure 2**). This similarity in soil P levels after 12 years of grain crop removal and no P addition reflects the large buffering capacity of these clay soils. Only the organic forage-grain cropping systems show a difference in the plant-available forms of soil P as determined by the detailed Hedley fractionation procedure (**Figure 2**), and the soil test results (**Table 1**).

Table 1. Soil test P after 12 years.

Rotation[1]	Management: Organic	Management: Conv.
	- - - - - - - - P, ppm[2] - - - - - - - -	
WPWF	30a	38a
WAAF	9b	21a
WAAF-M	14b	35a
Prairie	35a	

[1]Wheat (W), pea (P), flax (F), alfalfa (A), manure (M).
[2] ppm = parts per million; Levels followed by the same letter are not different at p=0.05.

We speculate that the difference in both plant-available and unavailable forms of P in the soils of the organic and conventional systems may be showing some shift in P forms with time. Without replenishment of plant-available P in the organic forage-grain system, P will be the most limiting nutrient in the future. BC

Ms. Welsh (e-mail: umwelsh@cc.umanitoba.ca) is a graduate student, Dr. Tenuta a soil microbiologist, and Dr. Flaten a soil scientist in the Department of Soil Science; Dr. Entz is an agronomist in the Department of Plant Science, all at the University of Manitoba. Dr. Grant is a Soil Scientist with Agriculture and Agri-Food Canada in Brandon, Manitoba.

ONTARIO

Fertigation Boosts Optimum Nitrogen for Tomatoes and Peppers

By Tiequan Zhang, Chin Tan, and Tom Bruulsema

Fertilizing vegetable crops requires a delicate balance between yield, quality, and environmental impact. Fertigation increases response to nitrogen (N) and provides greater opportunity to control rates to optimum levels.

Tomatoes and green peppers are vegetable crops that provide huge nutritional benefits. Their production also demands good nutrition. Intensive production methods, including the use of fertigation, have helped to make their production viable in Ontario. This benefits society by making nutrient-rich foods available with less need to transport over long distances. Field tomatoes grown on 19,000 acres generated C$78 million for Ontario producers in 2005, while green peppers on 2,900 acres generated C$13 million.

Intensive production methods, however, may not conform well with the regulation of nutrient management. Producers use high rates of N and phosphorus (P). This research aimed to determine how changes to N and P rates would affect yield, quality, and potential losses to the environment under intensive management using drip fertigation.

The experiments on both crops included four rates of N and three rates of P

Fertigation produces high yields of quality tomatoes.

Optimum yields and quality of peppers and tomatoes depend on adequate N and P nutrition.

in all 12 combinations. All of the P and 40% of the N requirement was applied preplant. The remaining N was supplied by fertigation. The soils were Granby sandy loams or loamy sands, with organic carbon content of 1.7%, at the research station in Harrow, Ontario. Soil P and K fertility was very high–generally above 60 parts per million (ppm) Olsen-P, and above 200 ppm exchangeable K.

Over three growing seasons—2003 to 2005—optimum marketable yields required N rates of 180 to 214 lb/A for green peppers, and 190 to 270 lb/A for tomatoes (**Figure 1**). These rates exceed current recommendations for this soil by two- to three-fold. These documented responses contribute toward the data required to make official changes to recommendations.

Removal efficiency (N in harvested fruit per unit of N applied) ranged from 50% to 80% for tomatoes fertilized at 240 lb/A, the mean optimum rate. At that rate, recovery efficiency (increase in N uptake compared to tomatoes grown without N fertilizer) ranged from 31% to 68%. Peppers were less efficient. Fertilized at their mean optimum rate of 200 lb/A, removal

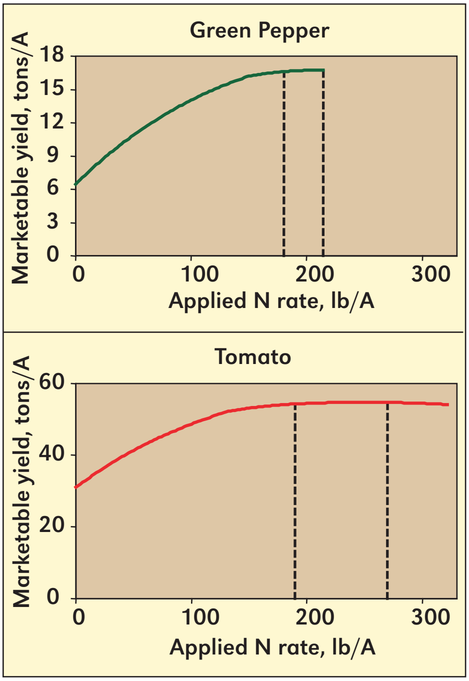


Figure 1. Response to applied N (3-yr. average). Segmented vertical lines indicate the range of optimum rates.

efficiencies ranged from 22% to 30%, and recovery efficiencies from 24% to 32%. While some vegetables show low efficiencies of nutrient removal and recovery, the figures for tomatoes are at least as good as typical values for corn.

When N rates exceeded optimum, the proportion of green tomatoes increased and soluble solids decreased. In some years, soluble solids decreased as petiole nitrate (NO_3^-) increased. In others, they increased with increasing stalk P concentrations. Phosphorus addition did not affect soluble solids. Previous research (Warner et al., 2004) from 1999 to 2002 found that N rate did not affect soluble solids, firmness, size, or color of marketable fruit of tomatoes.

For both tomatoes and peppers, rates of N above optimum tended to dramatically increase residual soil NO_3^- (**Figure 2**). Reducing rates below optimum had much smaller effects. In order to minimize NO_3^- losses to groundwater, it remains important that N be managed carefully.

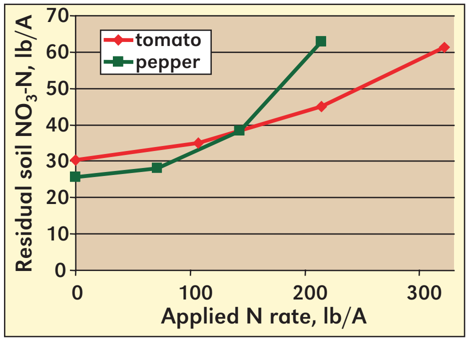


Figure 2. Residual soil NO_3-N to 40 in. depth, following tomatoes and peppers (3-yr. average).

Fertigation allows the producer to delay final decisions on N rates, and thus provides for more careful control.

On-farm trials comparing surface and sub-surface irrigation, with or without fertigation, showed that any form of irrigation increased tomato yields by 20% to 45%. Fertigation did not boost yields relative to drip irrigation. However, it offers the flexibility to adjust rates mid-season to account for weather and condition of the crop, since only 40% of the total fertilizer requirement is applied at planting.

In the first year of this study, P fertilizer increased the marketable yield of peppers, despite soil test levels so high that it would not have been recommended. In that year, the increased growth from P fertilization at 180 lb/A of P_2O_5 substantially reduced residual soil NO_3^- after harvest, keeping soil concentrations below 10 ppm. However, in the last 2 years, neither peppers nor tomatoes responded to P.

Considering that the soil test levels were in a range where no P is recommended, this indicates that response frequency may be sufficient to justify applying at least as much P as the crops remove, even at such high soil test levels. Crop removals of P_2O_5 averaged 75 lb/A for tomatoes and 24 lb/A for peppers. BC

Dr. Zhang (e-mail: zhangt@arg.gc.ca) and Dr. Tan are Research Scientists with Agriculture and Agri-

(Continued on page 10)

Research Notes

Chlorophyll Meter Readings Can Predict Corn Nitrogen Need and Yield Response

Earlier research indicated that chlorophyll meters (CM) can indicate nitrogen (N) stress in corn, but did not address whether the amount needed can be predicted. Based on 66 N rate experiments over a 4-year period in seven northcentral states, CM are highly significant predictors of economically optimum N rate (EONR). Predictions were stronger when based on relative readings, on readings made later in the growing season, and where N fertilizer had not been previously applied. Soil nitrate (NO_3^-) or soil N indices were much weaker predictors of EONR.

In irrigated corn, there are repeated opportunities to apply needed N during the growing season with irrigation water. In rainfed systems, the opportunity is more limited. The CM will only be useful in guiding N application rate if it can be the basis for a single quantitative rate recommendation.

The objective in this study was to develop calibrations to predict corn N need and yield response based on CM readings over a wide range of environments and growth stages to improve N rate recommendations and inform management decisions. Minolta SPAD chlorophyll meters were used to take the readings. All readings were taken midway between the stalk and tip of the appropriate leaf. A relative CM value was calculated as: *Relative CM value = (CM value/reference value)*. The reference CM value was specific to each experimental location and growth stage. It was calculated by averaging all readings from a group of high N treatments, instead of just the highest N rate.

The experiments included here are part of a cooperative regional research project, based on a shared experimental protocol… one of which was to evaluate the utility of CM both for predicting corn yield response to N and assessing N supply related to mineralization. The 66 N rates experiments were conducted in seven states: Illinois, Kansas, Michigan, Minnesota, Missouri, Nebraska, and Wisconsin.

Source: Scharf, P.C., S.M. Brouder, and R.G. Hoeft. 2006. Agron. J. 98:655-665.

For additional information, contact: scharfp@missouri.edu

Fertigation Boosts...from page 9

Food Canada in Harrow, Ontario. Dr. Bruulsema is PPI/PPIC Northeast Director, located at Guelph.

Acknowledgments

Funding support from Ontario Tomato Research Institute, Ontario Processing Vegetable Growers, Canadian Fertilizer Institute, Ontario Agri Business Association, and A&L Canada Laboratories Inc. is gratefully acknowledged.

References:

Warner, J., T.Q. Zhang, and X. Hao. 2004. Effects of nitrogen fertilization on fruit yield and quality of processing tomatoes. Can. J. Plant Sci. 84: 865–871.

Phosphite Fertilizers: What Are They? Can You Use Them? What Can They Do?

By C.J. Lovatt and R.L. Mikkelsen

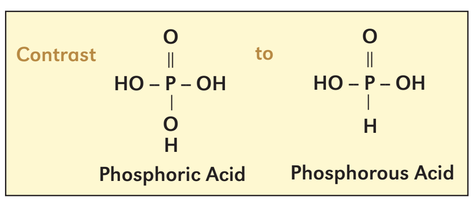
Interest is growing in phosphite as part of a total production program. Phosphite contains one less oxygen (O) than phosphate, making its chemistry and behavior quite different. Phosphite is more soluble than phosphate, making leaf and root uptake more efficient, thus high concentrations can be toxic for plants. Phosphite also has unique effects on plant metabolism. Phosphite supplied through the soil or foliage is slowly converted to phosphate. Soil and foliar applications are made at relatively low rates to prevent nutrition problems. For some plant species, phosphite may offer some unique benefits not seen with phosphate applications.

Phosphorus (P) is one of the essential elements required by all living organisms. But elemental P does not occur in nature because it is very reactive– rapidly combining with other elements such as O and hydrogen (H). When fully oxidized, P is bonded with four O atoms to form the familiar phosphate molecule. However, when it is not fully oxidized and H occupies the place of one O atom, the resulting molecule is called phosphite. This seemingly simple change in molecular form causes many significant differences that influences its relative solubility, plant uptake, and effect on plant metabolism and physiology.

Phosphorous acid (H_3PO_3) and its salt (phosphite) contain higher concentrations of P (39%) than traditional phosphate-based (H_3PO_4) fertilizer (32% P). Salts of phosphite are generally more soluble than the analogous salts of phosphate.

Since the fully oxidized phosphate is the most stable P form in the environment, phosphite undergoes a gradual transformation after addition to soil. Soil microorganisms are able to assimilate phosphite and release phosphate, gaining energy and nutrients during this biological conversion. Microbes will preferentially take up phosphate for their metabolism before taking up significant amounts of phosphite. The estimated half-life for phosphite oxidation to phosphate in soil is usually 3 to 4 months. However, due to its greater solubility, when phosphite is applied to soil during fertilization, it is more readily available to these microorganisms and plant roots than phosphate. Non-biological oxidation of phosphite may also occur gradually, but at a slower rate.

There is evidence that phosphite is adsorbed and attached to soil minerals to a lesser extent than phosphate. This property could possibly be used to enhance the mobility of applied P from a fertilizer band or from a drip emitter in soil. Although this potential benefit has not been investigated in detail, greater solubility has been utilized in the formulation of phosphite-based fertilizers that include calcium (Ca), magnesium (Mg), and potassium (K). Several studies have been conducted to determine the effectiveness of soil-applied phosphite



Phosphoric acid (phosphate) and phosphorous acid (phosphite) comparison. In phosphorous acid, the H is bonded directly to P and is always present.

as a nutrient source for crops. Early work with these materials focused on the toxic effects of phosphite and phosphorous acid on a variety of crops when used as the primary source of P.

When phosphite is supplied at concentrations equivalent to phosphate fertilization rates, most reports show that initially it is a poor source of plant nutrient for a short-cycle crop (**Figure 1**). Crops fertilized at high rates of phosphite consistently perform poorer than those fertilized with phosphate for the first weeks or months following nutrient addition. The biological oxidation process can be too slow (depending on soil conditions, temperature, and presence of phosphite-metabolizing microbes) to be of agricultural significance for some annual crops. However, when crops are replanted in the previously phosphite-fertilized soil, their performance is similar to crops grown in phosphate-fertilized soil. These toxic effects and the additional expense associated with phosphite materials limited further research for many years.

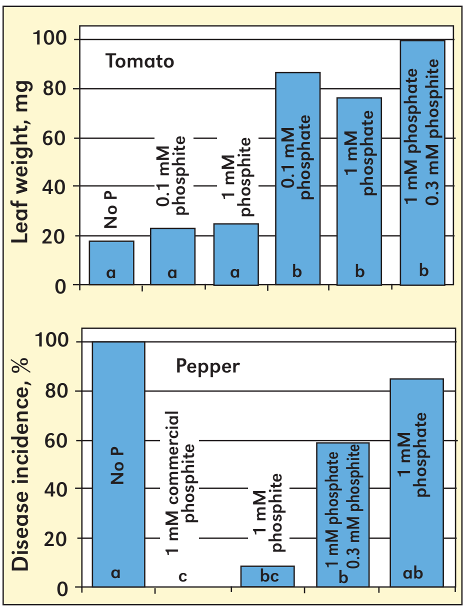


Figure 1. Effect of hydroponic P treatments on tomato growth (top) and *Phytophthora* infection (bottom) of peppers (Forster et al., 1998). Identical letters indicate there is no significant difference between treatments at the 5% level.

Recent work with phosphite has shown that at appropriate rates, it can provide stimulation to the plant which may not occur with phosphate. However, when used at recommended rates, phosphite supplies only 2 lb P_2O_5/A at each soil application, which may be far below crop removal rates. Less is known about the response of perennial crops to soil-applied phosphite sources, but this practice is growing too.

Interest in phosphite reemerged when a commercial product (aluminum phosphonate salt, called fosetyl-Al) was shown to move from the leaves to the roots in the phloem in the form of phosphite and provide control for some root diseases. Phosphite in roots has been shown to directly inhibit *Phytophthora* fungi and also stimulate the pathogen defense mechanisms in plants. While phosphite can effectively control specific species of Oomycetes, it has little effect on the majority of soil fungi. The relatively limited fungicidal effect—combined with its ability to stimulate plants to make a broad spectrum of biologically active metabolites—makes phosphite relatively benign to the environment and safe to use. However, as a treatment for pathogens other than *Phytophthora*, phosphite may reduce disease severity, but can be less effective than standard fungicides.

Other foliar-applied nutrients have the beneficial effect of reducing incidence of disease-causing organisms. Use of phosphite in some ways may be compared with other plant nutrients that have this benefit, although with different modes of action. For many years, foliar applications of zinc, manganese, copper, and sulfur have been used effectively for suppressing some plant pathogens. Similarly, single sprays of phosphate can induce systemic protection against pathogens, such as powdery mildew, in some annual and perennial crops.

Research shows that foliar applications of phosphite can replace phosphate in citrus and avocado crops suffering from P deficiency. The conversion of phosphite to phosphate may result from slow chemical oxidation or by oxidizing bacteria and fungi that have been found living on citrus and avocado leaves. There is consistent evidence that phosphite is more readily absorbed into plant tissues than phosphate. This has proven to be the case for citrus and avocado leaves, which are notoriously impervious to phosphate. In these and other crops, foliar application of phosphite has proven to be more than just a fungicide…it increases floral intensity, yield, fruit size, total soluble solids, and anthocyanin concentrations, usually in response to a single application. Phosphite is most effective when the rate and application are properly timed to match the needs of the crop. Since phosphite is chemically different from phosphate, these differences must be taken into consideration to avoid plant toxicity.

As an example of the beneficial effect of phosphite on plants, a single prebloom foliar application of phosphite to 'Valencia' oranges in Florida significantly increased flower number, yield, and total soluble solids approximately 10 months later at harvest compared with an untreated control (Abrigo, 1999). California navel oranges receiving foliar applications of phosphite in May and again in July produced more commercially valuable large fruit without reducing total yield (**Figure 2**). These results suggest that the effect from phosphite-based fertilizers was not due to the molecule's fungicidal properties, but to other growth-stimulating properties. Growers are encouraged to identify their production goal for the year…increased yield, increased fruit size, or improved fruit quality…and time phosphite applications accordingly. Production strategies are developed for a variety of tree crops, berry crops, onion, potato, and ornamental crops. Physiological responses to phosphite may be related to its effect on sugar metabolism, stimulation of the shikimic acid pathway, or internal hormonal and chemical changes.

Interest in using phosphite as part of a total production package is increasing, especially for some high-value crops. Phosphite fertilizers, if not formulated correctly, have significant potential to be phytotoxic and induce adverse reactions with other materials in the spray tank such as microelements and pesticides. All fertilizers, especially phosphite, should be used in close consultation with a crop professional to meet desired production goals. BC

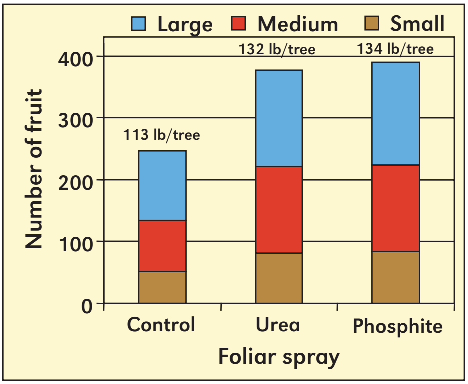


Figure 2. Effect of foliar-applied phosphite in May and July or foliar urea applied in July on fruit yield and size of naval oranges. Average "Large" fruit diameter is 3.3 in., "Medium" is 3.05 in., and "Small" is 2.8 in. (Lovatt, 1999).

Dr. Lovatt is Professor of Plant Physiology, Department of Botany and Plant Sciences, University of California-Riverside; e-mail: carol.lovatt@ucr.edu. Dr. Mikkelsen is PPI Western Region Director located at Davis, California.

Literature cited:

Albrigo, L.G. 1999. Effects of foliar applications of urea or Nutriphite on flowering and yields of Valencia orange trees. Proc. Fla. State Hort. Soc. 112:1-4.

Forster, H. J.E. Adaskaveg, D.H. Kim, and M.E. Stanghellini. 1998. Effect of phosphite on tomato and pepper plants and on susceptibility of pepper to Phytophthora root and crown rot in hydroponic culture. Plant Disease. 82:1165-1170.

Lovatt, C.J. 1999. Timing citrus and avocado foliar nutrient applications to increase fruit set and size. HortTech. 9:607-612.

Additional information at:
>www.ppi-ppic.org/phosphite/ref<.

Research Notes

Supplemental Foliar Potassium Applications with or without a Surfactant Can Enhance Netted Muskmelon Quality

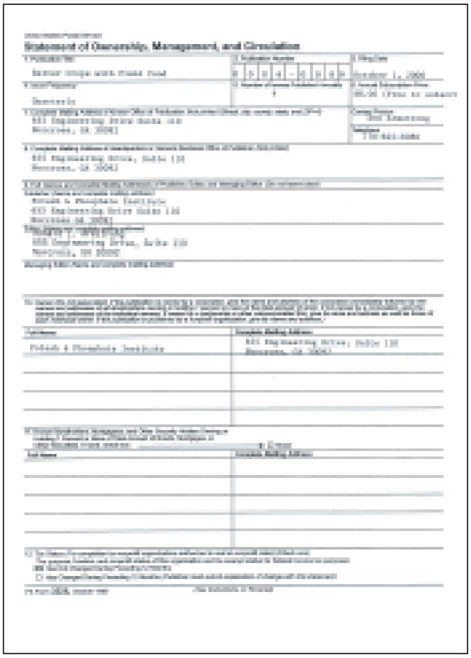
USDA-Agricultural Research Service (ARS) and Texas A&M University researchers at Weslaco, Texas, found that supplementing soil potassium (K) with foliar K applications during muskmelon fruit development and maturation improved fruit quality by increasing firmness, sugar content, ascorbic acid, and beta-carotene levels. This glasshouse study compared two K sources: potassium metalosate (KM), which is a glycine-complexed organic form, and potassium chloride (KCl).

Differences between the two K sources were minimal and use of a surfactant tended to have a positive effect on the response to supplemental foliar K applications. These quality improvements were obtained by implementing a simple management tool (foliar-applied K using generally available K compounds plus a surfactant) that growers can adopt all over the world. BC

Source: Lester, G.E., J.L. Jifon, and D.J. Makus. 2006. HortScience 41(3):741-744.

For additional information, contact: glister@weslaco.ars.usda.gov.

*This research was also supported by PPI/FAR, Project TX-51F. To find out more, visit the website: >**www.ppi-far.org/research**<.*


Statement of Ownership, Management, and Circulation

Fertilizer Tonnage Reporting in the U.S.—Basis and Current Need

By David L. Terry

National fertilizer use statistics are collected and published with cooperation between the Association of American Plant Food Control Officials (AAPFCO) and The Fertilizer Institute (TFI). Although the *Commercial Fertilizers* report includes some data challenges and limitations, it has tremendous value to the industry and others interested in nutrient use.

The most accurate and credible fertilizer use data in the U.S. are generated by the fertilizer regulatory programs in each state. Each state with a fertilizer law, with two exceptions, has a requirement of reporting fertilizer tonnage. There are two main purposes for the reports: (1) to generate income to support the regulatory program, and (2) to reveal the kinds and amounts of fertilizers being distributed in the state.

Prior to 1985, fertilizer use statistics in the U.S. were collected by the U.S. Department of Agriculture (USDA). They used not only tonnage reports from the states, but also some of their own estimates. (The USDA data are available from libraries that have a complete set of U.S. Government documents.) In 1985, the Tennessee Valley Authority (TVA) in Muscle Shoals, Alabama, assumed the mission of collecting and publishing the fertilizer use statistics. They relied exclusively on the tonnage data received from the various state fertilizer control agencies. The TVA continued this up to 1995, when a change in mission caused them to drop the publication of *Commercial Fertilizers*...which is a summary of the national fertilizer use data. At that time, AAPFCO and TFI combined forces to continue the publication. The TVA agreed to give AAPFCO all the software and procedures they had developed for *Commercial Fertilizers*. As Secretary of AAPFCO, I assumed the responsibility of collecting, editing, and publishing *Commercial Fertilizers.*

The National Fertilizer Use Data Collection Process

Section 7 (c) of AAPFCO's Model Fertilizer Bill states: "When more than one person is involved in the distribution of a fertilizer, the last person who has the fertilizer registered (is licensed) and who distributed to a non-registrant/licensee dealer, or consumer is responsible for reporting the tonnage and paying the inspection fee, unless the report and payment is made by a prior distributor of the fertilizer." The data required by the Model Bill include: county, amount (tons), the grade (analysis), and form of distribution (bag, bulk, fluid). Other information requested includes use (farm, non-farm) and fertilizer material codes.

In interpreting the data, we assume that the "last" registrant/licensee is most likely a "dealer" who will sell to the ultimate consumer...or is the farmer/consumer. Therefore, since most states follow this model, the tonnage reported is assumed to represent "use" or "consumption" of fertilizer in a given state. This assumption is further validated when we see "negative" tonnage reported. This occurs when a registrant reports sales to a "dealer" who subsequently does not sell the fertilizer and returns it to the registrant for credit. The registrant in turn reports the returned fertilizer to the state of record for credit.

No discussion of the collection of the national fertilizer use data would be complete without mentioning AAPFCO's Uniform Fertilizer Tonnage Reporting System (UFTRS). When tonnage reporting was discussed, the need for uniform reports among the states was cited as very important.

Each fall beginning around October 1, a notice is sent to each state control official requesting a copy of their tonnage database. All the data are now sent as electronic files, either via email or on compact disk (CD). The fertilizer year is July 1-June 30. For example, FY06 is July 1, 2005-June 30, 2006. (All states except North Dakota, South Dakota, Texas, and Vermont report their tonnage this way.) Once received, the databases from each state are edited, summarized, and published. Edit programs provided to us by TVA are used to correct various coding errors and to provide uniformity among the states' data for later summarization. The national fertilizer use data are published in two ways: a 35-page hard copy publication, *Commercial Fertilizers*, and electronically, in ASCII text format and in Lotus format. County-level data were available for 30 states for FY05 in the electronic version (**Figure 1**).

The *Commercial Fertilizers* publication has a section titled 'Data Sources' which

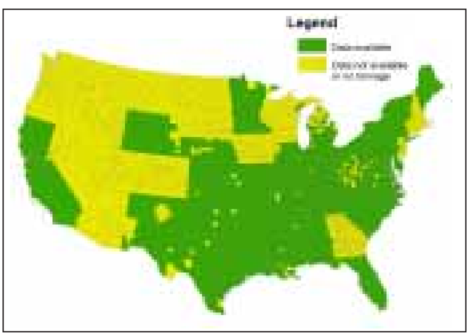


Figure 1. AAPFCO county fertilizer consumption data availability, 2005.
(Prepared for PPI by PAQ Interactive.)

details the characteristics of the tonnage data in the publication and should be consulted before using the data. Those characteristics are discussed in the full web version of this article, available at: **>www.ppi-ppic.org/bctonreprt<**.

Several states have reported budget problems and lowered priority of reporting the tonnage data. AAPFCO tries to help these states as best we can, but all the states need support from the industry to continue and to improve their tonnage reporting effort.

Value of the Data

Following are examples of the value and uses of the *Commercial Fertilizers* data.

- It continues to be one of the oldest agricultural databases in the U.S.
- It promotes industry stability by facilitating the ability of companies to plan and invest in supplying future fertilizer needs and is a critical service to the regulated industry.
- Agricultural professionals can evaluate how well farmers in a region are generally following recommendations for fertilizer use.
- Archived records of consumption that can be matched to crop demands and soil fertility levels help demonstrate fertilizer need.
- Help identify potential areas of environmental concern. County data are especially useful in evaluating any association with the presence of excess nutrients…e.g. nitrogen (N) and phosphorus (P) in surface and subsurface waters. It can also improve the efficiency of policies relative to fertilizer nutrient management.
- Separation of the data into the following categories is also useful for the industry:
  - farm and nonfarm consumption of nutrients
  - materials and mixed grade distribution
  - bag, bulk, or fluid

The data have been used by many.

- Local fertilizer dealers to track sales, determine warranted changes, evaluate sales in other market areas, provide data for investment capital decisions, and support studies for orderly growth and effective, efficient investments.
- Fertilizer industry market analysts, to determine market penetration, develop market trend analyses, study regional and national market conditions, and improve distribution capabilities.
- Universities, institutions, and governmental agencies to determine potential distribution and use problems, improve consistency of fertilizer recommendations, evaluate effectiveness and impact of soil test recommendations, estimate fertilizer use efficiency, develop the basis of environmental impact studies, determine trends in types and usage of materials, identify high payoff areas for research, and verify effectiveness of regulation or policy. **Figure 2** is an example of a map of county-level P budgets for Illinois created by merging the AAPFCO fertilizer use data with USDA crop yields, recoverable manure P estimates, and standard crop removal coefficients through an ongoing project by PPI and TFI to increase the quality and accessability of nutrient use information. The map shows that all except 12 Illinois counties in 2005 had negative P budgets…crops removed more P than was applied as fertilizer or recoverable from manure.

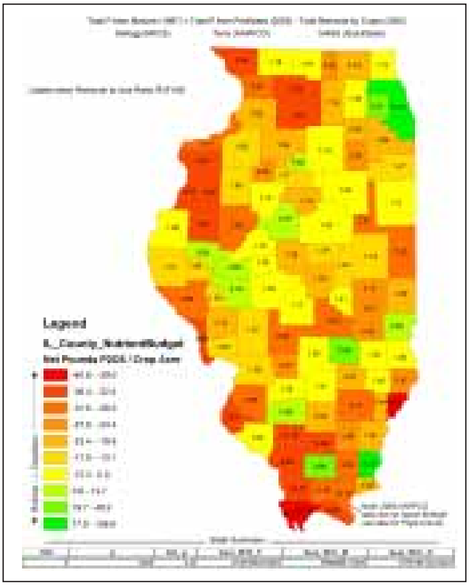


Figure 2. County P budgets for Illinois, 2005. (Prepared for PPI by PAQ Interactive.)

County-level data and descriptive maps can be used by:

- Financial institutions to evaluate operating/investment loans.
- Transportation systems to identify efficient distribution systems/ routes.
- Producers to determine availability of products.
- Extension specialists as educational impact tools.
- Control officials to track movement within the state, collect accurate tonnage fees, and develop inspectional programs so sampling is proportional to distribution.

Summary

The data reported by AAPFCO in the publication *Commercial Fertilizers* are the most accurate and credible source of fertilizer use data for the U.S. The data in the *Commercial Fertilizers* publication are available, valuable, used by people of various interests, and fragile in that the control offices collecting the data are under constant financial stress to collect and distribute the data. BC

Dr. Terry is the Coordinator of the Fertilizer Regulatory Program, Division of Regulatory Services, University of Kentucky, Lexington; e-mail: dterry@uky.edu.

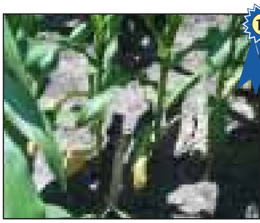
A longer version of this article containing more historical information and detail on the fertilizer consumption reporting process can be found at: ***>www.ppi-ppic.org/bctonreprt<.***

Results of Crop Nutrient Deficiency Photo Contest

Here are the results of judging of entries in the 2006 nutrient deficiency photo contest sponsored by PPI. "We appreciate the efforts of all who submitted entries," said Dr. Paul Fixen, PPI Senior Vice President and Americas Group Coordinator. "While the classic symptoms of crop nutrient deficiencies are not as common in fields as they used to be, they do still occur. Winning entries this year came primarily from university researchers working under controlled conditions. However, we hope that as the popularity of this contest increases, we will receive more qualifying entries from practitioners in the field." New contest information will be available in early 2007.

Following are images and descriptions of the first and second place entries in the four designated categories of the 2006 contest: Nitrogen (N), Phosphorus (P), Potassium (K), and Other (secondary nutrients, micronutrients, pH, etc).

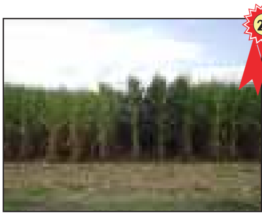
Nitrogen



Nitrogen deficiency in corn.

Location: Peanut Belt Research Station, Bertie County, North Carolina. Corn planted April 12, 2006; photo date June 16, 2006. Tissue analysis May 22 indicated N at 2.98%.

Entry by Dr. Carl R. Crozier, North Carolina State University; David Hardy, and Brenda Cleveland, North Carolina Dept. of Agric. and Consumer Services, Agronomic Division.



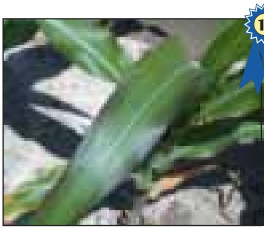
Nitrogen deficiency in corn.

Location: University of Kentucky Research and Education Center, Princeton.

Photo date August 5, 2003, at N study plots. Plants on left received no N, plants on the right received 150 lb N/A at planting.

Entry by Dr. Greg Schwab, University of Kentucky, Lexington.

Phosphorus



Phosphorus deficiency in corn.

Location: Peanut Belt Research Station, Bertie County, North Carolina. Corn planted April 12, 2006; photo date June 16, 2006. Growth stage V-9. Tissue analysis May 22 indicated P at 0.12%.

Entry by Dr. Carl R. Crozier, North Carolina State University; David Hardy, and Brenda Cleveland, North Carolina Dept. of Agric. and Consumer Services, Agronomic Division.

Phosphorus deficiency in cotton.

Location: Peanut Belt Research Station, Bertie County, North Carolina. Cotton planted May 3, 2006; photo date July 13, 2006, one week after first bloom. Tissue samples June 28 indicated P at 0.20%.

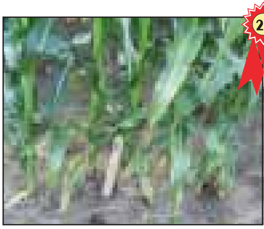
Entry by Dr. Carl R. Crozier, North Carolina State University; David Hardy, Brenda Cleveland, and Catherine Stokes, North Carolina Dept. of Agric. and Consumer Services, Agronomic Division.

Potassium

Potassium deficiency in soybean.

Location: Simpson, Illinois; Dixon Springs Agricultural Center, University of Illinois. Photo at early pod set, in check plot of long-term study. The K soil test was 100 parts per million (ppm) at beginning of study; deficiency symptoms began to appear in recent years.

Entry by Dr. Stephen A. Ebelhar, University of Illinois.

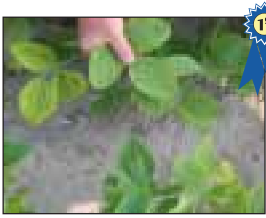


Potassium deficiency in corn.

Location: Peanut Belt Research Station, Bertie County, North Carolina. Corn planted April 12, 2006; photo date June 16, 2006. Tissue analysis may 22 indicated K at 0.81%.

Entry by Dr. Carl R. Crozier, North Carolina State University; David Hardy, and Brenda Cleveland, North Carolina Dept. of Agric. and Consumer Services, Agronomic Division.

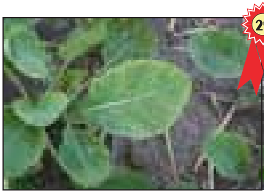
Other



Manganese (Mn) deficiency in soybean.

Location: Craighead County, Arkansas. Photo date July 5, 2006, growth stage V6 to V7. Grown on a Mhoon fine sandy loam with a water pH of 7.2 and soil organic matter of 1.9% in top 4 in. Soil test Mn was 0.7 ppm (M3) and plant tissue Mn was 4.8 ppm. Note the green veins and chlorotic leaves on the Mn-deficient plants.

Entry by Bobby R. Golden, Russ Delong, and Dr. Nathan Slaton, University of Arkansas, Fayetteville.



Sulfur (S) deficiency in canola.

Location: Langdon Research and Education Center, North Dakota. Photo date June 19, 2006. Comparison of S-based P fertilizer to no S applied; most recently expanded leaf comparison from adjoining plots. Research plots of John Lukach.

Entry by Dr. Terry A. Tindall, J.R. Simplot Company, Boise, Idaho.

Summing Up

These photos serve as excellent examples that can be used as references in the field. However, when deficiency symptoms do occur, irreparable yield losses have occurred. Tissue analyses are invaluable for confirming visual deficiency symptoms or for detecting "hidden hunger", when nutrient levels are too low but no symptoms have yet appeared. We hope this contest increases the awareness of proper nutrition and look forward to more great entries next year. BC

International Section

SOUTHERN LATIN AMERICA

Potassium Surface Runoff and Leaching Losses in a Beef Cattle Grazing System on Volcanic Soil

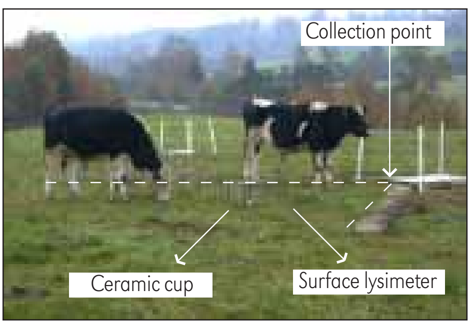
By Marta Alfaro, Francisco Salazar, and Nolberto Teuber

This article presents results of a study on potassium (K) losses through runoff and leaching in permanent pastures under beef production on volcanic soil in southern Chile. Losses due to runoff and leaching were low (4 kg K/ha/yr, on average), with 94% of the losses due to leaching. Increases in the stocking rate did not increase K losses.

Nutrient runoff from agricultural lands is generally considered a contributor to non-point surface water pollution. Chilean livestock production is concentrated in the southern part of the country and is largely based on a direct grazing system that has intensified over the last 10 years because of new commercial trade agreements signed by the country. This more intensive land use has increased amounts of nitrogen (N), phosphorus (P), and K fertilizer used per area, as well as the stocking rates and the intensity of rotational grazing.

Potassium losses from livestock grazing systems have been only partially studied, because of the lack of environmental impact from these losses. Nevertheless, K losses from grazed areas may represent a decrease in soil fertility over time, and thus an economic loss to farmers. The objective of this work was to quantify K losses in surface runoff and leaching from permanent pastures grazed with different stocking rates.

Potassium losses were evaluated in a closed beef cattle production system based on grazing at National Institute for Agricultural Research (INIA) Remehue (40º 35' S 73º 12' W), between March and December 2005. The soil at the experimental site is a volcanic andisol from the Osorno soil series (Typic Hapludands), which has 6% slope, more than 1 m of depth, high organic matter, and high K concentrations (**Table 1**). The 30-year average rainfall for the area is 1,284 mm/yr.



View of a surface lysimeter and ceramic cups used for the study of K losses in the beef cattle grazing system.

Stocking rates tested were 3.5 and 5.0 steers/ha, with an initial animal live weight of 212 ± 9.9 kg/animal (Holstein Friesian). Paddocks were divided into 45 strips and animals were managed under rotational grazing (one new strip every day) on a permanent pasture that had been continuously used for grazing with beef cattle for 20 years.

Table 1. Soil chemical analysis (0 to 20 cm) for the stocking rate treatments at the beginning of the experimental period, Feb. 2, 2005 (n=2, ± sem[1]).

Property	3.5 steers/ha	5.0 steers/ha	Category
Olsen P, ppm[2]	37.0 ± 11.6	28.0 ± 6.9	High
pH water	5.8 ± 0.05	5.7 ± 0.02	Slightly acidic
Organic matter, %	19.0 ± 3.5	15.0 ± 1.0	High
K, cmol(+)/kg, (ppm)	1.3 (507) ± 0.72	1.5 (585) ± 0.38	Very high
Ca, cmol(+)/kg, (ppm)	6.9 (2,760) ± 1.47	6.7 (2,680) ± 0.56	Intermediate
CEC, cmol(+)/kg	10.1 ± 2.61	10.0 ± 1.17	Intermediate
Sulfate-S, ppm	11.0 ± 0.4	12.0 ± 2.2	Intermediate

[1]sem = standard error of the mean. [2]ppm = parts per million.

Fertilizer treatments included 68 kg N/ha (45 kg in autumn and 23 kg in spring as sodium nitrate) and 69 kg P_2O_5/ha (in spring as triple superphosphate). No K fertilizer was added. These amounts and timings of fertilizer application represent a traditional management for beef farms in the area.

Three surface lysimeters were established at each treatment.

To quantify K losses in surface runoff, three surface lysimeters (5 x 5 m) were established in each treatment. Surface runoff samples were collected three times per week from the surface lysimeters between April 1 and December 15. Runoff samples were stored at 4 ºC until analysis for available K by atomic absorption spectrophotometry within one week of collection. The accumulated surface runoff was measured at each sampling date with the use of a graduated collector.

To measure K leaching losses, three ceramic cups were installed in each surface lysimeter at 60 cm depth. The sampling was carried out with every 200 ml of drainage between May 6 and August 31. Collected samples were frozen at minus 10 ºC until analysis. The volume of drainage lost by leaching was estimated as the difference between rainfall and evapotranspiration, once surface runoff was discounted.

Total K losses in surface runoff and leaching were calculated as the product of drainage and K concentration in the respective samples for each pathway, and then totals were added at the end of the season.

Analysis of variance was used to compare K concentrations and losses between treatments.

Results and Discussion

Total rainfall for the experimental period was 1,317 mm and total drainage below 60 cm was 941 mm. The main pathway for water movement was leaching, with no significant differences between treatments ($p = 0.05$; **Table 2**).

Average K concentration in surface runoff samples was greater than that of leachate samples (**Table 2**), because of the direct effect of urine transport in surface runoff samples. The dynamics of K concentration in surface runoff samples over time was not different between treatments ($p = 0.05$), but K concentration increased immediately after grazing and during spring time (September). This was also related to the urine transport in surface runoff, which has a high K concentration, and probably because of the increase in organic matter and fresh resi-

Table 2. Drainage (% of total drainage), K concentration in surface runoff and leachate samples (mg/L), and total K losses (kg/ha) in paddocks with different stocking rates (± sem[1]).

	3.5 steers/ha	5.0 steers/ha
Drainage		
Surface runoff	1% a	1% a
Leaching (> 60 cm)	99% a	99% a
K concentration (range), mg/L		
Surface runoff samples	22.0 ± 2.38 a (3 to 125)	23.0 ± 2.83 a (1 to 138)
Leachate samples	0.49 ± 0.04 a (0.05 to 1.47)	0.30 ± 0.02 b (0.1 to 0.89)
Total K losses, kg/ha		
Surface runoff	0.2 ± 0.009 a	0.2 ± 0.005 a
Leaching	4.7 ± 1.47 a	2.8 ± 0.24 a
Total	4.9 a	3.0 a

Different letters between columns indicate significant differences (p = 0.05).
Total rainfall for the period was 1,317 mm and total drainage collected for the period was 941 mm.
[1]sem = standard error of the mean.

due decomposition during spring, which increased K availability in the soil. Average K concentration in leachate samples was less than 1 mg/L, which is low for grazing paddocks, probably because this element was not added as fertilizer.

Similar to water movement, the main pathway for K loss was leaching (94%, on average). Losses in surface runoff were low because of the low amount of surface runoff generated by this soil type due to high infiltration and water holding capacity.

Total K losses were low (3 to 5 kg/ha/yr), again probably because no K was added as fertilizer. Other studies carried out on volcanic soil have found losses between 9 to 19 kg K/ha/yr. These studies attributed the occurrence of preferential flow as the main pathway for K loss, which was not observed in the present study.

The amount of K recycled onto the soil by the grazing animals can be estimated as 62 and 77 kg K/ha/yr, for the 3.5 and 5.0 steers/ha treatments, respectively. Thus, K losses represented only 6% of the K deposited in the soil by animals. In grazed areas where the pasture is also harvest for silage, K removal can reach 84 kg K/ha/yr. In this case, K should be added as fertilizer to correct the expected negative soil K balance produced by plant uptake/removal and K losses due to runoff and leaching.

Conclusions

This intensive beef cattle production system in southern Chile, based on grazing a volcanic ash soil, had little K loss via runoff and leaching (4 kg K/ha/yr, on average). In total, 94% of the losses were a result of leaching. An increase in the stocking rate did not have an impact on K losses from the system. Further research is required to complete this study as high variability between grazing paddocks and variable rainfall distribution between years may alter these conclusions. BC

Dr. Alfaro (e-mail: malfaro@inia.cl), Dr. Salazar, and Dr. Teuber are Researchers with the National Institute for Agricultural Research (INIA), Remehue Research Centre, PO Box 24-O, Osorno Chile. Phone: +56-64-233515. Fax: +56-64-237746.

Balancing Nutrient Use for Flue-Cured Tobacco

By Fan Su, Libo Fu, Hua Chen, and Lifang Hong

Field trials determined the optimal fertilizer rates for flue-cured tobacco production in Qujing, Yunnan Province. The study identified strategies for enhanced crop yield, quality, and profitability, as well as improved fertilizer use efficiencies.

For the 4 million flue-cured tobacco growers in Yunnan, the gap between current and potential yields is understandably of great interest. Balanced nitrogen (N), phosphorus (P), and potassium (K) fertilization is a crucial step towards improved profitability and productivity in this high value crop. The objective of this study was to quantify this relationship and use the responses of flue-cured tobacco to fertilizer as a starting point in providing science-based guidance for nutrient management in Yunnan's production centers.

Treatments were designed to compare a soil-test-based (Agro Services International method) 'optimum' (OPT) fertilizer application against three treatments which omitted N, P, or K, and six other unique NPK combinations (**Table 1**). Flue-cured tobacco was planted at a density of 15,000 plants/ha in a wheat-to-bacco crop rotation. Fertilizers were applied twice during the growing season with 60% applied basally and the remainder using topdressing. Six trials were conducted in Qujing over 6 years (2000 to 2006). This article covers the first 5 years of experimentation.

Improved growth of tobacco is clear. Quality was also improved.

The effects of fertilizer treatment on yield and income are summarized in **Table 2**. Relative to the OPT treatment, omission of N, P, or K reduced yields by 6 to 48%. Leaf yield was highest under the OPT and two other treatments that provided combinations of at least 195 kg P_2O_5/ha and 240 kg K_2O/ha along with 135 kg N/ha. Stem yields were consistently one-third to one-quarter of leaf yields, but followed a trend similar to that observed with leaf yields (data not shown).

Tobacco industry standards and price premiums demand that growers manage for the dual goal of achieving both high yields and a high quality product. In fact, the high value of flue-cured tobacco often depends more on its quality characters than yield. Therefore, tobacco leaf contents of sugar, nicotine, and protein were determined to evaluate the effect of fertilization on product quality (**Table 3**).

Table 1. NPK treatments (kg/ha) on tobacco in Qujing, Yunnan.

Treatment	N	P_2O_5	K_2O
OPT-N	0	195	240
OPT-P	135	0	240
OPT-K	135	195	0
$N_{135}P_{195}K_{180}$	135	195	180
$N_{135}P_{195}K_{240}$(OPT)	135	195	240
$N_{90}P_{195}K_{240}$	90	195	240
$N_{180}P_{195}K_{240}$	180	195	240
$N_{135}P_{150}K_{240}$	135	150	240
$N_{135}P_{240}K_{240}$	135	240	240
$N_{135}P_{195}K_{300}$	135	195	300

Table 2. Impact of nutrient management on flue-cured tobacco profit.

Treatment	Leaf weight, kg/ha	Production value, US$/ha	Cost, US$/ha	Profit, US$/ha	Profit, ±% vs. OPT
OPT-N	1,707 d[1]	1,465 e	282	1,183	-48.0
OPT-P	1,785 d	2,420 bc	279	2,141	-5.8
OPT-K	1,792 d	1,972 d	233	1,738	-23.5
$N_{135}P_{195}K_{180}$	2,389 c	2,612 abc	314	2,297	1.1
$N_{135}P_{195}K_{240}$(OPT)	2,766 a	2,614 abc	341	2,273	-
$N_{90}P_{195}K_{240}$	2,525 b	2,260 cd	321	1,939	-14.7
$N_{180}P_{195}K_{240}$	2,427 bc	2,481 abc	361	2,120	-6.7
$N_{135}P_{150}K_{240}$	2,468 bc	2,509 abc	327	2,182	-4.0
$N_{135}P_{240}K_{240}$	2,782 a	2,777 ab	355	2,421	6.5
$N_{135}P_{195}K_{300}$	2,819 a	2,797 a	368	2,429	6.9

[1] Numbers followed by the same letter are not significantly different.

Table 3. Impact of nutrient management on flue-cured tobacco quality.

Treatment	Sugar content, %	Nicotine content, %	Protein content, %	Sugar/ nicotine
OPT-N	18.95	3.52	9.92	5.38
OPT-P	24.43	4.50	11.33	5.43
OPT-K	23.86	4.33	11.69	5.51
$N_{135}P_{195}K_{180}$	25.89	4.32	11.59	5.99
$N_{135}P_{195}K_{240}$(OPT)	27.61	3.10	11.24	8.91
$N_{90}P_{195}K_{240}$	27.38	3.82	11.15	7.17
$N_{180}P_{195}K_{240}$	26.52	4.56	12.56	5.82
$N_{135}P_{150}K_{240}$	26.42	4.44	11.28	5.95
$N_{135}P_{240}K_{240}$	27.66	3.53	11.04	7.84
$N_{135}P_{195}K_{300}$	27.90	3.21	11.32	8.69

Table 4. Effect of nutrient management on nutrient allocation in tobacco.

	N content, %		P content, %		K content, %	
Treatment	Leaf	Stem	Leaf	Stem	Leaf	Stem
OPT-N	1.45	1.16	0.31	0.17	2.87	1.98
OPT-P	1.88	1.49	0.10	0.05	2.82	1.89
OPT-K	1.89	1.53	0.19	0.16	0.82	0.76
$N_{135}P_{195}K_{180}$	1.98	1.55	0.32	0.21	2.74	1.91
$N_{135}P_{195}K_{240}$(OPT)	2.52	1.66	0.36	0.22	3.14	2.42
$N_{90}P_{195}K_{240}$	2.04	1.36	0.26	0.17	2.76	2.38
$N_{180}P_{195}K_{240}$	2.50	1.65	0.26	0.19	2.95	2.35
$N_{135}P_{150}K_{240}$	1.95	1.58	0.32	0.23	2.75	2.29
$N_{135}P_{240}K_{240}$	2.48	1.63	0.36	0.22	2.99	2.44
$N_{135}P_{195}K_{300}$	2.49	1.66	0.35	0.21	3.13	2.41

The different nutrients and fertilizer rates had a considerable effect on sugar content in leaves, but did not influence protein. According to industry criteria, the OPT treatment produced better overall quality due to a higher preferred balance between nicotine and sugar contents.

In terms of economic returns to growers, differences in NPK application demonstrated a significant effect on profitability per hectare. Omission of N had the largest impact on net return, followed by K and then P. Although the OPT provided the best overall product quality as perceived by the processing industry, the yield and quality combination achieved by the treatment providing the highest K rate of 300 kg K_2O/ha did return the highest overall production value and best economic return to growers.

Maximum use efficiency for applied nutrients should fall in stride with those crop production systems which are both high yielding and most profitable. Plant nutrient allocation was determined by measurement of plant tissue nutrient concentrations. Leaf nutrient concentrations were sensitive indicators to nutrient omission and were consistently higher for treatments supporting the greatest yields (**Table 4**). The majority of macronutrients were transferred to the leaves. Leaf K concentrations were highest among the three macronutrients.

Similar to the yield response, N uptake and use efficiency was influenced by both P and K rate. Optimal N utilization by flue-cured tobacco was achieved with 135 kg N/ha, a minimum of 195 kg P_2O_5/ha plus 240 kg K_2O/ha (**Table 5**). High yielding treatments produced the highest N use efficiencies which ranged between 37 to 38%. Treatments omitting P or K returned remarkably low N use efficiencies of 8.7 and 9.1%, respectively.

The treatment effect on P and K use efficiency mirrored N use efficiency trends. The OPT was most favorable to P and K utilization by tobacco with no real advantage observed under higher fertilization rates. Omission plots consistently provided the lowest use efficiencies. Since flue-cured tobacco required much less P, the range of values was much lower than N or K.

Table 5. Effect of nutrient management on nutrient uptake and use efficiency in tobacco.

Treatment	N uptake, kg/ha	N use efficiency, %	P uptake, kg/ha	P use efficiency, %	K uptake, kg/ha	K use efficiency, %
OPT-N	30.8	-	6.2	2.1	59.3	16.7
OPT-P	42.5	8.7	2.1	-	61.7	17.7
OPT-K	43.1	9.3	4.4	1.2	19.3	-
$N_{135}P_{195}K_{180}$	57.4	19.7	9.0	3.6	77.9	32.5
$N_{135}P_{195}K_{240}$(OPT)	82.2	38.1	11.6	4.9	105.1	35.8
$N_{90}P_{195}K_{240}$	60.6	33.1	7.7	2.9	85.6	27.6
$N_{180}P_{195}K_{240}$	71.9	22.8	7.6	2.8	87.6	28.4
$N_{135}P_{150}K_{240}$	58.1	20.2	9.4	4.8	82.4	26.3
$N_{135}P_{240}K_{240}$	80.8	37.0	11.6	4.0	100.9	34.0
$N_{135}P_{195}K_{300}$	82.7	38.4	11.4	4.8	106.4	29.0

Note: Fertilizer use efficiency definition in this study is apparent fertilizer use efficiency (%) = (nutrient uptake by flue-cured tobacco in the nutrient treatment - nutrient uptake by flue-cured tobacco in the CK treatment) / amount of the nutrient applied in the fertilizer × 100%.

Optimum rates of NPK increased yields, profits, and nutrient use efficiency.

Conclusion

Based on these results, the selection of 135-195-240 kg N-P_2O_5-K_2O/ha as the OPT is an effective but conservative choice for this production system. Widespread adoption of the identified OPT over a fertilizer recommendation capable of achieving better results would likely be based on a need to ration scarce fertilizer K reserves within the region.

Although flue-cured tobacco leaf quality was best under the OPT NPK input level, increased awareness concerning the yield and profit advantages observed in this study under higher K and P input strategies...keeping current N input constant...should be stressed. Nutrient use efficiency, most critically for N, was equally as high under the pre-selected OPT and the study's most profitable combination of N, P, and K. BC

Mr. Su is Professor, Ms. Fu is Associate Professor, Mr. Chen is Assistant Professor, and Dr. Hong is Professor, Institute of Environment and Resources, Yunnan Academy of Agricultural Sciences. E-mail: gredbean@163.com.

The Impact of Soil Test-Based Fertilization on Tomato

By K.N. Tiwari, B.R. Gupta, R.K. Pathak, H.L. Sharma, and T.P. Tiwari

Current fertilizer use in tomato production in the central plain of Uttar Pradesh is generally confined to nitrogen (N) and phosphorus (P). This situation will not sustain tomato as an important cash crop system for northern India. A research and extension project has begun to effect positive change within the region.

Winter season-grown tomato production occupies 60,000 ha within Uttar Pradesh (North India) and is the major commercial crop for the region. Despite this, tomato growers have long-standing complaints regarding low yields, undersized fruit, premature fruit drop owing to loosely attached fruit, poor pulp content, disease susceptibility, and poor shelf-life.

The area is dominated by light-textured sandy loam soils largely deficient in N, P, and potassium (K). A recent appraisal of soil fertility status revealed N, P, and K deficiencies in 95%, 70%, and 52% of sites, respectively. Analysis of soils from fields located within Kanpur district villages selected for this study supports widespread K deficiency, with available soil levels ranging between 46 and 117 mg/kg. While farmers generally apply urea and diammonium phosphate (DAP), K fertilizer use is practically non-existent and farmyard manure is spread in limited quantities. Continuous cultivation of tomato under this management has seriously depleted nutrient reserves.

Farmers compare differences in fruit quality at a community field day extending trial results.

In this study, a series of adaptive trials was designed to: 1) study the response of applied K on yield and quality of the tomato crop, and 2) monitor the impact of balanced fertilization on farmers. The experiments were conducted on farm fields for 2 consecutive years with the following three treatments:

1. (FP) farmers' practice, which generally is applied urea at 80 kg/ha 0 plus DAP applied at 30 kg P_2O_5/ha
2. (FP+K) farmers' practice plus 60 kg K_2O/ha
3. (BF) a balanced treatment of 150-75-75 kg N-P_2O_5-K_2O/ha.

Sixteen (year 1) and 18 (year 2) experimental sites were established within four villages (i.e., Pura, Chain Newada, Radhan, and Arjun Purawa) representing a 1,000 ha cross-section of the tomato-growing area. Selected farm fields were different in both years. All experimental sites were low to medium in available K. The full quantity of P and half the quantities of N and K were applied at transplanting. The remaining quantities of N and K were applied 45 days after transplanting, at the time of 'earthing' or hilling. Recommended cultural prac-

Treatment	Plant height, cm	Basal girth, cm	Days till 50% flowering	No. of truss per plant	No. of fruit set per truss
BF	81	4.9	41	23	3.6
FP+K	70	4.5	44	21	3.0
FP	65	4.3	46	17	2.6
C.D.[1] at 5%	5	0.4	3	2	0.3

Table 1. Effect of various treatments on growth and flowering parameters of tomato.

[1]Denotes the critical difference

tices and plant protection measures were adopted uniformly for all treatments. Irrigation was provided as and when required. Standard chemical analyses of fruits were performed. Post-harvest storage life of tomato fruits was studied under ambient conditions.

Table 2. Effect of various treatments on quality parameters of tomato.

Treatment	Fruit weight, g	TSS (°Brix) at 14 days	Ascorbic acid at 14 days, mg per 100g juice
BF	105	5.9	350
FP+K	70	4.5	304
FP	65	4.3	241
C.D.[1] at 5%	4	0.4	26

[1]Denotes the critical difference.
TSS (°Brix) - Total soluble solids

Results and Discussion

Growth and development of reproductive parameters benefited significantly from balanced NPK fertilization. Plant height and basal stem girth were both increased compared to FP+K and FP. Time to crop flowering (50%) was reduced, and the number of flowers per truss was highest, for the BF treatment. In turn, a maximum number of fruit set per truss was noted under BF (**Table 1**).

Fruit quality characteristics also suggest great potential for improvement as the highest weight for individual fruits was noted under BF, followed by FP+K and FP (**Table 2**). The FP treatment resulted in maximum physiological weight loss after 14 days in storage. Storage advantages seemed apparent with fruits receiving BF, though the variation among treatments, prevented any statistical differences (data not given). Total soluble solids (TSS) in freshly harvested fruits varied little among treatments though the highest value did correspond with the BF treatment. The treatment effect on TSS became more pronounced during storage. However, after 14 days, fruits grown under BF still had the highest TSS content.

Treatments providing balanced fertilization appeared to enhance acid accumulation in freshly harvested fruits. Ascorbic acid (vitamin C) content was significantly higher in freshly harvested fruits under BF followed by FP+K (data not given). As described with TSS, ascorbic acid content tended to increase with storage duration. After 14 days, maximum ascorbic acid content was still observed under BF, followed by FP+K and FP.

Mean fruit yields were 41.5, 29.0, and 23.5 t/ha under BF, FP+K, and FP, respectively. An additional 60 kg K_2O/ha brought a 23% yield increase for FP+K over FP, while the BF treatment supported a 43% increase over FP **(Table 3).** Serious yield losses are apparent due to the omission of K, although an almost equivalent yield gap between FP+K and BF highlights the advantages gained through balanced nutrient supply. In economic terms, the mean net return from BF plots was 21.3 rupees (INR) per

Table 3. Mean yield (t/ha) of tomato under different treatments.

Year	No. of trials	BF	FP+K	FP
First	16	42.0	30.0	26.0
Second	18	39.0	28.0	21.0
Mean	–	41.5	29.0	23.5
Increase over FP, %	–	43	23	–

Table 4. Net returns over common farm practice.

Year	No. of trials	Net return, Rs/Rs invested BF	Net return, Rs/Rs invested FP+K	Net return, Rs/ha BF	Net return, Rs/ha FP+K
First year	16	20.0	17.9	32,000	8,000
Second year	18	22.5	31.5	36,000	14,000
Mean	34	21.3	24.7	34,000	11,000

1 US$ = 46.58 INR

unit invested above that from farmers' fertilizer practice (**Table 4**). Use of FP+K supported an additional INR 24.7 return per unit invested. Total returns over FP were INR 34,000/ha (US$730) in BF plots, and INR 11,000/ha (US$236) in FP+K plots.

Table 5. Impact analysis of balanced NPK fertilization.

Item	Number
Number of villages surveyed	6
Number of farmers contacted	96
Number of farmers who adopted balanced use of NPK as per recommendation	77
Average yield of farmers who adopted balanced fertilization	33.8 t/ha
Average yield under farmers' practice	22.8 t/ha
Mean yield increase with balanced use of NPK over farmer's practice	48%

On-farm trials with CSAUAT in Kanpur have caused many farmers to improve fertilization practices.

Impact Analysis

An impact analysis was conducted during the second year to assess outcomes and outreach from the first year's efforts. Farmer adoption of balanced fertilization in adjoining villages would largely be an outcome of a community field day. A survey was designed and 96 farmers from six neighboring villages were contacted to provide details about their fertilizer schedules for tomato.

A majority of farmers appeared convinced of the benefits of proper K use in their crops as 77 admitted to already adopting balanced fertilization (**Table 5**). For example, in the village of Makhan Newada, where no trials were conducted, farmers emulated those in nearby trial villages as 11 out of 12 farmers interviewed had enthusiastically adopted balanced use of NPK. Based on yield surveys, inclusion of K along with N and P sources was a gainful practice. The average yield was 34 t/ha for those using BF against 23 t/ha under a particular farmer practice. Most farmers indicated that fruit size and pulp content were also increased due to K fertilization and consequently their market prospects were enhanced. The impact would depend on the resources presently available to individual tomato growers, and would be expected to increase in significance as improved fertilization systems become more established. BC

Dr. K.N. Tiwari (e-mail: kntiwari@ppi-ppic.org) is Director, PPI/PPIC-India Programme. Dr. Gupta is Professor and Head, Dr. Pathak is Ex Professor and Head, Mr. Sharma is Ex Assistant Professor, and Dr. T.P. Tiwari is Assistant Professor, Department of Soil Science and Agricultural Chemistry, C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India.

Identifying Gaps in Mulberry Fertilization in Hubei Province

By Fang Chen and Jianwei Lu

A recent survey of the province's mulberry gardens identified a wide range of common practices that are significant barriers to sustained productivity.

Mulberry leaf production provides the sole uninterrupted source of food required by the silkworm (*Bombyx mori*). In turn, silk industries of the world depend on this one source. Silkworms produce valuable cocoons made of a single continuous thread of raw silk from 300 to 900 meters (m) long. An estimated 4,000 to 6,500 cocoons are required to make 1 kg of silk, and at least 30 million kg of raw silk are produced each year, requiring nearly 4.5 billion kg of mulberry leaves.

Fertilization plays a very important role for enhancing mulberry productivity and improving soil fertility. Local research suggests that proper nutrient management can increase mulberry leaf yields by 35% and can also improve leaf qualities (Tan et al., 1997; Wang et al., 2001). Hubei Province is one of the main silk production regions in China. Recent estimates of Hubei's area planted to mulberry place it at over 23,300 ha. Although mulberry planting occurs throughout Hubei, the largest activities occur in the eastern part of the province where 70% of the total area is located. High-yielding mulberry varieties have extended throughout Hubei, and soil nutrient removal has increased accordingly along with the frequency of soil nutrient deficiencies. Research shows that balanced fertilization is a key to advancing sustainable development of mulberry production within the province (Lu et al., 2004).

Higher rates of P and K and more balanced application could improve mulberry production in Hubei.

Since 2002, the authors have established balanced fertilization field trials and demonstrations for mulberry throughout Hubei. This work also included a comprehensive survey of 44 mulberry gardens in six counties. The survey collected information on the range of fertilization rates, measures, fertilizer products, and common nutrient management practices. The results of the survey provide the basis for the following discussion on mulberry leaf production in Hubei and identify the present limitations resulting from the continuation of common practices.

The survey of fertilizers available for mulberry found a selection of organic manures and commercial fertilizers (**Table 1**). Organic manures include compost, pond mud, human excreta, pig and cattle dung, and green manures. Commercial fertilizers included urea, ammonium bicarbonate, calcium superphosphate, potassium chloride (KCl), and two common compound fertilizer formulas, 12-16-7 and 15-15-15. It was evident that more site-specific formulas are required as a limited choice

Table 1. Status of manure and chemical fertilizer application on mulberry in Hubei (n=44).

	Nutrient sources	Number of samples	% of fields surveyed	Rate range, kg/ha	Average rate, kg/ha
Organic manures	Compost	23	52	12,000-120,000	50,220
	Pond mud	1	2	360,000	360,000
	Human excreta	1	2	9,000	9,000
	Pig/cattle dung	4	9	57,000-96,000	74,265
	Green manure	4	9	7,500-15,000	13,125
Fertilizers	Ammonium bicarbonate	39	89	488-4,500	1,680
	Urea	14	32	150-900	480
	Calcium superphosphate	9	20	375-1,500	855
	Compound fertilizer	5	11	750-1,125	825
	Potassium chloride	3	7	300-300	300
Total	Org. manure	0	0	-	-
	Fertilizer	11	25	-	-
	Org. manure + fertilizer	33	75	-	-

of fertilizer formulas would fail to provide the balanced quantities of nutrients required by the majority of mulberry fields in the province.

About 75% of mulberry fields used organic manures and 52% of these were composted materials. Of all the nitrogen (N) being applied, 74% was from commercial fertilizers. All mulberry fields used commercial N fertilizer — 89% used ammonium bicarbonate while 32% used urea.

Application of phosphorus (P) and potassium (K) fertilizers was generally inadequate across all sites surveyed. Of all the P being applied in Hubei, 70% originated from organic manures. In the more extensive production centers in the east, manures represented 92% of the total P supply. Commercial P fertilizer was utilized on 32% of mulberry fields, with 20% using calcium superphosphate and the remaining 12% relying upon compound sources. Of the five sites specifically using compound fertilizers, three belonged to a state-run silkworm breeding farm characterized as having greater awareness on science-based farming methods compared to those sites run by individual farmers. Only 18% of sites used K fertilizers with 7% specifically using KCl — the remaining 11% also relying on available compound fertilizer products. Organic manures represented 87% of the total K being applied.

Table 2. NPK application rates in mulberry production regions in Hubei.

Region		N, kg/ha	P_2O_5, kg/ha	K_2O, kg/ha
East (n=21)	Range	208-936	36-300	52-576
	Average	516	140	254
	Fertilizer	330	10	4
	Manure	186	129	249
Southwest (n=12)	Range	171-585	0-190	0-356
	Average	390	87	110
	Fertilizer	356	72	74
	Manure	34	15	36
North (n=11)	Range	192-870	0-165	0-258
	Average	405	96	98
	Fertilizer	330	39	0
	Manure	75	57	98
Total (n=44)	Range	171-936	0-300	0-576
	Average	453	114	176
	Fertilizer	338	34	22
	Manure	116	80	153

Nutrient application rates for mulberry fields were regionally-based with rates being highest in the east compared to the smaller production centers in the north and southwest (**Table 2**). The provincial averages for N, P, and K were: 453 kg N/ha (range = 171 to 936); 114 kg P_2O_5/ha (range 0 to 300); 176 kg K_2O/ha; (range 0 to 576). Nitrogen application was above 150 kg/ha for all fields and half were above 450 kg/ha (**Table 3**). Application of P and K was completely omitted from 14% and 25% of mulberry fields, respectively, and surveyors noted a great impact on mulberry leaf productivity in those cases.

Table 3. Distribution of NPK application rates for mulberry in Hubei.

Class, kg/ha	Number of samples	%	Average rate, kg/ha
		N fertilization	
>600	7	15.9	741
450-600	15	34.1	516
300-450	12	27.3	384
150-300	10	22.7	242
		P_2O_5 fertilization	
>225	3	6.8	250
150-225	15	34.1	166
75-150	16	36.4	99
0-75	4	9.1	51
0	6	13.6	0
		K_2O fertilization	
>300	7	15.9	390
150-300	16	36.4	244
75-150	7	15.9	130
0-75	3	6.8	46
0	11	25.0	0

For the mulberry gardens investigated, 25% used one annual nutrient application, which usually consisted of only manure applied in the winter season; 60% used two applications split between winter and summer; 10% used three splits; and only 5% use four split applications. Fertilization practices for the most advanced operations often included: 1) a basal dressing (about 10% of the total) in late February to early March prior to leaf emergence consisting of manure plus some fertilizer applied in a groove encircling the tree; 2) fertilizer (70% of the total) applied in holes located around the trees in June to early July after leaf harvesting and pruning. Some mulberry gardens will also broadcast urea and/or organic manure at this time; 3) fertilizer (about 15% of the total) applied after the summer silkworm sericulture in late August; and 4) fertilizer (about 5% of the total) applied in December after the entire year's sericulture (silk production) is completed.

Silkworms need a continuous supply of mulberry leaves.

Conclusion

The survey identified some significant nutrient management issues presently limiting mulberry production in Hubei. Great differences in fertilization rates and management levels exist among regions and even among mulberry gardens in close proximity. Nitrogen fertilization for mulberry has reached a relative high level in Hubei, but P and K rates are low and unbalanced with present N fertilization rates. Fertilization rates in the eastern region are higher than other regions and there is a larger dependence on manures, especially for P and K. In the southwest, fertilization and soil fertility are especially low and increased application of both manures and commercial fertilizers is advised. Split nutrient applications are under-utilized for mulberry and the minimum practice of three split applications is recommended in order to better match the seasonal nutrient requirements. BC

Dr. Chen (e-mail: fchen@ppi-ppic.org) is Deputy Director, PPI/PPIC China Program, and Professor, Wuhan Botanical Garden, CAS, Wuhan, 430074, China. Dr. Lu is with the Environment and Resources College, Huanzhong Agricultural University, Wuhan, 430070, China.

References (Chinese with English abstract)

Wang Bo, Dai Xuan-yin, and Ding Rue. 2001. Sericulture of Jiangsu, 3 (1): 13-15.

Tan Shun-you, Li Zhang-bao, and Lin Gao-tang. 1997. Sericulture of Hunan, (1): 7-9.

Lu Jian-wei, Xiong Jian-ping, and Chen Fang. 2004. Hubei Agricultural Sciences, (1): 59-62.

Avoid Tripping—Get Coordinated

"Have a nice trip? See ya' next fall!" quipped my junior high classmates after seeing me stumble in the school hall. I remember those days with my peers. We were teenagers going through rapid changes and growth spurts that left us all a little uncoordinated at times. We used humor to get through it, if you want to classify puns as humor.

A lot of what agriculture has been going through could be classified as a growth spurt: globalization of markets, ethanol production, biodiesel, nutraceuticals, genetic engineering, nutrient management plans, and site-specific management generating tsunamis of data. It's easy to trip. In these times, we need to be better coordinated. Here are a few suggestions.

Coordinate nutrients. Better communication between farmer and adviser will help allocate funds to the right overall combination of nutrients and/or lime. Proper nutrient management can also reduce environmental risks.

Coordinate sources. A sound strategy, when possible, is to combine occasional applications of organic sources with commercial fertilizer applications to keep levels of all nutrients at desired levels while taking advantage of more carbon.

Coordinate management. The way crops respond to nutrients depends heavily on other management practices. Nutrients also impact other parts of the crop production system. And not every field needs the same nutrient management strategy.

Coordinate information. Great value exists in looking at how things change over time. To make full use of data collected, store information in a systematic way for easy access and analyze with an eye to the questions you really want answered.

Coordinate risks. Examine how various risks are interconnected. For instance, keeping crops properly fed, which reduces agronomic risk, can also ensure that revenue won't be shorted – economic risk.

To avoid tripping, we need to understand how these different parts of the farming operation are related. **Staying coordinated, we will avoid tripping and can walk with greater confidence during agriculture's growth spurts.**

T. Scott Murrell

Scott Murrell
PPI Northcentral U.S. Director

BETTER CROPS
WITH PLANT FOOD
Potash & Phosphate Institute
Suite 110, 655 Engineering Drive
Norcross, Georgia 30092-2837

Periodicals Postage