BETTER CROPS

WITH PLANT FOOD

1998 Number 2

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BETTER CROPS WITH PLANT FOOD

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Our Cover: Spring planting, photo courtesy of AGCO.

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L O U I S I A N A

Influence of Starter Fertilizer on Corn Rotated with Cotton

By H.J. Mascagni, Jr. and D.J. Boquet

The early planting dates of mid-March to early April required for optimal corn production in Louisiana often expose seedlings to lower than optimal soil temperatures. These low temperatures may result in slow growth and reduced availability of soil P, even though levels of soil P may be considered adequate for plant growth.

Phosphorus deficiency symptoms on corn seedlings are commonly seen and are most pronounced on the sandy loam and silt loam Mississippi River alluvial soils with organic matter levels of 0.5 to one percent...soils such as Commerce silt loam (fine silty, mixed, thermic, nonacid, Aeric Fluvaquents). Soil temperature at the 2-in. depth in early March on a Commerce silt loam may be as much as 5º F lower than on a clay. Thus, symptoms of P deficiency that are common on sandy and silt loam soils rarely occur on the finer-textured silty clay and clay soils.

In-row starter fertilizer containing nitrogen (N) and phosphorus (P) increased corn yield, decreased harvest moisture in grain and advanced silking date in Louisiana studies on medium textured alluvial soils.

Placing small amounts of starter fertilizer in close proximity to the seed at planting could alleviate the effects of cold soil temperature on P uptake and early corn growth. The placement most thoroughly investigated has been 2 inches to the side and 2 inches below the seed. Placement of the starter directly with the seed has also been investigated. This method of application is practical and economic in a corn-cotton production system, since cotton producers typically use in-furrow equipment for insecticide and/or fungicide applications. The potential for injury to the seedling when there is direct contact between fertilizer and seed places greater emphasis on avoiding excessive starter fertilizer rates.

Dr. Rick Mascagni compares increased growth of corn which received starter fertilizer versus corn without starter.

Experiments were conducted for several years at the Northeast Research Station near St. Joseph, LA to evaluate the effectiveness of in-furrow starter fertilizers. The experiments were conducted on Commerce silt loam from 1991 through

1997 and on Mhoon silty clay loam (fine silty, mixed, thermic, nonacid, Typic Fluvaquents) in 1996. Some of these experiments included variables other than starter fertilizer. However, for this summary, only the main effects of starter fertilizer are reported.

Corn was planted from mid-March to early April at about 28,000 seeds/A. The formulations and rates of starter fertilizer that were applied in each year are presented in **Table 1**. Nitrogen as ammonium nitrate (NH_4NO_3) was broadcast prior to emergence at rates of 180 lb/A from 1991 through 1993 and 200 lb/A from 1994 through 1997. Cotton was the previous crop each year. Soil P levels (Ap horizon) in the test area were considered high each year, according to analyses conducted by the Louisiana State University Agronomy Department Soil Testing Laboratory.

Average grain yields ranged from 135 bu/A in 1991 to 206 bu/A in 1997 (**Table 2**). The in-furrow N-P starter significantly increased grain yield in 4 of 6 years. Significant responses ranged from an 8 bu/A (5.5 percent) increase in 1993 to a 25 bu/A (14.0 percent) increase in 1995. The average starter response over years was 8 bu/A.

At a cost of $1.40 to 1.55/gal for 10-34-0 or 11-37-0, and a corn price of $2.70/bu, the net return (in responsive years) to in-furrow starter application ranged from $17.35 to $66.55/A (assuming no fertilizer application equipment purchase).

Harvest grain moisture and mid-silk date reflected the effect of starter fertilizer on maturity. Each year, harvest grain moisture was lowest when starter fertilizer was applied (**Table 2**). Averaged across years, harvest grain moisture was reduced from 18.9 percent when no starter was applied to 17.9 percent when starter was applied. Similarly, number of days after planting to mid-silk was lowest each year when starter was applied. Averaged across years, mid-silk date was 73 days after planting with no starter and 69 days after planting with starter.

TABLE 1. Starter fertilizer formulations and rates used in experiments at the Northeast Research Station at St. Joseph, LA, 1991 through 1997.

Year	Formulation $N\text{-}P_2O_5\text{-}K_2O$	Rate, gals/A
1991	11-37-0	3
1992, '93, '95	11-37-0	4
1996, '97	10-34-0	5

It cannot be determined with certainty from these experiments whether the responses to starter fertilizer were due to the N or P component of the ammonium polyphosphate or to N and P in combination. In these studies, the total N requirement was applied at planting, providing adequate N for early growth and yield and possibly minimizing a starter-N response. Typical P-deficiency symptoms were also noted each year on corn leaves in the control (no starter) plots, but not in the plots receiving starter fertilizer, suggesting that P was likely the more important component of the starter fertilizer.

There did not appear to be a consis-

Phosphorus deficiency symptoms...purpling in leaves...are indicated on these corn plants.

tent relationship between starter response and climate. Early spring (March and April) air temperatures were below normal only in 1993 and 1996, whereas the largest yield responses to starter occurred in 1991 and 1995. The large yield response to starter in 1995 (**Table 2**) was probably related to the soil type in the experimental area, which was a sandy loam. These sandy, low organic matter, light colored, soils are cold-natured, and may not require unusually low ambient temperatures for P availability to be affected. Other research suggests that P deficiency can be further exacerbated by the use of extremely early planting dates and hybrids sensitive to P deficiency.

Summary

Application of in-furrow starter N-P fertilizer (ammonium polyphosphate) increased corn yield, decreased harvest grain moisture and advanced the silking date. Yield response to starter was significant in 4 of 6 years on medium-textured (sandy loam to silt loam) Mississippi River alluvial soils. Planting from mid-March to early April and using starter fertilizer would help to ensure consistent maximum yield production and minimal conflict with cotton production practices in both spring and fall. A starter fertilizer such as ammonium polyphosphate can be applied with the same in-furrow application equipment already used by producers to apply fungicide and insecticides at planting. BC

Dr. H.J. Mascagni, Jr. is Associate Professor of Agronomy and Dr. D.J. Boquet is Professor of Agronomy at Louisiana State University Agricultural Center's Northeast Research Station at St. Joseph and Winnsboro, LA, respectively. E-mail for Dr. Mascagni: HMascagni@agctr.lsu.edu)

TABLE 2. Influence of starter fertilizer on corn yield, harvest moisture, and mid-silking date at the Northeast Research Station at St. Joseph, LA, 1991 through 1997.

Year	Starter	Yield, bu/A	Harvest moisture, %	Mid-silk date, DAP
1991	No	135*	19.9*	69.1*
	Yes	147	18.5	64.5
1992	No	170^NS	23.1*	68.6*
	Yes	172	22.4	66.7
1993	No	140*	18.8*	73.9*
	Yes	148	17.9	71.2
1995	No	175*	16.1*	66.3*
	Yes	200	14.7	61.6
1996	No	178^NS	20.7*	82.8*
	Yes	171	19.9	79.4
1997	No	196*	14.8*	76.3*
	Yes	206	14.2	73.3

*Indicates that yield differences are significant at the 0.05 probability level.
^NS Non-significant at the 0.05 probability level.

"J. Fielding Reed PPI Fellowships" Awarded To Four Graduate Students

Four outstanding graduate students have been announced as the 1998 winners of the "J. Fielding Reed PPI Fellowship" awards by the Potash & Phosphate Institute (PPI). Grants of $2,000 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related sciences.

The 1998 winners were chosen from more than 20 applicants who sought the Fellowships. The four are:

- **Kipling S. Balkcom,** Iowa State University, Ames
- **Jean Brokish,** Purdue University, West Lafayette, Indiana
- **John Dennis Lauzon,** University of Guelph, Ontario
- **Grant Russell Manning,** University of Manitoba

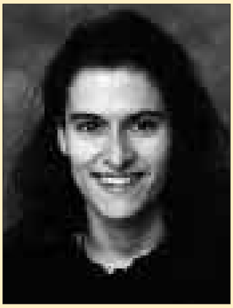
"Each year, we have the privilege of recognizing and encouraging an outstanding group of graduate students in agronomic sciences," said Dr. David W. Dibb, President of PPI. "All of the applicants this year and their educational institutions can take pride in the level of achievement represented."

Funding for the Fellowships is provided through support of potash and phosphate producers who are member companies of PPI.

Scholastic record, leadership, and excellence in original research are among the important criteria evaluated for the Fellowships. Following is a brief summary of information for each of the 1998 recipients.

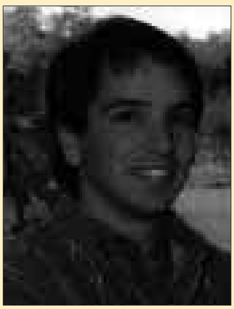
Kip Balkcom is a native of Midland City, Alabama. He earned both his B.S. and M.S. degrees from Auburn University. He is currently working toward his Ph.D. degree at Iowa State University. Included among his awards while at Auburn were the A. L. Smith Outstanding Graduate Student Award, 1996, and the Charles Chapman Memorial Scholarship, 1996. His research is focusing on 'smart' sampling of corn fields to reduce sampling costs and increase the accuracy of nitrogen (N) recommendations. By combining aerial photography with other field variables...yield, soil type, topography and other factors ...he hopes to be able to develop standardized protocols for corn fields in Iowa. He is planning a career in university research or Extension.

Jean Brokish was born in Dodgeville, Wisconsin. She studied for her B.S. degree at the University of Wisconsin - River Falls. She is currently working toward an M.S. degree at Purdue University. She has received many awards and honors during her college career, including the Northrup King Company Scholarship, 1994, and the American Society of Agronomy:

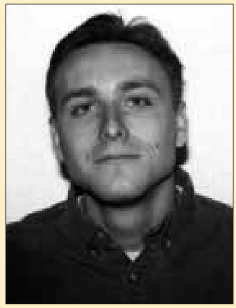


Outstanding Student Member Award, 1996. Her overall research objective is to improve understanding of phosphorus (P) desorption as influenced by soil properties. This will allow the development of improved P management strategies that will sustain optimum crop productivity while protecting water quality. Following graduate school, Jean would like to work in international agriculture.

John Dennis Lauzon comes from St. Thomas, Ontario. He received his B.S. and M.S. degrees from the University of Guelph and is currently studying for his Ph.D. there. Among his various scholarships and awards were the Kenneth McAlpine Pretty Scholarship, 1994, 1996 and 1997, and Ted Mcgrail Memorial Scholarship, 1994. The title of his research problem is "Seed-placed P Use with Corn: Its Benefits in Soils with Variable Phosphorus Levels and under Different Tillage Systems." The main objective of his studies is to determine the benefits of seed-placed P when used to manage soils with variable soil test P and when used in different tillage systems. Following his graduate studies, he would like to be a university professor.



Grant Russell Manning is a native of Pilot Mound, Manitoba, where he is involved in the family farm. He is currently studying toward an M.Sc. degree at the University of Manitoba, where he received his B.S.A. degree in 1997. He was the recipient of such awards as the Zeneca Agro Achievement Award in 1997 and the Steffansson Award for Excellence in Plant Science in 1996. He has received an NSERC post-graduate scholarship to focus on researching effects of numerous spatially-variable agronomic parameters on hard red spring wheat yield, in order to evaluate potential for making N recommendations based on soil-landscape properties. Following his graduate studies, he hopes to gain employment in the agriculture industry in Western Canada.



The Fellowships are named in honor of Dr. J. Fielding Reed, retired President of the Institute, who lives in Athens, Georgia. The Fellowship winners are selected by a committee of PPI scientists. Dr. A.E. Ludwick, PPI's Western U.S. Director, served as chairman of the selection committee for the 1998 Fellowships. BC

IDAHO

Potassium Fertilization of Russet Burbank Potatoes

By D.T. Westermann and T.A. Tindall

Potato tuber yields over 500 cwt per acre are being achieved by many of Idaho's potato growers. At this production level, over 240 lb K_2O/A can be removed by the tubers. Historic soil test information shows that extractable K concentrations have declined from more than 400 parts per million (ppm) in the late 1960s to the range of 100 to 200 ppm now.

A recent study re-evaluated the potassium (K) fertilizer requirements of Russet Burbank potato production under today's soil conditions and higher yield potentials. Potassium fertilization rates should be increased over what was previously considered adequate, particularly on coarse textured soils.

Five experiments were conducted on growers' fields between 1992 and 1995 with selected K rates, sources, placement or timing variables, including K-fertigation as treatments. Preplant broadcast applications were applied before spring tillage preceding planting, while banded K was placed in a single band 4 to 6 inches adjacent to the seed piece after planting.

Simulated K-fertigation applications were accomplished by spraying K solutions on during a sprinkler irrigation. Potassium sources were potassium sulfate (K_2SO_4), potassium chloride (KCl) or potassium thiosulfate (KTS). Soil textures varied from a silt loam to loamy sand, sodium bicarbonate ($NaHCO_3$) extractable soil K concentrations from 85 to 126 ppm in the top 12 inches of soil. The K status of each treatment was monitored by sampling the fourth mature petiole from the growing point, as well as vine, roots and tubers periodically sampled between early tuber growth and vine kill. Tuber yields, grades, and internal quality were determined for each plot at normal harvest.

Fertilizer Rate Recommendations

Total tuber yields across the experiments ranged from a low of 350 cwt/A to nearly 600 cwt per acre. Yield responses to K fertilization were from none to nearly 100 cwt/A. Tuber external quality parameters were generally high (greater than 70 percent U.S. #1 tubers), except for the lowest yielding experiment where other management factors affected yield. The 1987 University of Idaho fertilizer guide for

TABLE 1. Comparison of K fertilization rates at different soil test K concentration in 0 to 12 inches of soil.

Soil test K, ppm	Recommendations 1987 lb K_2O/A	1992-95 lb K_2O/A
25	250	600
50	200	500
75	150	400
100	100	300
125	50	200
150	0	100
175	0	0

potatoes contained a critical soil test K concentration of 150 ppm K in the top 12 inches of soil ($NaHCO_3$ extractable). Tuber yield data summarization from our studies showed that the concentration should be increased to 175 ppm K (**Table 1**). While this was not a large change, the K fertilization rate necessary to achieve maximum yields did change significantly. For example, the optimum K fertilization rate at a soil test K concentration (STKC) of 100 ppm was 300 lb K_2O/A in our study compared with 100 lb K_2O/A recommended in the 1987 fertilizer guide. Similar changes occurred at other STKCs. Growers may want to add 50 lb K_2O/A to the rates in **Table 1** for each 100 cwt/A tuber yield above 400 cwt to maintain their soil test K concentrations.

Potassium deficiency symptoms on leaves of potato plants.

Source and Timing Effects

Total tuber yields were generally 5 to 10 percent higher with K_2SO_4 than with KCl at the optimum fertilization rate applied preplant. The higher yield was from an increased yield of U.S. #1 tubers greater than 10 oz. Both K sources decreased specific gravities. However, tubers receiving KCl generally had gravities 0.001 to 0.004 units lower than those receiving K_2SO_4. At K fertilization rates greater than optimum, both sources had similar effects.

A preplant K application was more effective than splitting the same amount between preplant and fertigation or applying all the fertilizer via fertigation during tuber growth. In addition, preplant broadcasting was more effective than banding the K fertilizer shortly after planting. Spring preplant applications higher than 300 lb K_2O tended to decrease yields, particularly as KCl. Growers should consider other application options if they need to apply more than 300 lb K_2O/A such as applying a portion the previous fall or splitting the preplant application between KCl and K_2SO_4.

Fertigation and Petiole K Concentrations

Petiole K concentrations decreased with time after tuber initiation. Concentrations were generally higher with broadcast K compared with either banding or fertigation treatments. Petiole K concentrations should be above 6.5 to 7.0 percent until 30 days before vine kill to prevent K from limiting tuber yields in southern Idaho. Petiole K concentration responses to K-fertigation applications were slow, up to 15 to 20 days after an application. A preferred K-fertigation source was not identified. Individual K-fertigation applications should not exceed 30 lb K_2O/A during tuber growth and should not be made within 30 days before vine kill. Potassium fertigation applications may need to be repeated, but should not be closer than a 10 to 14 day internal.

Summary

Potassium fertilization rates for

(continued on page 12)

ARKANSAS

Rice Response to Phosphorus Application Timing

By N.A. Slaton, C.E. Wilson, Jr., S. Ntamatungiro and R.J. Norman

Rice response to P fertilization in Arkansas has been researched for the past 30 years with mixed results. Field studies conducted during the 1960s determined that P application tended to result in rice yield decreases despite significant increases in vegetative growth. Many of the tests were conducted on acid soils. Application of P to soils having pH greater than 6.5 often resulted in leaf chlorosis due to zinc (Zn) deficiency. These studies were conducted before Zn was recognized as a yield limiting nutrient in rice production. More recent studies, stimulated by reports of rice response to P on alkaline soils from Extension agents and rice growers in northeast Arkansas, have found significant yield increases from P application in 75 percent of the tests.

> Timing of phosphorus (P) application for rice in Arkansas can have a significant effect on total dry matter (TDM) and yield. Researchers are looking for results to guide recommendations.

Use of irrigation well water high in calcium bicarbonate has created alkaline soil conditions near water inlets in many Arkansas rice fields. Rice often exhibits bronzing on lower leaves, reduced tillering, erect leaves, and, if severe, death after flooding. All of these symptoms have been attributed to either P or Zn deficiency in high pH areas. In many instances, application of Zn has failed to prevent or alleviate the symptoms. Reduced soil conditions, created by continuous flood irrigation, generally increase P availability to rice by the reduction of ferric phosphates and hydroxides to more soluble ferrous forms. The release of P from reductant soluble P and ferric phosphates is often sufficient to supply rice P requirements. The predominant forms of P in alkaline soils are calcium phosphates. Soil reduction does not influence the solubility and subsequent availability of the calcium phosphate. Commonly used soil test methods, including Bray-1, Mehlich 3, and Olsen, tend to over predict P availability for rice and, are poorly correlated with rice response to P fertilization. As the frequency of P deficiency in Arkansas rice production fields increases, questions concerning application timing and rates are being asked by growers and consultants. Objectives of these tests were to evaluate

TABLE 1. Selected soil properties from P application timing studies conducted during 1997.

	Soil	0-4 inch Mehlich 3 soil test levels, ppm				
Location	pH	Ca	K	Mg	P	Zn
Brooks	6.6	1,435	65	209	14	9.9
Davis	7.6	1,970	74	277	10	2.0
Wimpy	8.0	2,830	66	349	28	20

rice response to rates and timing of P applied on silt loam soils differing in Mehlich 3 extractable P and soil pH.

Materials and Methods

Application timing studies were conducted in 1997 in three grower fields having different soil chemical properties (**Table 1**). Triple superphosphate was surface applied at rates of 0, 20, 40, and 80 lb P_2O_5/A prior to rice emergence (PE), preflood (PF), 7 days postflood (POF), and panicle differentiation or midseason (MS). Plots were managed identically to the surrounding field by cooperating producers. Total dry matter (TDM) was obtained by sampling a 3 ft. row three weeks after 50 percent heading. Grain yield was determined by harvesting 9 sq. ft. from the four middle rows of each 8 x 16 ft. plot with a small plot combine. Grain moisture was measured after harvest and adjusted to 12 percent moisture.

TABLE 2. Influence of P application rate on total dry matter production 3 weeks after 50 percent heading from three P timing studies in 1997.

Rate, lb P_2O_5/A	Total dry matter, lb/A		
	Brooks	Davis	Wimpy
0	18,699	14,847	18,244
20	19,689	16,497	17,076
40	20,045	17,460	18,084
80	22,952	16,826	18,191
LSD (0.05)	3,772	1,641	NS
Pr > F	0.048	0.064	.629
CV %	9.3	19.2	16.5

TABLE 3. Influence of P application rate on rice grain yield from three P timing studies conducted during 1997.

Rate, lb P_2O_5/A	Grain yield, bu/A		
	Brooks	Davis	Wimpy
0	191	110	143
20	182	145	148
40	171	153	155
80	178	142	156
LSD (0.05)	NS	23	NS
Pr > F	0.586	0.025	0.207
CV %	14.6	15.4	9.3

Results

Phosphorus rate significantly increased TDM measured three weeks after 50 percent heading at both the Brooks and Davis farms (**Table 2**). Only the 80 lb P_2O_5/A rate significantly increased TDM at the Brooks location. Phosphorus application rates of 20 lb P_2O_5/A and greater significantly increased TDM at the Davis site. Application timing did not affect TDM.

Significant grain yield increases were observed for both P rate and timing of application at the Davis farm. Application of 20, 40, or 80 lb P_2O_5/A increased grain yield compared to the untreated check (**Table 3**). Yields were highest when P was applied POF compared with at MS. The PE and PF applications also tended to produce higher yields than the MS application. This indicates that on soils that respond to P, fertilizer application should be made no later than the midtiller growth stage or shortly after flooding for most efficient use of fertilizer P. Data from the Wimpy farm suggest that P application at MS did not increase grain yield compared to the untreated check (**Tables 3** and **4**). However, a trend for grain yield to increase occurred for the 40 and 80 lb P_2O_5/A rates and the PE and POF application timing. A comparison of grain yields at the Davis farm for application timing (**Table 4**) to the 0 lb P_2O_5/A rate (**Table 3**) shows that the MS application tended to increase grain yield, but greater yield increases were obtained from the PE, PF and POF application timings. Additional studies are needed to determine if fertilizer P applied early in the growing season is subject to fixation on alkaline soils before crop utilization. Lower P rates applied at PF and POF tended to increase yields which suggests P may be fixed when applied before emergence.

Summary

Data from the P timing studies, and other P fertilization projects conducted during 1997 on alkaline silt loams, continue to show significant TDM and yield increases from P fertilization. Generally, acidic silt loam soils with acidic pH and following soybean in rotation have not shown rice yield increases from P fertilization in Arkansas. Fields that have been precision graded are an exception, since they typically respond to P fertilization for several years following leveling, regardless of pH. Phosphorus timing studies conducted during 1997 indicate that P should be applied before or during vegetative growth. Phosphorus applications made at MS in these field studies tended to produce lower yields than earlier applications on P responsive soils. Data also indicate that some benefit was obtained from either PF or POF P application at the Wimpy site. Additionally, yield data from the Davis farm indicate that P applied before emergence may be subject to fixation. Phosphorus applied either PF or seven days POF tended to produce the greatest overall yields at sites exhibiting a P response. More studies are needed to establish consistent trends among P application timings. Present and future research efforts are focused on development of more accurate P recommendations for rice. BC

TABLE 4. Influence of P fertilizer application timing on rice grain yield from three P timing studies conducted during 1997.

P	Grain yield, bu/A		
Timing	Brooks	Davis	Wimpy
Preemerge (PE)	184	145	150
Preflood (PF)	171	143	156
Postflood (POF)	172	157	156
Midseason (MS)	182	131	147
LSD (0.05)	NS	18	NS
Pr > F	0.611	0.018	0.410
CV %	14.6	15.4	9.3

The authors are with the Department of Agronomy, University of Arkansas. Dr. Slaton is Extension Agronomist-Rice, located at the Rice Research Extension Center, Stuttgart. Dr. Wilson is Extension Rice Specialist/Research Associate Professor, located at Monticello. Dr. Ntamatungiro is research specialist, located at Stuttgart. Dr. Norman is Professor of Soil Fertility, located at Fayetteville.
E-mail for Dr. Slaton: nslaton@comp.uark.edu.

Potassium Fertilization of Russet... *(continued from page 9)*

potato production in Idaho should be increased over what was previously considered adequate, particularly on coarse, sandy textured soils. Growers using the information from this study should be able to successfully manage the K needs of Russet Burbank potato production in Idaho. BC

Dr. Westermann is a Soil Scientist, USDA-ARS, Kimberly, Idaho. Dr. Tindall is Agronomist for J.R. Simplot Company, Pocatello, formerly Extension Soil Specialist, University of Idaho, Twin Falls.

Recent Idaho research indicates need for increased K application for higher potential yields of Russet Burbank potatoes.

MARYLAND

Intensive Wheat Research Provides Positive Yield, Profit Potential, and Nitrogen Efficiency Benefits

By F. Ronald Mulford

Maryland's intensive wheat management research began in the early 1980s. The goals at that time were to grow consistently 100 bu/A in research and to provide farmers with a wheat production system to double the 35 to 40 bu/A state average yields. By the late 1980s, research yields were consistently in the range of 110 to 120 bu/A, and educational programs were underway to introduce the system to farmers. Today, state average wheat yields are in the 60 to 65 bu/A range and increasing since the early 1980s at a trend of 1.5 bu/A per year as more and more farmers adopt an intensive wheat production system tailored to fit their site-specific conditions. Many farmers using intensive wheat production practices set and achieve yield goals of 80 to 110 bu/A.

The top yield in the 1997 Maryland intensive wheat research program was 151 bu/A. This is one of the highest yields recorded for wheat research in the state. These high yields were obtained in a systems management study where the goal is to increase yield levels, input efficiency and profit potential.

The current emphasis is on: (1) rate, timing, source, and efficiency of nitrogen (N) use; (2) source and timing of fungicides; (3) variety evaluation; and (4) no-till wheat production.

Systems Research and Yield

The top yield in 1997 was obtained by incorporating the following three practices into the intensive wheat production study.

(1) The first spring N application was made in mid-February. Many soil types on the Eastern Shore of Maryland have a sandy texture. Throughout typical winter periods there are many days when soil temperatures exceed 32º F. Each time this occurs, root growth is stimulated and N uptake occurs. After several of these occurrences residual N could be depleted and yield potential lost even though no top growth would be observed. It is environmentally responsible to apply only the amount of N wheat can utilize at any given time throughout the growing season.

(2) Ammonium sulfate $[(NH_4)_2SO_4]$ was utilized to increase the ammonium (NH_4) portion of the total N applied and to provide sulfur (S), an essential and often limiting nutrient on coarse-textured soils of the area. Previous research has shown that using a higher proportion of NH_4-N compared to nitrate-N (NO_3-N) in both corn and wheat production has given significantly higher yields.

(3) Tilt® fungicide was applied as a post-heading treatment during flowering at Feekes growth stage 10.3. (This application timing is not supported by the current Tilt® label.) Tilt® is registered for use until the ligule of the flag leaf emerges (Feekes growth stage 8.) No endorsement of Tilt® being applied on the head is suggested.

The treatment described was a comparison to the recommended timing for Tilt®. Novartis is in the process of finalizing the data necessary to support postheading treatments which will add flexibility in managing late season foliar and heading diseases.

The intensive wheat production study was established at two locations, on Mattapex silt loam and Galestown sandy loam soils. Systems-type research allowed us to investigate the role of new technologies in a previously developed intensive production system to improve the total package. A high yield potential variety (Quantum 706) was planted on October 14, 1996. Soil test levels for phosphorus (P) and potassium (K) were at University of Maryland recommended high levels. The fungicide was applied at a 4 oz/A rate on the head at flowering.

A total of 141 lb/A N, 50 lb/A P_2O_5, 50 lb/A K_2O, and 48 lb/A S were applied as follows:

- Preplant incorporated: 100 lb/A of 21-0-0-24...$(NH_4)_2SO_4$
- February (at green-up): 60-50-50-24 applied as 39 lb of N from 34-0-0 (ammonium nitrate, NH_4NO_3) and 21 lb of N and 24 lb of S from $(NH_4)_2SO_4$ (21-0-0-24); P_2O_5 from 0-46-0 (triple superphosphate, TSP); K_2O from 0-0-60 (potassium chloride, KCl)
- Feekes GS 6: 60 lb N as urea ammonium nitrate solution (UAN) streamed in 10-inch spacing.

Intensive wheat production offers increased profit potential and N use efficiency.

TABLE 1. Effect of N source and fungicide timing on wheat yields grown on the Eastern Shore of Maryland.

System	Mattapex silt loam	Galestown sandy loam
	yield, bu/A	
Current popular wheat production system	135	82
Potential new wheat production system	151	121
Yield increase	16	39

Table 1 shows the results from two locations where these three practices were compared with a currently popular intensive wheat production system that is the same except for the timing of the fungicide application and addition of $(NH_4)_2SO_4$. A total of 141 lb/A N was used in both systems. Yields were increased 16 and 39 bu/A at the Mattapex and Galestown locations, respectively.

TABLE 2. Effect of N source, S and fungicide timing on wheat yield and N efficiency.

Nitrogen source for Feb. application	Fungicide	Yield, bu/A	N efficiency, bu/lb N
NH_4NO_3	none	86	0.61
$(NH_4)_2SO_4$	none	94	0.67
$(NH_4)_2SO_4$	Tilt® at Feekes GS8	102	0.72
$(NH_4)_2SO_4$	Tilt® at flowering	112	0.79

All plots received 21-30-30-24 in the fall; 60 lb N as 30 percent UAN at Feekes GS6; 60 lb N as either NH_4NO_3 or $(NH_4)_2SO_4$ in February.

Nitrogen Efficiency

There is a concern by some that research designed to increase crop yields will have a negative impact on N

TABLE 3. Historic yields, estimated N use, and N use efficiency on wheat in Maryland.

Year	Wheat yield, bu/A	Estimated N applied, lb/A	N efficiency, bu/lb N
1990	75 (intensive management)	100	0.75
1997	85 (intensive management)	110	0.77
1997	151 (top research)	141	1.07

use efficiency. Systems-type research, where all interacting controllable production practices are managed at optimum levels, has been successful in increasing yields and improving input efficiency. The 1997 results provide a good example. Nitrogen efficiency was increased from 0.96 to 1.07 bu/lb N used on the Mattapex soil and from 0.58 to 0.86 on the Galestown soil (data not shown). A second study on a Galestown soil provides another example (**Table 2**). Ammonium sulfate increased yields 8 bu/A over the NH_4NO_3 treatment with the same rate of N. Tilt® used at flowering increased yields 10 bu/A. Nitrogen efficiency increased as yields increased.

Historic yields, fertilizer recommendations, and Extension farm management records can give us some idea of the N use efficiency trends on wheat in Maryland (**Table 3**). These estimates indicate that while the use of N on wheat has steadily increased, a proportional increase in yields has maintained the level of N efficiency for wheat production. An estimate of the yields and amount of N used by those growers that have adopted intensive wheat production practices would indicate they have had no negative impact on N use efficiency. In addition, growers using intensive wheat production practices have a more vigorous growing crop with greater root systems, more crop residues, quicker ground cover, and improved water use efficiency. All these factors are associated with improved environmental quality. Our latest research would indicate there is a potential to increase N efficiency and the other factors associated with environmental quality when intensively managing wheat.

Profit Potential

Table 4 shows the cost per unit of wheat produced for various yield categories as estimated from Extension farm management production cost guidelines in the region. Profit potential as measured by the unit cost of production increases as yields increase. There is a need to put emphasis on educational programs that encourage farmers to implement the intensive wheat production system and to help them keep abreast of adjustments to the system as they are developed in research. BC

TABLE 4. Estimated total production costs for wheat and costs per unit of production in Maryland.

Item	1977 state ave.	Intensive wheat farmer	Past intensive research	1997 top research
Yield, bu/A	60	85	125	151
Variable costs:				
preharvest (except N)	105	125	140	140
N costs	22	31	39	39
harvest costs	14	20	30	36
Total variable costs	141	176	209	215
Total fixed costs	85	100	110	110
Total costs	$226	$276	$319	$325
Cost per bushel	$3.76	$3.25	$2.55	$2.15

Mr. Mulford is Manager, Poplar Hill Facility of the Lower Eastern Shore Research and Education Center, University of Maryland, Quantico.

K A N S A S

Starter Fertilizer Interactions with Corn and Grain Sorghum Hybrids

By W.B. Gordon, D.A. Whitney and D.L. Fjell

No-tillage crop production systems have become common in the central Great Plains. Advantages of reduced-tillage systems include reduced soil erosion and increased water use efficiency. The high residue levels associated with no-tillage production can cause soils to be cooler and wetter than in conventional tillage systems. Cool, wet soils can reduce nutrient uptake and crop growth. Starter fertilizer applications have been effective in improving nutrient uptake even on soil high in available nutrients. Recent work in other states has suggested that hybrids may exhibit differential response to starter fertilizer application.

The objective of these studies was to evaluate corn and grain sorghum hybrid response to starter fertilizer in a no-tillage, dryland environment on soils high in available phosphorus (P).

Field experiments were conducted at the North Central Kansas Experiment Field near Belleville, on a Crete silt loam soil (fine, montmorillonitic, mesic Pachic Arguistoll) from the spring of 1995 through the fall of 1997. Analysis by the Kansas State University (KSU) soil test lab in the corn experimental area showed that initial soil pH was

Increases in early growth are found when starter fertilizer is applied for many corn and grain sorghum hybrids.

6.1; organic matter content was 2.4 percent; Bray-1 P and exchangeable potassium (K) in the top 6 inches of soil were 43 and 380 parts per million (ppm), respectively (both very high). In the grain sorghum area, soil pH was 6.5; organic matter content was 2.5 percent; Bray-1 P was 45 ppm (very high); and exchangeable K was 420 ppm (very high).

The experimental design was a split plot arrangement of treatments in a randomized complete block. Main plot treatments were corn hybrids, or grain sorghum hybrids. Sub-plots were starter fertilizer or no starter fertilizer. The liquid starter fertilizer consisted of 30 lb nitrogen (N) and 30 lb P_2O_5 supplied as ammonium polyphosphate (10-34-0) and urea ammonium nitrate (UAN). This N:P combination was selected because of its superior performance in a previous experiment. Starter fertilizer was applied 2 inches to the side and 2 inches below the seed at planting. Immediately after planting, N was knife applied to bring the total applied to each plot to 180 lb/A in the corn experiment and 150 lb/A in the grain sorghum experiment. Corn was planted in mid to late-April, grain sorghum in mid-May each year of the experiment.

Results of Corn Experiment

The basic goal of dryland corn production in Kansas is to plant as early in the spring as possible, so that silking occurs in late June and seed-fill begins in early to mid-July. With normal temperatures and sufficient subsoil moisture through mid-July, the corn can reach its full yield potential. Any factor that delays silking until July, when temperatures are normally hotter and the probability of rainfall is less than in June, can severely reduce grain yield. When averaged over the 3 years of the experiment, starter fertilizer consistently increased grain yield, shortened the period from emergence to midsilk, decreased grain moisture content at harvest, and increased total P uptake (grain plus stover) of Pioneer 3489, Pioneer 3346, Pioneer 3394, Cargill 7777, DeKalb 591, Northrup King 6330, and Northrup King 7333, but had no effect on Pioneer 3563, Cargill 6327, DeKalb 626, DeKalb 646, and ICI 8599 (**Table 1**). Yield in responding hybrids (hybrids in which the 3-year average yield was increased by starter fertilizer) was increased by an average of 17 bu/A and time to midsilk was shortened by six days (**Table 3**). Starter fertilizer reduced grain moisture at harvest by 20 percent in

TABLE 1. Starter fertilizer effect on grain yield, number of days from emergence to midsilk and grain harvest moisture of corn hybrids, 1995-1997.

	Grain yield, bu/A		Days to midsilk		Harvest moisture, %	
Hybrid	with	without	with	without	with	without
Pioneer 3563	106	105	74	74	15.9	15.9
Pioneer 3489	135	116	72	78	16.1	19.2
Pioneer 3346	142	122	74	80	15.8	20.2
Pioneer 3394	144	127	75	80	15.6	19.8
Cargill 6327	124	124	79	80	16.8	16.4
Cargill 7777	161	149	76	82	16.8	20.2
DeKalb 591	141	122	72	79	15.4	19.5
DeKalb 626	124	124	79	79	16.4	16.5
DeKalb 646	127	126	81	82	16.6	16.8
Northrup King 7333	126	110	76	82	16.8	21.0
Northrup King 6330	137	120	75	79	16.1	19.0
ICI 8599	120	120	77	77	14.8	14.7
LSD (0.05)	9		2		1.9	

responding hybrids (**Table 3**) and doubled the amount of dry matter at the six leaf stage of growth of all corn hybrids included in the experiment. Nitrogen and P uptake at this growth stage was also significantly increased.

Results of Grain Sorghum Experiment

Delay in growth and development of grain sorghum in Kansas increases the risk of plants being exposed to freezing temperatures in the fall prior to physiological maturity, thus reducing yield and quality. On average, an early killing frost occurs statewide in Kansas one out of every two years. The large amount of surface residue present in no-tillage systems can slow growth. Fertilizer placed in close proximity to growing seedlings can hasten maturity and avoid late-season low temperature damage. Starter fertilizer consistently increased yields, reduced the number of days needed from emergence to midbloom, decreased grain moisture content at harvest, and increased total P uptake of Pioneer 8505, Pioneer 8522Y, Pioneer 8310, DeKalb 40Y, DeKalb 48, DeKalb 51, DeKalb 55, and Northrup King 735, but had no effect on Pioneer 8699, DeKalb 39Y, Northrup King 383Y, and Northrup King 735 (**Table 2**). When

Plots being planted in Kansas study of response to starter fertilzer.

averaged over the 3 years of the experiment, starter fertilizer increased yield of responding hybrids by 15 bu/A and reduced the time to midbloom by 5 days (**Table 3**). In responding hybrids, starter fertilizer reduced grain moisture content by 25 percent. It increased 6-leaf stage dry weight and N and P uptake of all hybrids tested.

Conclusion

On this high soil test P soil, starter fertilizer consistently improved early season plant growth and nutrient uptake of all corn and grain sorghum hybrids tested. This early season growth advantage did

TABLE 2. Starter fertilizer effect on grain yield, number of days from emergence to midbloom and grain harvest moisture of grain sorghum hybrids, 1995-1997.

	Grain yield, bu/A		Days to midbloom		Harvest moisture, %	
Hybrid	with	without	with	without	with	without
Pioneer 8699	109	107	54	55	15.4	15.5
Pioneer 8505	138	122	55	60	17.9	23.7
Pioneer 8522Y	127	115	60	66	17.1	23.6
Pioneer 8310	133	118	64	68	15.8	21.6
DeKalb 39Y	104	103	58	59	13.9	13.8
DeKalb 40Y	131	113	60	66	15.6	20.8
DeKalb 48	129	115	61	67	14.7	20.8
DeKalb 51	134	115	61	67	15.9	21.1
DeKalb 55	130	114	64	69	16.5	21.0
Northrup King 383Y	117	117	60	61	14.6	14.9
Northrup King 524	125	114	58	63	15.5	20.0
Northrup King 735	128	127	62	63	19.6	19.6
LSD (0.05)	8		2		1.1	

TABLE 3. Summary of starter responsive and non-responsive corn and grain sorghum hybrids, 1995-1997.

Hybrid type	Number of hybrids	Yield response, bu/A	Reduction in: days to midsilk/bloom	Reduction in: grain moisture, % points
Corn:				
Responsive	7	17	5.7	3.8
Non-responsive	5	0	0	0
Sorghum:				
Responsive	8	15	5.4	5.5
Non-responsive	4	1	1.0	-0.1

not last into anthesis for all corn and grain sorghum hybrids. In this high residue, no-tillage production system, starter fertilizer consistently improved grain yield and hastened maturity for some but not all hybrids evaluated. However, seven of the eight highest corn yields and nine of the ten highest sorghum yields were treatments including starter. This indicates it is unlikely that all of the yield loss from not using starter can be avoided by hybrid selection. Results of this work suggest that responses to starter fertilizer in high residue systems can be beneficial for most hybrids even on soils testing very high in available nutrients. BC

Dr. Gordon is Agronomist North Central Kansas Experiment Field, Courtland; Dr. Whitney is Agronomy Extension Leader, and Dr. Fjell is Crop Production Specialist, Department of Agronomy, Kansas State University, Manhattan, KS.

Nutrient Management Planning Workshop Set for Danville, Illinois, August 17-18

In cooperation with the Illinois Fertilizer & Chemical Association (IFCA) and the Indiana Plant Food and Agricultural Chemicals Association, PPI and the Foundation for Agronomic Research (FAR) will sponsor a Nutrient Management Planning Workshop in Danville, Illinois, on August 17-18, 1998. The workshop will feature a step-by-step approach to building a complete farm nutrient management plan. Participants will learn how to collect, analyze and interpret site-specific data. Hands-on computer experience with several analytical and decision-making tools will provide an opportunity to work through the process with real farm data. Dr. Harold Reetz (PPI Midwest Director) and Dr. Scott Murrell (PPI Northcentral Director) are coordinating the program, which will focus on interpreting site-specific data from Midwest farms.

An exhibit area will feature the latest technology related to nutrient management planning and tools for crop and soil management.

For information, contact Dr. H.F. Reetz, PPI, 111 E. Washington St., Monticello, IL 61856-1640. Phone: 217-762-2074, FAX: 217-762-8655, and e-mail: hreetz@ppi-far.com.

This workshop is being held in conjunction with the Annual Midwest Ag Industries Expo (MAGIE), sponsored by IFCA and scheduled for August 19-20 at the Vermilion County Airport, north of Danville. BC

F L O R I D A

Starter Fertilizer: Nitrogen, Phosphorus, Corn Hybrid Response, and Root Mass

By Fred Rhoads and David Wright

In a greenhouse experiment, this study showed that a hybrid failing to respond to starter fertilizer, containing nitrogen (N) and phosphorus (P) under field conditions, produced a larger root system than one consistently producing a positive response. If starter response under field conditions is due to only one element (N or P) because the other is supplied in adequate amount from the soil, then it is not known whether each hybrid responds in the same manner to the other element. This report shows response of each hybrid to starter N and P varied independently of each other.

Not all corn hybrids show a positive grain yield response to starter fertilizer. Both N and P are considered essential ingredients in starter fertilizers to offset low N and P availability in cold soils. Characteristics of corn that influence response to starter fertilizer include rate of top and root growth, N and P uptake efficiency, and growth response to temperature. A hybrid having a high rate of root growth and uptake of N and P is expected to show little or no response to starter fertilizer compared to broadcast application. Therefore, a positive response to starter fertilizer is expected of a hybrid having a slow rate of root growth and/or low nutrient uptake rate.

Corn hybrids, 'Deltapine G4733' and 'Northrup King 508', were selected for greenhouse experiments because Deltapine G4733 consistently gave a highly positive grain yield response to starter fertilizer and NK508 consistently failed to respond in a starter fertilizer field experiment at NFREC, Quincy, Florida. The hybrids were seeded in pots containing 2 kg of soil...with low P, less than 15 parts per million (ppm) of Mehlich-1 P...from the A horizon of Norfolk loamy fine sand (fine loamy, siliceous, thermic, Typic Kandiudult) on March 17 in a glasshouse at Quincy. Six seeds were planted in each pot (1.5 liter soil volume), and plants were thinned to two per pot at the two-leaf stage.

In this experiment, N rate was 200 mg per pot (about 200 lb/A) and P rate was 273 mg P_2O_5 per pot (about 273 lb/A) for all treatments mixed with total soil volume (broadcast) or banded 2 inches below the surface and 2 inches horizontally from seed. Nitrogen was banded with P, broadcast with P, and banded alone. There were three treatments for each of the two hybrids. The source of K for this experiment was K_2SO_4 at 415 mg pot (about 415 lb/A) mixed with total volume of soil.

The experiment was harvested 41 days after seeding. Average minimum temperature was 52ºF while average maximum temperature was 75.5ºF. Roots were separated from the soil by screening and washing with tap water. Yield of both tops and roots was deter-

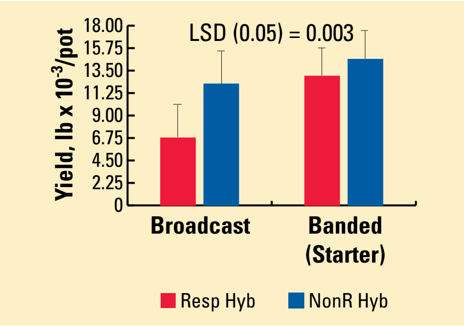


Figure 1. Corn hybrid top growth with broadcast vs. banded N.

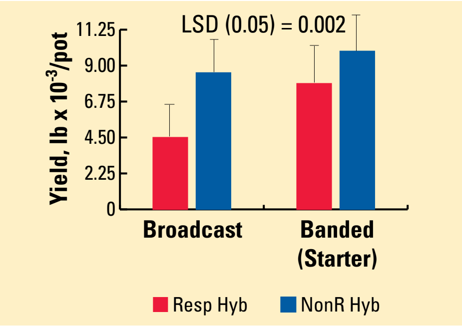


Figure 2. Corn hybrid root growth with broadcast vs. banded N.

mined after drying to constant weights at 160ºF.

The nonresponsive hybrid (NK508) from the field experiment did not respond to starter N with increased top or root growth as shown by error bars representing the least significant difference (LSD) in **Figures 1** and **2**. However, the responsive hybrid (G4733) responded to starter N with both increased top and root growth. But root growth of the nonresponsive hybrid was greater than that of the responsive hybrid with either broadcast or banded N. Banding N does not influence absorption by the root system by increasing solubility or mobility. Rather, it allows access to much greater amounts of N in a much smaller root volume. This study suggests that where mixing nutrients with the entire soil volume does not reduce solubility or mobility, hybrids with most rapidly expanding root systems are less likely to respond to band placement of nutrients or starter fertilizer.

Response to starter P was similar between hybrids (**Figures 3** and **4**) as measured from top and root growth. There was no difference between hybrids in top growth with broadcast P (**Figure 3**). However, top growth increased 78 percent in the nonresponsive hybrid and only 62 percent in the responsive hybrid due to starter P. Root mass was always greater for the nonresponsive hybrid, which supports the hypothesis that nonresponsive hybrids should have greater root mass. But root mass does not explain why both hybrids responded to starter P.

In soils that fix or immobilize P, most

(continued on page 24)

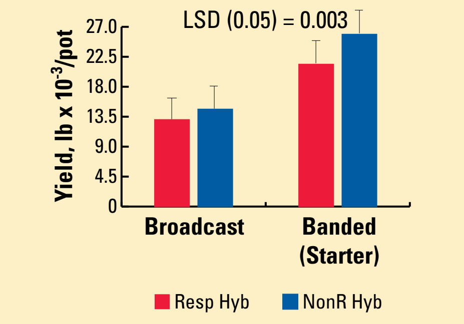


Figure 3. Corn hybrid top growth with broadcast vs. banded P.

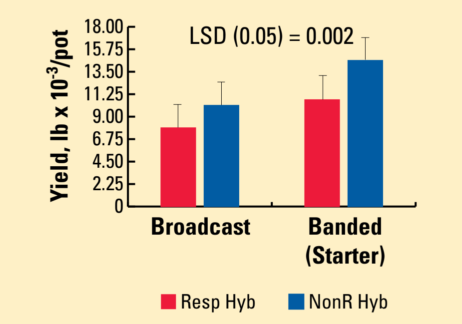


Figure 4. Corn hybrid root growth with broadcast vs. banded P.

CANADA

Application of Precision Farming to Potato Production in Québec

By R.R. Simard, M.C. Nolin and A.N. Cambouris

Potato production in Québec occupies about 45,000 acres. The mean marketable yield is 205 cwt/A, and the production cost is about $1,400/A. Nutrition of the potato crop is critical. Fertilizers are usually applied at a uniform rate. However, large yield variability is normally encountered in many fields. This may be ascribed to differences in soil fertility, texture or other factors such as localized pest infestation or weeds. Producers are very interested in variable rate (VR) application of nutrients.

> Variable rate application of phosphorus (P) and potassium (K) on potatoes improves yield and tuber quality, increases profitability and nutrient use efficiency, and reduces soil test variability.

Precision farming began in the province of Québec four years ago with the use of global positioning system (GPS) and yield monitors on grain combines. The mapping of soil pH for VR application of lime was initiated in 1995. Potato yield monitors have been used in the field since 1996. Precision farming in potato production aims at improving yields, tuber quality and profitability, optimizing fertilizer and pesticide inputs, and reducing environmental risks. The VR application will have particular impact on the zones of low soil fertility. The improvement in profitability will originate from yield increases from areas of higher fertilizer needs, and in decreasing over-fertilization where yield potential is limited. The environmental benefits will come from refined nitrogen (N) application and slower P accumulation from unused fertilizer.

A project was initiated in 1996 to investigate the economic and agronomic efficiency of variable rate application of P, K and lime on the potato crop. The study is being carried out at the Joseph-Rhéaume research farm of Laval University in Sainte-Croix de Lotbinière in Québec. Soil samples were collected on

TABLE 1. Distribution of soil texture, pH, and soil test values at the Sainte-Croix site (106 samples drawn from 5 acres).

	Clay	Silt	Sand	SOM	pH water	pH $CaCl_2$	P	K	Ca	Mg	Al
	%						lb/A				ppm
Mean	18	33	49	5.5	6.5	5.6	80	99	3,704	90	1,511
SD[1]	5	18	16	2.4	0.5	0.5	51	54	1,773	49	324
Minimum	8	11	17	0.1	5.7	4.6	7	26	868	29	692
Maximum	36	70	72	12.5	8.1	7.2	245	302	10,885	305	2,330

[1]SD refers to standard deviation, a measure of variability. Approximately two-thirds of the field area will fall within the range one standard deviation above and below the mean.

Blended fertilizer combinations, lb/A

Blend	N	P_2O_5	K_2O	code
1	121	205	214	
2	121	205	192	
3	121	205	143	
4	121	192	214	
5	121	192	192	
6	121	192	143	
7	121	170	214	
8	121	170	192	
9	121	170	143	
10	121	129	214	
11	121	129	192	
12	121	129	143	
13	0	0	0	

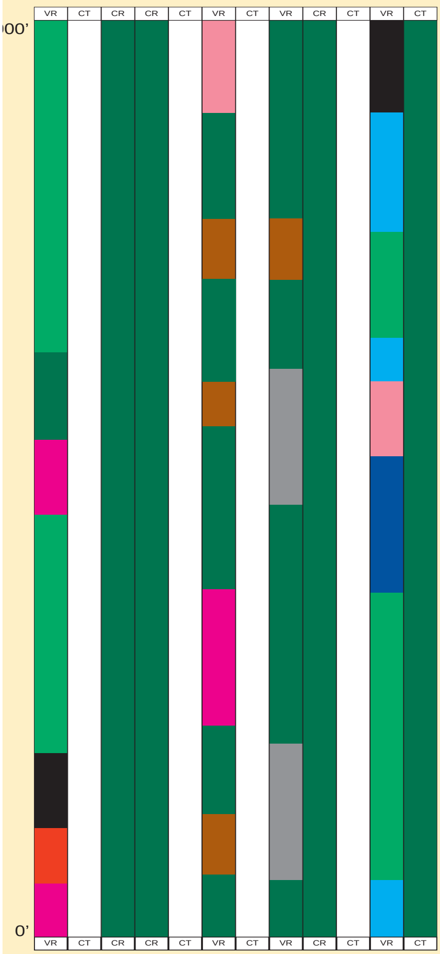


Figure 1. Map of treatments on 5-acre field in 1997.

a 50-foot grid in a 5-acre field and analyzed for pH, Mehlich 3 extractable nutrients, nitrate-N (NO_3-N) and soil texture. A soil survey was also carried out according to a 100-foot grid.

Spring soil test values were highly variable (**Table 1**). The distributions were also somewhat skewed, as is typical for soil properties, so that the median values for P and K were 67 and 88 lb/A, respectively, much lower than the mean values. Maps of pH showed that liming was unnecessary.

The soil is poor in P and K and has a very high P sorption capacity, as indicated by high aluminum (Al) levels. Where soil Al levels exceed 1,600 parts per million (ppm), P recommendations are usually increased by 15 to 20 percent. About 40 percent of this field would fall in the high Al category.

The P and K maps derived from 106 sampling points were examined. Based on existing recommendations and the limitations imposed by equipment, combinations of 2 rates of P and 3 rates of K were chosen for the VR treatment. Rates of 170 and 190 lb/A P_2O_5 were combined with rates of 140 to 210 lb/A K_2O. The range of P_2O_5 rates was widened to 130 to 205 lb/A P_2O_5 in 1997. The detailed soil map showed that four different soil series (soil types) were present. Neubois loam has a high CEC, is rich in Al and is highly erodible. Le Bras humic loam, located in a small depression, is very rich in organic matter and P, but has poor drainage and a high Al content. Valère sandy loam has low CEC and nutrient availability, while Sainte-Croix sandy clay loam has high pH.

In both years, three treatments were imposed on the field in strips 6 rows wide and 1,000 ft. long (**Figure 1** shows the 1997 treatments). In 1996, the constant rate (CR) treatment was 155 lb/A of N, 190 lb/A of P_2O_5 and 190 lb/A of K_2O.

The VR application resulted in a $11/A saving in fertilizers. The marketable yield of the VR treatment was not different from the CR treatment, but was much larger than in the control treatment (CT), (**Figure 2**). The VR also had equivalent yields to CR for different tuber categories: Canada #1 small, Canada #1 and Canada #1 large. However, the VR had higher N and P concentrations but less K than in CR. Calculations of the compositional nutrient diagnostic (CND) index showed that VR had the best nutrient equilibrium among treatments and that K was the most yield limiting nutrient at this site. The VR application increased the uniformity of soil test levels sampled at harvest. In 1997, the marketable potato yield was 30 cwt/A greater in the VR than in the CR treatment (**Figure 2**).

At this site, variable rate application of P and K gave potato yields equal to or greater than those with constant rate. Potassium was the most limiting nutrient. The fertilizer savings the first year were almost equal to the commercial cost of mapping the site. The agronomic and economic benefits of precision fertilizer application in potato production are very encouraging. . BC

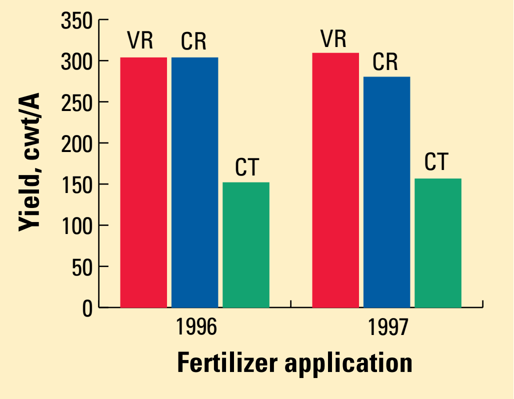


Figure 2. Marketable yield of potato as affected by variable rate (VR), constant rate (CR) or control (CT) fertilizer application.

R.R. Simard , M.C. Nolin and A.N. Cambouris are scientists with Agriculture and Agri-Food Canada and the Horticultural Research Center, Laval University, Ste-Foy, Québec.

Starter Fertilization... *(continued from page 21)*

of the broadcast P is not available to corn seedling roots because of the intimate contact between soil and P, while banding P minimizes fixation and immobilization by reducing P and soil contact. Therefore, size of root system is not important when the band is near the seed under these circumstances. However, at warm temperatures in soils with high residual P or those that do not fix P, hybrids with larger root systems may not respond to starter P. In cold soils, hybrids with larger root systems may respond to starter N as well as P because root growth of all hybrids is reduced by low temperature. BC

Dr. Rhoads is Professor of Soil and Water Science and Dr. Wright is Professor of Agronomy, Institute of Food and Agricultural Sciences, North Florida Research and Education Center, Quincy.

VIRGINA

Effect of Method and Time of Potassium Application on Cotton Lint Yield

By A.O. Abaye

Previous studies across the Cotton Belt demonstrated the importance of K fertilization on cotton yield and fiber quality. Three levels of preplant, split (preplant + first flower) soil-applied, and foliar-applied K were compared to untreated control on DPL-50. Foliar applications were made every two weeks and weekly starting from first flower. Potassium nitrate (KNO_3) was the K source for foliar treatments and potassium chloride (KCl) was utilized for soil treatments. Lint yield was measured for each treatment. Averaged over soil-applied treatments, K application increased lint yield. The increases averaged over the 3 years were 115 lb/A for preplant soil-applied K, and 138 lb/A for split soil-applied K. Weekly foliar K application increased lint yield over the untreated control. However, no increase in lint yield occurred when foliar application was made two weeks apart. Similar results had been reported for cotton grown in various environmental conditions.

Virginia research indicates the importance of plant available potassium (K) at the time of cotton boll filling. Lint yields were higher with split soil-applied and foliar K applications.

About 105,000 acres of cotton were grown in Virginia in 1997, compared with only 100 acres in 1988. Almost all of the cotton produced in the state is grown on coarse-textured soils that are subject to nutrient leaching. Potassium nutrition is important for every aspect of cotton yield and quality. Research conducted in Arkansas and California showed increased yield and quality of cotton in response to K fertilization. There is no information available in Virginia that show the effects of soil- and foliar-applied K on cotton yield and quality. The objectives of this experiment were: 1) To determine the effect of different levels of split vs. single applications of K on cotton lint yield, and 2) To evaluate the effect of varying levels of foliar- vs. soil-applied K on cotton yield.

TABLE 1. Soil analysis, 1993-1995.

Year	Soil depth, in.	pH	Nutrients, lb/A P	K	Ca	Mg
	0 to 6	6.1	52	198	912	66
1993	6 to 12	6.0	50	144	864	86
	12 to 18	6.0	10	190	720	138
	0 to 6	6.3	64	160	814	84
1994	6 to 12	6.4	46	156	744	78
	12 to 18	6.5	14	154	768	132
	0 to 6	5.9	78	74	672	50
1995	6 to 12	5.7	76	68	600	42
	12 to 18	5.7	14	68	312	28

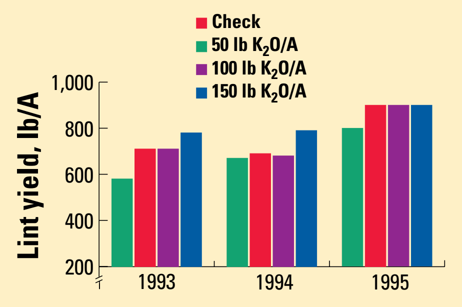


Figure 1. Influence of soil applied K on cotton lint yield. K_2O treatments: at planting = 50, 100, 150 lb/A applied once.
Treatment effect ($p<0.05$); year effect ($p<0.01$).

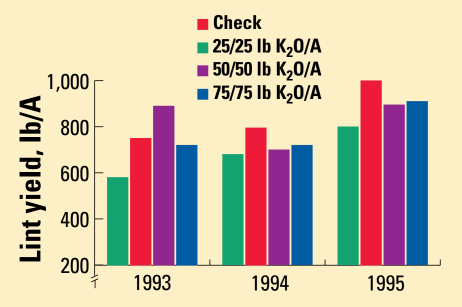


Figure 2. Influence of soil applied K on cotton lint yield. Treatments: split, at planting and first flower = 5/25, 50/50 and 75/75.
Treatment effect ($p<0.05$); year effect ($p<0.01$).

The experiment was conducted at the Tidewater Agricultural Research and Extension Center, Holland (Coastal Plain), Virginia, for 3 years. The soil was Nansemond (coarse-loamy, silicious, thermic, Aquic Hapludults). Four different levels of K_2O were applied prior to planting (0, 50, 100, and 150 lb/A). In addition, each of the three levels of soil-applied K were also applied in a split application with half at planting, the other half at first bloom. Additionally, K in the form of KNO_3 at 2, 4 and 6 lb/A was foliar-applied at each rate beginning at first bloom and at 3, 5, and 7 weeks after first bloom to cotton that received the soil test recommended rate of 50 lb K_2O/A. In 1995, a separate experiment was established with the foliar treatments being applied at 5 to 7 day intervals. Foliar applications were made using a carbon dioxide (CO_2) hand-driven sprayer at a rate of 10 gal/A. Nitrogen (N) in the form of foliar-urea was applied to plots that did not receive foliar KNO_3 (except the control plots) in order to avoid treatment differences due to N.

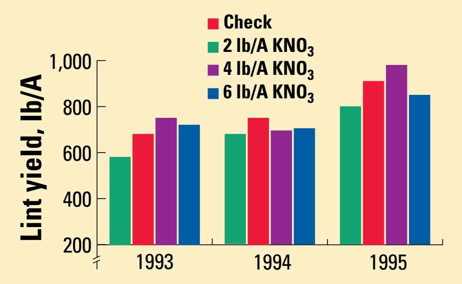


Figure 3. Influence of foliar applied KNO_3 on cotton lint yield. Treatments: foliar applied, in 2-3 weeks interval after first flower (each treatment split 3x)
Treatment effect ($p<0.05$); year effect ($p<0.01$).

Soil tests indicated K levels ranged from low to high for the 3 experimental years (**Table 1**). Adding K by any method increased lint yields (**Figures 1, 2** and **3**) compared with the untreated control 2 out of the 3 experimental years (1993 and 1995). Average lint yield increased from 579, 679 and 797 lb/A in the untreated control treatment to 727, 724 and 949 lb/A in the preplant soil applied treatments for 1993, 1994 and 1995, respectively. This yield increase was 148, 45, and 152 lb/A lint for 1993, 1994 and 1995, respectively (**Figure 1**). Similarly, lint yields were increased from 575, 679, 797, lb/A in the untreated control treatment to 786, 738, and 938 and in the split (preplant and pre-bloom) treatment for 1993, 1994 and 1995, respectively (**Figure 2**). The highest increase in yield was 211 lb/A for 1993 and 131 lb/A for 1995 for the split treatment. Foliar treatments applied in 2 to 3 week intervals in addition to soil applied K did not increase yields compared with the untreated control for 1993 and 1994. However, a slight increase in yield was observed in 1995 (**Figure 3**). Foliar KNO_3 applied at 5 to 7 day intervals resulted in significant yield increase over the untreated plots (**Figure 4**). This increase in yield was 175 lb/A. The higher lint yield for the split soil-applied and foliar KNO_3 treatments indicates the importance of plant available K at the time of boll filling.

Several researchers have shown increased yield of cotton in response to foliar K treatments. Oosterhuis (1976) reported a significant yield increase due to foliar fertilization by KNO_3. The lack of significant response to foliar treatment in our research could be due to the lower KNO_3 rate used compared to previous researchers who foliar-applied KNO_3 at a rate of 10 lb/A. BC

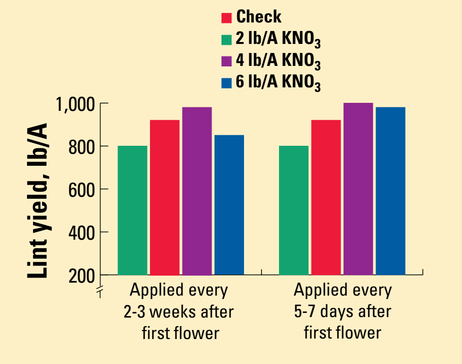


Figure 4. Foliar applied KNO_3 on cotton lint yield, 1995.
Treatment effect ($p<0.05$).

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Building a Smarter Fencepost

The need for field recordkeeping and assuring that production practices are matched to the proper crop in the correct field have never been more important. Precision management and applications tailored to specific genetic varieties increase the reasons for accurate communication.

A new signpost marking system uses identification decals applied to a plastic sheath that fits over a steel post. The user can mark individualized stickers or obtain custom pre-printed stickers for identification of crops and fields. This deters misapplication and aids in tracking crops. The system is also compatible with bar coding and electronic identification systems which can retain and transfer information. The product is called POSTMARK™ Field Identification Systems. BC

A versatile signpost marking system can help verify field location for scouting, soil sampling, fertilizer or chemical application, and harvesting.

Source: Agricultural Information Technologies, Inc., Iroquois, South Dakota.

CALIFORNIA

Boron Mobility and Consequent Management in Different Crops

By Patrick H. Brown and Hening Hu

Boron deficiency and toxicity occur throughout agricultural regions worldwide. To identify and correct an imbalance of B requires knowledge of the processes governing uptake, remobilization and distribution in the plant.

Mobile or Not Mobile in Plant Tissue?

Boron is now known to be mobile in the phloem of all species that utilize polyols (complex sugars) as a primary photosynthetic metabolite. In these species a polyol-B-polyol complex is formed in the photosynthetic tissues and is transported in the phloem to currently active sink regions such as vegetative or reproductive meristems. In species that do not produce significant quantities of polyols, B once delivered to the leaf in the transpiration stream cannot reenter the phloem, resulting in essentially complete phloem immobility.

In species for which B is immobile, B moves with the transpiration stream and once it enters a leaf it tends to remain. Thus, B will accumulate at the sites of termination of leaf veins. A steep gradient in B concentration has often been found such that B concentration in petioles and midribs < middle of lamina < margins and tips. This principle is illustrated in **Figure 1** in which the distribution of B within a mature leaf of walnut and apple is contrasted. In walnut, in which B is immobile, the highest B accumulation occurred at the tip and margin of the leaf.

It has been accepted that the uptake of boron (B) is a passive (non-metabolic) process and that it is a phloem immobile element, so once incorporated into tissue, it cannot be remobilized to supply the needs of other plant tissues. Recent work by Brown and co-workers, however, has now demonstrated that the physiology (mobility) of B varies dramatically between plant species and that our current knowledge of the symptoms and management of B nutrition must be re-examined on a species by species basis.

Boron Distribution in Plant Tissue

Figure 1 also illustrates B distribution in apple. In this species leaf B concentrations were significantly lower than in walnut, and there was very little difference in B accumulation across the leaf.

TABLE 1. Boron concentration (ppm dry wt.) in leaf and fruit organs of four tree species.

	B mobile		B immobile	
Organ	Almond	Apple	Pistachio	Walnut
Leaf	42	41	130	295
Hull	170	51 (peel)	33	40
Shell	34	34 (pulp)	2	9
Kernel	43	54 (core)	1	4

This uniform low distribution of B in apple does not correlate with leaf venation pattern and is not consistent with the hypothesis that B distribution is determined solely by transpiration. This same leaf distribution was observed in almond, peach and plum, suggesting that B distribution in these species is not governed by transpiration and is suggestive of phloem B mobility. Evidence of phloem B mobility or immobility can also be discerned from the distribution of B within different organs of a given species. For example, under field conditions pistachio and walnut both contain the highest B concentration in mature leaves and the lowest B concentration in fruit and seed tissue (**Table 1**). In contrast, almond or apple grown at the same site had highest B concentration in hull (fruit tissue), with much lower B in the leaves (**Table 1**).

The concentration of B in leaves of different ages within a species can also provide evidence of B mobility. The occurrence of higher B concentrations in old or mature leaves in comparison to younger leaves is evidence of B immobility, while higher B concentrations in younger leaves is an indication of B mobility since these leaves have transpired less water than older leaves. The results in **Table 2** suggest that B is phloem immobile in pecan, tomato, strawberry and walnut, while B is phloem mobile in apple, apricot, pear, grape, loquat, peach, celery, olive, and pomegranate. These differences in the site of accumulation of B in tissues will, in turn, determine where within a plant the symptoms of B toxicity will occur.

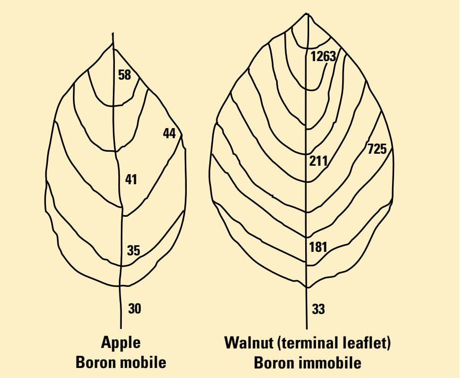

Figure 1. Leaf B concentration (ppm) in field grown apple and walnut. Leaves were collected at the end of the growing season. The two species were grown in close proximity and received the same irrigation.

Boron Toxicity Symptoms

The difference in B mobility also results in difference in the expression of B toxicity symptoms. Because plants in which B is immobile always accumulate B in the tip and edge of old leaves like walnut in **Figure 1**, B toxicity symptoms in those species are always exhibited as leaf tip and edge burn (**Figure 2a**, pistachio). On the other hand, for those plants in which B is mobile, instead of the marginal leaf burn, these species exhibit B toxicity as die back in young shoots (**Figure 2b**, almond), profuse gumming in the leaf axil and the appearance of brown, corky lesions along stems and petioles (**Figure 2c**, almond). Die back induced by B toxicity has been reported in almond, apple, apricot, cherry, peach, pear, plum, and prune etc. The occurrence of these ‘unusual’ symptoms of B toxicity are not,

Figure 2a. Boron is immobile in pistachio, so toxicity symptoms appear as leaf tip and edge burn.

however, restricted solely to the members of the Prunus, Malus and Pyrus genera as discussed earlier. For example, celery responds to B toxicity by producing deformed young leaves, "bitter" and misshapen stems, while the tip burn symptom is absent. Boron is known to be phloem mobile in celery, since celery like the members of the Prunus genera, utilizes a polyol as a primary transported photosynthate. The two kinds of B toxicity symptoms described above are a consequence of the difference in B mobility. In short, for those species in which B is immobile, B toxicity is exhibited as tip/edge burn of old leaves, while for those in which B is mobile, meristematic dieback is the primary symptom of B toxicity.

Diagnosis and Fertilization

In general, for the majority of plant species, B is phloem immobile, however B is phloem mobile in many important crop species such as those presented in **Table 2**. Preliminary evidence also suggests that many other crop species may exhibit phloem B mobility (i.e. coffee) though this is yet to be verified.

The difference in B mobility indicated above also profoundly influences the diagnosis of plant B status and the correction of deficiencies and toxicities. Currently practiced sampling techniques and symptom descriptions have been based on the premise that B is not mobile in the plant. Selection of tissue samples and determination of critical nutrient concentrations are all fundamentally dependent on the phloem mobility of B. **Table 2** illustrates that B does not accumulate in the older leaves of species in which B is mobile. Thus, old leaves are not suitable for determination of B toxicity. Rather young apical leaves or fruit tissue may be a superior indicator in these species (**Table 1, 2**). This observation has led to the widespread use of hull B as a determinant of B status in almond in California. In species with limited B mobility however, the B concentration in the old leaves (**Table 2**) remains a good indicator of B toxicity.

For the diagnosis of B deficiency, the use of a recently matured, or fully expanded leaf is inappropriate if B is phloem immobile since the B concentration of a developed leaf may not reflect the B status of growing tissues for which a constant B supply is most critical. This can only be achieved by sampling growing tissues. This is an inherently difficult and inconsistent process. However, it is the only valid approach. By contrast, in species that exhibit mobility, mature leaves are appropriate for assessing B deficiency since their content reflects the B status of the entire plant, including young growing tissues. In these species B depletion in the soil will not impact meristematic

TABLE 2. Leaf B concentration (ppm dry wt.) along a shoot in various plant species.

Species	Basal	Middle	Apical	Remarks
Pecan	303	119	30	B-immobile
Tomato	721	318	94	B-immobile
Strawberry	512	176	68	B-immobile
Walnut	304	127	48	B-immobile
Apple	50	56	70	B-mobile
Apricot	45	60	81	B-mobile
Pear	42	57	62	B-mobile
Celery	32	49	104	B-mobile
Grape	74	55	88	B-mobile
Loquat	72	101	162	B-mobile
Olive	42	51	56	B-mobile
Peach	53	57	208	B-mobile
Pomegranate	21	20	111	B-mobile

growth until the soluble B pool of mature tissues has also been depleted.

The management of B fertilization in plants is directly influenced by patterns of B mobility. Experimental evidence clearly demonstrates that foliar applied B can be retranslocated to the growing organs in species with significant phloem B mobility. This suggests that foliar B application can be used effectively at any time functional leaves are present to correct B deficiency, and to supply B to future flower and fruit tissue. The significant benefits of foliar B application on fruit set that has been observed in many tree species such as almond, plum, prune and others is a consequence of this mobility. In species in which B is immobile, however, foliar applied B cannot be retranslocated from the site of application and cannot supply the B requirements of tissue not yet formed. Hence, in these species B applications must be made directly to the tissue of interest. In fruit crops, where B is essential for the flowering process, this means that B applications can only be effectively used if applied directly to the flower buds or flowers themselves.

Figure 2b. (At left) Boron is mobile in almond, and toxicity may cause dieback in young shoots.

Figure 2c. (At right) Profuse gumming in the leaf axil and appearance of brown, corky lesions along stems and petioles are symptoms of B toxicity in almond.

Summary

Knowledge of the relative mobility of B within a particular species determines the approach that should be used to sample and diagnose B status. This knowledge also determines the optimum fertilization strategy that should be used and helps in our understanding of the causes and consequences of B deficiency. Further work is underway to fully characterize the patterns of B mobility in diverse plant species. However, the following predictions can now be made about several important field crops.

- In corn, wheat, alfalfa and vegetable crops except those mentioned earlier, B is immobile and must, therefore, be supplied at all stages of plant growth.
- Foliar application can be used to correct deficiency in current tissues but will have minimal effect on new plant growth.
- In some species, there may be cultivars in which a small amount of mobility may occur.

This may explain the differences in sensitivity to B deficiency that are occasionally observed between cultivars. Further work on this topic is required. BC

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Ag Scientists – Take the Lead

What are agricultural scientists concentrating on in their programs? Genetic engineering? Complex plant and soil chemistry? New pesticides? Increased production? All are important. But the public is uninformed about most of it.

What does reach the public? Recently, two items received full page newspaper headlines:

"Historic Global Warming Pact Reached"

"Population Will Outstrip Food Production By 2025"

Undoubtedly these are distressing problems that need to be solved. How scientifically are we arriving at the answers? And what role are ag scientists playing in finding the solutions?

Especially disturbing is the matter of feeding the world. In the early 1960s, a book titled *Famine 1975* predicted disaster and outlined the areas that would starve. And in the 1950s, a widely acclaimed scientist predicted in *The Population Bomb* that "in the 1970s hundreds of millions of people are going to starve to death." Both predictions were wrong. World population has more than doubled since 1950, but food supplies have more than tripled.

Don't expect the answers to come from politicians or self-proclaimed authorities who are fundamentally misinformed. Facts on saving the planet and feeding the world must come primarily from ag scientists. But they must do a better job of assuming their responsibility and selling the public on their expertise and importance.

Americans are concerned because they are confused. Ag scientists, it is time to take the lead.

J. Fielding Reed

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