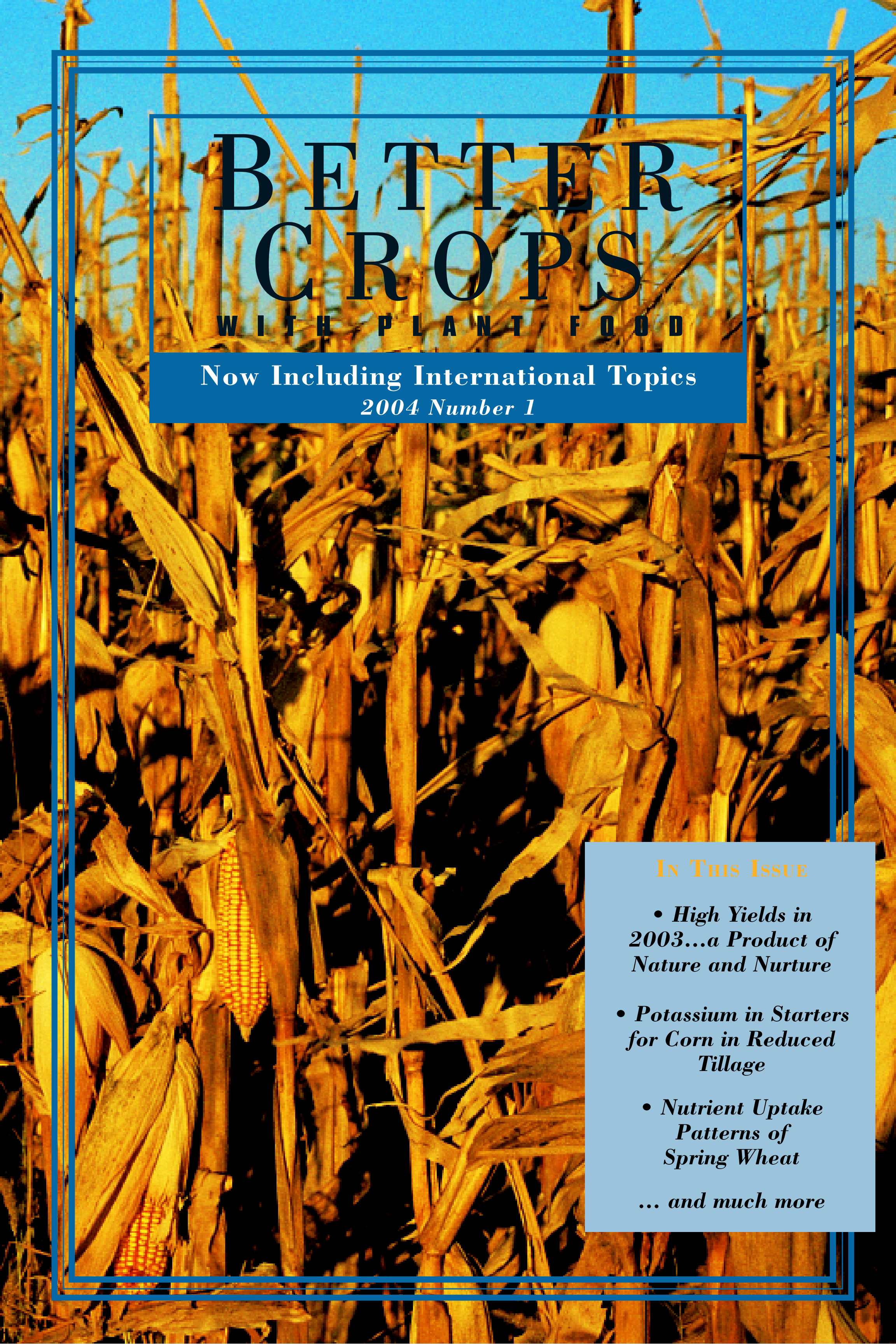


BETTER CROPS

WITH PLANT FOOD

Now Including International Topics

2004 Number 1

IN THIS ISSUE

- *High Yields in 2003...a Product of Nature and Nurture*
- *Potassium in Starters for Corn in Reduced Tillage*
- *Nutrient Uptake Patterns of Spring Wheat*

... and much more

BETTER CROPS WITH PLANT FOOD

Vol. LXXXVIII (88) 2004, No. 1

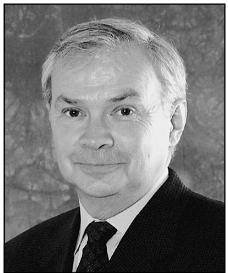
Our Cover: Mature corn at harvest time.
Photo Credit: Dr. Adrian Johnston, PPI/PPIC

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

CONTENTS

M.M. Wilson Reelected Chairman, W.J. Doyle Elected Vice Chairman of PPI and FAR Boards

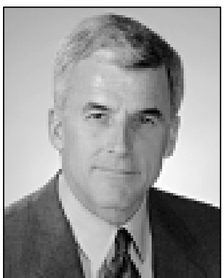
Michael M. Wilson, President and Chief Executive Officer (CEO) of Agrium Inc., was re-elected Chairman of the Potash & Phosphate Institute (PPI) Board of Directors at a recent meeting. He will also serve as Chairman of the Foundation for Agronomic Research (FAR) Board of Directors for the coming year. **William J. Doyle**, President and CEO, Potash Corporation of Saskatchewan Inc. (PotashCorp) will serve as Vice Chairman of the PPI and FAR Boards.



M.M. Wilson

"These leaders bring an impressive background of achievement in the industry and we certainly welcome their talents in these key responsibilities for the year ahead," said Dr. David W. Dibb, PPI President.

Mr. Wilson joined Agrium (formerly known as Cominco Fertilizers) in 2000 with more than 25 years of management and executive management experience in the chemical industry. His most recent position before coming to Agrium was as Executive Vice President and President, Methanol, with Methanex Corporation in Vancouver.



W.J. Doyle

As President and CEO, Mr. Wilson has responsibility for all of Agrium Inc. He is a graduate of the University of Waterloo, Ontario, with a degree in Chemical Engineering.

Agrium Inc. is a leading global producer and distributor of fertilizers and other agricultural products and services. The company produces and markets three primary groups of fertilizers: nitrogen, phosphate, and potash.

Mr. Doyle, new Vice Chairman of the PPI and FAR Boards, was appointed CEO on July 1, 1999, after 12 years as a key member of the PotashCorp management team. PotashCorp is the world's largest integrated producer of nitrogen, phosphate, and potash. He joined the company as President of PCS Sales in 1987, assuming responsibility for the sales and distribution of all potash produced by the company. In March 1995, he was appointed Executive Vice President of PotashCorp, where he took charge of all sales for the company—including phosphate and nitrogen—following a series of acquisitions. In July, 1998, he was named President and Chief Operating Officer.

Mr. Doyle serves on the boards of Canpotex Limited and The Fertilizer Institute (TFI). He is Chairman of the Production and International Trade Committee for the International Fertilizer Industry Association (IFA).

In other action of the PPI Board, Mr. Douglas A. Pertz was elected Chairman of the Finance Committee. Mr. Pertz is Chairman of the Board and CEO of IMC Global Inc.

FAR Leadership

During the recent meeting of the FAR Board of Directors, **Dr. Harold F. Reetz, Jr.** of Monticello, Illinois, was elected to become President of FAR effective January 1, 2004. Dr. Reetz joined the PPI staff in 1982, serving as Midwest Regional Director. Dr. Terry L. Roberts, PPI Vice President and Vice President of the Potash & Phosphate Institute of Canada (PPIC), and Dr. Paul E. Fixen, PPI Senior Vice President, North American Program Coordinator, and Director of Research, will serve as vice presidents of FAR. BC

K A N S A S

Use of Potassium in Starters for Corn in Reduced Tillage Production Systems

By W.B. Gordon

Application of starter phosphorus (P) and potassium (K) at corn planting often results in improved crop performance and yield. This starter effect is commonly attributed to improved early season nutrient availability and increased tolerance of early season stresses associated with cool, moist soil conditions. The results of two north central Kansas experiments exploring the effect of starter K in irrigated ridge-till corn production are reported in this article. Starter K improved corn yield in both studies, despite high soil test K levels.

The use of conservation tillage has increased in recent years because of its effectiveness in conserving soil and water. Potassium deficiency can be a problem on soils that have been managed with reduced tillage practices. The large amount of residue left on the soil surface can depress soil temperature early in the growing season. Low soil temperature can interfere with plant root growth, nutrient availability in soil, and crop nutrient uptake.

Soil temperature influences both K uptake by roots and K diffusion through the soil. Low soil water content or zones of soil compaction also can reduce K availability. Potassium uptake in corn is greatest early in the growing season and accumulates in plant parts at a relatively faster rate than either dry matter, nitrogen (N), or P. Cool spring temperatures can limit early-season root growth and K uptake by corn.

In plant physiology, K is the most important cation not only in regard to concentration, but also with respect to physiological functions. A deficiency in K affects such important physiological processes as respiration, photosynthesis, chlorophyll development, and regulation of stomatal activity. Plants suffering from K deficiency show a decrease in turgor resulting in reduced resistance to drought. The main function of K in biochemistry is its function in activating many different enzyme systems involved in plant growth and development. Potassium also influences crop maturity and plays a role in reducing disease and stalk lodging in corn. The appearance of K deficiency in fields managed with conservation tillage systems has been reported with greater frequency in recent years and has become a legitimate concern for producers.

Starter fertilizer applications have proven effective in enhancing nutrient uptake and yield of corn, even on soils

Potassium in starter fertilizer can boost early season corn growth and yield in some conditions.

Table 1. Starter fertilizer effects on V6 dry weight, K uptake, days from emergence to mid-silk, and yield of corn. Three-year average from Experiment 1, 2000-2002.

Treatments $N-P_2O_5-K_2O$, lb/A	V6 dry weight	V6 K uptake	Days to mid-silk	Grain yield, bu/A
	-------- lb/A	--------		
0-0-0 check	210	6.2	79	162
30-15-0	382	10.9	71	175
15-30-5	355	15.2	71	173
30-30-0	395	11.2	71	184
30-30-5	460	15.2	68	195
LSD (0.05)	28	1.5	2	10

that are not low in available nutrients. The objective of these two studies was to determine if K applied as a starter at planting could improve K uptake and yield of corn on soils that had been managed in a ridge-tillage production system.

Two separate studies were conducted at the North Central Kansas Experiment Field. Both experiments were conducted on a Crete silt loam soil in areas that had been ridge-tilled since 1984. Both sites also were furrow irrigated. Potassium deficiencies had been observed in these two areas prior to the initiation of the studies. Ear leaf K concentrations had proven to be below published sufficiency ranges.

Experiment 1. This field experiment was conducted for three crop years, 2000-2002. Soil test results showed that initial pH was 6.2 and organic matter was 2.4%. Bray-1 P in the top 6 in. of soil tested high…40 parts per million (ppm), while exchangeable K tested very high…420 ppm. Soil test results in this experiment and in Experiment 2 are from composite samples (0 to 6 in. depth) that came from equal amounts of soil taken from the center, the shoulder, and middle of the row. Treatments consisted of the liquid starter fertilizer combinations 30-15-5, 15-30-5, 30-30-0, and 30-30-5 (total lb $N-P_2O_5-K_2O/A$). A no starter check was also included. Starters were made using 28% urea ammonium nitrate (UAN), ammonium polyphosphate (10-34-0), and potassium thiosulfate (KTS, 0-0-25-17). Nitrogen was balanced so that all plots received 220 lb N/A regardless of starter treatment. On plots receiving no K as KTS, ammonium sulfate was included in order to eliminate sulfur (S) as a variable. Starter fertilizer was applied 2 in. to the side and 2 in. below the seed at planting (2x2 starter).

The 30-30-5 starter treatment increased corn 6-leaf stage dry matter and tissue K content, decreased the number of days from emergence to mid-silk, and increased grain yield as compared to the 30-30-0 treatment (**Table 1**). A small amount of K applied as a starter on this soil testing high in K resulted in better growth, more nutrient uptake, and 11 bu/A greater yield than starter that did not include K. In all cases, the 30-30-5 starter also was superior to the 15-30-5 treatment, indicating that N is an important element of starter fertilizer composition in this system. All starter treatments improved growth and yield over the no-starter check.

(continued on page 9)

Table 2. Starter fertilizer effects on V6 dry weight, K uptake, days from emergence to mid-silk, and yield of corn. Two-year average from Experiment 2, 2002-2003.

Treatments $N-P_2O_5-K_2O-S$, lb/A	V6 dry weight	V6 K uptake	Days to mid-silk	Grain yield, bu/A
	-------- lb/A	--------		
0-0-0-0 Check	208	6.9	82	161
30-15-0-0	290	8.8	76	185
30-15- 5-5	312	12.8	76	189
30-15-15-5	395	16.2	72	198
30-15-25-5	398	16.9	72	197
30-15-15-0	398	16.1	72	198
LSD(0.05)	31	1.9	2	11

MONTANA

Nutrient Uptake Patterns of Spring Wheat

By R.O. Miller and J.S. Jacobsen

At the end of the season, nitrogen (N) and phosphorus (P) were primarily located in the grain, while potassium (K) and chloride (Cl) were most abundant in stems.

When in the season does spring wheat have the greatest demands for various nutrients? In what plant parts are nutrients primarily located during the season? How does this change? To answer these questions, we conducted a study to closely monitor, during the growing season, the nutrient content in above-ground plant portions of hard red spring wheat. Although this study was conducted in 1987, the results are as relevant and instructive today as they were then, particularly as management intensity increases.

The study area was located in the Gallatin Valley of Montana. The soil was an Amsterdam silt loam. (For additional soils information, please visit >**http://www.nris.state.mt.us/nrcs/soils/**<). In the upper 12 in. of soil, analysis showed: organic matter, 2.4%; cation exchange capacity, 22.5 cmol(+)/kg; nitrate (NO_3^-)-N, 25 lb/A; Olsen P, 20 parts per million (ppm); and ammonium acetate exchangeable K, 320 ppm.

Additionally, 17 lb NO_3^--N/A was present at the 1 to 4 ft. depth. Nitrogen was applied as urea, broadcast and incorporated at a rate of 50 lb N/A. This rate was based on recommendations considering soil NO_3^- levels and a yield goal of 65 bu/A, lower than historical levels due to water limitations for irrigation.

Accumulated growing degree units (GDUs) were recorded throughout the season by subtracting the sum of the minimum and maximum temperatures and dividing by 2. The lowest allowable daily minimum temperature was set at 32°F. The highest allowable daily maximum temperature was set at 75°F.

Hard red spring wheat 'Success' was planted on April 19, 1987, at a rate of 21 seeds/ft^2 in 7 in. rows. The crop was sampled 16 times throughout the growing season (**Table 1**).

At each date, four locations of approximately 2.7 ft^2 in size were sampled. Whole plant samples were taken from Haun growth stages (HGS) 1.8 until 5.2. In subsequent samplings, plants were separated into leaves, stems, and heads. From HGS 12.1 to maturity, grain was separated from the head.

Table 1. Sampling dates and associated growth stages.

Sampling date	GDU	Haun growth stage	Description
4/29	139	1.8	1 fully expanded leaf
5/05	213	2.8	2 fully expanded leaves, early tiller
5/10	295	3.8	3 fully expanded leaves
5/14	360	4.5	4 fully expanded leaves, mid-tiller
5/19	420	5.2	5 fully expanded leaves
5/29	527	6.4	stem lengthening
6/03	579	7.0	flag leaf visible
6/08	660	8.0	flag leaf extending
6/13	749	9.2	boot swollen
6/19	849	10.2	first spikelet visible
6/29	1011	11.5	anthesis > 50% complete
7/05	1120	12.1	kernel visible, watery
7/13	1232	13.1	medium milk
7/21	1362	14.0	soft dough
7/31	1566	15.0	hard dough
8/13	1791	16.0	maturity

The accumulation of dry matter (DM) during the season is shown in **Figures 1 and 2**. Rapid DM accumulation occurred: 1) when the flag leaf was visible and extending (HGS 7.0 to 8.0), 2) during head emergence and elongation (HGS 10.0 – 11.0), and 3) during early grain fill (HGS 12.0 to 13.5). After early grain fill, leaves, stems, and heads lost dry matter, with the largest percent losses coming from the stems. The total DM produced at maturity was 6.3 t/A, with a grain yield of 91 bu/A (adjusted to 12% moisture). Approximately 38, 16, 37, and 9% of the total dry matter was in the grain, heads, stems, and leaves, respectively.

Nitrogen uptake patterns during the season are shown in **Figure 3**. It should be noted that N deficiencies did occur during the season due to above normal precipitation during flowering and grain fill, so total uptake as well as accumulation rates do not reflect those under conditions of sufficient N. This deficiency may have affected uptake patterns of all nutrients to some degree.

The most rapid N uptake occurred early in the season, from approximately two leaves fully expanded (HGS 2.0) to a fully expanded flag leaf (HGS 8.0). Another increase in N uptake rate occurred during flowering and early grain fill (HGS 11.5 to 12.0). Total N accumulated in this study was 105 lb N/A. Approximately 80, 6, 9, and 5% of this total was partitioned among the grain, heads, stems, and leaves, respectively **(Figure 1)**. Uptake and removal rates averaged 1.15 and 0.92 lb N/bu, respectively (**Table 2**).

Phosphorus accumulation rates are shown in **Figure 4**. More

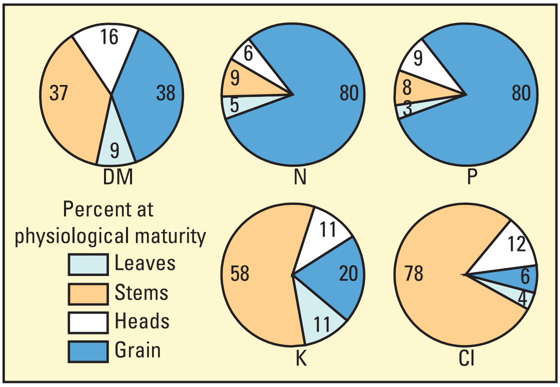


Figure 1. Percent of each nutrient partitioned in the leaves, stems, heads, and grain at physiological maturity.

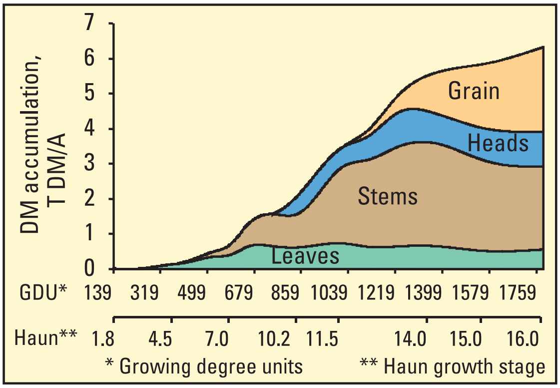


Figure 2. Cumulative accumulation patterns of DM in above-ground plant portions.

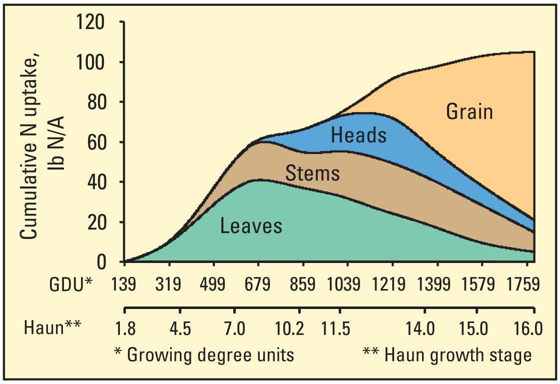


Figure 3. Cumulative N accumulation patterns in above-ground plant portions. Note: N deficiencies were observed in this study.

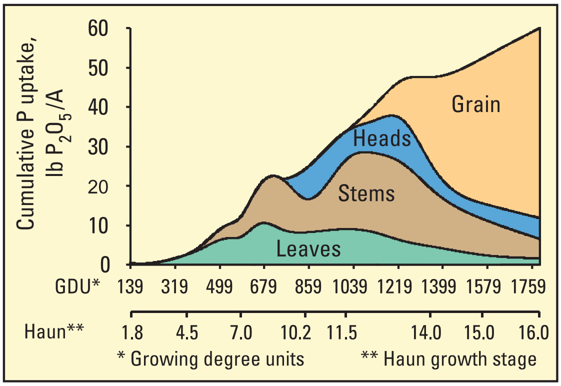


Figure 4. Cumulative P_2O_5 accumulation patterns in above-ground plant portions.

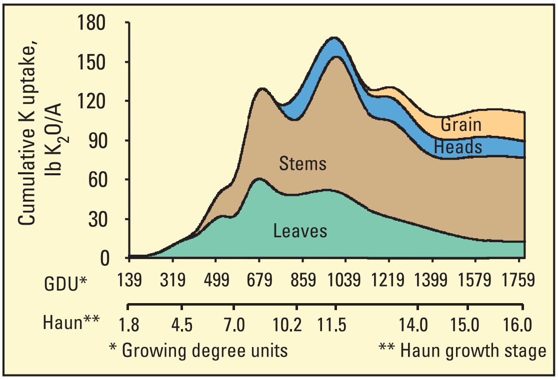


Figure 5. Cumulative K_2O accumulation patterns in above-ground plant portions.

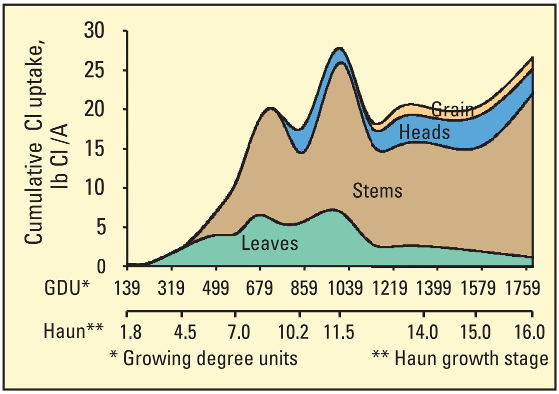


Figure 6. Cumulative Cl accumulation patterns in above-ground plant portions.

rapid uptake occurred from the time the flag leaf became visible (approx. HGS 7.0) and remained accelerated through early grain fill (approx. HGS 12.5). During the remainder of the grain fill period, P from heads, stems, and leaves was repartitioned into the grain. Total P accumulation at maturity was 60 lb P_2O_5/A, with 80, 9, 8, and 3% in the grain, head, stems, and leaves (**Figure 1**). Average uptake and removal rates were 0.66 and 0.53 lb P_2O_5/bu (**Table 2**).

Potassium and Cl had very similar uptake patterns (**Figures 5 and 6**). Both showed rapid uptake by stems from about the time five fully expanded leaves were visible (HGS 5.0), through stem elongation, until flag leaf extension (HGS 8.0). Another burst of uptake by the stems coincided with head emergence (HGS 10.0) through stem elongation and up to the beginning of flowering (HGS 11.5). Interestingly, for both K and Cl, this latter burst of uptake was the period of maximum uptake, which was 167 lb K_2O/A and 28 lb Cl/A. At the onset of anthesis, levels of both nutrients began to decline. These declines likely occurred because of nutrient leaching from physiologically mature plant portions, such as older leaves. Unlike K, Cl accumulation began increasing again in the stem from the hard dough stage (HGS 15.0) through maturity.

Levels present at maturity were near maximum uptake levels for Cl, but were well below maximum for K. Total K and Cl uptake present at maturity were 111 lb K_2O/A and 27 lb Cl/A. For K, 20, 11, 58, and 11% of this total were partitioned among grain, heads, stems, and leaves. Percent of total Cl was 6, 12, 78, and 4 for grain, heads, stems, and leaves (**Figure 1**). Uptake and removal rates at maturity were 1.22 and 0.24 lb K_2O/bu and 0.29 and 0.02 lb Cl/bu (**Table 2**). Maximum uptake rates earlier in the season were 1.84 lb K_2O/bu and 0.30 lb Cl/bu.

Table 2. Average uptake and removal rates observed in this study.

	N[1]	P_2O_5	K_2O	Cl
	---------- lb/bu ----------			
Uptake				
At maturity	1.15	0.66	1.22	0.29
At maximum uptake	1.15	0.66	1.84	0.30
Removal				
At maturity	0.92	0.53	0.24	0.02

[1]Note: N deficiencies were observed in this study.

Summary

Uptake patterns vary considerably from nutrient to nutrient. At the end of the season in this irrigated spring wheat study, most of the N and P were located in the grain. Most of the K and Cl were found in the stems. Total uptake of N and P peaked near physiological maturity, whereas maximum uptake of K and Cl occurred earlier in the season during head emergence and stem elongation, and ended with flowering.

Dr. Miller (e-mail: rmiller@lamar.colostate.edu) is Affiliate Professor with the Soil & Crop Sciences Dept., Colorado State University, Fort Collins. Dr. Jacobsen is Interim Dean and Director, Professor, Montana State University, Bozeman.

Corn...(continued from page 5)

Experiment 2. This 2-year experiment was conducted during the 2002-2003 growing seasons on a site that was lower in soil test K than the previous experiment. Analysis showed that initial soil pH was 6.9; organic matter was 2.5%; Bray-1 P was high…35 ppm, and exchangeable K was 150 ppm (very high). Treatments consisted of liquid starter fertilizer rates of 0, 5, 15, or 25 lb K_2O/A applied in combination with 30 lb N, 15 lb P_2O_5, and 5 lb S/A. A 30-15-15-0 treatment was included to separate the effects of K and S. The K source used in this treatment was KCl (muriate of potash). The source of K used in all other treatments was KTS. Starter fertilizer was again applied 2 in. to the side and 2 in. below the seed at planting. Nitrogen was balanced on all plots to give a total of 220 lb/A.

Grain yield was maximized with application of 15 lb of K_2O/A in the starter (**Table 2**). Addition of 15 lb K_2O/A to the starter increased grain yield by 13 bu/A over the starter containing only N and P. No response to S was seen at this site. All combinations improved yields over the no-starter check.

Even though soil test K was in the high range, addition of K in the starter fertilizer increased early season growth and yield of corn. At this site, 15 lb K_2O/A was required to reach maximum yield. In the previous experiment on a soil much higher in available K, only 5 lb K_2O/A was needed to maximize yields.

Conclusion

Nutrient management in conservation tillage systems can be challenging. The increased amounts of crop residue present in these systems can cause early season nutrient deficiency problems that the plant may not be able to overcome later in the growing season. Early season P and K nutrition is essential for maximizing corn yield. In these experiments, addition of K to starters containing N and P has been shown to improve early season growth, nutrient uptake, earliness of maturity, and yield of corn grown in a long-term ridge-tillage production system.

Dr. Gordon is Professor, Department of Agronomy, Kansas State University, North Central Kansas Experiment Field; e-mail: bgordon@oznet.ksu.edu.

MISSISSIPPI

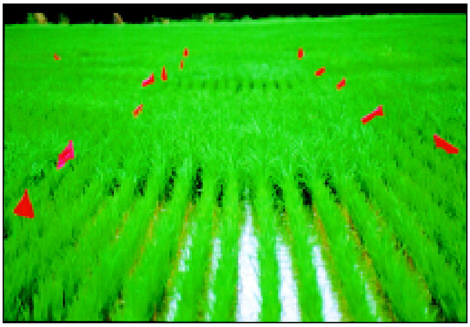
Defining and Managing Yield Zones for Rice and Soybeans—A Case Study

By T. Walker, M. Cox, W. Kingery, S. Martin, L. Oldham, and J. Street

Temporal yields, recorded with precision farming tools, in leveled fields can help define management zones. Low yields were associated with low soil phosphorus (P) and compaction in cut areas. Variable rate (VRT) P application increased the whole field yield and reduced yield variability.

Approximately 1.1 million acres of soybeans and 250,000 acres of rice were produced in Mississippi's Delta region in 2003. Because of the alluvial nature of Delta soils, the variability in soil properties can be extensive. In addition to this natural variability, the practice of precision land-leveling fields for irrigation purposes can significantly contribute to soil and crop variability. Soil and crop variability that results from the land-leveling process is now being more accurately quantified by using precision farming (PF) tools such as differential-corrected global positioning systems (DGPS), yield monitors, and geographical information systems (GIS).

The implementation of PF tools is not just beneficial to researchers. If used correctly, PF tools have the ability to help producers operate more efficiently, which often increases cash-flow. The use of PF tools has increased since the technologies became commercially available in the mid-1990s. One important PF tool used by many rice and soybean producers in the Mississippi Delta is DGPS yield monitors. DGPS yield monitors allow producers the ability to collect enormous amounts of data each year. However, after having collected multiple years of yield data, many producers have begun to experience difficulties in data management and synthesis, which can limit the implementation of site-specific production practices into their crop management program. This implementation inability has caused many producers to question the feasibility of this technology. The objectives of this research were to use PF tools to: 1) define zones within a rice/soybean production field where yields were consistently high, average, or low; 2)



Phosphorus deficiencies affect rice production by decreasing tillering, delaying maturity, and decreasing yield and milling quality.

Rice maturity differences caused by P-deficiencies. Plot on left had sufficient P applied prior to flooding. Plot on right had P applied at ½in. internode elongation.

determine the factors that caused the yield variability and address those factors; and 3) determine the economical feasibility of implementing these technologies in a production environment.

Approach

A 35-acre field in Bolivar County, MS, was selected in the spring of 2003 to test the ability to couple historical field data and soil sampling to determine crop management zones. The predominant soils in this field were Forestdale (Fine, smectitic thermic Typic Endoaqualfs) silty clay loam and Dundee (Fine, silty, mixed, active, thermic Typic Endoaqualfs) silt loam.

This field was precision land-leveled in the summer of 2000. 'Cocodrie' rice was planted in April of 2001 and harvested in September. Glyphosate-resistant soybeans were planted in April of 2002 and harvested in September. DGPS yield monitor data were collected for both crops. These yield data were normalized using the Multi-Year Yield Analysis technique which defines crop management zones based on 1) actual yields relative to the whole field yield average; and 2) the stability of these yields across years, crops, and varieties. Three crop management zones were defined for this study: high, average, and low. The high yielding zone was defined by yields that were greater than 120% of the field average with a coefficient of variation (CV) less than 30%. The average yielding zone was defined by yields that ranged from 80 to 120% of the whole field average and had a CV of less than 30%. Low yielding zones were defined by yields that were less than 80% of the field average and had a CV of less than 30%. The field was then soil sampled on a 2-acre grid in which each yield zone was represented.

The soil samples were analyzed for Lancaster-extractable…Mississippi State University (MSU) method…nutrients and soil pH. Management zones were initially defined based on yield. Further definition of the management zones was accomplished using soil sample analyses and a topographic map that identified areas where the topsoil was either 'cut' or 'filled' in the land-leveling process. Soil test P concentrations ranging from very low (VL) to high (H), according to MSU Extension Service (MSU-ES) recommendations, were used to develop a VRT-P application strategy in 2003. 'Cocodrie' rice was planted in April of 2003 and harvested in September.

Table 1. Crop yield average and coefficient of variation (C.V.) over time.

Year	Crop	Average, lb/A	C.V., %
2001	Rice	6932	38.9
2002	Soybean	2662	23.6
2003	Rice	7159	22.2

Results and Discussion

Yield. Rice yield in 2001 was highly variable **(Figure 1 and Table 1)**. Though the yield variability was much less in the subsequent soybean crop, the apparent yield zones appear to be consistent with what was seen in the previous rice crop **(Figure 2)**. The yield zone consistency was confirmed by performing a Multi-Year Yield Analysis **(Figure 3)**, in which three management zones where defined: high yield, average yield, and low yield. Soil test P results indicated that a P application was warranted over the majority of the field, but the southern portion of the field had a greater probability of obtaining a yield response **(Figure 4)**. Analyses of the yield data collected from the 2003 rice crop indicated a substantial decrease in variability compared to the 2001 rice crop **(Table 1)**. **Figure 5** indicates a definite increase in rice yield in the P-limiting area of the field, as a likely result of VRT P application. Weather differences or other factors may also be involved.

Combining the topographic map **(Figure 6)** with **Figure 3** indicates that P fertility may not be the only source of yield variability. The 'fill' area in **Figure 6** is consistent with the high-yielding area in **Figure 3**. In addition, the 'cut' area…except for where P is limiting…is consistent with the average yielding area. One hypothesis that could be proposed

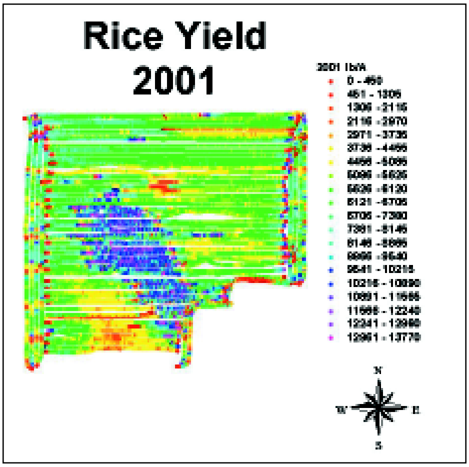


Figure 1. 2001 rice yield map.

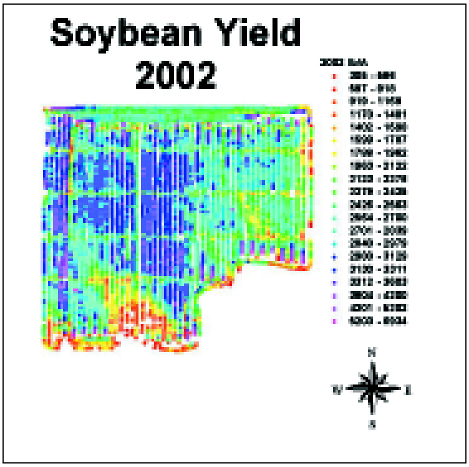


Figure 2. 2002 soybean yield map.

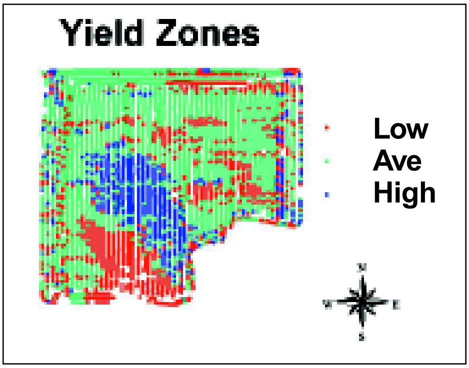


Figure 3. Normalized yield from 2001 and 2002.

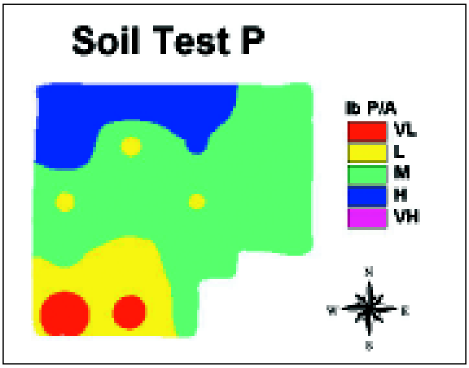


Figure 4. Spring 2003 extractable-P levels.

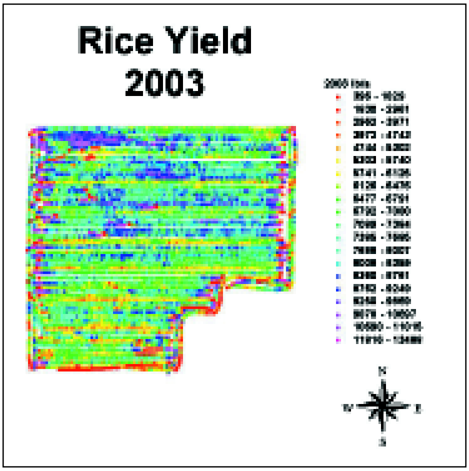


Figure 5. 2003 rice yield map.

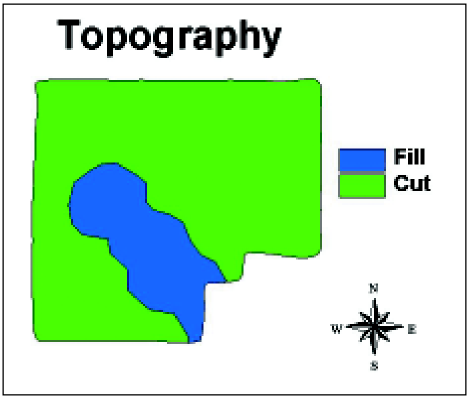


Figure 6. Topography map defining areas of cut and fill.

from these data is that compaction may be limiting yields the first two years after precision land-leveling.

Research that was recently published by the authors indicated a strong correlation between the total volume of soil that was cut and the difference in yield compared to the fill area. A second hypothesis that may further define the decrease in in-field variability from 2001 to 2003 is that organic matter additions (e.g. crop stubble) from the previous cropping years aided in the restoration of the disturbed microbiological ecology that was caused by the land-forming process.

Economics. A question that is asked often by producers when discussing the implementation of PF is: "Will this technology pay for itself?" A cost-analysis was conducted for the field from which these data are reported. When comparing the whole field average rice yield in 2001 to that of 2003, the net increase in grain of 227 lb/A would amount to a net return of $21.44/A. The cost of applying these PF technologies would be approximately $16.57/A. The MSU-ES recommends that when fields have been recently land-leveled, soil samples should be randomly collected and composited based on whether the area has been 'cut' or 'filled'. If this method had been used, based on the soil samples that were collected from areas of 'cut' and 'fill', it is highly probable that a blanket application of 30 lb P_2O_5/A would have been recommended. This would have cost $12.96/A , or $453.60 for the 35-acre field. That is less than the cost of the VRT-P treatment. However, studies by MSU scientists indicate that if P had been uniformly applied at the recommended rate, maximum rice yields would not have been obtained in the area of the field where soil test P was in the VL to L range. That theoretically would have resulted in a lower whole-field yield average.

Conclusions

Use of PF tools (i.e., DGPS yield monitors, GIS, grid soil sampling, and VRT), coupled with topography maps (i.e. "cut" and "fill" maps), successfully defined management zones, determined yield limiting factors, and addressed one of the key limiting factors: inadequate P fertility. These tools decreased whole-field yield variability and increased total rice production. Although there was an added expense of applying P with VRT, this method was more agronomically appropriate. More precise application of P to areas of need helped to maximize yield and resulted in more consistent production of rice within management zones. Higher crop yields and potentially greater uptake of applied P should also result in reduced environmental P risks. BC

Research Project No. MS-10F.

Dr. Walker is Assistant Professor of Agronomy, located at the Delta Research and Extension Center in Stoneville, Mississippi; e-mail: twalker@drec.msstate.edu. Dr. Cox is Associate Professor, Dr. Kingery is Professor, and Dr. Oldham is Associate Extension Professor, all in the Dept. of Plant and Soil Sciences at Mississippi State University. Dr. Martin is Associate Extension Professor of Agricultural Economics and Dr. Street is Extension Rice Specialist at the Delta Research and Extension Center in Stoneville.

Acknowledgments

Sincere appreciation is expressed for research funds provided from the following sources: Advanced Spatial Technologies for Agriculture, Mississippi Rice Promotion Board, and the Foundation for Agronomic Research (FAR). Also, sincere appreciation is expressed to Mr. Delbert Dean, who was the cooperating producer, as well as Mr. Scott Lanford and Mr. Grady Jackson for their technical support.

Nutrient Management for Onions in the Pacific Northwest

By D.A. Horneck

Both quality and yield of onions are essential attributes for profitability. Nutrient management makes a major contribution to this widely grown vegetable.

Onions represent the third-largest fresh vegetable industry in the U.S. The per capita consumption of onions is around 18 lb/year. They are a high-value crop, where both high yield and quality are important economic considerations. Successful onion production depends on careful nutrient management, as well as other management techniques, pest issues, and climatic factors. Onions are grown in many environments across the country, as shown in **Figure 1**. The management strategies recommended here are based on data gathered over many seasons and varieties in Oregon, Idaho, and Washington.

An onion bulb is different from other root crops (such as sugar beets) or a stem-produced potato. Each onion layer is called a "scale" in botanical terminology and is comprised of the base of an individual leaf. Hence, the number of leaves is important in determining bulb size. A premium price is paid for a large onion, so they are sorted and marketed according to size, ranging from *Super Colossal* (>4¼ in. diameter) to *Mediums* (2¼ to 3 in.). The market for smaller onions is limited and less valuable. Important quality factors for onions include bulb shape, scale color, scale thickness, scale retention, number of scales, bulb firmness, number of growing points, paper quality, and neck thickness.

Onions have a small root system that limits their ability to acquire nutrients from the soil. Source: www.extento.hawaii.edu/IPM/onion/onion4.jpg

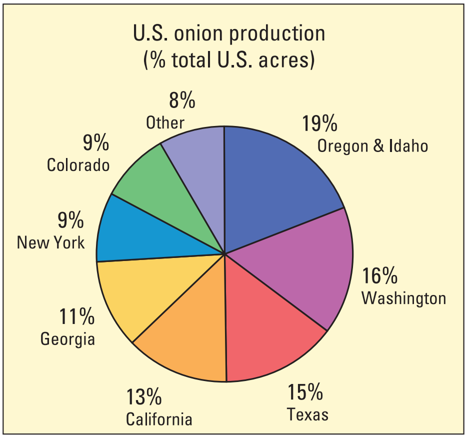


Figure 1. Percent of U.S. onion production acreage in top-producing states.

Onions have a sparsely branched root system, with most of the roots in the top foot of soil (**see photo**). This shallow rooting pattern has important implications for the limited availability of relatively immobile nutrients such as phosphorus (P), potassium (K), and some micronutrients. Mobile nutrients such as nitrate and sulfate can be easily lost from the shallow root zone by excessive irrigation.

Nitrogen. The nitrogen (N) concentration in harvested onion bulbs on a dry weight basis is similar among red, yellow, and white varieties. Total crop N uptake averages about 140 lb N/A, with between 70 to 90% of the N contained in the bulb at harvest. The N uptake rate during the early bulb growth period is from 1 to 3 lb N/A each day. Split applications of N fertilizer are commonly made during the growing season.

Phosphorus and Potassium. Onions are highly dependent on mycorrhizal fungi for P acquisition from soil. These fungi, living in close association with the roots, produce a network of threadlike hyphae that extends far into the soil, greatly increasing the absorptive surface area of the root system. The P fertilizer recommendation for onions following fumigation may be 25% greater than on non-fumigated soils.

Since P is essential for rapid root development, a deficiency typically reduces bulb size and delays maturation (**see photo**). Total P uptake for a bulb yield of 840 cwt/A was 20 to 25 lb P/A (45 to 55 lb P_2O_5/A) at the time of harvest (**Figure 2**). Specific P fertilizer recommendations are based on the soil test P concentration, the amount of calcium carbonate present in the soil, and the history of fumigation.

Incorporation of fertilizer P into the planting bed is always recommended. Banded P applications have been more effective than broadcast applications in

Onions respond to banded P applications with larger plants (on left) and earlier maturity than plants growing with broadcast P.

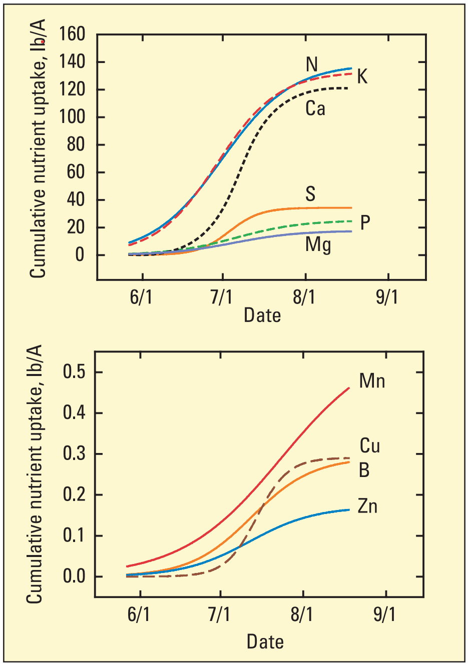


Figure 2. Cumulative nutrient uptake by onions (bulb and tops) for yellow onions grown near Connell, Washington. Fresh weight bulb yield was 840 cwt/A grown with furrow irrigation.

western Oregon. However, in Idaho, no advantage was found for banded applications compared with broadcast. Placement of ammonium phosphate fertilizers next to the seed should be avoided due to potential danger of ammonia toxicity.

Nearly equal amounts of N and K are removed in harvested onions, ranging from 130 to 190 lb K_2O/A. While K deficiencies are rare in some areas, regular K fertilization is typically needed on many sandy soils with a low cation exchange capacity. Potassium application rates should be based on soil test results, with applications typically required when sodium bicarbonate-extractable K falls below 100 ppm.

Although less desirable, when reliable soil test information is not available, K fertilization can be based on crop removal rates to prevent soil depletion. Potassium is an important factor in plant water

(continued on next page)

NORTH AMERICA

High Yields in 2003... a Product of Nature and Nurture

By P.E. Fixen

Those of us privileged to be part of crop production agriculture typically experience about 40 growing seasons in the core part of our professional careers. Certain seasons serve as benchmarks that we use to index all other seasons. For many corn growers, both producers and researchers, 2003 was such a benchmark because of the high yields experienced. These seasonal differences are products of nature...what nature provided in terms of growing season length, precipitation amount and distribution, solar radiation, day and nighttime temperatures, absence of "acute stress" such as hail or wind storms, etc. However, the impact of these products of nature can be greatly influenced by how we nurture the crop. What we reap is clearly a product of both nature and nurture.

On-going Midwest studies designed to learn how to produce the highest corn yields attainable in a specific environment generated interesting data under 2003 growing conditions. The following four brief accounts (on pages 17, 18, 19, and 20) feature some of these studies. Future issues of *Better Crops* will contain more information on individual research projects. In this section, we focus on specific lessons illustrated in the 2003 season and on an exciting development in the science of crop modeling that promises to markedly improve our ability to determine the attainable yield potential at specific sites. In other words, stay tuned to future issues because there is more to come. BC

Dr. Fixen is PPI Senior Vice President, North American Program Coordinator, and Director of Research; e-mail: pfixen@ppi-far.org.

Onions... (continued from page 15)

relations, cell wall formation, and energy reactions in the plant. When required, K should be applied pre-plant or after onions progress past the 4-leaf stage to avoid problems associated with excessive soluble salts, since onions are very sensitive to water stress during the seedling stage and during bulb growth.

Substantial amounts of other essential nutrients...especially calcium (Ca), sulfur (S), and magnesium (Mg)...are also rapidly accumulated during the growing season. They must be available in adequate quantities to supply the rapidly growing crop. Due to the shallow nature of the root system, these nutrients must be present in relatively large amounts in the surface soil. Soil testing is the best way to monitor the nutrient status of the root zone.

Conclusions

Onions are widely grown across North America. Research from the Pacific Northwest shows that onions are very responsive to nutrient applications. Proper nutrient management results in larger and more profitable onion yields. BC

Dr. Horneck is with Oregon State University; e-mail: don.horneck@oregonstate.edu. *Additional information about nutrient management for onions is also available from the publication: D.M. Sullivan, B.D. Brown, C.C. Shock, D.A. Horneck, R.G. Stevens, G.Q. Pelter, and E.B.G. Feibert. 2002. Nutrient Management for Onions in the Pacific Northwest. PNW 546. Oregon State University.*

What Was *My* Attainable Yield Potential for Corn in 2003?

By A. Dobermann and D.T. Walters

A useful parameter in developing site-specific soil and crop management plans is an estimate of the attainable yield of the specific sites being managed. Comparison of the attainable yield to the yields being experienced defines the site-specific yield gap available to exploit. Crop simulation models of the past have generally under-predicted corn yields in high yield environments and have required input data not readily available. Hybrid Maize is a crop simulation model just completed by our research team at the University of Nebraska and is our attempt to overcome both of these limitations. It will be available to the public within the next few months.

The model is designed to either run on site-specific input data or utilize default input values when actual data are unavailable. Weather inputs are standard temperature and solar radiation data available from weather stations. Data for the current season can be utilized as it is available and historical data used for the remaining season for real-time simulation of yield. Additional inputs include date of seeding or emergence, date of maturity or growing degree day requirements for maturity, plant population, seeding depth, precipitation and irrigation amounts, initial topsoil moisture content, topsoil and subsoil texture and bulk density, and maximum rooting depth.

The high yielding 2003 season provided a good test of the accuracy of Hybrid Maize. **Table 1** shows predicted and actual yields measured in the studies summarized later in this article series. The yields shown are for the input combination that provided the highest treatment mean for each experiment or factor level shown in the table. The model was in very good agreement with the measured yields, which reflects well on model accuracy. Since the model assumes that nutrient and pest stress is minimal, these results also suggest that nutrients and pests were not likely limiting yields in the specific treatments reported.

Table 1. Comparison of measured corn yields to those predicted by Hybrid Maize in 2003 studies.

	Grain yield, bu/A	
Location – treatment	Measured[1]	Predicted
U. of Nebraska (Lincoln) –corn following soybeans; 35,000 ppa; intensive management	285	287
Kansas State U. (Scandia) – 28,000 ppa; 300 lb N; 4-way split; high P, K and S application	223	219
Kansas State U. (Scandia) –42,000 ppa; 230 lb N; 4-way split; high P, K, and S application	251	252
U. of Illinois Morrow Plots –corn/oats/hay rotation; lime plus commercial fertilizer	261	240[2]

[1] Treatment with highest yield in the study. (ppa=plants per acre)
[2] Default values used for dates of critical growth stages, initial soil moisture, soil bulk density, and rooting depth.

Research Project No. NE-11F.

Dr. Dobermann and Dr. Walters are with the University of Nebraska, Department of Agronomy and Horticulture; e-mail:adobermann2@unl.edu.

NEBRASKA

Plant Population and Fertilization Impacts on Irrigated Corn in Nebraska

By D.T. Walters and A. Dobermann

Since 1999, a team of researchers at the University of Nebraska has been conducting studies to understand the yield potential of corn and soybeans and how management affects it. The crop model discussed in the previous article was a product of this team. The research compares continuous corn to a corn-soybean rotation and evaluates how plant population and nutrient management impact yield. In addition to determining productivity, the research involves an integrated assessment of profitability, input use efficiency, energy balance, and environmental consequences.

A small subset of the information generated from this study is summarized in **Table 1**. Primary tillage was fall moldboard plow from 1999-2002 and mini-moldboard in 2003; row spacing was 30 in.

For the first 4 years, yields increased with population, especially under intensive nutrient management. Likewise, somewhat greater nutrient response occurred at the higher populations. Due perhaps to a change in hybrid or to the nature of the latter part of the growing season, no response to population and no interaction between population and nutrient management occurred in 2003. However, yields were the highest measured in the 5 years.

A satellite study adjacent to the main study evaluated the impact of narrowing row spacing from 30 in. to 15 in. Yields increased from 295 bu/A at 30 in. to 314 bu/A at 15 in. Increasing plant population above 30,000 plants per acre did not increase yield with this hybrid (Pioneer 31N28).

It is meaningful to consider these data in light of the 162 bu/A average irrigated corn yield for the state of Nebraska from 1999 through 2002. The comparison is another illustration of the yield gap that exists between what is normally achieved and what today's germplasm can produce under proper management. Narrowing that yield gap requires use of the entire growing season by appropriate selection of hybrids and planting dates, establishing optimum plant populations, minimizing nutrient and pest stresses, and in irrigated systems, minimization of water stress. BC

Table 1. Impact of nutrient management and plant population on yield of irrigated corn following soybeans in Nebraska.

	Avg. of 1999-2002			Year 2003 only		
	Nutrient management			Nutrient management		
Population	M1	M2	Resp.	M1	M2	Resp.
plants/A	Grain yield, bu/A					
28-31,000	222	231	9	268	285	17
35-41,000	230	244	14	272	285	13
38-47,000	230	246	16	265	279	14

M1: UNL fertilizer recommendation for 200 bu corn except initial soil test levels were 70 parts per million (ppm) Bray P-1 (VH) and 350 ppm K (VH).
M2: Intensive management aimed at 300 bu/A yield goal ..higher N rate with 3 or 4-way split; P and K applied annually; S, Fe, and Zn in 1999 and 2000.
Soil: Kennebec silt loam.

Research Project No. NE-11F.

Dr. Walters and Dr. Dobermann are with the University of Nebraska, Department of Agronomy and Horticulture; e-mail: dwalters1@unl.edu.

Plant Population and Fertilization Impacts on Irrigated Corn in Kansas

By W.B. Gordon

A high-yield irrigated corn research project in north central Kansas was completed in the fall of 2003. Four years of data investigating the effects of fertilization...nitrogen (N), phosphorus (P), potassium (K), and sulfur (S)...rates and timing, and corn plant population have been collected. Some highlights of this research are shown in **Table 1**.

Results show a strong interaction between plant population and nutrient management, thus illustrating the importance of using a systems approach when attempting to increase yields. Increasing plant population failed to increase yield unless fertility was increased simultaneously, and a significant portion of the fertility response was lost if plant population was not increased. In 2003, over 60% of the response to increased fertility was lost at the lower population.

This 4-year study also reinforces the critical need for soil test calibration and nutrient management research that is conducted at high yield levels using cultural practices and varieties relevant to today's farming practices. The standard P+K+S recommendations at these two locations would not have produced maximum attainable yields. BC

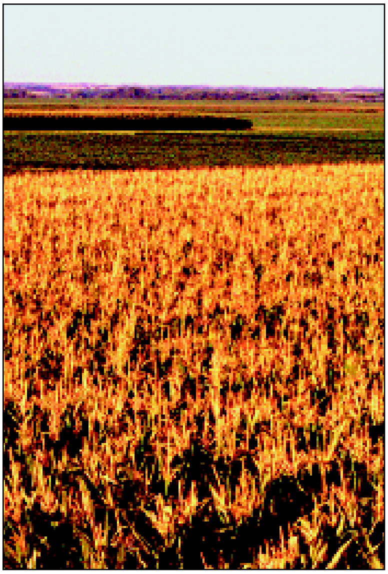
Research Project No. KS-33F.

Dr. Gordon is Professor, Department of Agronomy, Kansas State University, North Central Kansas Experiment Field; e-mail: bgordon@oznet.ksu.edu.

Table 1. Interaction between population and nutrient management for irrigated ridge-till corn in Kansas.

	$P_2O_5 + K_2O$ + S, lb/A[1]			
Population	N=2 splits 30+0+0[2]	N=2 splits 100+80+40[3]	N=4 splits 100+80+40[3]	P+K+S Resp.
plants/A	Grain yield, bu/A			
	Carr sandy loam, average of 2000-2002			
28,000	162	205	206	43
42,000	159	223	222	64
	Crete silt loam, 2003			
28,000	176	203	220	27
42,000	174	247	251	73

[1] Plus 230 lb N/A with 2 splits (preplant, V4) or 4 splits (preplant, V4, V8, VT).
[2] KSU recommendation. Carr site Bray P-1 = 20 parts per million (ppm), K = 240 ppm; Crete site Bray P-1 = 25 ppm, K = 180 ppm.
[3] Drop out comparisons showed all three nutrients contributed to the response in 2001-2002, but only P and K at the 2003 site.



Historic Morrow Plots Produce Their Highest Corn Yields in 2003

By R.E. Dunker

Established in 1876 and now the oldest experimental plots in North America, the Morrow Plots at the University of Illinois continue to provide important information on effects of nutrient management, crop rotations, and other production factors. Located in the center of the campus, the plots are seen by thousands of students and others every day, yet few really appreciate the significance of this campus cornfield.

In recent years, the divergence of yields for the different management systems has become dramatic. Highest yields are obtained on the plots with crop rotations. Top yields for plots fertilized with cow manure and those fertilized with commercial fertilizers are approximately the same, and topped 260 bu/A in 2003.

Table 1 illustrates the dramatic impact of crop rotation and fertilization on corn yields. Even in an excellent year like 2003, these two production factors had major effects on yield. These plots have been important to evaluate the long-term impact of fertilization on soil properties and crop yields across different rotations.

Mr. Dunker is Agronomist & Superintendent, Crop Sciences Research & Education Center, University of Illinois; e-mail: r-dunker@uiuc.edu.

Table 1. Impact of crop rotation and fertilization on corn yield in the Morrow Plots at the University of Illinois, 2003.

Treatment description	Crop rotation: Contin. corn	Crop rotation: Corn-oats-hay	Crop rotation: Corn-soybean
	- - - - - - - - Grain yield, bu/A - - - - - - - -		
No nutrients applied	59	164	104
Lime and N+P+K fertilizers since 1954	170	261	206

Morrow Plots on July 16, 2003 showing differences in tassel emergence.

International Section

This edition of *Better Crops with Plant Food,* which is published by PPI/PPIC, includes a section of international articles. Here's why: *Better Crops International* will no longer be published as a separate magazine. There are several reasons for this change, including efficiency and adapting to better serve the various audiences.

Better Crops International originated in 1985 and was typically published two times each year, going primarily to readers outside North America. Because *Better Crops with Plant Food* is published four times each year, international articles will now appear more frequently.

Better Crops with Plant Food has a long history and has continually adapted through the years to effectively deliver agronomic research information in a practical, interpretive style. We appreciate the ongoing interest of the thousands of readers of this magazine. The PPI/PPIC website (**>www.ppi-ppic.org<**) also offers ready access to current and past issues of *Better Crops with Plant Food,* available as PDF files.

Dr. Christian Witt Named Director of PPI/PPIC/IPI Southeast Asia Program

C. Witt

Dr. Christian Witt, a well known and innovative soil scientist, is the new Director of the reorganized Southeast Asia Program, effective February 1, 2004. Based in Singapore, this program is now being operated as a joint mission of PPI/PPIC and the International Potash Institute (IPI). The region includes Indonesia, Malaysia, the Philippines, Thailand, Myanmar, Laos, Vietnam, Cambodia, and Papua New Guinea.

"We are very happy that Dr. Witt has accepted this position. He is highly qualified for the responsibility and is already familiar with the challenges and opportunities in the region," said Dr. David W. Dibb, President of PPI. Dr. Adolf Krauss, Director of IPI, in Basel, Switzerland, joined in announcing the new operating arrangement.

Dr. Witt is a native of Germany. He received his B.S. and M.S. degrees at the University of Hamburg, then earned his Ph.D. in 1997 at Justus-von-Liebig University in Germany.

From 2000 through 2003, Dr. Witt worked as Affiliate Scientist in Soil Science with the Crop, Soil and Water Sciences Division, International Rice Research Institute (IRRI), in the Philippines. He served as coordinator of the workgroup "Reaching Toward Optimal Productivity" of the Irrigated Rice Research Consortium (IRRC). Dr. Witt is co-developer of the site-specific nutrient management approach in irrigated rice and developer of training and promotional material, including the standardized leaf color chart for nitrogen management. BC

Ginger Response to Potassium in Anhui Province

By Li Lujiu, Guo Xisheng, Gao Jiejun, Ding Nan, and Zhang Lin

The Huaibei plain in Anhui Province of Southeastern China is a major ginger production center. Ginger is a high income alternative for farmers and three years of research suggest a large opportunity cost when omitting potassium (K) from fertilizer recommendations.

Ginger is a root crop that is highly valued by China's people for its strong flavor and reported health benefits. Agronomically, ginger takes up large amounts of nutrients. One crop can absorb about 400 kg nitrogen (N)/ha, 145 kg P_2O_5/ha, and 950 kg K_2O/ha from the soil. This especially high K requirement makes ginger sensitive to low soil K supply. Nonetheless, ginger growers in southeastern China tend to rely on fertilizer sources that contain only N and phosphorus (P). As a result, available soil K levels in the region's ginger fields are dropping steadily and K imbalances have predisposed the crop to serious disease and insect damage.

Close-up view of ginger root tubers.

In addition to loss of root yield, crop quality is also reduced. Because K supply is inadequate, farm income is suboptimal and is reducing the viability of this normally highly remunerative crop. Proof regarding the benefits of balanced fertilization was needed in order to change fertilizer management practices and the cost (or lost income) of soil K deficiency on ginger production.

Replicated randomized complete block design (RCBD) small plot trials were conducted at three sites in Linquan County, Anhui. Basic soil properties for the sites are provided in **Table 1**. Six combinations of N and K were selected for trials at the Yangji and Tanpeng locations, while seven NK treatments were tested at the 'Farm' site (**Table 3**). The fertilizers used were urea, diammonium phosphate, and potassium chloride. Phosphorus was supplied at 90 kg P_2O_5/ha. All P and K were

Table 1. Basic soil properties of the three study sites, Anhui, China

			Available nutrients, mg/kg								
Year/Site	pH	O.M., %	K	N	P	S	B	Cu	Fe	Mn	Zn
1999/Yangji	6.1	0.82	66.5	26.4	8.6	14.2	0.32	1.9	12.2	11.0	1.9
2000/Tanpeng	6.4	0.57	70.4	12.0	24.9	8.8	nil	1.3	21.3	1.9	0.9
2001/Farm	6.2	0.57	77.2	15.0	40.1	3.6	0.48	2.9	84.3	83.3	1.5

Table 2. Effect of selected NPK treatments on growth characteristics of ginger, Anhui, China.

Treatments	Plant height, cm: Mid-growth stage	Plant height, cm: Harvest stage	Stem circumference, cm: Mid-growth stage	Stem circumference, cm: Harvest stage	No. of branches: Mid-growth stage	No. of branches: Harvest stage	Weight of top growth, g	Weight of tubers, g
Low N								
$N_{300}K_0$	43.5	61.8	5.0	5.1	6.1	6.3	75.0	329.3
$N_{300}K_{150}$	52.3	83.1	5.1	5.7	6.8	7.8	119.0	610.7
$N_{300}K_{300}$	54.0	86.9	5.3	6.6	7.8	9.6	130.0	609.0
Mid N								
$N_{375}K_{150}$	51.1	75.4	5.2	5.6	8.6	8.0	150.0	609.6
$N_{375}K_{300}$	54.2	80.2	6.5	6.6	8.3	8.4	176.0	548.5
$N_{375}K_{450}$	60.8	83.8	6.8	6.3	10.6	10.6	176.0	657.1

Phosphorus was supplied at 90 kg P_2O_5/ha.

applied basally, along with 60% of the N rate. The remaining N was top-dressed in two split applications. The local "lion-head" variety was germinated at the beginning of April, transplanted within the first 10 days in May at a planting density of 106,000 plants/ha, and harvested at the end of October.

Effect of K Application on Ginger Plant Growth

Potassium has an obvious growth promoting effect on ginger (**Table 2**). Plant height, stem circumference, number of branches, and tuber weight per plant greatly increased with increasing rates of N and K with the majority of high values resulting with 375-90-450 kg N-P_2O_5-K_2O/ha. Field notes indicated that leaf color was more vibrant and plant growth was vigorous and robust when K was supplied. Enhanced resistance to plant disease and insect infestation was also noted. For example, burnt leaf disease typically afflicts plants in the latter stages of growth, but was rarely observed when fertilized with NPK. Hence, the rates and frequencies of crop protection chemicals were substantially lowered for the period of study. As a result, profitability was increased.

Table 3. Yield response and economic benefit from NPK application in ginger, Anhui, China.

Year /Site	Treatments	Yield, t/ha	Increase, t/ha	Yield increase, %	Income increase, US$/ha
Yangji 1999	Low N				
	$N_{300}K_0$	39.9	-	-	-
	$N_{300}K_{150}$	53.3	13.4	34**	1,608
	$N_{300}K_{300}$	52.8	12.9	32**	1,548
	Mid N				
	$N_{375}K_{150}$	50.3	10.4	26**	1,248
	$N_{375}K_{300}$	51.9	12.0	30**	1,440
	$N_{375}K_{450}$	58.6	18.7	47**	2,244
Tanpeng 2000	Low N				
	$N_{300}K_0$	32.0	-	-	-
	$N_{300}K_{150}$	39.2	7.2	22*	864
	$N_{300}K_{300}$	42.3	10.3	32**	1,238
	Mid N				
	$N_{375}K_{150}$	38.2	6.2	19*	744
	$N_{375}K_{300}$	39.7	7.7	24*	924
	$N_{375}K_{450}$	43.2	11.2	35**	1,344
'Farm' 2001	Mid N				
	$N_{375}K_0$	31.2	-	-	-
	$N_{375}K_{375}$	42.9	11.7	38**	1,404
	$N_{375}K_{450}$	43.2	12.0	39**	1,440
	$N_{375}K_{525}$	42.9	11.7	38**	1,404
	High N				
	$N_{450}K_{375}$	43.7	12.5	40**	1,500
	$N_{450}K_{450}$	44.0	12.8	41**	1,536
	$N_{450}K_{525}$	41.9	10.7	35**	1,284

Phosphorus was supplied at 90 kg P_2O_5/ha.
*, ** Differences significant at the 5% and 1% level, respectively.

Ginger yield comparison.

Ginger Yield Response to K

As with crop growth characters, K fertilizer significantly affected yield (**Table 3**). At Yangji (1999), treatments increased tuber yields by 26 to 47% (34% average). At Tanpeng (2000), the range was 19 to 35% (27% average). At the 'Farm' site (2001), the range was 35 to 41% (38% average). In 1999 and 2000, yields stagnated as N rate was increased from the low to mid range and K was increased from 150 to 300 kg K_2O/ha. A better yield was achieved when the mid N level was combined with high K_2O (450 kg/ha), an indication of improved N to K balance. Mid N rate results in 2001 tended to agree with the two previous years and suggest no yield benefit from K application rates beyond 450 kg K_2O/ha. The high N regime tested in 2001 provided no clear evidence of a yield advantage beyond results obtained using the set of mid N treatments.

Farmer weighing harvested ginger tubers.

Ginger Production Economics

Based solely on the yield advantage, the economics of ginger production were greatly improved with balanced fertilization (**Table 3**). Compared to the farmer practice at Yangji and Tanpeng, income was increased by US$744 to US$2,244/ha, proving the value of investing in rational quantities of N, P, and K fertilizers. Maximum benefit at these sites was obtained with the mid N rate (375 kg N/ha) used in combination with 450 kg K_2O/ha. At the 'Farm' site, the high N rate along with 450 kg K_2O/ha proved most profitable. This result suggests a possible N limitation at the two other study sites. Inadequate and imbalanced nutrient input is allowing soil K deficiency to prevail in the ginger production areas of southeastern China and is the main barrier for growers to break through in order to move closer to maximum economic yield.

Rational use of K promotes ginger growth and tuber yield. The impact of balanced fertilization on the long-term viability of ginger production is clearly demonstrated in this research. BC

The authors are with the Soil and Fertilizer Institute, Anhui Academy of Agricultural Science, China. E-mail: lilujiu@yahoo.com.cn.

Balanced Fertilization Increases Cauliflower Yield and Marketability

By Feng Wenqiang, Tu Shihua, Liu Yinfa, Qin Yusheng, and Liao Minglan

Potassium (K) is the main yield-limiting factor, but proper levels of magnesium (Mg) and molybdenum (Mo) significantly increased cauliflower yield, farmers' net income, and product marketability. This technology should be extended to all vegetable growers on the Chengdu plain.

Cauliflower showing K deficiency symptoms.

Located on the Chengdu plain in Sichuan Province, Pengzhou County has a long vegetable growing history. Over the last two decades the region has been developed into a national vegetable production base. Soils on the Chengdu plain are characterized by light texture and low K content. Vegetable growers have tended to use nitrogen (N) and phosphorus (P) fertilizer, but apply little or no K in their fertilization programs. This imbalance is intensifying soil nutrient deficits and is severely limiting productivity in the region. Cauliflower is a popular vegetable having a strong traditional market and acceptance by consumers and high economic returns to the farmer. However, cauliflower yield and quality are sensitive to low soil K supply. Hence, the region would benefit from a fertilizer management plan that provides optimal soil K availability.

A replicated field experiment conducted in Li'an township used seven treatments based on soil analyses supplying one rate of N and P fertilizer and various combinations of K, Mg, boron (B), and Mo (**Table 1**). Nitrogen and K were applied basally in four splits at pre-seeding, seeding, flower bud emergence, and flower head peak growing stage. Ammonium molybdate [$(NH_4)_6Mo_7O_{24}$] was applied as a foliar spray during flower bud emergence.

Table 1. Plant nutrients applied in the different treatments (kg/ha) in Pengzhou, Sichuan.

Treatment	N	P_2O_5	K_2O	Mg	B	Mo
1	207	75	-	-	-	-
2	207	75	225	-	-	-
3	207	75	450	-	-	-
4	207	75	225	-	7.5	-
5	207	75	225	-	-	20
6	207	75	225	29.4	-	-
7	207	75	225	29.4	7.5	20

Nutrient sources were urea, single-superphosphate (SSP), potassium chloride (KCl), magnesium sulfate ($MgSO_4$), borax, and $(NH_4)_6Mo_7O_{24}$.

Yield and Income Benefits

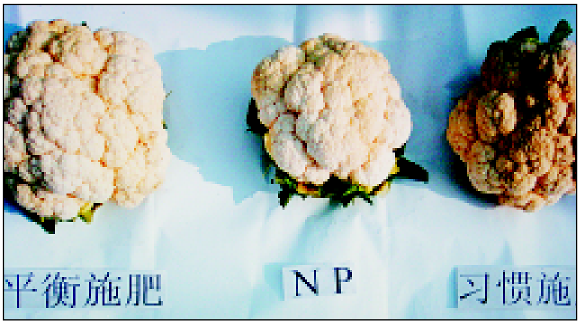
Results found that K fertilizer was the most yield-limiting factor for cauliflower (**Table 2**). Yield increased

Table 2. Effect of balanced fertilization on cauliflower yield and profitability, Sichuan, China.

Treatment	Yield[1], t/ha	Yield increase, %	Cost of fertilizer, $US/ha	Net profit, $US/ha
1	17.6c	0	122	4,165
2	29.1b	65.3	186	6,903
3	29.9ab	69.9	250	7,034
4	29.2b	65.9	188	6,925
5	29.4ab	67.0	186	6,976
6	29.6ab	68.2	223	6,988
7	30.3a	72.2	225	7,156

[1] Means with the same letters are not significantly different at p=0.05 level. $LSD_{0.05}$=0.8
The cauliflower variety was Donghua, planted at a density of 33,800 plants/ha.

with K application rate up to 225 kg/ha, beyond which yields changed little and higher production costs reduced the net return. Individually amongst the nutrients applied, B had the least impact on yield while the effects of Mg and Mo were greater. A maximum yield was obtained with the complete treatment supplying N, P, K_{225}, Mg, B, and Mo.



Cauliflower heads in storage as affected by balanced fertilization. Result in farmers' practice is shown at right, NP in center, and balanced treatment at left.

Marketing Benefits

Potassium application produced large increases in plant height and head weight and diameter (**Table 3**). However, compared to plants receiving NPK_{225}, the addition of B, Mg, and Mo fertilizers, either separately or in combination, appeared to enhance these marketable plant characteristics even more. Total plant biomass was definitely affected by K, although similar advantage from the complete treatment was less apparent.

Potassium fertilizer prolonged product shelf life and reduced moisture loss from harvested heads. Compared to NP alone, NPK_{225} increased shelf life by six days. When B, Mo, or Mg fertilizer was applied individually, a further 1 to 4 days of storage time resulted. The complete treatment provided an additional 6 days (27 in total) and moisture loss was substantially minimized. These two traits are very important when considering their impact on transportation and consumer appeal, thereby ensuring premium prices.

Table 3. Effect of balanced fertilization on cauliflower marketability, Sichuan, China.

No.	Plant height, cm	Head weight, g	Head diameter, cm	Biomass, t/ha	Shelf life, days	Moisture loss[2], %
1	45.8	530	10.1	36.8	15	20.5
2	61.5	870	12.8	79.6	21	15.2
3	61.9	910	13.6	81.2	21	14.7
4	61.4	880	13.0	79.9	22	15.1
5	62.3	880	13.3	81.1	25	14.8
6	62.0	900	13.3	81.6	25	14.0
7	62.6	920	13.8	81.8	27	11.2

[1] Shelf life refers to the number of days after harvest until vegetables turn brown or rot.
[2] Amount of moisture lost during storage.

Field Demonstration Program Results

As part of an extension program designed to transfer the research results into farmer practice and increase community awareness on the benefits of balanced fertilization, six farmers'

Cauliflower with balanced fertilization at left compared to NP treatment at right.

Table 4. Demonstrating the effect of balanced fertilization (BF) on cauliflower yield, Sichuan, China.

Household	Treatment	Yield, t/ha	Yield reduction vs. BF ±%
Zhang Huaifu	BF[1]	40.5	–
	FP_1[2]	35.4	-14.4
	FP_2[3]	30.9	-31.1
Zhang Huaitian	BF	30.1	–
	FP_1	25.0	-20.3
	FP_2	30.7	+1.8
Zhang Huaitian	BF	39.8	–
	FP_1	30.7	-21.9
	FP_2	35.4	-12.6
Liu Yonghuai	BF	31.8	–
	FP_1	25.4	-25.1
	FP_2	28.2	-12.8
Liu Yonghuai	BF	42.9	–
	FP_1	34.7	-23.7
	FP_2	39.1	-9.8
Liu Zhonghan	BF	43.9	–
	FP_1	36.0	-22.2
	FP_2	39.4	-11.6

[1] 112.5, 90, and 22.5 kg K_2O/ha (KCl) applied basally, at flower bud emergence, and at flower head peak growth, plus 1,500 kg slaked lime/ha, 30 kg Mg/ha ($MgSO_4 \cdot 7H_2O$) applied basally, and 750 kg 0.05% $(NH_4)_6Mo_7O_{24}$ as foliar spray at flower bud emergence stage.
[2] 41, 62 and 104 kg N/ha as urea applied basally, flower bud emergence, and flower head peak growth, respectively, plus 90 kg P_2O_5/ha (SSP) applied basally.
[3] 750 kg 15-15-15/ha applied basally plus 128 kg N/ha (ammonium bicarbonate) at flower bud emergence.

field demonstration trials were established throughout the county to contrast balanced fertilization (BF) with two farmer practices (FP_1 and FP_2) (**Table 4**).

Five out of six demonstration trials found that farmers' fertilizer practices produced far less yield (from -9.8 to -31.1%). In the majority of cases, FP_1 (i.e., NP fertilization) produced lower yields than FP_2 which used a 15-15-15 compound fertilizer and ammonium bicarbonate as part of the fertilization package. Reliance on these two fertilizer sources is largely based on product availability and not the conditions of the site. It is apparent that common farmer practice supplies an imprecise nutrient prescription which is not matched to the region's soils or the nutrient demands of cauliflower.

Conclusions

Field experiments on the Chengdu plain found K to be the main yield-limiting factor, although Mg and Mo deficiencies significantly affected cauliflower quality factors. Balanced fertilization can significantly increase cauliflower yield, marketability, and farmers' net income. Extension of this technology to vegetable growers in southwestern China will raise farmer income and further improve the region's reputation for producing quality vegetable produce. BC

Mr. Feng Wenqiang is Associate Professor, Mr. Qin Yusheng, and Ms. Liao Minglan are Assistant Professors, Soil and Fertilizer Institute, Sichuan Academy of Agricultural Sciences, Chengdu, China. Liu Yinfa is Technician in vegetable management in Pengzhou County. Dr. Tu is Deputy Director, PPI/PPIC China Program; e-mail: stu@ppi-ppic.org.

Potassium Responses Observed in South Australian Cereals

By Nigel Wilhelm and Jonnie White

Recent field trials in the dryland cropping region of South Australia have demonstrated that unrecognized potassium (K) deficiencies have the potential to severely limit yields.

Potassium deficiency is not currently recognized as a problem in the dryland cropping regions of South Australia. However, the 2001 National Land and Water Resources Audit reported that the region had a highly negative K balance (that is, much more K is exported off-farm in produce than is replaced in fertilizer). Recently it has become apparent that, on some soil types, poor growth of cereal crops may be attributable to K deficiency. In 2002, the South Australian Research and Development Institute (SARDI) established an experimental site in a farmer's field near Laura in the mid North region of South Australia to examine the extent to which cereals may respond to K. The experimental site was on an undulating field with a duplex soil (sandy loam topsoil over a clay loam to clay, calcareous subsoil) and an average annual rainfall of 470 mm. Three field trials were established to test: 1) K rate response, 2) NxPxK interaction, and 3) K application method.

Soil chemical properties from each individual trial area are shown in **Table 1**. Wheat was no-till sown in June and harvested in December 2002. The 2002 season was particularly dry. However, growth of wheat in the trials appeared quite vigorous in the high K treatments. The best treatment at the site yielded 2.78 t/ha, comparable to the region's yield potential based on the amount of rain received.

Rate Response Trial This trial received basal applications of 56 kg nitrogen (N)/ha, 46 kg P_2O_5/ha, 15 kg sulfur (S)/ha, and 1 kg zinc (Zn)/ha. Eleven rates of K (between 0 and 180 kg K_2O/ha) were applied as muriate of potash (MOP) drilled under the seed row at planting.

Table 1. Soil chemical properties measured from trial areas at the Laura site, South Australia.

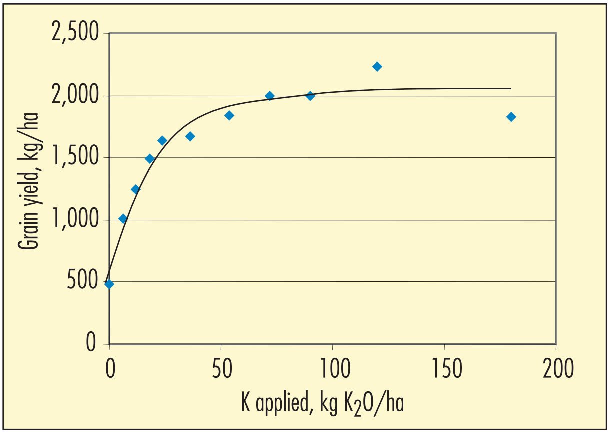
	Rate response trial		Application trial		NxPxK trial	
Parameter	0-10 cm	10–20 cm	0-10 cm	10–20 cm	A horizon	B horizon
Water pH	7.3	8.1	6.2	6.8	6.6	8.0
Colwell K, mg/kg	45	46	121	53	42	69
Colwell P, mg/kg	27	17	25	16	16	5
Nitrate N, kg/ha	20	11	11	6	4	3
Sulfur, mg/kg	12	11	14	7	6	23
Exchangeable Ca, meq/100 g	5.8	8.5	4.9	5.8	4	11.6
Exchangeable Mg, meq/100 g	0.5	0.5	0.4	0.7	0.4	1.7
Exchangeable Na, meq/100 g	0.10	0.08	0.10	0.06	0.04	0.09
Exchangeable K,meq/100 g	0.13	0.07	0.08	0.14	0.11	0.18
Walkley-Black organic carbon, %	1.4	1.0	1.6	1.0	0.9	0.7

Wheat at tillering, grown with 0 (left) and 120 kg K_2O/ha (right).

Establishment was not affected by the rate of fertilizer K. Early growth was poor on plots without K fertilizer, with plants being paler, weaker, and poorly tillered compared to those grown with a high rate of K (**see photo**). Dry weight of shoots at tillering increased markedly with K. Without K, shoot dry weights were only 190 kg/ha, but increased to more than 700 kg/ha with high rates of K fertilizer. The K concentration of the youngest emerged leaf blades (YEB) at tillering also responded, with maximum dry weight of shoots not obtained until YEB K concentrations were approximately 2%, consistent with published critical values for wheat. The concentration of copper (Cu), Zn, manganese (Mn), and boron (B) in YEB were largely unaffected by rates of K, but the concentration of all other nutrients increased where plants were stunted by K deficiency. This was especially true for calcium (Ca), magnesium (Mg), and sodium (Na), for which concentrations increased by 0.8, 1.7, and 15 times, respectively, from the 180 kg K_2O/ha to nil treatments.

Grain yield was severely affected by K deficiency in this trial. Plots without K yielded less than 500 kg/ha on average, while high rates of K increased yields to more than 2,000 kg/ha (**Figure 1**). While high rates of K were necessary to maximize grain yield, even 6 kg K_2O/ha doubled yield compared to the nil treatment. A Mitscherlich fit of grain yield against rates of applied K estimated that 40 kg K_2O/ha was necessary to achieve 90% of maximum yield. The rate of K had little impact on grain protein. Average protein content for this trial was 9.6%, suggesting that the 56 kg N/ha applied was barely sufficient for normal growth and yield of wheat. The proportion of grain passing through a 2 mm sieve (or screenings percentage) increased at K application rates that resulted in very low yields (less than 24 kg K_2O/ha), suggesting that grain yield is more sensitive to K deficiency than grain size.

Figure 1. Grain yield in response to K application in the rate response trial.



Application of K at seeding had no effect on the concentration of K in grain, with an average of 0.45% across the trial. Given on-farm wheat prices in 2002 of A$210/t for APW grade grain, application of K fertilizer at A$450/t would have been highly economical, even at rates above those required for 90% maximum yield. Assuming grain from all treatments had made APW grade, **Table 2** indicates gross income from grain, value of K fertilizer applied, net income after K fertilizer costs, and return per K fertilizer dollar invested. In this year, net income per hectare was maximized at 120 kg K_2O/ha.

NxPxK Interaction Trial This split-plot trial comprised one of five N+phosphorus (P) fertilizer combinations (15N + 23P_2O_5, 15N + 46 P_2O_5, 56N + 23 P_2O_5, 56N + 46 P_2O_5 and 112N + 46 P_2O_5) making up main plots and K applied to sub plots at 0, 60, or 120 kg K_2O/ha as MOP drilled below the seed at planting. This trial also received basal S and Zn applications. Shoot dry weight increased markedly with K fertilizer applied at 60 kg K_2O/ha, but doubling the rate of applied K caused no further increase in shoot weights. A similar response was measured for grain yield (**Figure 2**). Unfortunately, no plant data were available for K_2O applied at 100 kg/ha with the highest rate of N application. Increasing rates of N or P did not improve shoot weights or grain yield unless K had also been applied.

The concentration of K in the YEB at tillering also responded to K application. Without added K, YEB concentrations were very low (1.2% or less). In contrast, all plots receiving K had YEB K concentrations above 2%, except for those with the highest N application (1.9%). This may suggest that 60 kg K_2O/ha was not sufficient where N had been applied at the highest rate. In this trial, grain protein decreased where K was applied, presumably due to a dilution of the available N over a larger grain yield. Increasing the rate of applied N resulted in higher protein content, and P application rate had no effect. The lowest grain protein in the trial (8.9%) occurred with low N, low P, and the highest K rate. The highest grain protein (12.7%) occurred with the highest rates of N and P, and 60 kg K_2O/ha.

Application Method Trial This trial received the same basal nutrient applications as the rate response trial. Potassium was applied as MOP either drilled below the seed at planting (13 kg or 60 kg K_2O/ha), broadcast prior to seeding (60 kg K_2O/ha), broadcast at tillering (60 kg K_2O/ha) or a split application drilled at seeding and broadcast at tillering (30 + 30 kg K_2O/ha)

Establishment was not affected by any of the application techniques used. However, tillering shoot dry weights and K concentration in the YEB were higher where K had previously been applied. Broadcast K at tillering was applied onto dry soil and

Table 2. The economics of K application at the Laura site in 2002, South Australia.

K_2O rate, kg/ha	Gross income, A$/ha	K fertilizer cost, A$/ha	Net income after K fertilizer, A$/ha	Return on K fertilizer, A$ gained/A$ spent
0	96	0	96	-
6	214	5	209	25
12	269	9	260	18
18	314	14	300	15
24	351	18	333	13
36	352	27	325	8
54	396	41	355	6
72	429	54	375	5
90	422	68	354	4
120	468	90	378	3
180	387	135	252	1

little rain fell for the next four weeks. During this time, MOP granules were still evident on the soil surface.

Banding 60 kg K_2O/ha below the seed at planting resulted in the highest grain yield of 2,000 kg/ha. Banding produced 320 and 840 kg/ha more grain than the same rate of K either broadcast before seeding or at tillering, respectively (**Figure 3**). The split application was almost as effective as the same amount of product all banded at seeding. Grain yield was 1,000 kg/ha where no K was applied. This was double the yield of plots without K in the other two trials, presumably due to the inherently higher soil K in this part of the experimental site.

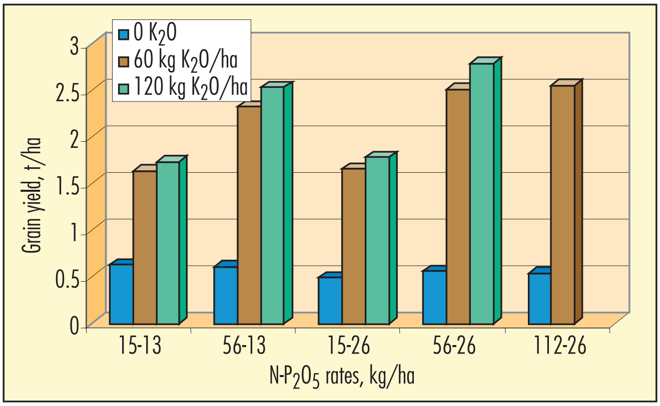


Figure 2. Grain yield in response to the application of K at various N and P rates.

Conclusions

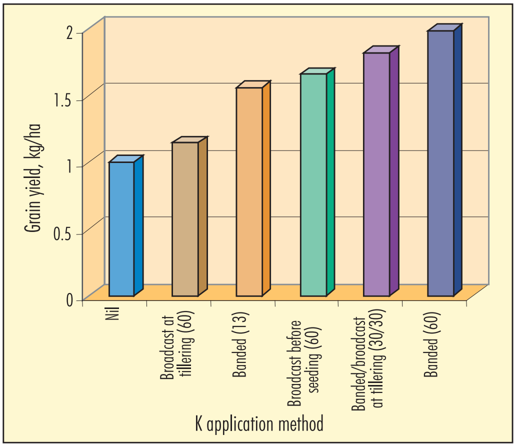
Severe K deficiency was confirmed in these trials, with yield and grain quality markedly improved by K fertilization. Rates of at least 60 kg K_2O/ha were necessary to fully correct K deficiency and produce maximum grain yield of acceptable quality. However, the basal rate of N used (56 kg/ha) was insufficient to avoid N deficiency, as demonstrated by low grain protein, and so a higher rate of K may have been required if adequate N was supplied.

Tools for diagnosing K deficiencies include soil and plant analysis and identification of visible plant deficiency symptoms. In these trials, plants deficient in K were weak, pale, had few tillers and showed signs of chlorosis on the tips and margins of older leaves. **Wheat in soils with levels of up to 120 mg/kg of bicarbonate extractable (Colwell) K responded markedly to K application**, well above the 50 to 60 mg/kg considered adequate for normal wheat production in the sandy soils of Western Australia, suggesting that critical levels for K may need to be revisited. On the other hand, it appeared that published critical values for K concentration in the YEB at tillering were consistent with responses observed in this trial.

Banding K fertilizer below the seed row at planting was the most effective application method. Broadcasting at tillering was ineffective, partly because of dry weather for a long period after application. BC

Dr. Wilhelm is with the South Australian Research and Development Institute. Dr. White is with Agrow Australia and Canpotex; e-mail: jrwhite@bigpond.net.au.

Figure 3. Grain yield in response to K application technique (amounts shown in brackets, kg K_2O/ha).



COMMITMENT

Pat and I had dinner this past Thanksgiving with Donna, her family, and a few other friends. It was the second time we have accepted Donna's invitation to join them, although she has asked us to come every year since our house was built here on Amelia Island.

Why am I telling you this? Because Donna was our builder. And she built the houses for other families in the neighborhood who were also guests at the dinner. It strikes me as something special that we all continue to maintain such a good relationship with her family. The reason is simple. Donna is a talented builder, and she is totally committed to her homeowners. She is also involved in the local community and is widely recognized for her commitment to excellence and her willingness to serve others.

In today's world, some corporations make headlines in the news media because of their upper management ripping off employees, stockholders, and customers. Donna took a different approach and, as a result, has become highly successful and respected over a relatively short period of time. She has done it because she is committed to hard work and stands behind her product. On a smaller scale, her business principles reflect those of the companies that support the Potash & Phosphate Institute (PPI).

The Institute, now in its 68th year, is recognized worldwide for its excellence and integrity in scientific agronomic market development. Although it has been supported all these years by fertilizer companies, it stands as a highly respected organization that provides unbiased scientific information to agriculture.

The Institute's member companies are competitors, each working for market share and decent profits. Individually and collectively they are respected industry leaders. A common bond and a measure of their commitment to customers is their support of PPI. Through good and bad times alike, they have stood firm in that support. Adjustments have been made to accommodate existing economic environments, but the commitment has endured for 68 years and continues.

Commitment to excellence characterizes Donna's company and each of the PPI members. They all deserve a tip of the hat for the contributions they make to their respective industries and to local and world society as well.

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

Periodicals Postage