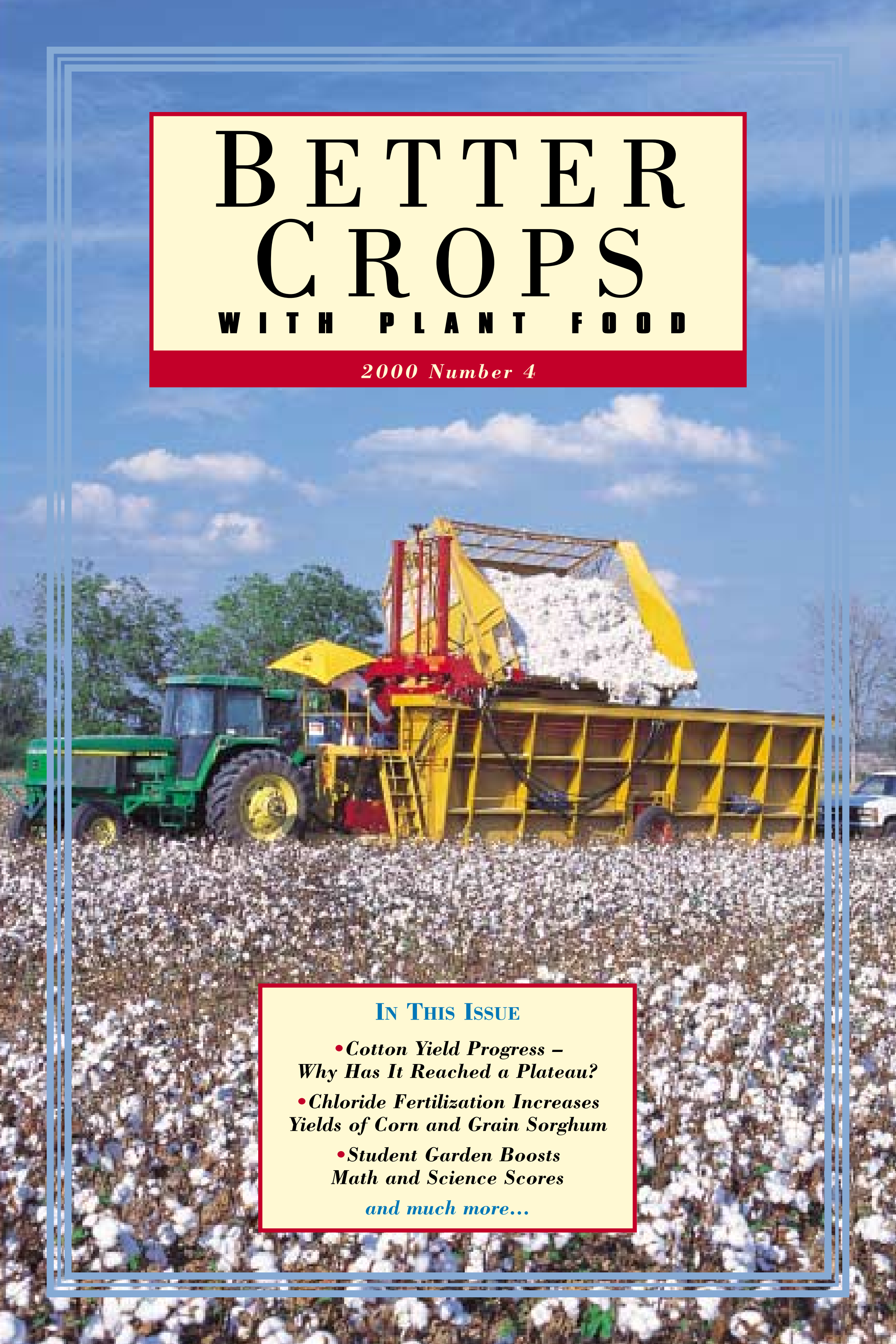
BETTER CROPS
WITH PLANT FOOD

2000 Number 4



In This Issue

- *Cotton Yield Progress – Why Has It Reached a Plateau?*
- *Chloride Fertilization Increases Yields of Corn and Grain Sorghum*
- *Student Garden Boosts Math and Science Scores*

and much more...

BETTER CROPS WITH PLANT FOOD

Vol. LXXXIV (84) 2000, No. 4

Our Cover: Cotton harvest...boll buggy dumping cotton into module maker.
Photo Credit: Debra Ferguson/www.southern-images.com

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-far.org

CONTENTS

Sustainable Agriculture – A Modern Perspective

By B.C. Darst

What is sustainability? What do we mean when we talk about sustainable agriculture? Webster's II New Riverside University Dictionary defines sustainability as *keeping in existence; maintaining; enduring; withstanding*. Sustainable agriculture encompasses all the above. It includes considerations for future food adequacy and also addresses such issues as resource use efficiency, profitability for farmers, and impact on the environment. In order for agriculture to sustain, to meet today's world food needs as well as those in the future, it must protect and improve air, soil and water quality; that is, it must be environmentally friendly. It must also do a better job of communicating with its clientele...world food consumers.

> Sustainable agriculture is not a new concept. Sustainable systems have evolved over thousands of years ... employing new knowledge, experience and understanding and implementing new technology as it is proven beneficial.

Agriculture Must Produce More Food per Unit of Land

In early 2000, world population stood at 6.0 billion people. It is projected to reach 8.0 billion by 2025, a 33 percent increase in only 25 years. During that period, little change in total arable land available for food production is expected. In fact, arable land per person continues to shrink, forecast to fall from slightly more than 1.1 acres in 1965 to about 0.5 acre by 2025. If agriculture is to be sustainable, it must feed a growing world population. Higher yields must happen and will be the result of improved management. Their production will include:

- Higher input and resource use efficiencies, including nutrient balance, nutrient application rates, and land use;
- Adequate crop protection, including an appropriate mix of cultural practices, judicious use of pesticides, and genetically enhanced crops;
- Advanced genetics, including traditional plant breeding and products of biotechnology;
- Crop management practices which minimize soil erosion;
- Enhanced soil productivity, including improved tilth and biological components;
- Improved water quality and irrigation management.

Is Today's Production Agriculture Efficient and Sustainable?

If one selects today as the point of comparison, then looks back a few years in time, it becomes obvious that agriculture in the U.S. has been sustainable. The trends we see also give us hope that future sustainability is within our grasp. Improvement in nutrient use efficiency is one important reason why. Consider that:

- Nutrient use efficiency has been increasing. During the last 25 years, nitrogen (N) use efficiency by corn farmers in the U.S., that is, corn produced per pound of N applied, has gone up by more than 30 percent and continues to rise.
- During the 1960s and 1970s, U.S. farmers generally applied more phosphorus (P) and potassium (K) than crops

removed. Soil fertility levels were often built into high and very high ranges to support the production of higher crop yields. However, some state nutrient budgets are now showing that more nutrients, particularly P and K, are being removed than are being replaced. Farmers need to monitor their crop nutrient requirements on a site-specific basis, then provide them in order to sustain the continuing increases in crop yields that will be required to feed the growing world population.

- There are soils that have received heavy nutrient loads, especially through the application of animal manures and biosolids. Care must be taken to develop nutrient management plans for such soils that meet agronomic requirements, but do not exceed safe levels from an environmental standpoint. Site-specific nutrient management recommendations are being developed for much of the U.S. that help to avoid the potential negative environmental implications of both excessive and inadequate nutrient application. These guidelines are leading to an improved use efficiency of both manufactured mineral fertilizers and organic waste, such as animal manure and sewage sludge, resulting in improved crop utilization of nutrients.
- During the Dust Bowl days, U.S. farm land was being eroded at a rate of 30 to 40 tons per acre. After the Dust Bowl, with contour plowing, terracing, and other conservation practices, erosion rates dropped to less than 15 tons per acre. Progress has continued. Soil loss by wind and water erosion is now about 4.5 tons per acre per year and decreased by 35 percent from 1987 to 1997. Conservation tillage...now used on more than one-third of U.S. crop land or about 100 million acres...and other sound management practices are primary factors in lowering erosion rates.

During the Dust Bowl days in the U.S. in the 1930s, farmland was being eroded at the rate of 30 to 40 tons/A each year.

As a result of the above and other improvements in production management, average crop yields in the U.S. have nearly tripled since 1940 and continue to rise. In fact, if the crop we produced in 1990 had been grown using 1940 technology, an additional 470 million acres of crop land of similar productivity would have been required.

It should be noted that agriculture has not solved all the challenges associated with long-term sustainability. The above examples show how far agriculture has progressed in the U.S. However, in the U.S. and in the rest of the world as well, much remains to be done to help ensure sustainability in the future. As farmers continue to achieve higher and higher yields per unit of land farmed, it is incumbent upon them to leave the land more fertile and productive than they found it so that future generations can be fed. To do so will require the adoption and use of production technologies based on the latest in scientific research. In order to remain dynamic...responding to the growing world demand for its products... agriculture must be aggressive in moving forward, with emerging technologies as a primary driving force.

Agriculture Must Address Several Challenges to Remain Sustainable

Sustainable agriculture requires the efforts of all the world's farmers. Large scale enterprises and small holder agriculture have a role to play in the increasingly intensive business of growing crops. To sustain both large and small farmers, the public must continue to provide infrastructure to move agricultural inputs and outputs, the educational resources for knowledge generation and transfer, and the regulatory framework to assure a stable business climate. This includes development of mechanisms to assure consumers that food will be safe and of high quality.

Ultimately, successful implementation of sustainable crop production practices will involve adaptation to local soil and management practices specific to each region...and each farm, even every field...and include the innovation of those farmers with a strong commitment to land stewardship. Here are some of the challenges agriculture must address in the future.

- Pressures from so-called experts to cut back on purchased inputs, activities of certain environmental groups, low crop prices, and other factors often influence the farmer to use less and less inputs such as fertilizers, but still expect more at harvest time. Residual fertility will not last forever. Farmers who indiscriminately cut back on fertilizer use should understand that they cannot sustain production as they will be able to do if they follow science-based, site-specific management principles.
- Genetic diversity is narrowing for many food crops while remaining broad for crop pests. Reduction in the number of products available for crop protection and opposition to genetically enhanced crops will make meeting expanding world food requirements more difficult. The global public must be educated to this fact.

Conservation tillage practices are now used on about 100 million acres, or one-third of U.S. farmland.

- The economic viability of farmers and the agribusiness firms which serve them is impacted by low crop prices, poor return on capital investment and labor, government policies...including low food costs for consumers, rising costs of goods and services, changing technologies, marketing challenges, regulations, and other factors. Agriculture must address these issues more effectively. If farmers cannot achieve acceptable profitability, agriculture will not be sustainable.
- Environmental concerns and restrictions on input use will likely become more difficult and expensive in the future. In most cases, doing a better job of protecting the environment will add costs to farming operations and will require improved management in other areas to compensate for these costs.
- Farmers and farm numbers will continue to decline, making efficiency of production even more critical to the sustainability of agriculture. It is critical that there be meaningful research and education programs to address the changing agricultural environment, yet support for such programs is on the decline.
- Consumer awareness of the workings of agriculture remains low, while suspicions of the overuse of inputs, especially fertilizers and crop protection chemicals, continue to be significant. Agriculture must find a more effective way to address this issue.

Summary

Discussion on the issues that affect the sustainability of agriculture is healthy. However, we can't continue to debate whether or not modern technology should be a part of food production systems unless we are willing to accept increased starvation. The world moves on and so must agriculture...producing more food per acre, doing it efficiently and in a manner that is more profitable for farmers while remaining environmentally friendly. BC

Dr. Darst is Executive Vice President of PPI, located at Norcross, Georgia. E-mail: bdarst@ppi-far.org

U.S. COTTON BELT

Cotton Yield Progress – Why Has It Reached a Plateau?

By W.R. Meredith, Jr.

Cotton, like most U.S. crops, is experiencing severe economic stress. Relief will come in the form of higher commodity prices, lower production costs, and higher yields. Some progress in improving fiber quality and reducing expensive production inputs has been made. However, further improvements need to be associated with yield increases. Yields of most field crops have been increasing during the last several decades.

Despite many changes in cotton technology, it is evident that yields in the U.S. are at a plateau and have been for about 15 years. Some, but not all, of the causes for this lack of yield increases have been identified.

Average U.S. cotton yields per acre are indicated in **Figure 1**. The yield curve from 1961 to about 1999 indicates an average increase of 5.99 lb/A/year. However, inspection of the yield curve shows a plateau from 1961 to 1979. This was followed by 10 years of increasing yields/A, as a result of better insect control, crop management, and the introduction of new germplasm into breeding programs. However, quadratic analysis of the yields from 1980 to 1999 shows that yields peaked in about 1992 (**Figure 2**).

Dr. Hal Lewis, an independent cotton breeder working with the American Cotton Producers Association, analyzed cotton yield trends and reached a similar conclusion. He also showed that the year to year variation within the last 20 years, is four times greater than within the previous 20-year period. **Figure 1** shows the great year to year variation.

What are the major factors impacting yield? They include weather, management, rise of new pests, and variety improvement.

Weather. Certainly year to year variability has a big impact on yield, but is it responsible for the yield plateau? Abnormal weather would need to cover the entire Cotton Belt from Carolina to California. Such weather patterns also would have to negatively affect other major crops. Weather scientists have indicated that the earth's climate has gradually been getting warmer. Higher temperatures could have plus and minus effects

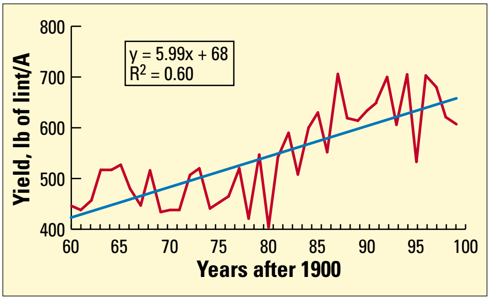


Figure 1. Average yield of U.S. cotton from 1961 to 1999.

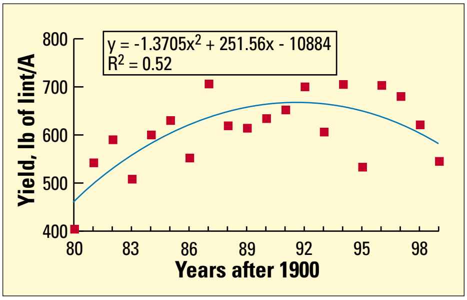


Figure 2. Average yield of U.S. cotton from 1980 to 1999.

on yield. Higher temperatures with drought would decrease yields, but also would extend the growing and harvest season. The increase in carbon dioxide (CO_2) would be expected to increase photosynthesis. There has been no definitive model that accurately associates weather variability with the yield plateau.

Management. The change in management can be addressed as changes in mechanization, agronomy, pest control, and communications. Improvements in equipment have resulted in greater crop management efficiency and handling ease. Precision planters, combined with better seed quality and seed treatments, have resulted in earlier plantings with less plant stand losses and need for replanting. Better placement and timing of fertilizer, pesticides, growth regulators, and crop terminators occur because of better equipment. Modern cotton pickers and strippers result in faster, more efficient harvesting. Modules for storing unginned cotton prevent the loss of harvesting time due to gin overloading.

Agronomically, more management attention is paid to crop development. Crop growth is managed with growth regulators. More acres are irrigated, especially in the Midsouth. Pest control due to precise consulting, area-wide pest control programs, and use of transgenic varieties has resulted in less crop losses and need for pesticides. The rapid transmittal of technology and information has allowed better timeliness in applying technology.

One would assume that the combined effects of these modern management tools and information would have a positive effect on yields.

New Pests and Problems. Since yields have not been increasing when they were expected to increase, are there new pests or problems that we have not detected? There have been cases of new weeds and isolated cases of outbreaks of insects, generally referred to as minor insects. These problems are not sufficiently large on a national basis to explain the observed plateau. The occurrence of "bronze wilt" has mystified many growers and researchers. The sudden wilting and subsequent severe loss of yield have not been adequately explained by pathologists, physiologists or geneticists. Such losses have been primarily on varieties descending from one genetic background and have been confined to a few acres. Shifting to other varieties has essentially reduced the losses to zero, but the so-called susceptible varieties do not always exhibit the syndrome. The increase in reniform nematodes is believed to affect a much wider production area. It is more difficult to research this problem than that of many other pests. The direct evidence associating the presence of reniform nematodes with yield losses is limited. However, the circumstantial evidence of the increase in reniform populations in grower fields with a yield decline is great. Another problem, also not yet resolved, is the low organic matter level of many soils where continuous cotton has been grown for many years.

Variety Improvement. Two methods have been used to measure yield changes due to variety improvement. The first method was to use the average yield of 15 tests conducted as part of the National Cotton Variety Tests and involved six U.S. cotton growing regions. As indicated in **Table 1**, the combined regression analysis over all six regions shows a regression coefficient (slope, or m, in the equation with form of Y = mX + intercept) for yield on test year of 6.05 lb lint/A/year. This is almost identical to the national average yields (**Figure 1**) with a slope of 5.99 lb lint/A/year. A segmented regression analysis of the variety tests partitioned the data into two time periods: 1960 to 1981 and 1982 to 1996. Inspection of **Figure 1** shows a similar national trend with a major increase in yield

Weather, management, new pests, and variety improvement are some of the factors affecting cotton yield.

TABLE 1. Regression equations for average cotton yield (lb lint/A) on year of test for six U.S. regions involving 15 locations.

Region	Years	Intercept	Slope or reg. coef. (SE)	Average yield, lb lint/A	2nd period - 1st period
East	1960-96	707	+ 7.55 X (1.25)*	877	
	1960-81	826	– 3.38 X (6.18)	798	
	1982-96	921	+ 9.47 X (14.25)	987	189
Delta	1960-96	938	+ 7.45 X (1.96)**	1,072	
	1960-81	1,024	– 3.70 X (3.92)	986	
	1982-96	1,238	– 5.45 X (7.28)	1,204	218
Central	1960-96	795	+ 6.00 X (2.48)*	908	
	1960-81	864	– 4.95 X (4.71)	815	
	1982-96	1,233	– 28.01 X (8.28)	1,041	226
Plains	1960-96	669	– 1.72 X (2.48)**	637	
	1960-81	804	– 16.90 X (4.66)	625	
	1982-96	581	+ 10.44 X (9.65)	654	29
West	1960-96	823	+ 8.30 X (2.76)**	1,001	
	1960-81	809	+ 9.31 X (5.80)	914	
	1982-96	1,240	– 19.53 X (11.51)	1,104	190
Far West	1960-96	1,034	+ 6.94 X (3.23)*	1,169	
	1960-81	1,094	– 0.15 X (7.91)	1,082	
	1982-96	1,204	+ 6.91 X (11.75)	1,253	171
Combined analysis	1960-96	832	+ 6.05 X (1.25)**	941	
	1960-81	891	– 1.78 X (2.37)	870	
	1982-96	1,075	– 4.51 X (5.21)	1,043	173

X = Years after the initial year of the period (1960 or 1982).
SE = Standard error of regression coefficient.
*, ** = Indicates significantly different than 0.0 at the 0.05 and 0.01 probability levels, respectively.

occurring in the early 1980s. Five of the six cotton-producing regions show increases in yield (slopes) ranging from 6.00 to 8.30 lb/A/year for the entire 1960 to 1996 period. The exception is the Plains region where the year to year variability was of such magnitude that no clear trend was detectable. The average yield of the variety tests of the five regions for the early and late time periods was 919 and 1,118 lb/A, respectively, or an increase of 199 lb/A (**Table 1**). The increase in yield from 1982 to 1996, over the yield from 1960 to 1981, for the Plains region was 29 lb/A. The increase in yield in the early 1980s was due to the introduction of new pesticides and new germplasms. The new germplasm came from state and USDA Agricultural Research Service (ARS) enhancement programs. Within the two time periods, no progress for yield was made due to breeding. Analysis of the National High Quality Tests (data not shown), which involved nine Midsouth states, also showed a quadratic curve with yields increasing until about 1988 and then decreasing.

Since variety tests measure both genetic and management inputs, a second method of analysis was used to estimate breeding progress. This method relates yield to year of variety release. At Stoneville, we have conducted four such tests as indicated in **Table 2**. Average lint yield and the linear regression of lint yield on year of variety release, for six varieties common to all four tests, are indicated in **Table 2**. The average yield of the six common varieties was highest for the earliest test, 1,089 lb lint/A, and lowest for the latest test, 759 lb lint/A. The regression of yield on year of variety release (slope) shows a decline of 9.1 to 4.7 lb/A for the earliest to the latest tests. Statistical analysis indicates signifi-

TABLE 2. Annual lint increase due to breeding as indicated in tests comparing varieties with different variety initial release years.

Years of tests[2]	No. of varieties	Release years covered	Average yield of six common varieties[3], lb lint/A	Slope, lb lint/A/year[1]
1967-68	13	1922-62	1,089	9.1a
1978-79	17	1910-78	921	8.5a
1992-93	16	1938-93	780	5.4b
1998-99	38	1938-99	759	4.7b

[1]Significant differences between regression coefficients (slopes) indicated by different letter, as determined by "t" test.
[2]All variety tests conducted at Stoneville, MS.
[3]Six varieties in all tests were DPL Smooth Leaf, DPL 14, DPL 16, Stoneville 2B, Stoneville 5A, and Stoneville 213.

cance at the 0.05 probability level between the slopes of the first two and last two tests.

A subset of 23 varieties in the latest test released since 1983 is given in **Figure 3** and shows no significant trend due to variety improvement (slope = 3.5 lb lint/A/year).

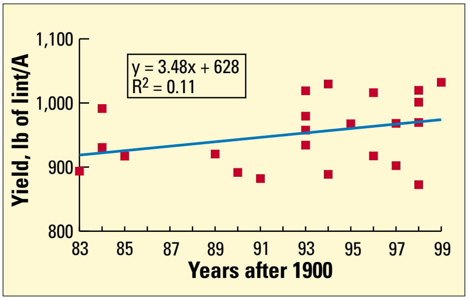


Figure 3. Increase in yield due to breeding from 1983 to 1999.

Summary

Current varieties have a very narrow genetic base with similar pedigrees. The narrowing of the genetic base has been associated with the decline in public germplasm enhancement programs. The use of transgenics with the major objective of "added value traits" has been very effective on the added value traits, but has had no effect on average yields. Research and grower experiences have shown that corn-cotton rotations will result in some yield increase. This practice reduces reniform nematodes and in some cases increases soil organic matter. In all likelihood, there are other factors limiting yield that have not been identified by research or grower experience. These factors probably encompass all areas of cotton production. If the U.S. cotton industry is going to survive in a competitive world, it cannot depend on a strategy of no yield increase. BC

Dr. Meredith is Research Leader, Midsouth Area, USDA-ARS, Crop Genetics and Production Research Unit, 141 Experiment Station Road, P.O. Box 345, Stoneville, MS 38776-0345; phone: 662-686-5322, fax: 662-686-5398.

KANSAS

Chloride Fertilization Increases Yields of Corn and Grain Sorghum

By Ray Lamond, Vic Martin, Collin Olsen, and Kirby Rector

Research across Kansas and the Great Plains has shown wheat responds consistently to Cl fertilization, particularly when soil Cl levels are less than 20 lb/A (0 to 24-inch depth). Chloride sensitive cultivars often show 5 to15 bu/A yield responses when Cl is applied. These results have prompted the question: What about Cl needs on corn and grain sorghum?

> Two years of data from Kansas research indicate that corn and grain sorghum are likely to show economic yield response to chloride (Cl) if soil test levels at the 0 to 24-inch depth are less than 20 to 25 lb/A.

To address this question, studies were conducted at several sites in Kansas during 1998 and 1999 to evaluate Cl rates and sources on corn and grain sorghum. Chloride rates (0, 20, 40 lb/A) and sources, including potassium chloride (KCl), calcium chloride ($CaCl_2$), and sodium chloride (NaCl), were evaluated during the course of this work. All Cl treatments were surface broadcast at planting time.

Nitrogen (N) and other needed nutrients were balanced on all treatments. Plant samples (leaf opposite and above primary ear on corn and flag leaf on grain sorghum) were taken at tassel (VT)/boot stage (Stage 5) for nutrient analyses. Plants were rated for disease and stalk rot, but levels were extremely low at all sites. Grain yields were determined (corn corrected to 15 percent moisture and grain sorghum to 13 percent moisture). All soil Cl values were determined from samples taken from surface to a depth of 24 inches.

The effect of Cl fertilization on corn is shown in **Tables 1** and **2**. Corn grain yields were not significantly affected by Cl fertilization in 1998. However, soil tests at both research sites were above 20 lb Cl/A. In 1999, corn grain yields were significantly increased, with both sites below 20 lb Cl/A soil test. The average corn response to Cl in 1999 was 6 bu/A.

TABLE 1. Effects of Cl fertilization on corn, 1998.

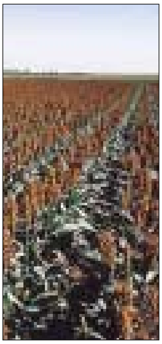
Cl rate, lb/A	Cl source	Osage Co. Yield, bu/A	Osage Co. Tassel Cl, %	Riley Co. Yield, bu/A	Riley Co. Tassel Cl, %
0	—	133	0.29	107	0.12
20	NaCl	133	0.38	114	0.30
40	NaCl	137	0.37	112	0.39
20	KCl	133	0.36	108	0.28
40	KCl	133	0.36	116	0.37
LSD (0.10)		NS	NS	NS	0.06
Soil test Cl (0-24 in.), lb/A		40		24	

TABLE 2. Effects of Cl fertilization on corn, 1999.

Cl rate, lb/A	Cl source	Brown Co. Yield, bu/A	Brown Co. Tassel Cl, %	Marion Co. Yield, bu/A	Marion Co. Tassel Cl, %
0	—	123	0.16	94	0.15
20	KCl	124	0.29	106	0.18
40	KCl	129	0.40	107	0.55
20	NaCl	119	0.29	104	0.42
40	NaCl	134	0.46	108	0.59
20	$CaCl_2$	120	0.21	101	0.23
40	$CaCl_2$	127	0.32	96	0.32
LSD (0.10)		10	0.11	7	0.13
Soil test Cl (0-24 in.), lb/A		19		14	

TABLE 3. Effects of Cl fertilization on grain sorghum, 1998.

Cl rate, lb/A	Cl source	Marion Co. Site A Yield, bu/A	Site A Boot Cl, %	Site B Yield, bu/A	Site B Boot Cl, %	Site C Yield, bu/A	Site C Boot Cl, %	Osage Co. Yield bu/A	Osage Co. Boot Cl, %	Riley Co. Yield, bu/A	Riley Co. Boot Cl, %
0	—	62	0.10	63	0.06	87	0.09	125	0.17	101	0.06
20	NaCl	70	0.32	74	0.30	112	0.25	121	0.25	106	0.19
40	NaCl	76	0.48	69	0.47	109	0.33	130	0.29	112	0.23
20	KCl	70	0.29	69	0.26	107	0.15	129	0.23	114	0.18
40	KCl	76	0.42	72	0.38	103	0.26	122	0.29	118	0.21
LSD (0.10)		8	0.07	7	0.06	15	0.07	NS	0.07	11	0.04
Soil test Cl (0-24 in.), lb/A		16		9		20		52		12	



Also, tassel-stage leaf Cl concentrations were significantly increased at all sites. Chloride sources performed similarly, except that $CaCl_2$ resulted in somewhat lower leaf Cl concentrations than either KCl or NaCl, but still much higher than the check treatments.

Grain sorghum yields were significantly increased by Cl fertilization at eight of nine sites over the two years (**Tables 3** and **4**). The lone non-responsive site had a soil Cl level of 52 lb/A and had a history of annual application of KCl. Other sites had much lower soil Cl, mostly below 20 lb Cl/A. The average response among these eight sites was 11 bu/A. Boot stage leaf Cl concentrations were significantly increased at all sites. The larger yield responses were noted at sites with the lowest check treatment leaf Cl levels. In most cases, application of 20 lb Cl/A was enough to achieve response. All Cl sources evaluated performed similarly.

Summary

Results to date suggest that if Cl soil test levels are low (less than 20 to 25 lb/A, 0- to 24-inch depth), corn and grain sorghum are likely to respond economically to Cl fertilization. The responses noted seem to be a nutrient response to Cl as disease pressure was very low the two years of this work. Application of 20 lb Cl/A appears sufficient in most cases, and all Cl sources evaluated performed similarly. BC

Three of the authors are with Kansas State University. Dr. Lamond is Professor/Extension Specialist, Soil Fertility; Dr. Martin is Associate Professor/Research Agronomist, Sandyland Experiment Field; and Mr. Olsen is Graduate Research Assistant. Mr Rector is Agronomist for Ag Services, Hillsboro, Kansas.

TABLE 4. Effects of Cl fertilization on grain sorghum, 1999.

Cl rate, lb/A	Cl source	Brown Co. Yield, bu/A	Brown Co. Boot Cl, %	Marion Co. Yield, bu/A	Marion Co. Boot Cl, %	Stafford Co. Yield, bu/A	Stafford Co. Boot Cl, %	Osage Co. Yield bu/A	Osage Co. Boot Cl, %
0	—	93	0.15	98	0.13	132	0.04	96	0.18
20	KCl	98	0.28	109	0.36	142	0.31	98	0.20
40	KCl	108	0.49	111	0.51	144	0.28	104	0.22
20	NaCl	96	0.40	106	0.36	146	0.25	109	0.23
40	NaCl	104	0.55	107	0.47	139	0.48	115	0.26
20	$CaCl_2$	102	0.30	109	0.38	144	0.21	96	0.23
40	$CaCl_2$	95	0.44	105	0.49	141	0.33	105	0.23
LSD (0.10)		12	0.13	7	0.06	11	0.09	9	0.04
Soil test Cl (0-24 in.), lb/A		17		12		21		31	

GEORGIA

Student Garden Boosts Math and Science Scores

By Ann Nunan, Blanche McElfresh, and Jerry Johnson

In 1997, the Griffin-Spalding County School System Science Center and other cooperators initiated a scientifically designed service learning project directed toward urban, seventh-grade students. The students from Kelsey Avenue Middle School in Griffin, Georgia, are involved in the planning, planting, care, and harvesting of a vegetable garden with the produce directed to a local food bank. Crops grown in the garden include summer squash, cucumbers, corn, peppers, tomatoes, and sweet potatoes. The garden is located inside the University of Georgia Experiment Station Research and Education Garden at Griffin.

Agriculture and gardening can be great teaching tools for making math and science more understandable to students. That fact has been demonstrated by a collaborative effort involving the Spalding County, Georgia, school system and several partners.

Objectives of the project go much further than simply teaching students the art of gardening, however. They include determining how this type of hands-on learning might impact student math and science skills. Pre- and post-tests of a class of seventh graders compared the learning of students directly involved in the project with a control group.

Post-test results have shown that students participating in the project gained significantly more knowledge than students not participating. For example, in the 1998-1999 school year, students participating in the project averaged about 15 points higher in science and more than 10 points higher in math than the control group (**Table 1**).

TABLE 1. Descriptive statistics for grade 7.

Subject	Group	Number of students	Pre-test mean	Post-test mean	Mean gain
Science	Project	22	3.50	20.61	17.11
	Control	70	3.37	5.76	3.39
Math	Project	22	21.91	30.41	8.50
	Control	70	18.76	19.87	1.11

One of the participating students said, "It's amazing. Before (the project), I wasn't getting it. But now, I'm learning a lot." Another classmate agrees. "This class made it seem easy. They gave us a test before we started, and we all failed. At the end, we all made A's, and it was a difficult test," he said.

The garden serves as an instrument for teaching. First, the students plan out a grid on paper for

Transferring their plans to the actual garden space, students gain experience with a range of measurement situations and geometry principles.

the garden's design. Then they use a string to lay out the grid on the garden site. This shows them where to plant seeds and young plants. But it also provides real-world application for using math skills such as geometry and measurement.

The seventh-grade students involved in the project continue to visit the garden during the summer months to harvest the vegetables and deliver the produce to the food pantry. The project also has the added advantage of helping urban youth appreciate how...and where...their food is grown. One student said that, before the class, he didn't know sweet potatoes grew under ground. Others made similar comments...most did not have previous experience working with growing plants.

Students at the garden project learn from a variety of information sources and activities as they plan the plots.

The project also helped improve the students' work ethic. They learned that growing the garden was tough work, but were willing to do it because of the end result – sharing their bounty with needy people. Perhaps their increased awareness of helping to meet the needs of others, though not measured in the study, was as valuable as were improvements in their learning skills. BC

Ms. Nunan and Ms. McElfresh are teachers in Spalding County, Georgia. Dr. Johnson is a plant breeder with the University of Georgia College of Agriculture and Environmental Sciences (UGA-CAES), Griffin.

This project is funded in part by a service learning grant from the Georgia Department of Education. The garden class is a collaborative effort of Akins Feed and Seed of Griffin, the Griffin (Georgia) Utility Club, UGA-CAES, Potash & Phosphate Institute (PPI), and Foundation for Agronomic Research (FAR), of Norcross, Georgia.

Editor's Note: Dr. Noble R. Usherwood, PPI Southeast Director, and Katherine Griffin of the PPI communications staff have been involved in support of the "Learn and Serve Garden" since its beginning. They agree that the project has been effective in achieving unique educational experiences for students while also providing them a new perspective on agriculture and food production. Leaders of the project have presented reports on progress at the annual meetings of the American Society of Agronomy.

Precision Agriculture – An International Journal on the Science of Precision Agriculture

Precision Agriculture promotes the most innovative results coming from research in the field of precision agriculture. It provides an effective forum for disseminating original and fundamental research and experience in the rapidly advancing area of precision farming. There are many topics in the field of precision agriculture. Topics that are addressed include, but are not limited to, natural resources variability, managing variability, engineering technology, profitability, environment, and technology transfer. The Editors-in-Chief are Pierre C. Robert, University of Minnesota Precision Agriculture Program, St. Paul, MN, USA, and John Stafford, Silsoe Solutions, Bedford, UK. More information on the journal is available on the web at http://www.wkap.nl/journalhome.htm/1385-2256.

WASHINGTON

Potassium and Specific Gravity of Potato Tubers

By Joan R. Davenport

> Potassium (K) fertilizer, particularly potassium chloride (KCl), has been reported to reduce potato tuber specific gravity. The research reported here was conducted over the course of three years, including one growing season associated with very poor potato specific gravity throughout Washington state. Potassium fertilizer was associated with a reduction in tuber specific gravity only when 50 to 75 percent of the fertilizer was applied during the growing season. This occurred in only one of the three years of the study, and it did not matter if the fertilizer was KCl or potassium sulfate (K_2SO_4). Neither source caused a reduction in tuber specific gravity during an extremely hot growing season.

Potato growers are paid based on a combination of yield and tuber quality factors. Tuber specific gravity is an important quality factor. For processing potatoes there is a range of specific gravities that is considered optimal. Typically, if there is a reduction in payment related to tuber specific gravity it occurs when specific gravity is low.

Many factors influence tuber specific gravity. Climatic conditions will determine if a growing region has a "good" or "bad" year for gravity. However, over the years, K fertilizer has been recognized for its influence on specific gravity.

In the 1970s, research results from Idaho reported that tuber specific gravity was reduced with increased K fertilizer rate. The same study concluded that the reduction in specific gravity was more pronounced when K was applied in the Cl form than when K_2SO_4 was used. In the 1980s and 1990s, scientists in Idaho and Oregon studied potato response to K fertilizer and found a slight, but statistically significant, decrease in tuber specific gravity when K fertilizer was used, but no difference between sulfate (SO_4) or Cl forms.

From 1997 to 1999, a research project was conducted in Quincy, Washington, in the Columbia Basin, an area where potato production is quite extensive. This project studied both liquid and granular K fertilizers on potato production, using KCl and K_2SO_4. The study was conducted on a combination of Russet Burbank and Norkota Russet potatoes. Other than a zero K control, each year the research plots were fertilized with the K rate recommended based on soil testing. Annual rates ranged from 325 to 400 lb K_2O/A. In-season K fertilization consisted of two equal applications (tuber initiation and early tuber bulking) for the 50 percent in-season treatment and three equal applications (tuber initiation, early tuber bulking, and late tuber bulking) for the 75 percent in-season treatment.

During the three years of this study, the 1998 growing season was extremely hot (**Figure 1**), and tuber specific gravity was low throughout the growing region.

The results of different K fertilizer treatments are shown in **Figure 2**. In all three years of this study, tuber specific gravity was similar whether potatoes were fertilized with KCl or K_2SO_4. Moreover, for the duration of this study, K fertilizer did not appreciably reduce specific gravity when compared to the control (no K) treatment.

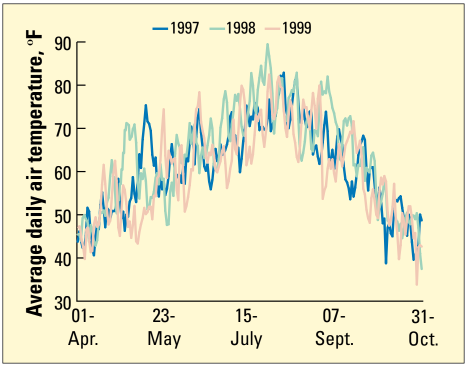


Figure 1. Average daily air temperature in Quincy, Washington, from 1997 to 1999.

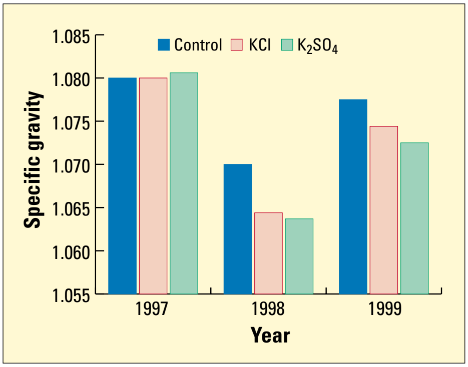


Figure 2. Average potato tuber specific gravity with KCl and K_2SO_4 fertilizers.

In 1999, there was a tendency for slight reduction in tuber specific gravity when some of the K fertilizer was applied in-season (**Table 1**). This reduction was statistically significant only once with the Cl form. More important than the impact on specific gravity, this research showed that delaying 75 percent of the K application until in-season actually decreased crop yield.

The results of this Washington research do not support the research conducted in the 1970s, but do support the results from later studies. Potassium chloride fertilizer does not adversely affect the potato specific gravity when used according to soil test recommendations. The results do indicate in-season applications of K fertilizers can have an adverse effect on tuber specific gravity. In addition, applying 75 percent of the season's K in-season reduced crop yield.

Thus, when soil test values indicate a need for K fertilizer, KCl or K_2SO_4 can be used without adversely affecting tuber specific gravity, regardless of the weather conditions. This research suggests that the best crop yield and tuber specific gravity result when K fertilizer is applied preplant versus applying some of the K during the growing season. BC

Dr. Davenport is Assistant Professor/Soil Scientist at Washington State University, Irrigated Agriculture Research and Extension Center, Prosser. E-mail: jdavenp@tricity.wsu.edu

Research by Dr. Davenport in Washington state is investigating effects of K fertilizers on specific gravity of potato tubers.

TABLE 1. Average potato tuber specific gravity and yield for different K fertilizer treatments in 1999.

Potassium fertilizer				
Source	Form	% applied in-season	Specific gravity	Yield, tons/A
None	N/A	0	1.0775 a	33.80 abc
Sulfate	Granular	0	1.0750 ab	35.09 a
Chloride	Granular	0	1.0775 a	34.44 a
Sulfate	Liquid	0	1.0725 ab	32.64bc
Chloride	Liquid	0	1.0775 a	31.68bc
Sulfate	Liquid	50	1.0750 ab	34.48 a
Chloride	Liquid	50	1.0700 b	31.25 bc
Sulfate	Liquid	75	1.0725 ab	30.73 c
Chloride	Liquid	75	1.0725 ab	27.17 d

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$.

QUEBEC

An Agri-Environmental Model for Potato Phosphorus Recommendations

By L. Khiari and L.E. Parent

Phosphorus fertilization is essential for obtaining high potato yields, but it is also a potential non-point source of water pollution. Potato farmers usually apply P in large excess of P removal by the crop since the potato has limited root development and explores only a small portion of the soil volume. In addition, the potato crop is grown in acid soils, where added P is fixed to a great extent as Al and iron (Fe) phosphates.

Since the plant absorbs soluble P, and soluble P can affect the quality of surface water, a suitable agri-environmental P recommendation model for the potato crop should integrate the environmental risk and the crop response to fertilization. Part of the environmental risk is often assessed using a P saturation index, while crop response probability to fertilization is related to soil test P. We have found that a M-III P saturation index could be used to simultaneously assess environmental risk and make recommendations for the potato crop.

A phosphorus (P) saturation index derived from the commonly used Mehlich-III (M-III) soil test can be an effective tool for the development of P fertilizer recommendations that simultaneously optimize potato yields and minimize risk of water contamination. The ratio of P to aluminum (Al) forms the basis for an integrated agri-environmental model.

Defining a P Saturation Index

The environmental risk of loss of P from the soil has been assessed in the Netherlands from the degree of P saturation (DPS), computed as P/(Fe+Al) from molar concentrations of oxalate-extractable P, Fe, and Al. Recently, the ratio of P/Al in M-III extracts was found to correlate closely

Researchers are seeking tools for development of P fertilizer recommendations that optimize potato yields and minimize risk of water contamination.

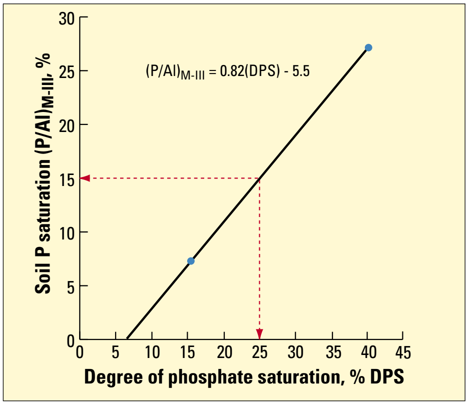


Figure 1. Relationship between degree of phosphate saturation (% DPS) and soil P saturation as $(P/Al)_{M\text{-}III}$.

with such P/(Fe+Al) molar ratios in Quebec soils. In our acid coarse-textured potato soils, we found by a fractionation procedure that soluble inorganic P was mainly sorbed by Al-oxyhydroxide (79 percent of added P), while Fe-phosphate made up only 9 percent of added P. Thus, P sorption in Quebec soils is related primarily to soil Al.

The DPS value of 25 percent used in the Netherlands as the environmental critical value corresponded to a $(P/Al)_{M\text{-}III}$ ratio of 15 percent [based on parts per million (ppm); see **Figure 1**]. Consequently, a P fertilizer rate exceeding P removal by the crop would be at risk environmentally for soils testing above 15 percent as $(P/Al)_{M\text{-}III}$. It must be ascertained whether fertilizing the crop according to P removal above this critical value would negatively affect tuber productivity.

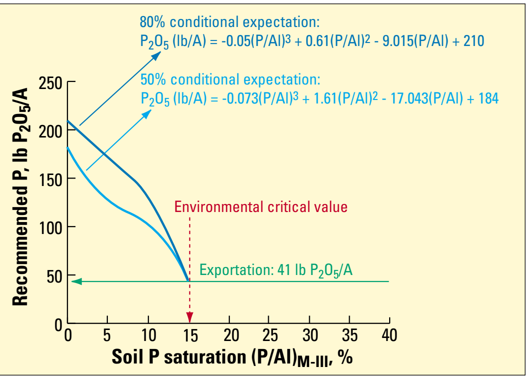


Figure 2. Agri-environmental P recommendation models for potato production in Quebec.

TABLE 1. Comparison of P recommendations for five example soils based on $P_{M\text{-}III}$ (CPVQ, 1996) or the $(P/Al)_{M\text{-}III}$ percentage (agri-environmental approach).

Mehlich-III determination			Recommended levels of P_2O_5, lb/A		
$P_{M\text{-}III}$, lb/A	$Al_{M\text{-}III}$, lb/A	$(P/Al)_{M\text{-}III}$, %	CPVQ (1996)	Conditional expectation 50%	80%
61	3,124	2.0	192	156	194
168	2,643	6.4	130	122	165
237	2,800	8.5	94	111	147
313	2,180	14.4	58	55	58
417	1,782	23.4	27	41	41

The Agronomic Model

In the agronomic model, we combined 78 field experiments conducted in Quebec over the past 30 years. Fertilizer trials were made of three blocks and three to six P levels in the range of 0 to 270 lb P_2O_5/A with 45 lb P_2O_5/A intervals. Percentages of total tuber yield were computed across experimental sites by dividing yield in the control plot by maximum yield in fertilized treatments, then multiplying by 100. Yield percentages were sorted in an ascending order of their $(P/Al)_{M\text{-}III}$ percentages. The partitioning between high and low response probabilities below and above a soil critical level was obtained iteratively using the Cate-Nelson procedure. The critical level as $(P/Al)_{M\text{-}III}$ was 8 percent, the starting value for constructing fertility groups.

In order to build an agri-environmental model based on the $(P/Al)_{M\text{-}III}$ percentage for making P fertilizer recommendations, agronomic and environmental models must be combined. As a result, five fertility and environmental risk groups were constructed as follows for potato production in Quebec acid coarse-textured soils:

- Extremely low fertility and extremely low environmental risk group: 0-2 percent as $(P/Al)_{M\text{-}III}$
- Very low fertility and very low environmental risk group: 2-4 percent as $(P/Al)_{M\text{-}III}$
- Low fertility and low environmental risk group: 4-8 percent as $(P/Al)_{M\text{-}III}$
- Medium fertility and medium environmental risk group: 8-15 percent as $(P/Al)_{M\text{-}III}$
- High fertility and high environmental risk group: greater than 15 percent as $(P/Al)_{M\text{-}III}$

(continued on page 20)

Phosphorus Deficiency in Seedling Corn – Crop Rotation Considerations

By Shabtai Bittman, Grant Kowalenko, and Derek Hunt

Silage corn (*Zea mays* L.) is grown on approximately 20,000 acres in the coastal region of British Columbia as a forage for the local dairy industry. While soil test P levels on dairy farms are generally medium to high in the region due to the addition of manure, it is not uncommon for farmers to report P deficiency symptoms at the 3- to 6-leaf growth stage of the corn crop. Cool soil temperature is the main reason given for the purpling of corn seedlings, with the high yielding corn hybrids considered most likely to display the color change because of high levels of the pigment, anthocyanin.

Early season colonization of silage corn by vesicular arbuscular mycorrhizae (VAM) is influenced by previous crop in the rotation. Growing silage corn on either fallow or stubble of a non-VAM colonizing crop like canola can result in early season phosphorus (P) deficiencies that limit harvested silage yield and reduce dry matter at maturity.

In an attempt to evaluate the impact of early season P deficiency on silage corn production, research staff at the Pacific Agri-Food Research Centre in Agassiz, have been monitoring the fertilizer and crop management practices used in research trials. They have regularly observed that the purple coloration and stunting of well-fertilized corn corresponds to cropping practices in the previous year. Corn planted in the previous year's alleyways showed severe purpling and stunting, whereas the corn planted in areas previously growing corn flourished. Typically, these alleyways were fallowed using a rotovator. The most severe stunting was observed on soil areas that were fallowed for several years. Having P-starved corn plants growing next to P-sufficient plants on soils with abundant levels of soil test P was a major problem for the corn hybrid testing program being managed at the Centre.

The phenomenon of P deficiency in young plants growing on previously fallowed soils has been well documented for corn, wheat and other crops. There is considerable information that points to inadequate populations of VAM in fallow soils as the cause of this P deficiency. In fact, the current opinion of many researchers is that young seedlings require an established network of VAM hyphae to enhance early season P uptake. The spores of VAM, which have long-term persistence and found almost everywhere in agricultural soils, require substantial time to develop a sufficient network. Cool soils influence the activity of VAM, slowing their early season development. As a result, farmers routinely use low rates of starter P with the seed at planting of corn to try and overcome this early season deficiency.

At present, P recommendations in Canada do not take the VAM status of a soil into consideration. Two reasons may be suggested:

1) There is no convenient test for VAM in the soil, especially one that can be used prior to planting.
2) Relatively few studies on VAM have evaluated crop yield.

No attempt has ever been made to systematically develop soil test correlations for P in concert with assessment of VAM in Canada.

This is despite clear indication that common farming practices...such as summerfallow, crops planted following ‘cruciferous’ and other non-VAM crops, intensive tillage, and flooding...may affect P nutrition in young crops. Today farmers need to know not just when starter P is required, but also when it is not required to achieve optimum yield. In particular, the strategic use of P in heavily manured soils is critical.

To evaluate the effect of rotation on early season silage corn, P nutrition research trials were established in the coastal region of British Columbia. Data were collected on corn growth in 1995, 1997 and 1998, with the plot area in the pre-seeding year managed with corn, summerfallow or canola. Locally adapted silage corn hybrids were planted between early May and early June at a rate of 30,000 to 32,000 seeds per acre using 30-inch row spacing. Fertilizer, except P, was broadcast at recommended rates. Nitrogen (N) was applied as ammonium nitrate at 180 to 225 lb N/A broadcast prior to seeding. On some treatments, fertilizer P was side banded at a rate of 60 lb P_2O_5/A at seeding, while on other treatments no P was applied. Plants were sampled at several growth stages for tissue P concentration and VAM colonization at the 3-leaf stage. Silage yield and percent dry matter were measured at the dent stage.

In all three years of the study, colonization of corn roots by VAM was significantly lower after fallow than after corn (**Table 1**). The effect of planting corn after canola on VAM was equivalent to planting corn after fallow. These results are consistent with previous research on corn. However, in this study the application of P fertilizer had little effect on VAM colonization, in contrast to many published reports. There was no evidence of an interaction between the previous

TABLE 1. Influence of P application and previous crop on VAM colonization, seedling tissue P, silage dry matter yield, and silage dry matter percentage at Agassiz, BC in 1995, 1997 and 1998.

Previous	1995		1997		1998	
crop	-P	+P	-P	+P	-P	+P
	VAM count					
Corn	107a[1]	115a	290a	302a	140a	136a
Fallow	80b	98b	213b	187b	66b	74b
Canola	N/C[2]		190b	179b	63b	73b
	3-leaf stage tissue P, %					
Corn	0.29a		0.28	0.34	0.17b	0.19a
Fallow	0.22a		0.28	0.33	0.15c	0.17b
Canola	N/C		0.28	0.35	0.16bc	0.17b
	6-leaf stage tissue P, %					
Corn	0.41a		0.27b	0.31a	0.27ab	0.29a
Fallow	0.37b		0.20c	0.27b	0.17c	0.24ab
Canola	N/C		0.21c	0.27b	0.17c	0.23b
	Corn silage dry matter yield, tons/A					
Corn	9.54a		5.76ab	6.26a	8.15ab	8.78a
Fallow	9.23a		5.31b	5.90ab	6.71c	7.20bc
Canola	N/C		5.63ab	6.03ab	6.84c	7.20bc
	Dry matter content, %					
Corn	29.1a		26.2	27.6	44.3ab	44.8ab
Fallow	28.3a		26.1	27.8	38.6b	46.4a
Canola	N/C		26.3	26.9	36.4b	42.7ab

[1]Numbers in columns followed by the same letter are not statistically significant at P = 0.05.
[2]N/C – data not collected for canola stubble in 1995.

crop and P application on VAM colonization.

Corn seedling tissue P at the 3-leaf stage showed a positive response to fertilizer P addition. However, it was not influenced to any great extent by previous crop (**Table 1**). At the 6-leaf stage, previous crop did affect tissue P content significantly. As the season progressed, the influence of crop management or P addition had a minor impact on plant tissue P concentration (data not shown).

At harvest of the corn silage, the effect of previous crop was generally greater for the unfertilized than the fertilized treatments, with significant differences in 1998 (**Table 1**). While the differences were small, the trend over all trials was for increased corn yield and earlier maturity...as shown by lower percent dry matter (DM)...after corn than after fallow or canola. The trend was observed even when adequate P was applied.

The results of this research confirm what previous studies have shown. That is, the colonization of corn by VAM is influenced by previous crop in rotation. They also provide new information indicating that the colonization of corn roots by VAM was not negatively influenced by side banded P application, a treatment that in most instances improved the final silage yield and DM percent.

Early season colonization of corn roots by VAM had a positive effect on seedling tissue P concentration. Side banding P fertilizer can correct low P uptake associated with poor colonization of corn roots with VAM. However, this may not fully compensate for low P when there is poor root colonization. BC

Dr. Bittman is Forage Agronomist, Dr. Kowalenko Soil Scientist, and Mr. Hunt Senior Research Technician at the Pacific Agri-Food Research Centre in Agassiz, British Columbia. E-mail: bittmans@em.agr.ca

An Agri-Environmental Model... *(continued from page 17)*

The P Recommendation Model

Optimum P rates were ranked in an ascending order within a given soil fertility group as defined above, and P rates corresponding to conditional expectations of 50th and 80th percentiles were recorded. The 50th percentile is the P rate at which 50 percent of the soils in the class produce an optimal yield. The 80th percentile is the P rate that produces optimal yield 80 percent of the time. Both P recommendation models are presented in **Figure 2**.

For recommendation models, the P rate stabilized at 41 lb P_2O_5/A for $(P/Al)_{M\text{-}III}$ exceeding 15 percent. For the 80 percent conditional expectation model, up to 200 lb P_2O_5/A would be recommended below 15 percent $(P/Al)_{M\text{-}III}$. Above an environmental threshold of 15 percent, the recommendation is 41 lb P_2O_5/A. Correspondingly, a P removal of 41 lb P_2O_5/A would be obtained with tuber yield of 375 cwt/A, assuming P removal of 0.11 lb P_2O_5/cwt of tubers. The largest difference between the present Quebec fertilizer recommendation, based on P alone, and the proposed model based on P saturation occurs above the 15 percent critical value (**Table 1**). Above 15 percent, our model recommends more P than present recommendations.

Thus, the $(P/Al)_{M\text{-}III}$ ratio provides a reliable and unifying criterion for making environmentally acceptable and agronomically efficient fertilizer P recommendations for sustaining potato production. The critical value of 15 percent for the $(P/Al)_{M\text{-}III}$ ratio appears to be an acceptable agri-environmental criterion for the potato crop grown in Quebec light-textured soils. A similar agri-environmental model is currently being developed for corn across a larger range of soil textural classes. BC

Dr. Khiari is research associate and Dr. Parent is professor of soil fertility at the Department of Soil Science and Agri-food Engineering, Laval University, Sainte-Foy, Quebec, Canada. E-mail: lotfi_khiari@yahoo.com and leon-etienne.parent@sga.ulaval.ca

MISSISSIPPI

No-Tillage Cotton Responds to Potassium Fertilization on High CEC Soils

By Jac J. Varco

> Results of a Mississippi study indicate that potassium (K) requirements for cotton in no-tillage production may be greater than for conventional tillage cotton, especially on soils with high cation exchange capacity (CEC). Improved water retention with no-tillage as well as the effect of K on water use efficiency may be at least partially responsible for the effects observed in this research.

Implementation of no-tillage practices for cotton has prompted questions regarding the application of fertilizer K due to its limited-mobility in soil. Fertilizer K is commonly broadcast and incorporated into the soil with tillage. Surface placement without incorporation in no-till and reduced-till conditions may lower the effectiveness of K fertilization due to soil test K stratification in the shallow surface soil. Additionally, cotton is primarily a tap-rooted crop, which may limit surface soil feeding.

A shift towards higher soil test levels to maximize profitability may be required for no-till conditions. Modern cotton cultivars grown from the Midsouth to the Southeast are fast-fruiting, high-yielding, and early maturing. Since total K requirements of modern varieties have not decreased, the K uptake period has been compressed. This may require higher soil test K levels to meet the period of high demand.

Potassium deficiency symptoms in modern varieties are often observed in the upper canopy (immature leaves) rather than in older mature leaves, possibly due to a heightened demand by developing bolls. The expression of symptoms progresses from flowering through boll formation.

A K response study was begun in 1992 on a Leeper silty clay loam soil at the Mississippi State University (MSU) Plant Science Research Center to determine the validity of current soil test recommendations for early

Cotton leaves showing upper canopy K deficiency.

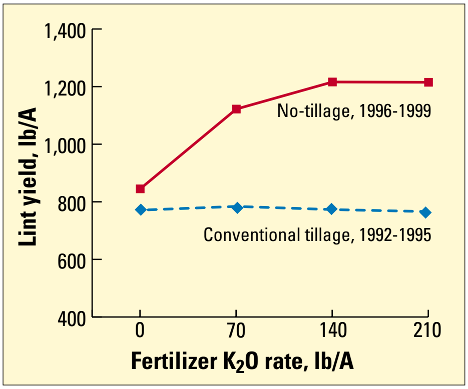


Figure 1. Cotton lint yield response to fertilizer K rate as influenced by tillage.

maturing cotton varieties. To provide a wide range in K availability, rates of 0, 70, 140, and 210 lb K_2O/A were broadcast prior to planting each year. From 1992 through 1995, fertilizer treatments were incorporated with tillage. From 1996 through 1999, strict no-tillage production practices were used. Tillage for 1992 through 1995 included fall subsoiling and hipping followed by rehipping in the spring after fertilization and bed knockdown and smoothing with a do-all just prior to planting. For all treatments and years, a rate of 120 lb N/A was applied as a 50/50 split at planting and early squaring. Cotton variety DES 119 was planted in 1992 through 1995, and Suregrow 125 was grown in 1996 through 1999.

The average K soil test prior to fertilization in 1992 was 157 parts per million (ppm)...314 lb/A, Mississippi Lancaster method...and was categorized within the upper limit of the medium soil test category. (The Lancaster method extracts approximately 15 to 20 percent more K than Mehlich III.) At this level, a low probability of a response would be predicted according to MSU Extension Service recommendations. Lint yield did not respond to applied K with conventional tillage (**Figure 1**).

In contrast, a dramatic yield response to applied K was found with no-tillage. Maximum agronomic yield was predicted at a rate of about 172 lb K_2O/A, using the four-year average for no-tillage. On this soil, Lancaster-extractable K would have to be near 218 ppm (436 lb/A) to optimize yields. Year-to-year variation in yield was greatest with conventional tillage, and increasing K rate with no-tillage appeared to reduce this variability in yield. Most notable is the fact that growing season rainfall was less for 1996 through 1999 (1996, 18.6 in.; 1997, 16.7 in.; 1998, 12.8 in.; 1999, 11.8 in.) compared to 1992 through 1995 (1992, 20.5 in.; 1993, 15.2 in.; 1994, 26.2 in.; 1995, 17.3 in.).

Although direct comparisons within years between tillage systems are not possible, the results indicate that K was not a limiting factor at the initial soil test levels with conventional tillage. For no-tillage, however, the results indicate that K was a limiting factor and that higher soil test levels may be required for silty clay loam soils with a CEC higher than 25 $cmol_c$/kg (meq/100 g). The observed response with no-tillage could be due at least partially to benefits such as increased water availability, which may have improved the marginal productivity of fertilizer K. The yearly trend in yield for no-tillage relative to K rate and growing season rainfall is shown in **Figure 2**. A decline in yield was evident for the 0 and 70 lb K_2O/A treatments with a decline in growing season rainfall,

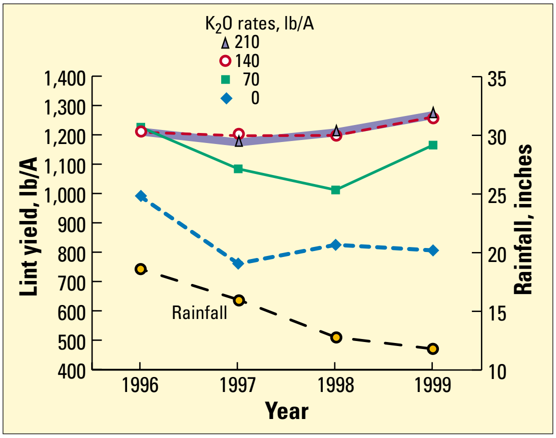


Figure 2. No-till cotton lint yield as influenced by fertilizer K rate and rainfall each year.

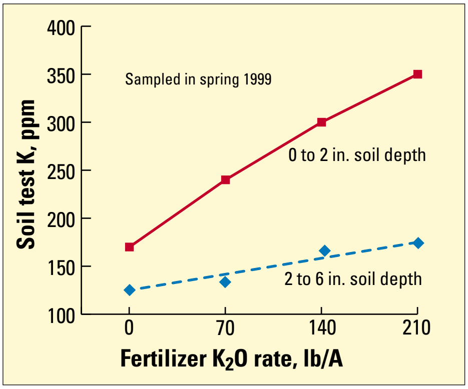


Figure 3. Soil depth effects on retention of applied fertilizer K under no-tillage conditions. (Soil test K is Lancaster-extractable.)

while at the two greatest rates, yield appeared to become less affected by year-to-year variation in rainfall (i.e. moisture deficits). Thus, increased K availability appears to have improved water use efficiency.

Vertical stratification of applied fertilizer K was apparent in this study after adoption of no-tillage practices (**Figure 3**). Soil test K increased the greatest in the shallow 0- to 2-in. depth. Only a slight increase was apparent in the 2- to 6-in. depth. Surface deposition of K from crop residues would also contribute some to this effect due to the elimination of tillage. Due to the high CEC (greater than 25) and mineralogy, this soil has a high capacity to adsorb K and limit its movement. Although leaching would not be expected on this soil, the high shrink-swell potential could cause some movement of surface soil into cracks formed during dry periods.

Results of this study suggest that K requirements for no-tillage cotton may be greater than for conventional tillage cotton, especially on high CEC soils. Improved water retention with no-tillage as well as the effect of K on water use efficiency may at least be partially responsible for the effects observed in this study. BC

Dr. Varco is Professor of Soil Fertility in the Plant and Soil Sciences Department, Mississippi State University. E-mail: jvarco@pss.msstate.edu

In Memory of Dr. Larry C. Bonczkowski, 1953-2000

Dr. Larry C. Bonczkowski, a well known agronomist and dedicated leader in fertilizer industry programs, passed away June 30, 2000. From December 1993 until his untimely death, he served as Manager, Agronomy Services, for Agrium U.S. Inc. in Denver, Colorado. Previously, he worked for Growmark, Inc. in Illinois and for Great Salt Lake Minerals Corporation.

In his professional career, Dr. Bonczkowski was responsible for providing technical agronomic information to staff and customers, delivering dealer and farmer meetings, conducting training programs, facilitating research and development programs, serving as liaison with land-grant universities, and participating at various regional and national events.

A native of Madison, Kansas, Dr. Bonczkowski grew up on the family farm and attended Kansas State University. After receiving his M.S. degree in 1977, he joined the Cooperative Extension Service in Kansas as Northeast Area Crop Protection Specialist. He completed his Ph.D. degree in 1989. Dr. Bonczkowski became a highly respected authority on chloride nutrition of wheat and other crops and later was active in addressing issues related to heavy metals and fertilizers.

He was a Certified Professional Agronomist and an active member of the American Society of Agronomy and the Soil Science Society of America. Also, he was a member of the Ag Retailers Association, the Fluid Fertilizer Foundation Board of Directors, and the Program Committee of the Great Plains Soil Fertility Association. Dr. Bonczkowski served on committees of The Fertilizer Institute and the Program Advisory Group of PPI.

A memorial fund was established at Kansas State University to provide an annual scholarship to a graduate student in soil fertility. Dr. Bonczkowski is survived by his wife, Patty, two sons, his mother, and a brother. BC

A New Website at PPI

Since the Institute's creation more than 65 years ago, *Better Crops* (BC) has been its flagship publication. It serves PPI well in helping our staff to achieve the Institute's mission "to advance the appropriate use of P and K in crop production systems through the worldwide development and promotion of scientific information that is agronomically sound, economically advantageous, and environmentally responsible." On September 9, we introduced another powerful tool to strengthen communications with our various global audiences, the 'new and improved' www.ppi-ppic.org (and www.ppi-far.org) website.

There are 26 individual websites embedded in the www.ppi-ppic.org system, including 12 in North America and 14 internationally. The Foundation for Agronomic Research (FAR; www.ppi-far.org), has a site, as do the Senior Vice Presidents for both North American and international programs. Scientific regional directors have websites, some with their own URLs, and there is an educational site for students and teachers. Directors have the autonomy to post informational materials (articles) dealing with their regions, in their local languages. There are regional profile pages that, when completed, will provide the user with facts such as crop acreages, yields, fertilizer consumption, production trends, and other data and which will point to other links that give further documentation.

A fully searchable database is now available for use by all our website visitors. By providing certain key words, the user can search for numerous topics involving nutrient management. The database is being populated by PPI staff and will become more useful with time.

Let me suggest that you visit our website and see for yourself that it should be book marked as one of your 'favorites' when it comes to nutrient management and crop production. The site was designed with you in mind, so we ask that you give us your impressions. You can contact your local regional director by clicking on the map on the home page or you can e-mail me at bdarst@ppi-far.org. We look forward to hearing from you.

BETTER CROPS WITH PLANT FOOD

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

Periodicals Postage