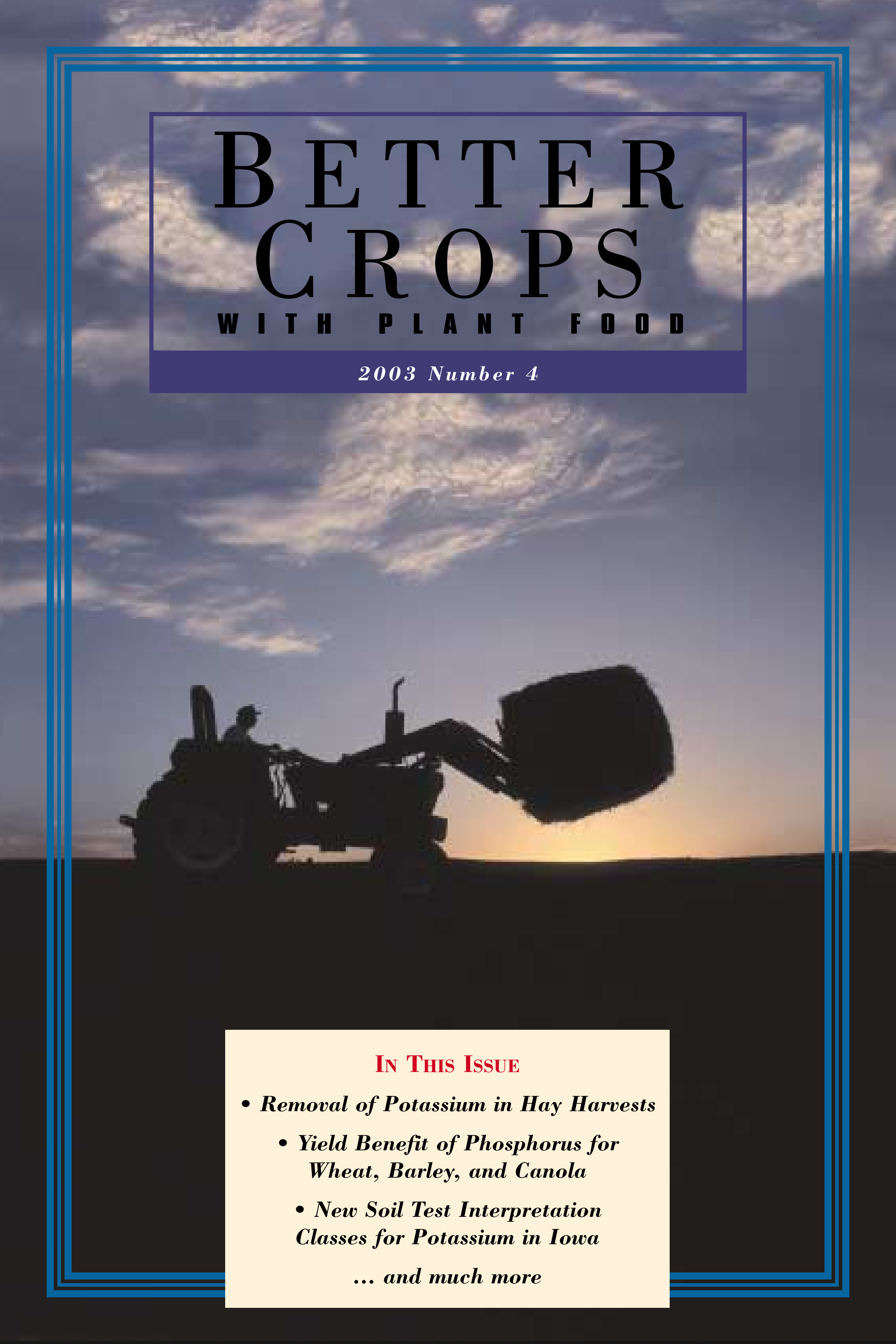
BETTER CROPS WITH PLANT FOOD

2003 Number 4



IN THIS ISSUE

- *Removal of Potassium in Hay Harvests*
- *Yield Benefit of Phosphorus for Wheat, Barley, and Canola*
- *New Soil Test Interpretation Classes for Potassium in Iowa*

... and much more

BETTER CROPS
WITH PLANT FOOD

Vol. LXXXVII (87) 2003, No. 4

Our Cover: Bringing in the hay.
Photo Credit: AGCO Corporation

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.

CONTENTS

PPI/PPIC on the Web: www.ppi-ppic.org

Learn more about PPI/PPIC programs, research support, publications, and links by visiting the website at **www.ppi-ppic.org**. From the central website, visitors may reach the various individual regional sites where PPI/PPIC programs are at work.

NORTH AMERICA

Removal of Potassium in Hay Harvests—A Huge Factor in Nutrient Budgets

By C.S. Snyder

Crop nutrient demand is growing in much of North America because crop yields are increasing and with them crop nutrient removal. An overview of the recent nutrient budget (removal minus input) in North America was reported in *Better Crops with Plant Food* last year (2002, No. 2:20-22). In this article, the focus is on K removal by all hay crops in North America.

It is estimated that over half of the land area in the U.S. is used for grasslands, to provide feed for livestock and to convert fiber to milk and meat for human consumption. So, it is not surprising that forages are often referred to as "the backbone of sustainable agriculture." A large percentage of these grasslands is specifically targeted for hay production to offset feed expenses during winter and during drought, and surplus forage in grazed pastures is frequently harvested for hay.

Evaluation of nutrient budgets reveals that harvested hay crops are responsible for 46% of the potassium (K) removed by all crops in North America. Harvested hay crop K removal is equivalent to 91% of the K fertilizer applied to all crops in North America.

Nutrient balance is just as important with forages as it is for other crops. To assure that forage production is indeed sustainable, harvested nutrients must eventually be replaced. Inadequate fertilization and/or nutrient imbalance prevent many producers from achieving desired forage yields and quality, and they can also adversely affect animal health and decrease weight gain and milk production.

Most forage and livestock producers recognize the need for nitrogen (N) fertilization, but often overlook the comparable

Hay harvest removes large amounts of nutrients, particularly K, from fields.

TABLE 1. Nutrient removal by harvest of major forages.

Forage	N	P_2O_5	K_2O
	Dry matter basis, lb/t		
Alfalfa[1]	56	15	60
Annual ryegrass	68	16	67
Bahiagrass	43	12	35
Bermudagrass	46	12	50
Bromegrass	36	13	59
Clover[1]-grass	50	15	60
Fescue	38	18	52
Orchardgrass	50	17	62
Sorghum-sudan	40	15	58
Timothy	38	14	62
Vetch[1]	56	15	46
	67% moisture basis, lb/t		
Corn silage	8.3	3.6	8.3

[1]Legumes obtain most of their N from the air.

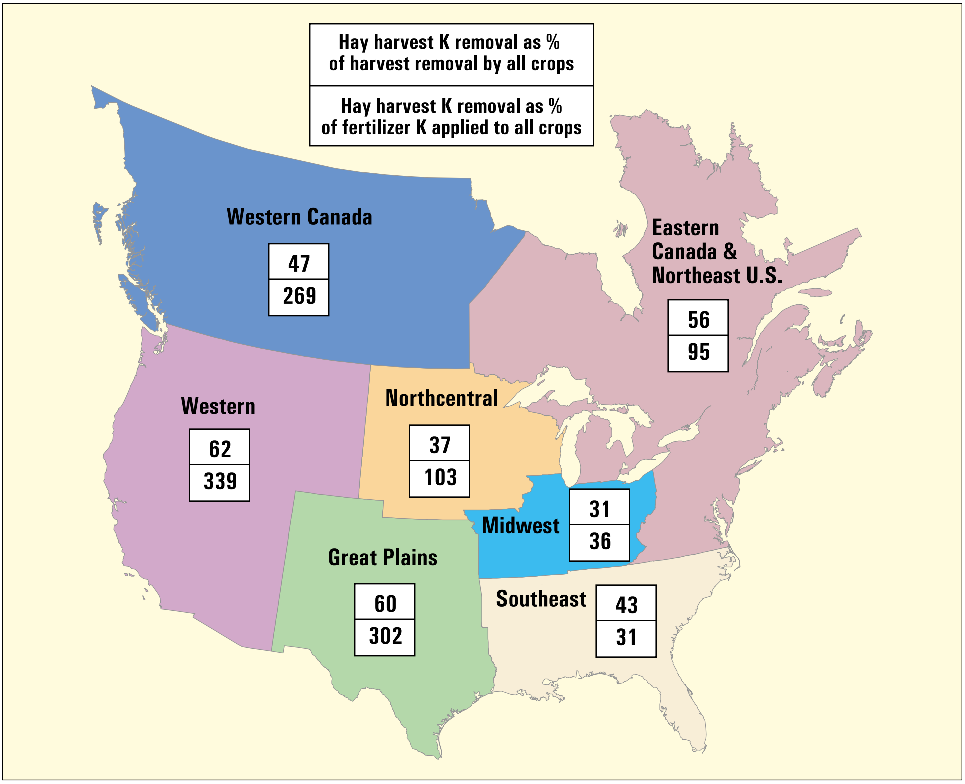


Figure 1. Forage hay harvests are a large portion of total crop K removal and the total K_2O applied annually to all crops.

forage demand for K. Potassium utilization by forage grasses exceeds utilization by any other agronomic crop in the world. Most forage crops have a K concentration ranging from 1.6 to 3.2% of the dry matter.

Table 1 illustrates nutrient removal by some of the major forages in North America. High yields of these forages result in high nutrient removal. For example, harvesting 6 t/A (dry matter) alfalfa removes about 360 lb K_2O...and bermudagrass removes about 300 lb/A. This can lead to a significant decline in soil fertility levels over time if soil fertility is not properly managed.

About 78 million grassland acres are harvested for hay yearly, which is about 19% of the total grain, fiber, and oilseed crop acreage in North America (**Table 2**). (***Note:*** *non-hayed grassland acreage is not reported by national agricultural statistics services*). In some regions, hay acreage accounts for at least one-third of the total crop acreage. Crop harvest in North America removes over 21 million lb of K_2O annually. It may be surprising that harvested hay crops account for 46% of all K consumption in North America, and that it dominates all crop K removal in three regions (**Table 2**).

In several North American regions, hay harvests are mining soil K reserves. **Figure 1** illustrates regional differences in the magnitude of the annual hay harvest removal compared to annual K fertilizer sales. In all of North America, annual hay harvests alone remove K equivalent to 91% of all fertilizer K sold and applied to all crops annually.

The impact of hay harvest K removal on forage nutrient budgets at the national, regional, and local levels is clear. Continued under-replacement of K will take a toll on the productivity and competitiveness of the forage-livestock system, as soil test levels

TABLE 2. Hay acreage and K_2O consumption among U.S. and Canadian regions.

PPI region	All hay acres[1], thousand acres	Total crop acres (incl. all hay), thousand acres	All hay/ total crop acres, %	All hay K_2O removal, million lb	Alfalfa K_2O removal/ all hay K_2O removal, %	Total crop (incl. all hay) K_2O removal, million lb	All hay K_2O removal/ total crop removal, %	Fertilizer K_2O applied to all crops (incl. all hay)[2], million lb	All hay K_2O removal/ all fertilizer applied, %
Eastern Canada & Northeast U.S.	12,482	34,985	36	1,511	47	2,612	58	1,586	95
Great Plains	11,130	64,390	17	1,479	43	2,468	60	490	302
Midwest	9,170	66,336	14	1,183	41	3,821	31	3,319	36
Northcentral	15,600	111,419	14	2,291	78	6,164	37	2,214	103
Southeast	7,085	35,690	20	754	2	1,741	43	2,415	31
Western	9,357	28,769	33	1,926	81	3,119	62	568	339
Western Canada	13,103	76,585	17	786	71	1,658	47	292	269
North America Total	**77,927**	**418,174**	**19**	**9,930**	**58**	**21,583**	**46**	**10,884**	**91**

Sources: U.S. National Agricultural Statistics Service; Statistics Canada; and PPI/PPIC/FAR Technical Bulletin 2002-1.
[1]Acreage information based on 2001 data from Canada and 2000 data from the U.S.
[2]Crop K consumption is average of 1998-2000; K applied to all crops from PPI/PPIC/FAR Technical Bulletin 2002-1.

decline below the optimum range.

Forage and livestock producers, fertilizer dealers, and crop advisers have many opportunities to relieve chronic K shortages with progressive K management. Soil testing can be used in concert with forage and hay analyses to develop nutrient budgets for individual pastures and hay meadows, or management zones within grasslands. Good K fertility management can benefit farmers, livestock, rural communities, and the urban public. **Optimum forage K management can lead to increased forage production, greater farm profitability, and protection and preservation of soil and water resources.** BC

Dr. Snyder (e-mail: csnyder@ppi-far.org) is PPI Southeast Regional Director, located at Conway, Arkansas.

Get E-mail Updates from PPI/PPIC/FAR for Free

PPI/PPIC/FAR and their forerunners have been supporting agronomic research and developing educational programs for nearly 70 years.

Now these organizations are offering a timely method of delivering current information and updates on topics of interest to individuals who want to receive notice electronically.

Visit the website **>www.ppi-ppic.org<** and look for the icon shown.

Simply fill in the registration screeen on-line and select the topics or publications that fit your interests. Soon, you will begin receiving a brief e-mail to alert you when something new is posted to the website that fits your choices. This is a free service. And be assured that we will not share your information with anyone. BC

SOUTH DAKOTA

Phosphorus Variability in Fields with Homestead Histories

By J.L. Kleinjan, C.G. Carlson, and D.E. Clay

Historical management practices can have a significant impact on soil test P levels. The Homestead Acts of the early 19th century resulted in the formation of 160-acre farms in South Dakota. Many of these farms had small areas where livestock were confined. When manure accumulated in or near these areas for extended periods of time, soil test P levels became higher in them than in the surrounding field. These areas of elevated P soil test levels, termed "hot spots", are still evident today and have been detected through more intensive soil sampling procedures **(Figure 1)**.

> When collecting cores, avoiding areas known to have elevated levels of phosphorus (P) produces samples that are more representative of the soil test P levels present in the majority of the field.

Hot spots can affect fertility evaluations of a field. A common practice in the western Corn Belt is to take a single composite soil sample from a field to determine the average fertility level. When cores unknowingly taken from a hot spot are mixed with cores from the remainder of the field, soil test results become too elevated to accurately represent the average fertility of the majority of the field. Depending on levels present, this may result in under-fertilization of significant areas. If hot spots can be avoided during sample collection, it may be possible to more accurately represent the fertility of a field and to reduce the variability in

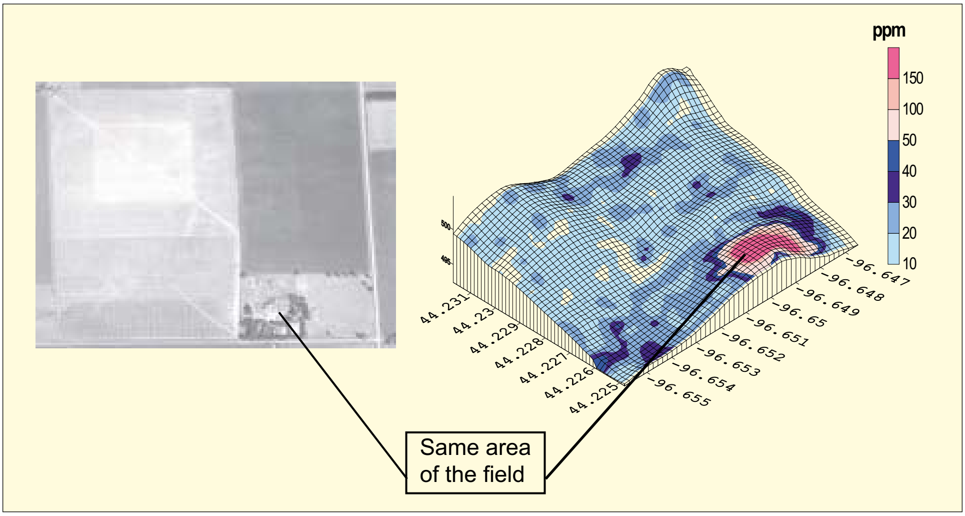


Figure 1. A 1956 historical aerial photograph showing the location of farmstead buildings now removed (left) and a map of soil test P showing elevated levels in the same approximate location (right).

TABLE 1. Proportional area and average Olsen P soil test levels for various areas within fields.

Field ID	Estimated hot spot radius, ft.	Proportion of field area, %		Average Olsen P soil test level of each area, ppm		
		Hot spot	Non hot spot	Whole field	Hot spot	Non hot spot
1	590	11	89	23.5	76.6	16.9
2	590	21	79	31.9	91.7	16.2
3	490	9	91	21.1	71.3	16.0
4	1,310	29	71	42.0	96.2	19.9
5	660	19	81	7.4	13.2	6.1
6	490	3	97	7.0	17.1	6.6
7	660	19	81	10.1	26.0	6.5
8	660	23	77	40.2	85.6	27.0
9	660	16	84	9.9	23.4	7.4
10	660	18	82	13.3	21.3	11.6
11	590	26	74	21.4	31.5	17.8
12	N/A	10	90	16.6	40.3	13.9
Average		**17**	**83**			

a set of intensive soil samples taken from it.

A study was conducted on 12 fields in six counties in eastern South Dakota (**Figure 2**). Historical information about manure applications, fertilization, tillage, and other factors affecting soil test P levels (such as livestock over-wintering) was obtained through producer correspondence and aerial imagery. Intensive soil samples (0 to 6 in.) were collected using various approaches from 1995-2000 and analyzed for Olsen P [parts per million (ppm)]. Aerial photographs from 1939 to 1984 were collected from Natural Resources Conservation Service centers. Recent (less than 10 yr. old) aerial photographs were obtained online at >**www.terraserver.com**<.

Contour maps were created of Olsen P levels in each field, using the kriging interpolation technique. An exponential decay function was used to describe the relationship between Olsen P level and distance from the center of the hot spot. The distance where the slope of the regression line decreased toward zero was taken to be the approximate cutoff point for the hot spot radius. The extent of the non hot spot area was figured by subtracting the calculated hot spot area from the total field area.

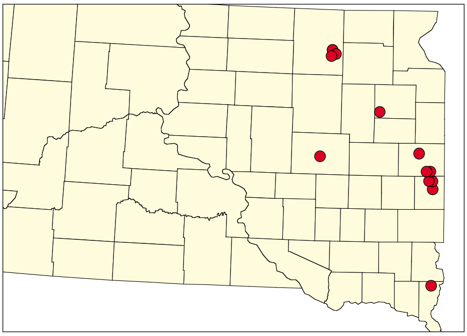


Figure 2. Location of study fields in eastern South Dakota.

Each field studied contained a P hot spot. **Table 1** shows the porportional size of both hot spot and non hot spot areas in each field. Radii of hot spots ranged from approximately 490 to 1,310 ft., with 660 ft. being most common. Hot spots ranged from 3 to 29% of the total field area with Olsen P levels 7.1 to 76.3 ppm higher than the remainder of the field. In three of the fields (6, 7, and 9), average soil test levels from hot spots indicated no need for P fertilization, whereas average levels from non hot spot areas did.

Excluding hot spots from sampling has the potential to reduce variability in Olsen P levels, as measured by the coefficient of variation (CV). Variability in samples across the whole field was compared to variability of only non hot spot areas (**Table 2**). In all but one case (field 11), non hot spot areas were less variable than the entire field. On average, non hot spots had a CV of 55.2% compared to an average whole field CV of 95.9%.

Avoiding hot spots while sampling is critical for collecting representative samples. As shown in **Table 1**, hot spots uncovered in this study make up a minor portion of the total

TABLE 2. Coefficient of variation for samples collected across the whole field, the hot spot, and the non hot spot areas in each field.

Field ID	Whole field	Hot spot	Non hot spot	Reduction in CV (whole field - non hot spot)
	.... CV			
	.... %			
1	112.3	66.2	59.2	53.1
2	190.9	126.6	56.2	134.7
3	116.6	83.3	37.5	79.1
4	107.1	47.7	90.5	16.6
5	58.1	58.3	24.6	33.5
6	57.1	60.2	47.0	10.1
7	114.9	83.1	27.7	87.2
8	75.4	33.1	50.0	25.4
9	90.9	64.5	54.1	36.8
10	58.6	46.0	52.6	6.0
11	69.6	47.0	75.8	-6.2
12	99.4	80.1	87.1	12.3
Average	**95.9**	**66.3**	**55.2**	**40.7**

field area. However, as **Table 2** demonstrates, they contribute greatly to soil test P variability. When attempting to collect a soil sample, including cores from hot spot areas inflates results beyond what is representative of the majority of the field. Collecting cores only from the less variable non hot spot areas increases the probability that a representative sample can indeed be collected. It also increases the chances that fertilizer recommendations based on the soil sample will be appropriate for the majority of the field area.

Conlusion

Reviewing old field photos is useful for determining where farmsteads were and where high concentrations of nutrients are now likely to be. When taking a composite sample, avoiding the collection of cores in close proximity to a farmstead or abandoned farmstead will result in more representative samples and more accurate fertilizer recommendations.

Mr. Kleinjan is a research associate (e-mail: jonathan_kleinjan@sdstate.edu); Dr. Carlson (e-mail: carlson@ces.sdstate.edu) and Dr. Clay are with the Plant Science Department, South Dakota State University, Brookings.

TOOLBOX

PKalc Software Checks Nutrient Budgets

"Toolbox" is a feature on the PPI/PPIC website which holds free downloadable software tools for improved nutrient management.

One useful tool is called PKalc (v.1.13), a simple nutrient budget calculator which helps users determine if phosphorus (P) and potassium (K) nutrient additions are keeping up with removal by crops. It is an Excel spreadsheet which enables developing a multi-year, multi-crop nutrient budget. PKalc was originated as part of a project supported by a grant from USDA-Cooperative State Research, Education, and Extension Service (CSREES), through the Initiative for Future Agriculture and Food Systems (IFAFS).

Users of PKalc input crops grown and yields, plus a list of nutrients added (fertilizer and manure). The program then estimates total crop nutrient removal and calculates total nutrient additions and the resulting net budget of P and K. Default crop removal coefficients can be changed if the user prefers. The estimated net P and K budgets are intended to get farmers and their consultants thinking about whether or not fertilization programs are meeting goals.

Detailed user instructions are included as pop-up comments within the spreadsheet. A Quick Start Guide and Power Point slide set also provide background information and selected state-level data.

PKalc and other useful programs can be accessed for free at:

>www.ppi-ppic.org/toolbox<.

The Critical Role of Nutrient Management in Mint Production

By B. Brown, J.M. Hart, M.P. Wescott, and N.W. Christensen

Mint (spearmint and peppermint) has been grown in the U.S. as a specialty crop for hundreds of years. Mint is primarily grown for the oil produced from its leaves. While relatively few growers produce mint, the U.S. is the world-leading producer of mint oil. The top-producing states in the U.S. are located north of the 41st parallel, where the right amount of daylight and favorable conditions produce high yields and quality of oil (**Figure 1**).

Research results from the Pacific Northwest demonstrate the importance of fertilizer nutrients in the production of mint, used to add flavor to a wide variety of specialty products.

Mint, a perennial plant that produces no seed, is planted in rows using roots dug from existing fields. Typically, by the second year the mint rhizomes have spread sufficiently to create a solid plant stand. The oil, stored in glands on the underside of the leaves, is recovered after the plant is cut, dried in windrows, and hauled from the field to a steam distillery.

An acre of mint generally produces about 85 lb of peppermint and 110 lb of spearmint oil. **Table 1** lists the amounts of mint oil used in some products.

Careful nutrient management is essential to balance high biomass growth and production of high quality oil—two essential ingredients for profitable production. This article summarizes region-wide research results conducted in the Northwest U.S. Additional details are available directly from the authors.

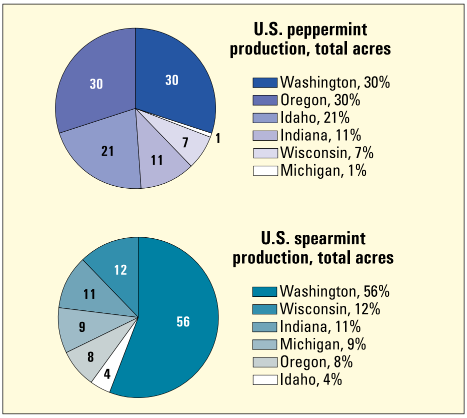


Figure 1. Percentage of U.S. mint production acreage in top producing states.

TABLE 1. Approximate production from mint.

A 400-lb drum of mint oil:	
	400,000 tubes of toothpaste
	5,000,000 sticks of gum
	20,000,000 mint candies
One ounce of mint oil:	
	62 tubes of toothpaste
	780 sticks of gum
	3,125 mint candies
One drop of mint oil:	
	2.5 tubes of toothpaste
	31.25 sticks of gum
	125 mint candies

Nitrogen (N) Management

Nitrogen management is challenging for mint production. Since little opportunity exists for mechanical incorporation, fertilizer N is typically applied to the soil surface.

Mint requires approximately 200 to 250 lb N/A to support optimum growth. Multiple applications of N through the growing season are commonly made to maintain a continuous nutrient supply for maximum oil production. Slow-release N sources can be used, but must release nutrients sufficiently quickly to maintain active vegetative growth and development of new leaves for maximum oil production.

Threshold values for stem nitrate concentrations have been determined as a guide for fertilization during the growing season. Additionally, critical levels for leaf chlorophyll content using a SPAD meter have been established as an aid to adjusting in-season N fertilization rates. When N supplies are limited, plant biomass and oil yields are reduced.

This peppermint plant was grown with complete nutrition. Various nutrient deficiencies can hurt production.

Phosphorus (P) Management

An adequate supply of P is important through the growing season (**Figure 2**) and also to stimulate new root growth after harvest. Fertilizer P is typically applied prior to crop establishment and then surface applied following harvest as recommended by soil testing. Phosphorus removed with harvest ranges from 44 to 88 lb P_2O_5/A based primarily on the biomass removed.

Potassium (K) Management

Mint has a constant demand for K during the growing season (**Figure 2**) and an average yield of mint biomass of 3 t/A removes over 300 lb K_2O. Soils with a low K-supplying capacity can become depleted in K with this high rate of crop nutrient removal. Potassium fertilizer can be applied in the fall or the early spring according to the soil test.

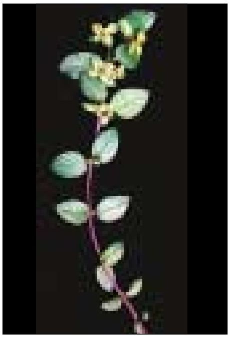
Rapid shoot and root growth during the summer can strain the soil nutrient supply

Nitrogen Deficient

Phosphorus Deficient

Potassium Deficient

Sulfur Deficient



Nitrogen deficiency is manifested as chlorosis beginning in the older leaves and progressing to the entire plant. Stunted growth and red leaves are also observed with inadequate N supplies.
Symptoms of low P supplies include increased purple pigmentation on the leaves and stems. The stunted plants may also have unusually dark green leaves that are smaller than normal.
Low K supplies may be exhibited with stunted plants that have bronzing on the leaf margins, with interveinal chlorosis commonly observed.
Symptoms of low soil S are stunted plants that have chlorosis, beginning with the younger leaves.

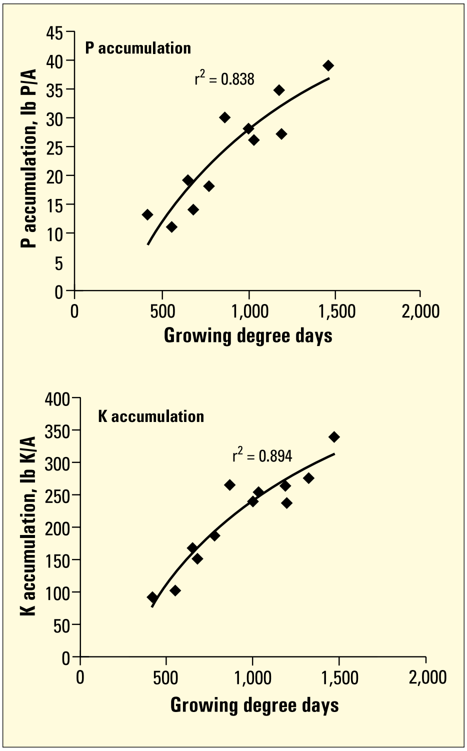


Figure 2. Accumulation of P and K by peppermint during the growing season in the Willamette Valley of Oregon, using base of 5°C (Hart et al., 2003).

and limit growth if adequate nutrient supplies are not present.

Sulfur (S) Management

Sulfur is applied to mint more frequently in higher rainfall areas of the northwestern U.S. High rates of sulfate (SO_4)-S application have no effect on oil quality. However, application of elemental S on mint leaves results in conversion of one peppermint oil component (Germacrene-D) to undesirable mint sulfide. Elemental S should only be used at low application rates when needed for disease control, at least 30 days prior to harvest.

The U.S. is the largest producer of mint, grown for the oil produced from its leaves.

Conclusion

Fertilization is an important part of the overall management of mint. Timely soil testing and tissue testing are essential tools for production of maximum yield of high-quality mint oil. BC

Dr. Brown (e-mail: bradb@uidaho.edu) is with the University of Idaho. Dr. Hart and Dr. Christensen are with Oregon State University. Dr. Westcott is with Montana State University.

Additional information about nutrient management for mint is available from the authors or from these sources:

Brown, B. 2003. Mint soil fertility research in the PNW. Western Nutrient Management Conf. 5:54-60.

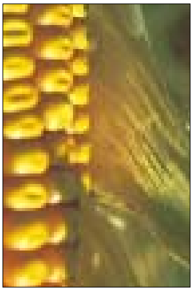
Hart, J., N. Christensen, M. Mellbye, and G. Gingrich. 2003. Nutrient and biomass accumulation of peppermint. Western Nutrient Management Conf. 5:63-70.

Westcott, M.P. 2003. Peppermint nutrient deficiency symptoms. Western Nutrient Management Conf. 5:61-62.

Additional images showing deficiency symptoms are available at the following website: >http://ag.montana.edu/warc/Peppermint deficiency symptoms_files/frame.htm<.

New Soil Test Interpretation Classes for Potassium

By A.P. Mallarino, D.J. Wittry, and P.A. Barbagelata



A need to update Iowa soil test K interpretations was first suggested during the middle 1990s by an increasing frequency of K deficiency symptoms in corn and soybeans, even in some soils that tested Optimum according to the current soil test K interpretations at that time.

Iowa soil test potassium (K) interpretation classes have been reclassified to reflect crop responses to K fertilization at higher soil test levels.

The Optimum category included a range of 90 to 130 parts per million (ppm) K measured with the ammonium acetate test on 0 to 6 in. samples dried at 95 to 104°F. In addition, field experiments designed to evaluate K placement methods often showed larger than expected yield responses in soils testing Optimum, and small responses in soils testing within the High category. In the past, deficiency symptoms and large yield responses were rare for the Optimum category, for which only maintenance K fertilization based on crop removal is recommended.

Soil test calibration experiments have confirmed that soil test K interpretations in use sometimes recommended too little or no K fertilizer for soils with a high probability of yield response.

Figure 1 shows the relationship between relative corn yield and ammonium acetate extractable K. Data for soybeans and for the Mehlich-3 soil test extractant were

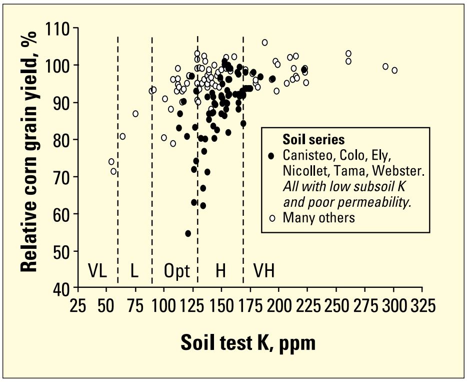


Figure 1. Relationship between relative corn yield and ammonium acetate soil test K values for various Iowa soils. VL, L, Opt, H, VH are abbreviations for the Very Low, Low, Optimum, High, and Very High soil test interpretation classes. Interpretation classes were used until October 2002.

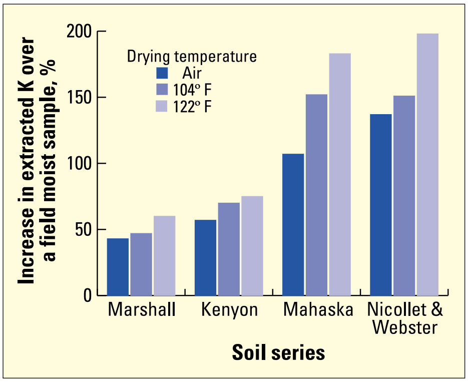


Figure 2. Example of the effect of sample drying temperature on K extracted from dried samples using the ammonium acetate procedure. All results are compared to those attained from the same procedure conducted on field-moist samples.

TABLE 1. Previous and current soil test interpretation classes for K (for Iowa soil series with low subsoil K).

Soil test category	Previous recommendations: Soil test K, ppm	Corn	Soybean	New recommendations: Soil test K, ppm	Corn	Soybean
		K_2O rate, lb/A			K_2O, lb/A	
Very low	0-60	120	90	0-90	130	120
Low	61-90	90	75	91-130	90	90
Optimum	91-130	40	65	131-170	45	75
High	131-170	0	0	171-200	0	0
Very high	171+	0	0	201+	0	0

Notes: The fertilizer amounts recommended for the Optimum category assume corn yields of 150 bu/A and soybean yields of 55 bu/A. More complete tables are available at the Iowa State University Extension Publication PM-1688. Website: >www.extension.iastate.edu/Publications/PM1688.pdf<

similar (not shown). The black points in the figure denote data for Iowa soil series in which the response to K was much larger than current interpretations would predict. The white points are those behaving according to expectations. All series represented by black points have low subsoil K. The white points include soil series with either low or high subsoil K in approximately similar proportions (not shown). Thus, dividing soils into those with either high or low subsoil K concentrations only partially explained crop response differences.

Several reasons could explain both the increased soil test K requirement for many soils and the large response variation across soils with similar soil test K levels. Ongoing research is addressing these issues and no firm conclusions are possible at this time. However, one likely reason relates to a change made in 1989 from interpretations based on analyses of field-moist samples to dried samples. When that transition was made, the relationship of soil test K results from both sample preparation techniques was established (soil test correlation). This relationship was used to adjust soil test K results of dried samples to the calibration data established with field-moist samples.

Ongoing investigations into this area are revealing that this relationship was not a good approximation under all conditions. Variation in soil properties likely changes the ratio of extracted K of field-moist and dried samples. As an example, the data in **Figure 2** show the difference in extracted K for samples dried at different temperatures relative to field-moist samples. Differences in amounts of K extracted from dried or field-moist samples varied with drying temperature, soil series, and soil moisture content. While this likely explains some of the differences found between K tests of dried and moist samples, there are other important factors to consider as well. Moisture relations during the growing season partly associated with internal soil drainage and landscape position may also be important.

Soil test calibration data in **Figure 1** and data in **Figure 2** suggest at least two contrasting groups of soil series for which soil test K interpretations should be different. However, there is substantial variability below soil test K levels of approximately 170 ppm and our research needs to be extended to many other soils and environmental conditions. **Given the current lack of resolution in classifying soils and/or environmental conditions according to differences in probabilities of crop response, our immediate solution was to reclassify soil test K interpretation classes for all soils.**

Table 1 shows how the new soil test interpretation classes are now defined. The range defined as Very Low was extended upward to 90 ppm. What was previously classified as Low, Optimum, and High are now classified as Very Low, Low, and Optimum, respectively. The lower limit of the Very High class was shifted upward to

201 ppm. Rates of recommended K have also been increased for some classes, not only for corn and soybeans (as shown in the table), but also for other crops. However, field calibration data for other crops are less complete. These changes reflect crop responses to K observed at higher soil test K levels.

We hope to refine these recommendations further as more calibration experiments are conducted and results analyzed. The complete new Iowa K recommendations are available in the Iowa State University Extension Publication PM-1688, available at this website: >**www.extension.iastate.edu/Publications/PM1688.pdf**<

Summary

Unpredicted yield responses to K fertilization at higher soil test K levels have led to redefinitions of soil test K interpretation classes based on recent calibration research.

Crop responses are now considered more likely up to higher soil test K levels. Recommended rates of K have also increased for some classes to recognize larger K needs to optimize yield or better reflect K removal with harvest.

Dr. Mallarino (e-mail: apmallar@iastate.edu) is Professor, Soil Fertility; Dr. Wittry is Assistant Scientist; and Mr. Barbagelata is Graduate Research Assistant, all with the Department of Agronomy, Iowa State University.

Annual Statement of Ownership

Statement of ownership, management, and circulation (required by 39 U.S.C. 3685) of *Better Crops with Plant Food*, published four times a year at 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. General business offices of the publisher are located at 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Name and address of publisher is Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Name and address of editor is Donald L. Armstrong, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. There is no managing editor. Owner is Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. There are no known bondholders, mortgages, or other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities. Issue date for circulation data below: 2003, No. 3 (August, 2003). The average number of copies of each issue during the preceding 12 months is: (a) Total number of copies (new press run): 16,578; (b) Paid and/or requested circulation: (1) Paid/requested outside-county mail subscriptions: 9,583; (2) Paid in-county subscriptions: 0; (3) Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution: 5,824; (4) Other classes mailed through the USPS: 1,688; (c) Total paid and/or requested circulation: 11,095; (d) Free distribution by mail: (1) Outside-county: 235; (2) In-county: 0; (3) Other classes mailed through the USPS: 50; (e) Free distribution outside the mail: 1,183; (f) Total free distribution: 1,468; (g) Total distribution: 12,563; (h) Copies not distributed: 4,015; (i) Total: 16,578; (j) Percent paid and/or requested circulation: 88%. The actual number of copies of single issue published nearest to filing date is: (a) Total number of copies printed: 15,075; (b) Paid and/or requested circulation: (1) Paid/requested outside-county mail subscriptions: 3,292; (2) Paid in-county subscriptions: 0; (3) Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution: 5,568; (4) Other classes mailed through the USPS: 1,865; (c) Total paid and/or requested circulation: 10,725; (d) Free distribution by mail: (1) Outside-county: 270; (2) In-county: 0; (3) Other classes mailed through the USPS: 50; (e) Free distribution outside the mail: 1,183; (f) Total free distribution: 1,503; (g) Total distribution: 12,228; (h) Copies not distributed: 2,847; (i) Total: 15,075; (j) Percent paid and/or requested circulation: 88%. I certify that all information furnished above is true and complete. I understand that anyone who furnishes false or misleading information on this statement or who omits material or information requested on the statement may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including multiple damages and civil penalties).

Donald L. Armstrong, Editor

WESTERN CANADA

Yield Benefit of Phosphorus Fertilizer for Wheat, Barley, and Canola in Alberta

By R.H. McKenzie, E. Bremer, L. Kryzanowski, A.B. Middleton, E.D. Solberg, D. Heaney, G. Coy, and J. Harapiak

Phosphorus fertilizers are applied annually to almost all cereal and oilseed crops grown on the Canadian Prairies. Their benefit to crop yield was first demonstrated in studies conducted from 1928 to 1930 and their use expanded rapidly from the early 1940s until the late 1960s. Since 1975, the import of P in fertilizers to the three Prairie Provinces has been approximately equal to the export of P in grain.

The widespread use of P fertilizers has likely contributed to a reduced yield response of P fertilizer. A recent review of fertilizer trials in Saskatchewan found that prior to 1970, P fertilizer increased wheat yield by an average of 26% (874 trials). After 1970, P fertilizer increased wheat yield by an average of only 11% (252 trials).

To evaluate the current P responses in Alberta, small plot fertilizer trials were conducted from 1991 through 1993 at 154 locations across the province. About 28% of locations were on Brown (Aridic Boroll) or Dark Brown (Typic Boroll) soils, 45% were on Black (Udic Boroll) soils, and 27% were on Gray (Boralfic Boroll) soils.

About 80% of the locations were on stubble (recrop) land and 20% were on fallow land. At each location, fertilizer responses were determined for barley, spring wheat, and canola (at some locations, only one or two crops were tested).

The average yield response to phosphorus (P) fertilizer across the 154 locations included in this study was 10%. Net returns in the year of application were maximized by application of 20 to 35 lb P_2O_5/A.

The replicated field trials included the treatments 0, 13, 26, and 39 lb P_2O_5/A applied as monoammonium phosphate (MAP). Treatments were applied with the seed except at the highest application rate for canola. To avoid germination damage in canola, application was split with 13 lb P_2O_5/A seed placed and 26 lb P_2O_5/A banded prior to seeding. Nitrogen (N) and any other required fertilizer nutrients were banded prior to seeding. The best-rated crop varieties were used in each region.

TABLE 1. Effect of soil type, crop, and year on response to fertilizer P additions.

Crop	Soil type	Frequency of grain yield response[1]	Grain yield increase over check, %	Yield increase, bu/A
Barley	Brown	57	8	5.7
	Black	78	8	6.4
	Gray	63	18	7.8
	All	68	10	6.5
Wheat	Brown	57	7	2.8
	Black	72	8	3.7
	Gray	59	12	3.9
	All	64	9	3.5
Canola	Brown	39	8	2.6
	Black	40	9	3.2
	Gray	68	20	4.3
	All	45	11	3.1

[1]% of sites where check < fertilized.

Soil samples were obtained during the previous fall at locations in southern Alberta or just prior to trial establishment at locations in central or northern Alberta. Available soil P was determined using the modified Kelowna method (0.15 M NH_4F, 1.0 M CH_3COONH_4, 0.5 M CH_3COOH). At maturity, crop yields were collected and expressed on a dry weight basis. Yield data from each experimental site was subject to an analysis of variance and only those experimental sites that had a coefficient of variation of less than 20% were used in the analysis.

In total, fertilizer responses were recorded at 143 barley sites, 141 wheat sites, and 108 canola sites. Two thirds of the cereal sites and just under half of the canola sites had a significant ($p < 0.05$, LSD) yield increase due to P application (**Table 1**). The average increase in yield due to application of P fertilizer was 10%. This is similar to the 11% yield response reported for 252 trials conducted across Saskatchewan between 1970 and 1991.

Differences in average P fertilizer response were small among crop types (**Table 1**). The only significant difference was a slightly smaller percentage yield gain for wheat than for barley or canola.

Soil type significantly affected P fertilizer response, depending on crop type (**Table 1**). The grain yield increase due to P fertilizer, expressed as percent of unfertilized check, was significantly greater for barley and canola on Gray soils relative to Black or Brown soils, but was similar for wheat.

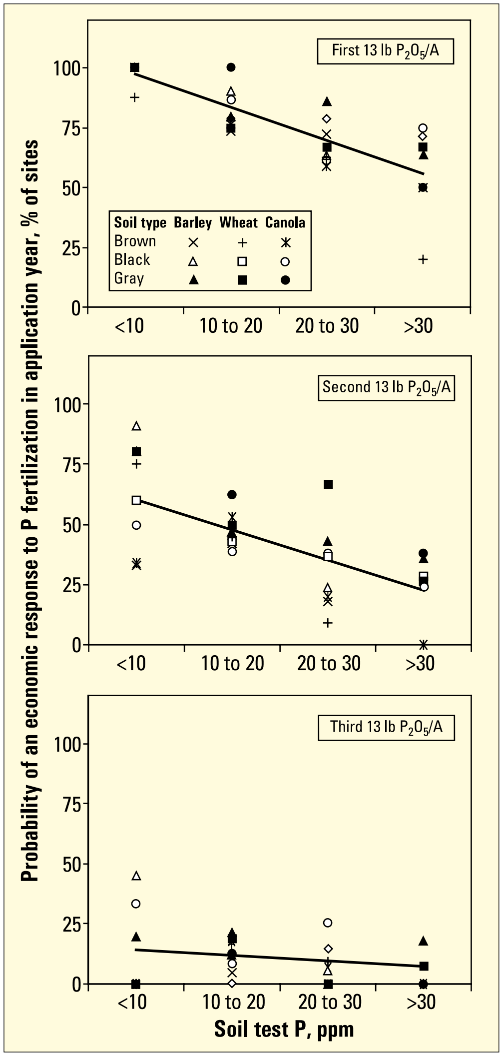


Figure 1. Probability of an economic increase in yield due to application of three increments of P fertilizer for barley, wheat, and canola on various soil types.

One factor that contributes to differences in P fertilizer response among crop types is P acquisition strategy. Canola roots lower the pH within the rhizosphere more effectively than cereal roots, allowing canola to deplete acid-soluble P fractions more effectively than cereals. This strategy is likely to be most effective in calcareous soils and may partially account for the less frequent and smaller response of canola in Brown and Black soils than in the more acidic Gray soils. A second factor that may contribute to differences in crop response to P fertilizer is the "starter" effect of P fertilizer. The importance of starter fertilizer in cool soils may account for the greater P fertilizer response in Gray soils, which are found in regions characterized by cooler spring (May-June) air temperatures.

An alternative method of presenting fertilizer recommendations that is useful when factors other than fertility greatly influence crop response is based on

Grain yield increase due to P fertilizer was significantly greater for barley and canola on Gray soils relative to Black or Brown soils in Alberta.

probability diagrams. Using the response functions determined for each site and fertilizer-to-grain cost ratios, the probability (% of sites) of an economic increase in yield as a function of soil test and fertilizer rate can be determined (**Figure 1**). It is important to remember that this applies to the application year only, and does not take into consideration any residual P from the applied fertilizer that will be available in future years. The probability of an economic increase in yield due to application of the first 13 lb P_2O_5/A was high for all crops and soil test levels, declining from close to 100% when soil test P was less than 10 parts per million (ppm) to about 60% when soil test P was more than 30 ppm. Crop type and soil zone had little influence on the probability of an economic increase with the first increment of fertilizer addition.

With the second increment of 13 lb P_2O_5/A, a wider variation in the probability was observed. The probability of an economic P fertilizer response at the lowest soil test level was least for barley and canola in Brown soils. The probability of an economic increase in yield with the third increment of 13 lb P_2O_5/A was low for all soil test levels and crops. Maximum profits for fertilizer P applied in that year were achieved if sites were fertilized at rates that provided an approximate 40% probability of an economic increase. At this level, rates of required P fertilizer ranged from about 20 lb P_2O_5/A at high soil test P levels to about 35 lb P_2O_5/A at low soil test P levels.

Since this work was completed in 1993, soil test summaries indicate that about 60% of Alberta soils test medium or below in soil P, and would likely respond to fertilizer P application. An evaluation of crop production and fertilizer use in 2001 found that fertilizer additions accounted for 87% of crop removal in the province. These results indicate that any change in soil P since this study was carried out have been minor.

The average yield response to P fertilizer at the 154 locations included in this study was 10%. This increase was much smaller than reported in early studies on the Canadian Prairies, likely due to a gradual increase in residual soil P fertility caused by the regular application of P fertilizer. Despite this weak response, the application of 20 to 35 lb P_2O_5/A generally provided optimum returns in the application year. The probability of a profitable yield benefit declined with increasing fertilizer rate or soil test P level.

The results of this study support the use of soil testing to establish the availability of soil P and develop suitable fertilizer management practices. BC

Dr. McKenzie (ross.mckenzie@gov.ab.ca) and Mr. Middleton are with the Crop Diversification Division, Alberta Agriculture, Food and Rural Development, in Lethbridge. Mr. Kryzanowski is with the Crop Diversification Division, Alberta Agriculture, Food and Rural Development, in Edmonton. Dr. Heaney is with Norwest Labs in Edmonton, and Dr. Bremer, Mr. Solberg, Mr. Coy, and Mr. Harapiak are private agronomic consultants in Alberta.

ONTARIO

Soybean Cultivar Responses to Potassium

By T.Q. Zhang, T.W. Welacky, I. Rajcan, and T.W. Bruulsema

Soybeans remove large amounts of potassium (K) from soils. A 4-year study in southwestern Ontario shows that common fertilizer sources differ little in their effects on soybean yield and quality.

Soybeans in Ontario grow on more than 2 million acres of land. The crop produces a farm gate value averaging C$620 million (1998-2000), rivaling that of corn. Soybean harvest removes a lot of K, about 60 thousand tons of K_2O annually, in comparison to corn harvest (including silage), which removes about 49 thousand tons.

In typical Ontario crop rotations, soybeans often follow corn. Harvested for grain, corn usually leaves behind large amounts of K in stover. For this reason, many producers apply sufficient K to their corn to supply the following soybean crop. When soybeans follow crops other than corn, questions arise as to the appropriate way to meet K needs. Previous research in the southern U.S. indicated that some soybean cultivars were sensitive to chloride (Cl) in muriate of potash (KCl) fertilizers.

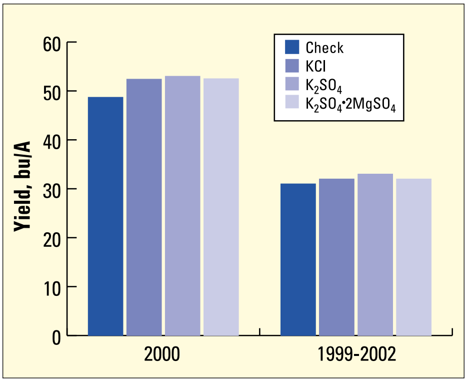


Figure 1. Soybean yield response to K was economic only in the year 2000. Mean of five cultivars.

The purpose of this study was to determine whether soybean cultivars in Ontario differed in responsiveness to K and in sensitivity to Cl. The treatments included a check, KCl, sulfate of potash (K_2SO_4), and sulfate of potash magnesia ($K_2SO_4 \cdot 2MgSO_4$, K-Mag). All sources provided K at 85 lb K_2O/A.

The soybeans were grown on a clay loam soil near Harrow in southwestern Ontario. They followed a rotation crop in 1999 and 2001. However, in 2000 and 2002, the treatments—cultivars and fertilizers—were applied in the same plots as the previous year. Thus, the 2000 and 2002 crops produced results from cumulative effects of two years of fertilizer application. They also followed soybeans, which is not recommended for optimum pest and disease control.

Soil test K ranged from 90 to 135 parts per million (ppm), rated medium to high. It was not depleted much where K was not applied within any 2-year period, indicating the soil had a high capacity to supply K.

Soybeans responded to K with only small yield gains over the 4-year period (**Figure 1**). While K increased both the 4-year average and the year 2000 yields statistically ($p = 0.0061$ and $p = 0.0000001$, respectively), the response was economic only in 2000. Averaged over cultivars and years, all three K sources produced similar effects.

The three K sources did not differ in their overall effect on quality. **Table 1** shows that K caused very slight changes in protein, oil, and sugar content. While the five cultivars differed substantially in these qualities, they did not respond differentially to K or to K sources.

The trials produced evidence of subtle yield interactions among cultivars and sources. Sulfate of potash magnesia slightly increased the yield of four of the cultivars, but it depressed the yield of S20-20 (**Figure 2**). The two cultivars OAC Arthur and AC756 showed a slight preference for sulfate as a K source, while Harovinton, RCAT Angora, and S20-20 showed preference for Cl (**Figure 3**).

These interactions, while significant statistically, should not be over-generalized. Particularly in the case of the interaction with Cl, there was evidence of an additional interaction with years as well. The existence of such complex interactions is interesting, but further understanding of the plant physiology and the relation to the growing environment will be necessary before making practical management recommendations. Potassium sources also interacted with cultivars and years with respect to incidence of several diseases.

The cultivar-source interactions are perplexing in that they were not consistent with cultivar types. Both RCAT Angora and S20-20 are full-season oilseed type cultivars —but they differed in their response to $K_2SO_4 \cdot 2MgSO_4$. Both Harovinton and AC756 are high-protein, food-grade cultivars—but they differed in their response to Cl. OAC Arthur has much shorter maturity (Group 00) than the other cultivars (Group 2)—but it did not distinguish itself in terms of any responses to K or K sources.

Overall, these data show no particular advantage to any one K source for soybean production in general. It is possible, however, that specific cultivars may show preferences for one source over another depending on local growing conditions.

TABLE 1. Potassium slightly increased oil and sugar, but decreased protein content of soybeans. Mean of five cultivars over 4 years, 1999-2002.

Fertilizer treatment	Protein,	Oil, %	Sugar,
With K	41.9	21.6	11.0
Without K	42.3	21.4	10.9

Dr. Zhang (e-mail: zhangt@agr.gc.ca) is Research Scientist in Soil Fertility and Root Ecology, and Mr. Welacky is Field Crop Biologist, both with Agriculture and Agri-Food Canada in Harrow, Ontario. Dr. Rajcan is Assistant Professor of Soybean Breeding and Genetics at the University of Guelph. Dr. Bruulsema is PPI Regional Director, Eastern Canada and Northeast U.S., located at Guelph, Ontario.

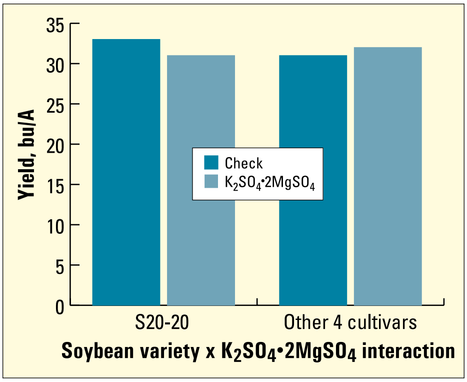


Figure 2. Variety S20-20 responded differently to $K_2SO_4 \cdot 2MgSO_4$ than the other four cultivars. Mean of 4 years, 1999-2002.

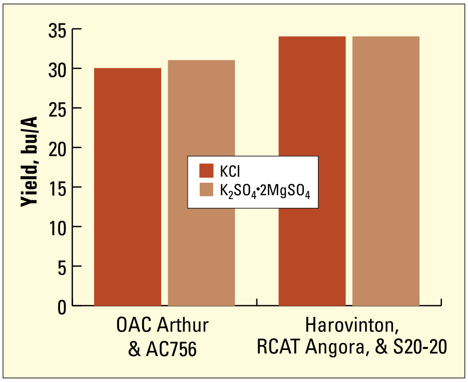


Figure 3. Cultivars showed slight differences in preference for Cl or sulfate sources. Mean of 4 years, 1999-2002.

NORTH CAROLINA

Tracking Phosphorus Response of Cotton

By C.R. Crozier, B. Walls, D.H. Hardy, and J.S. Barnes

Current P management recommendations for cotton in North Carolina are based on soil test levels. Although P responses have been characterized for numerous crops, there is very little information from North Carolina, or other states, regarding cotton yields at different Mehlich-3 extractable P levels. Plant tissue analysis is primarily used to assess the nitrogen (N), potassium (K), sulfur (S), and micronutrient status, but can also provide useful information concerning P sufficiency. We are interested in the degree to which the P fertilization program in North Carolina successfully avoided P limitations. This information might help producers decide whether or not a sufficiency level strategy is adequate or a build-maintenance strategy is warranted.

Dramatic crop responses to phosphorus (P) gradients highlight the need for adequate P fertility. Leaf tissue analysis should be a useful indicator of the effectiveness of a fertilization strategy based on soil testing, and may serve to identify conditions where either a sufficiency level or a build-maintenance strategy is most appropriate.

Our work characterized response of cotton to P gradients at three long-term soil fertility sites (**Table 1**).

Soil test P

Fertilizer treatments resulted in readily detectable soil fertility gradients and lint yield responses for all site-years (**Figures 1a, 1b, 1c, 1d, 1e**). We used a linear-plateau regression procedure to mathematically define the break point (critical level) between two portions of the response relationship: a region of linear yield increase and a plateau region. Yield plateaus were identifiable for 4 of these 5 site-years (**Table 2**). In some cases, since few sample points existed beyond the plateau level, additional data are needed to clearly demonstrate critical levels. The mean Mehlich-3 soil P level at which the yield plateau was attained was 40 parts per million (ppm) at the Tidewater site and 21 ppm at the Peanut Belt site. Higher yields at the Tidewater site, and perhaps soil differences, may have been responsible for differences between these sites. No yield plateau was observed at the Piedmont site. Yields at this site suffered from drought stress, and it had been abandoned from the research

TABLE 1. Field sites and characteristics. North Carolina experiments reported here were conducted 1998-2002.[1]

Research station	Soil series[2]	Date established	P treatments, lb P_2O_5/A	Mehlich-3 soil test P gradient[3], ppm[4]
Peanut Belt	Goldsboro	1982	0, 20, 40, 80	8 to 95
Piedmont	Hiwassee	1985	0, 20, 40, 80	0 to 14
Tidewater	Portsmouth	1966	0, 20, 40, 80, 120	20 to 109

[1]P treatments were applied intermittently over years, but annually during the years reported here, 1998-2002.
[2]Goldsboro = Aquic Paleudult; Hiwassee = Rhodic Kanhapludulf; Portsmouth = Typic Umbraquult.
[3]Range of soil test values observed at most recent sampling date.
[4]ppm is equivalent to mg/kg.

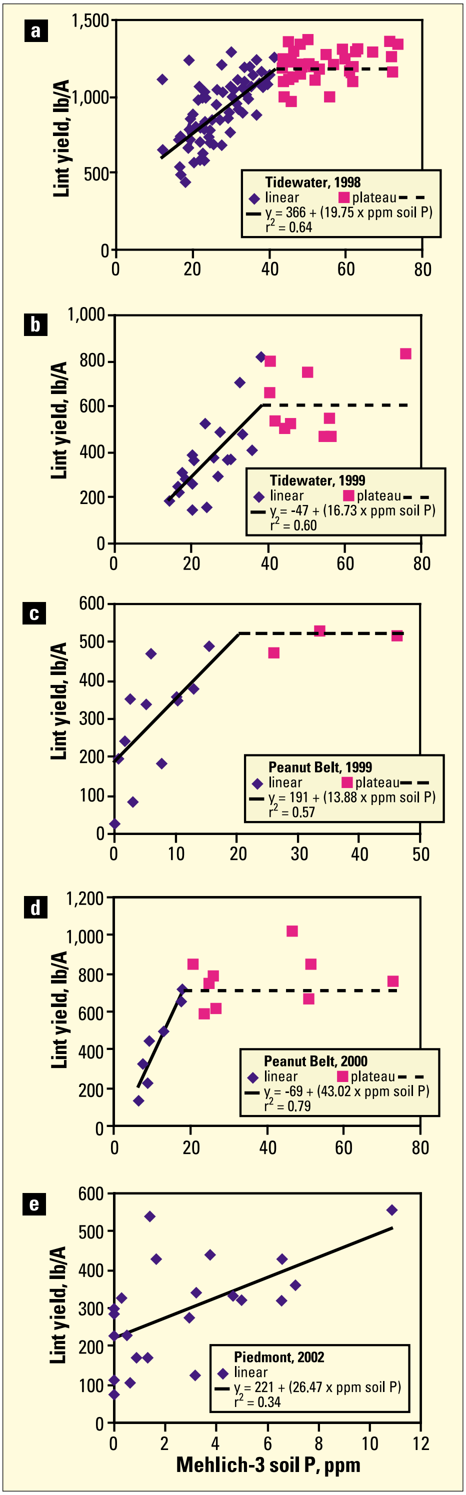


Figure 1. Yield response of cotton to soil Mehlich-3 P levels at (a) Tidewater Research Station 1998, (b) Tidewater Research Station 1999, (c) Peanut Belt Research Station 1999, (d) Peanut Belt Research Station 2002, and (e) Piedmont Research Station 2002.

TABLE 2. Mehlich-3 soil P levels at yield response plateau (critical level) based on linear-plateau regression models. Symbols (---) indicate no yield plateau was observed.

Site	Year	Soil P concentration at yield plateau, ppm
Tidewater	1998	41.8
Tidewater	1999	38.3
Peanut Belt	1999	22.1
Peanut Belt	2002	19.1
Piedmont	2002	---

treatments for several years prior to the 2002 crop. Additional P applications may be needed to expand the range of soil test P levels at the Piedmont site.

Leaf P

Likewise, yield increased as leaf P concentration increased, with critical levels or plateaus also identified for 3 of the 5 site-years based on leaf samples collected one week after first bloom (**Figure 2a, 2b, 2c, 2d, 2e**).

Mean leaf P levels at which yield plateaus were attained declined from 0.31% P the week prior to first bloom, to 0.20% five weeks after first bloom (**Table 3**). In contrast to differences between sites observed for soil data, yield responses to leaf P gradients appeared similar for the Tidewater and Peanut Belt sites. As with the soil test P response, no yield plateau was observed at the Piedmont site in response to leaf P concentration.

Although there are not many published critical levels and there is variation among the reports, our responses seem similar to values reported previously. A recent study reported a critical soil test P level of 12 ppm at the Peanut Belt site, which was lower than

TABLE 3. Leaf P levels at yield response plateau based on linear-plateau regression models. Leaf sampling dates are relative to first bloom. Symbols (- - -) indicate no yield plateau was observed.

Site	Year	Sampling date	Concentration at yield plateau, %
Tidewater	1998	+1 week	0.242
Tidewater	1999	+1 week	0.208
Peanut Belt	1999	+1 week	0.225
Peanut Belt	1999	+3 week	0.254
Peanut Belt	1999	+5 week	0.181
Peanut Belt	2002	-1 week	0.310
Peanut Belt	2002	+1 week	- - -
Peanut Belt	2002	+3 week	- - -
Peanut Belt	2002	+5 week	0.223
Piedmont	2002	-1 week	- - -
Piedmont	2002	+1 week	- - -
Piedmont	2002	+3 week	- - -
Piedmont	2002	+5 week	- - -

our results (**Table 4**). Yield potential in the previous study (Cox and Barnes, 2002) may have been limited by inadequate K, which is now being applied at higher rates for our work. Mehlich-1 extractable critical P levels summarized by Chapman (1966) ranged from 8 to 12 ppm for sandy Coastal Plain regions. Higher production levels with adequate overall fertility levels, newer crop varieties, and the use of different soil extractants may explain differences among studies. Our leaf tissue data reflect a similar trend of declining P over time as in the currently used sufficiency ranges for the Southeast (Mitchell and Baker, 2000): 0.20 to 0.65% for the vegetative/early bloom stage; 0.15 to 0.60% for the late bloom stage. They are also similar to data summarized by Chapman (1966), suggesting a critical level of 0.28% at first square and

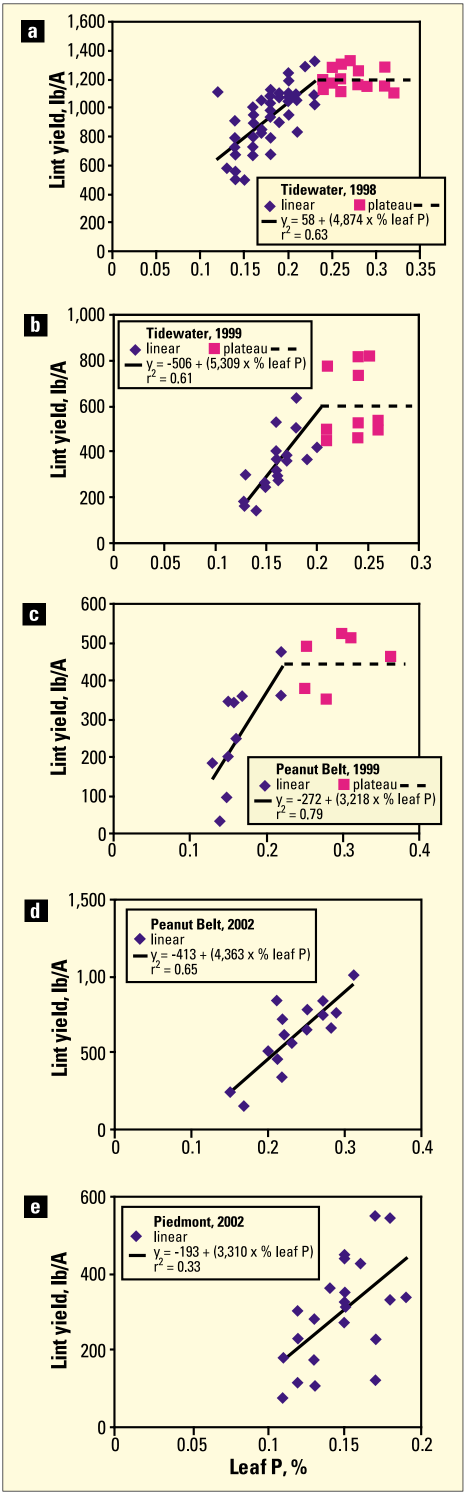


Figure 2. Yield response of cotton to leaf P levels in samples collected 1 week after first bloom at
(a) Tidewater Research Station 1998,
(b) Tidewater Research Station 1999,
(c) Peanut Belt Research Station 1999,
(d) Peanut Belt Research Station 2002,
and (e) Piedmont Research Station 2002.

TABLE 4. Soil and leaf critical P levels for optimal yields or sufficiency ranges based on this study and other references.

Parameter	Our work[1]	NC Coastal Plain study, Cox & Barnes, 2002	Southern region guidelines, 2000	Literature review, Chapman, 1966
Soil P, ppm	Tidewater: 40 Peanut Belt: 21 (Mehlich-3)	12 (Mehlich-3)	- - -	Clays: 6 to 7 Sands: 8 to 12 (Mehlich-1)
Leaf P, %				
-1 week	0.310	- - -		0.28[2]
+1 week	0.225	- - -	0.20-0.65[3]	- - -
+3 week	0.254	0.210		0.20[4]
+5 week	0.202	- - -	0.15-0.60[5]	- - -

[1]Response plateau not identified all site-years. [2]First square. [3]Early bloom. [4]Flowering. [5]Late bloom/maturity.

0.20% during the flowering period.

Conclusions/Future Directions

Dramatic crop responses to soil test and leaf tissue P gradients highlight the need for adequate P fertility. Leaf tissue analysis should be a useful indicator of the effectiveness of a fertilization strategy based on soil testing, and may serve to identify conditions where either a sufficiency level or a build-maintenance strategy is most appropriate.

Our leaf data appear very similar to previously published values, while our soil data suggest higher P levels may be warranted for the Tidewater region soils than indicated in other studies limited to the sandy Coastal Plain environment. Differences between our results and previous publications illustrate the value of maintaining these long-term soil fertility tests: they permit periodic reassessment of fertilizer recommendations with newer varieties, new management practices, and different soil regions. Results from long-term studies encourage better cooperation among researchers to understand what might cause differences in crop responses.

There are only a limited number of similar long-term research sites in other states, which represent an opportunity for regional coordination to enhance understanding of the relationship among soil test concentrations, plant tissue concentrations, and crop yield.

Better fertilizer rate decisions made possible through such research should enhance farm profits and reduce any negative environmental impacts of farming.

Dr. Crozier is located at the V.G. James Research and Extension Center of North Carolina State University (e-mail: carl_crozier@ncsu.edu). Dr. Walls and Dr. Hardy are with the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) Agronomic Division. Mr. Barnes is with the Tidewater Research Station, Plymouth.

Acknowledgment—*-Funding has been provided by Cotton Incorporated, Project #01-992NC.*

References

Chapman, H.D. (ed.) 1966. Diagnostic criteria for plants and soils. University of California, Division of Agricultural Sciences.

Cox, F.R. and J.S. Barnes. 2002. Peanut, corn, and cotton critical levels for phosphorus and potassium on Goldsboro soil. Commun. Soil Sci. Plant Anal. 33:1173-1186.

Mitchell, C.C. and W.H. Baker. 2000. Plant nutrient sufficiency levels and critical values for cotton in the southeastern U.S. In C.R. Campbell (ed.) Reference Sufficiency Ranges for Plant Analysis in the Southern Region of the United States. Website at: >www.agr.state.nc.us/agronomi/saaesd/s394.htm<

Leaders and Followers

Leadership is a state of mind, a presence. It sets the few apart from the multitudes. It helps to define character and, in many cases, brackets people according to their talents or ambitions or initiatives. While it is true that some folks are born to lead, I'm convinced that most leaders are self-made, whether they follow careers in the public or private sector. In a like manner, most followers are self-made as well.

Leaders aren't necessarily super intelligent, and followers aren't necessarily lacking in gray matter. One of my heroes was Winston Churchill, a great world leader at a critical time in history. Nobody ever accused him of being a genius, but he possessed great courage and willpower. He seemed to sense his role as a leader of the free world and pursued it with great vigor. He took risks and found success.

At the same time, our society is full of intelligent under achievers. For whatever reason(s), they will never reach the level of leadership they might have attained, even approaching that of Churchill. Many folks depart this world without having challenged their minds and bodies. They were contributors to society, but could have done so much more.

We need both leaders and followers. That's what makes the global system work. There are agricultural leaders—scientists, corporate presidents, farmers, educators—that are willing to step out and take a risk. It might involve the testing of a new product, piece of equipment, or even a new method of soil sampling. Leaders are willing to experiment and explore. They are not afraid to fail, because they have confidence that their successes will outnumber the failures and will always tip the balance in the favor of progress. When success does come, the followers are quick to use it to best advantage.

During the past decade or so we have seen startling inroads made in agriculture—brought on by the fusion of space age technology with other scientific facts and skillfully managed crop production systems. Yields have improved, and environmental protection has been enhanced. Most have benefited—suppliers, producers, and consumers. The contributions of leaders and followers to the betterment of mankind must be gratifying. And maybe they will encourage some of those followers to step up to the challenge of leading agriculture to even greater accomplishments.

BETTER CROPS
WITH PLANT FOOD

Potash & Phosphate Institute
Suite 110, 655 Engineering Drive
Norcross, Georgia 30092-2837

Periodicals
Postage