BETTER CROPS WITH PLANT FOOD

1995 Number 1

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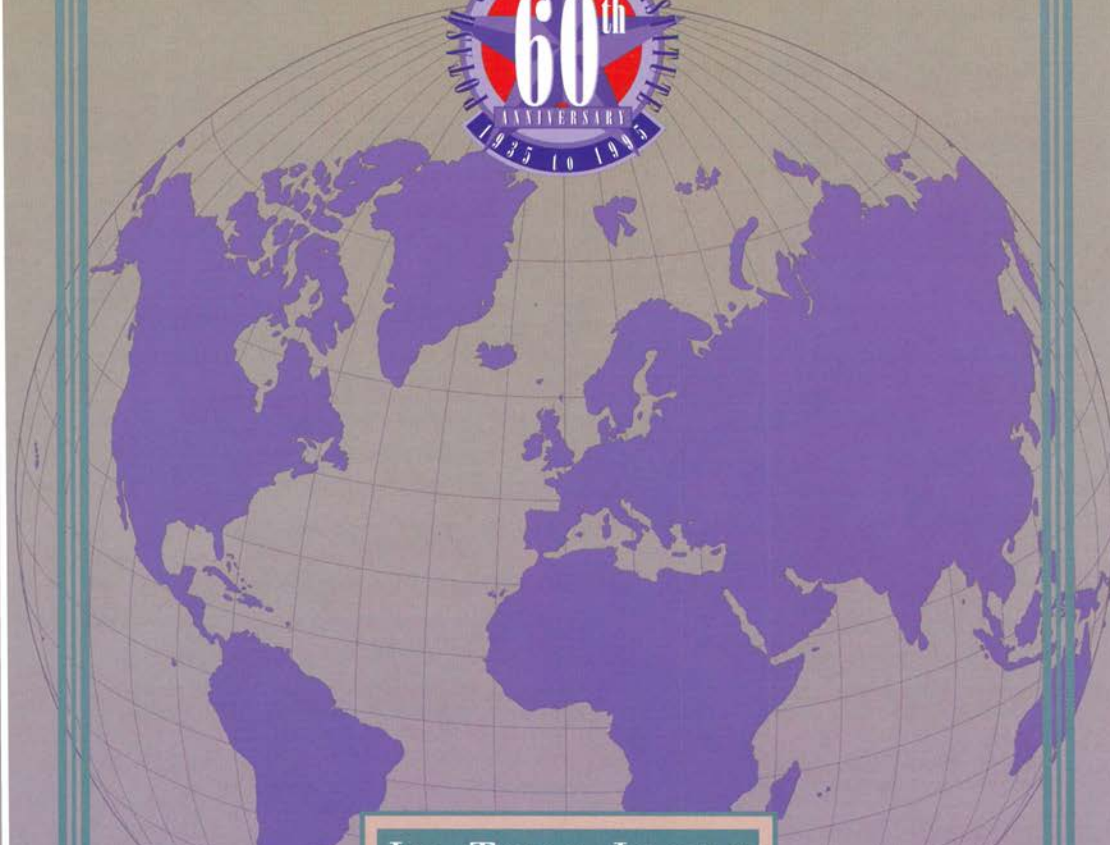

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BETTER CROPS
WITH PLANT FOOD

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Our Cover: PPI was founded in 1935 and observes its 60th year in 1995.

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Better Crops is Changing... But it's Still the Same

Beginning with this issue, ***Better Crops with Plant Food*** *(BC) and* ***Better Crops International*** *(BCI) are being combined into one magazine. There are several reasons why PPI has chosen to consolidate the publication of our two BCs.*

Up to now, BC featured articles mainly from North America; BCI highlighted research from the rest of the world. We believe that many crop production principles and concepts cross geographic and political boundaries. Combining the BCs allows us to introduce new technology to a broader audience base. Further, BCI was published only twice each year. The new BC will offer quarterly information updates to our international readers.

And, that leads me to the final reason for combining BC and BCI. PPI is truly a more international organization. We feel the new BC best reflects this change by carrying articles of interest on new technology from around the world.

During 1995, PPI will be observing its 60th year. BC has been a part of the Institute since the beginning in 1935. Indeed, it preceded PPI by 12 years, first being published in September of 1923. In 1927, BC was combined with ***Plant Food****, which was begun in Holland a year earlier. That combination was only the first of many changes that BC would undergo during the next 68 years...the joining of BC and BCI being the latest.*

One thing that has not changed is PPI's dedication to publishing a science-based, unbiased accounting of soil fertility, plant nutrition and crop growth technology innovations. In the first year of PPI, 1935, editorial policy of BC was stated as follows:

> ***"To stimulate interest in all factors pertaining to more efficient crop production and to give accurate information on such subjects. In developing more efficient agriculture, we believe one of the most important factors is sound research..."***

That policy has not changed. We are still committed to giving our readers quality and accuracy. As you adjust to the new BC, its format and content, we hope you feel this most recent change is for the better. Let us hear from you.

B.C. Darst
Executive Vice President

1995

C.E. Childers Elected Chairman, John U. Huber Vice Chairman of PPI and FAR Boards of Directors

Charles E. (Chuck) Childers, Chairman, President and CEO of the Potash Corporation of Saskatchewan Inc. (PCS), has been elected Chairman of the Potash & Phosphate Institute Board of Directors. He will also serve as Chairman of the Foundation for Agronomic Research (FAR). John U. Huber, President, Kalium Chemicals, Ltd., is the new Vice Chairman of the PPI and FAR Boards.

C.E. Childers

"We are happy that these industry leaders accepted these key responsibilities with the PPI and FAR Boards," said Dr. David W. Dibb, President of PPI.

Mr. Childers became President and Chief Executive Officer of PCS in Saskatoon, Saskatchewan, Canada in March of 1987. He was elected Chairman in 1990. Mr. Childers has served as Chairman of Canpotex Limited, the offshore marketing company owned by Saskatchewan potash producers. He also served on the Board of Saskatchewan Potash Producers Association, including two terms as Chairman. He was appointed to the Council as well as Chairman of the Finance Committee of the International Fertilizer Industry Association (IFA).

Mr. Childers was born in West Frankfort, IL, and graduated from the University of Illinois with a Bachelor of Science Degree in Mine Engineering.

Mr. Childers is Vice-Chairman of the Fertilizer Industry Advisory Committee (FIAC) to the Food and Agriculture Organization of the United Nations and is Past-Chairman of the Board of The Fertilizer Institute (TFI). He is a member of the Board of Directors of QUNO Corporation and Battle Mountain Gold Company.

In October 1994, Mr. Childers received an Honorary Doctor of Law Degree, conferred by the University of Saskatchewan in recognition of his service, leadership and contributions to the local and world communities.

Mr. Huber was named President of Kalium in 1991, soon to be followed by appointment to President of Phoenix Chemical Company in East Dubuque, IL, a nitrogen production facility, and in 1993, Executive Vice President of Kalium and Phoenix' parent, The Vigoro Corporation. He currently serves as Chairman of the Board of Directors of the Canadian Potash Export Association (Canpotex).

Born in rural Saskatchewan, Canada, Mr. Huber earned a degree in Chemical Engineering from the University of Saskatchewan.

Throughout the 1960s and mid-70s, Mr. Huber served in various supervisory positions at Kalium. In 1975, he was named Plant Manager of the company's main potash facility, and, over the next 15 years, held various management positions including General Manager-Canadian Operations and Vice President of Sales.

John U. Huber

In other action of the PPI Board, Mr. P. Rodney Wilson, Vice President, General Manager, of Texasgulf Phosphates, was elected chairman of the Finance Committee. Mr. Joseph Hausback of Cargill, Incorporated and Mr. James Nelson of New Mexico Potash were named to the PPI Board. New members of the FAR Board are Mr. Steve Dewey of AlliedSignal, Dr. Ray Hoyum of Western Ag-Minerals and Dr. Julian Smith, representing the Fluid Fertilizer Foundation. ■

PPI Announces Ignacio Lazcano-Ferrat as Director for Mexico and Northern Central America

IGNACIO LAZCANO-FERRAT has joined the PPI staff as Director, Mexico and Northern Central America. He is responsible for the agronomic research and education programs of the Institute in the region.

Ignacio Lazcano-Ferrat

"We are enthusiastic about the new opportunities developing in Mexico and Central America," said Dr. David W. Dibb, President of PPI. "Ignacio is very well qualified to direct the efforts of PPI in the area. His diverse background and knowledge of production agriculture will be valuable."

Born in Celaya, Guanajuanto, Mexico, Mr. Lazcano-Ferrat studied agronomy in Querétaro. He worked for the National Commission for the Sugar Industry, with responsibility for sugar beet and sugarcane experimental plots in Baja California and the Sinaloa Valley. He designed and supervised improved sampling and analysis techniques for sugar production.

Mr. Lazcano-Ferrat earned a masters degree in plant sciences at the University of California, Riverside, in 1987 and is currently completing the final requirements for his Ph.D. degree in plant physiology at the same university.

Since 1992, his experience includes responsibility in the food technology department of the university in Querétaro and more recently with the University of Celaya, promoting applied plant nutrition in the "El Bajio" area of Mexico.

The PPI program in Mexico and northern Central America will work closely with the INPOFOS office already established in Quito, Ecuador, under the direction of Dr. José Espinosa.

Mr. Lazcano-Ferrat will be based in Querétaro, north of Mexico City. ■

Site-Specific Integrated Crop Management Systems Conference Set for June 26-30, 1995

PPI is coordinating a Site-Specific Integrated Crop Management Systems Conference scheduled for June 26-30, 1995 in Champaign, IL. Special pre-conference workshops June 26-28 will focus on technology related to site-specific management, with the main conference on June 28-30.

Co-sponsors for the conference include the Foundation for Agronomic Research, the National Center for Supercomputer Applications, the University of Illinois, the CC Net Agriculture Committee, The Fertilizer Institute, the Agricultural Retailers Association, the Illinois Fertilizer & Chemical Association, and possibly others.

The program will include invited speakers on a variety of related topics, volunteer poster papers (June 28-29), indoor and outdoor exhibits of site-specific technology and applications, field and laboratory tours, equipment demonstrations, and small group discussions. The intended audience includes researchers and educators working on site-specific management systems, agribusinesses involved in the development and implementation of site-specific systems, and farmers and their advisers who are interested in learning more about site-specific management systems.

Participants may use this conference to obtain continuing education (CEU) credits for the Certified Crop Adviser Program. Details on CEU credits will be included in the registration materials.

For program details and registration information, contact the Potash & Phosphate Institute, 2805 Claflin Road, Manhattan, KS 66502 to request this information. Phone (913)776-0273, fax (913)776-8347. ■

Food for the Future–PPI's Role in Influencing Plant Nutrient Management

By David W. Dibb

Sustainability is one of the most compelling issues in agriculture. One of PPI's roles is to demonstrate that nutrient management, including the phosphorus (P) and potassium (K) supplied by commercially produced fertilizers, is a key component of sustainability.

SOME would define sustainability as simply maintaining production indefinitely at current levels. An even more restricted definition would be to accept and maintain some lower level of productivity indefinitely . . . since many simply equate sustainability with less inputs. PPI agrees with those who believe that true sustainability must include increasing production to meet the expanding food, fiber and fuel needs of a continually increasing global population.

The fact that a significant segment of the world population is currently not receiving an adequate diet must be a part of the sustainability equation. There are literally hundreds of millions of people . . . over 20 percent of the world's population by some estimates . . . who would upgrade their diets, above some "minimum level of adequacy," given the opportunity.

Population Growth

World population must be one of the major considerations in sustainability. Recent projections shown in **Table 1** indicate population will exceed 6 billion people by the year 2000 and 8.3 billion by the year 2025. Others estimate it will stabilize at 10 billion by 2100.

Table 1. World population and arable land trend estimates.

Year	Population, millions	Arable land, million hectares	Hectare/ person
1965	3,027	1,380	0.46
1980	4,450	1,500	0.34
1990	5,100	1,510	0.30
2000	6,200	1,540	0.25
2025	8,300	1,650	0.20

To put the population increase into a clearer perspective with regard to agricultural sustainability, over the next 10 years food will be required for nearly 100 million additional people per year, just to stay even. That is equivalent to adding about four Canadas each year. Perhaps even more striking is the thought that tomorrow morning there will be approximately 250,000 additional mouths to feed.

. . . in most developing countries . . . the greatest environmental degradation and human suffering clearly come from inadequate and imbalanced nutrient use and not from over-application.

One of the major problems related to this population increase is that about 90 percent of it will be in developing countries where there is already a deficit of food. Considerable debt in many of these countries precludes the purchase of needed food and presents a major problem in developing the resources necessary to improve agriculture.

Consumption Growth

Table 2 lists global food production in 1990 at about 4.6 billion gross tonnes. Over 90 percent of the human diet was direct plant products. If per capita food consumption were to remain constant, the 8.3 billion people in the year 2025 would require an additional 2.6 billion gross tonnes of food production, almost a 60 percent increase. But, over one billion people have marginal diets which, if improved to adequate levels, would

Dr. Dibb is President of PPI, located in Norcross, GA.

Table 2. World food production, 1990.

	Million tonnes production			
	Gross tonnage	Edible matter[1]	Dry protein[1]	Increase, % 1980-90[2]
Cereals	1,970	1,640	165	20
Roots and tubers	575	154	10	5
Legumes, oilseeds, nuts	300	204	68	29
Sugarcane and sugar beet[3]	125	125	0	20
Vegetables and melons	450	53	5	26
Fruits	345	47	2	17
Animal products	850	168	74	24
All food	4,615	2,390	397	20

[1]At zero moisture content, excluding inedible hulls and shells
[2]1979-81 and 1989-91 averages used to calculate changes
[3]Sugar content only Source: 1990 FAO Production Yearbook

require a 100 percent increase in production to nine billion tons, or a steady increase of 2 to 2.5 percent per year.

Yield Increases: The Challenge

The United Nations Food and Agriculture Organization (FAO) estimates that only 24 percent of future food needs can come by putting new land into production. The remaining 76 percent will have to be produced by increasing crop yields on currently farmed lands.

Taking into account a modest increase in arable land, the area per person will decrease about one-third to 0.20 ha by the year 2025 (see **Table 1**). In China, the average is already down to 0.09 ha/person in 1993. This means that average yield per hectare will have to increase at least 65 percent to meet projected food needs at the nine billion gross tonnage level cited earlier. While this seems a daunting task, there are reasons to believe that such increases can be achieved.

Table 3. Highest U.S. average vs. reported world yields (tonnes/hectare) for selected crops.

Crop	Highest U.S. average (Year)[1]	Developing countries[2]	Reported world record[3]
Corn	8.4 (1994)	1.3	21.2
Soybeans	2.7 (1994)	1.3	7.9
Wheat	2.7 (1990)	1.6	14.5
Sorghum	4.1 (1992)	0.9	21.5
Potatoes	36.6 (1993)	9.1	94.2

[1]USDA data; [2]Wortman & Cummings; [3]PPI Survey

One reason is that average crop yields are well below the levels that have been reached in high yield trials around the world. This includes developed, as well as developing agriculture, as shown in **Table 3**. Another reason is that where technology has been applied, increases have exceeded the increases needed in the projection noted. Still another is that recent yield projections for the U.S., made by U.S. Department of Agriculture (USDA) economists for four key grain crops, are in line with yield increases that will be needed.

Yield Increases: The Process

Decades of agricultural research have provided the foundation for today's yields. Since agriculture is a dynamic system, continuous yield-enhancing research must be a high priority. Much of the technology applied to increase yields two or three times in China, the U.S., India, and other countries, was developed 10, 20 and 30 years ago.

A disturbing trend, however, is that investments in agricultural research are declining dramatically. Agronomy departments in the U.S. are being dissolved, international research centers are losing funding and the developed countries are cutting back on agricultural technology aid to developing countries (in PPI we struggle with budget because of industry changes at a time when PPI's role in encouraging practical production research is even more important). All of this decreased investment in research is occurring at a time that is critical to the development of the new scientific facts that will have to be the foundation of yield breakthroughs 20 or 30 years from now.

Even FAO, which is viewed as the advocate of food production in the world, is under considerable pressure to shift its emphasis from food production to environmental concerns. This is a sad situation

Table 4. Balanced fertilization increases crop yields in India.

Crop	Season, condition[1]	Number of trials	$N-P_2O_5-K_2O$ kg/ha	Percent yield response to: N	NP	NPK
Rice	K,U	380	120-60-40	49	74	99
Rice	K,I	9,634	120-60-60	27	51	56
Rice	R,I	5,686	120-60-60	28	51	53
Wheat	R,I	10,133	120-60-60	59	95	114
Corn	K,U	53	90-60-60	85	107	129
Chickpea	R,U	1,325	20-40-20	36	59	77

[1]K=Kharif, R=Rabi (seasons); I=irrigated; U=unirrigated

because in most developing countries, where FAO has its mandate, the greatest environmental degradation and human suffering clearly come from inadequate and imbalanced nutrient use and not from over-application.

Nutrients: Supply and Balance

One factor that is closely and directly correlated to yield increases and total production is nutrient supply. Nutrient source, whether organic or inorganic, is not a major question when it comes to supplying these needed nutrients. Both are simply the transfer of nutrients from one location to another–to a location which is more convenient (or available) for the growing crop to use. Availability of adequate nutrients is the question. Where available, both sources should be used together as increasing amounts of nutrients have to be supplied to increase production.

Both correct amounts and correct ratios of applied nutrients are critical to nutrient management and sustainability.

Nutrient mining is one of the key issues that influences current and future productivity . . . especially in Africa, Latin America and parts of Asia. Results from low input systems in the Peruvian Amazon, where newly slashed and burned tropical rain forest was initially productive, demonstrate how quickly they are mined of native nutrients and how within three years they are robbed of their productivity without adequate replacement.

While it is clear that increasing production relies on greater availability of nutrients, it is also important to understand that **nutrient balance** becomes the **key** to sustaining production. This is true for several reasons. First of all, each additional increment of yield becomes more difficult to achieve, thus greater management precision is required. Also, economics and environmental protection are important components of sustainability. Nutrient balance also affects these areas dramatically.

Both correct amounts and correct ratios of applied nutrients are critical to nutrient management and sustainability. Imbalance allows mining of the most deficient nutrients in the soil. Once the critical level is reached, yield falls dramatically . . . even though large aggregate amounts of nutrients might have been applied. Research trials over a number of years, summarized in **Table 4** for several crops throughout India, for example, have demonstrated the importance of balanced fertilization to increased crop yields.

Again, it is important to note that to assure sustainable production, nutrient balance must be supported by adequate nutrient supplies. The nutrient ratio applied in India may be closer to balanced than the ratio in China. However, amounts applied are so low that soil mining, degradation and food shortages in India are a

Table 5. Comparison of nutrient balance and application rates in India and China.

Country/Year	Nutrient ratio, $N:P_2O_5:K_2O$	Nutrients applied, kg/ha $N-P_2O_5-K_2O$	Cereal yield, tonnes/ha
India, 1991	5.9:2.4:1		
India, 1993	9.8:3:1	66.4	1.9
China, 1991	10:3:1		
China, 1993	8.4:2.6:1	*196	4.2

*150 if "unreported-unofficial" area is included

Robert E. Wagner Award Expanded by PPI

THE ROBERT E. WAGNER AWARD is being broadened in scope to better reflect the Institute's expanding international role. Established by the PPI Board of Directors in 1988, the Award recognizes distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The MEY concept, also known as most efficient yield, can provide a solid foundation for better meeting world food needs.

Dr. R.E. Wagner

The Award honors Dr. Wagner, retired President of PPI, for his many contributions to agriculture, to the fertilizer industry and to society in general. He is widely recognized for originating the MEY management concept . . . for more profitable, efficient agriculture.

In its new form, the Award will allow for worldwide candidate nominations and will have two categories . . . one for a senior scientist, one for a younger scientist under the age of 40. The recipient in each category will receive a $5,000 monetary award.

A committee of noted international authorities will select recipients of the Award on an annual basis. The Award will recognize outstanding achievements in research, extension or education. The focus will be on efficient management of plant nutrients and their positive interaction in fully integrated farm production systems. Such systems improve net returns, lower unit costs of production and maintain environmental quality.

The format for preparation of nominations for this Award can be obtained by contacting the Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, Georgia 30092-2821; phone (404)447-0335 ext 203, fax (404)448-0439. Private or public sector agronomists, crop scientists and soil scientists from all countries are eligible for nomination.

The first recipients for the Award will be selected in 1995. ■

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much greater problem than in China, and the average yields are also much lower, as shown in **Table 5**.

Whether in China, in India, in Canada or in the U.S., wherever increased yields are a necessity, the only way that balanced fertilization and sustainable high yields will be achieved is through the increased supply of commercial fertilizer nutrients.

Nutrient Balance: Beyond NPK

Nutrient balance discussions are often confined to nitrogen (N), P and K because of their major importance in crop production. Also, they are most often the limiting factors that need to be addressed in solving nutrient deficiencies. Balance, however, goes beyond NPK. For instance, in a survey of soils throughout China, 22 percent were deficient in sulfur (S) and 13 percent deficient in magnesium (Mg).

Clearly, nutrient balance goes beyond NPK and will not be achieved without adequate availability of commercial fertilizer nutrients.

Summary

In order to meet all objectives of sustainable agriculture . . . increased food, feed and fiber, profitability, efficiency of input use and an appropriate concern for the environment . . . a balance of adequate levels of nutrients is the key component. It is critical that nutrient balance, including the ready availability of needed commercial fertilizer nutrients, be an objective rather than a casualty of policy decisions.

PPI's role is to ensure that plant nutrient P and K are recognized as a part of and not apart from sustainability and that they are managed in balance with other nutrients and production inputs. ■

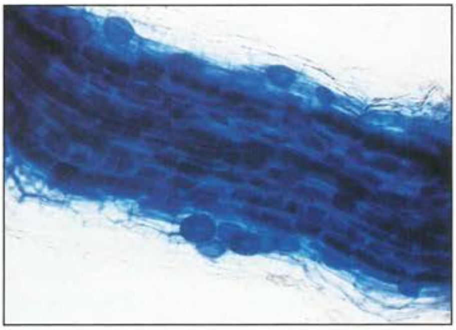
Mycorrhiza–An Essential Part of Most Plant Root Systems

By J. R. Ellis

Mycorrhiza are a group of beneficial soil fungi, living in the soil and colonizing plant roots. Research shows that these fungi have significant effects on ability of plants to absorb nutrients. Fallowing and flooding can severely diminish the numbers of these beneficial organisms, increasing crop plant dependence on nutrients supplied in starters, such as phosphorus (P).

ALMOST all important agricultural crops are mycorrhizal–that is, they can be colonized with mycorrhizal fungi. Mycorrhiza are a group of beneficial soil fungi which live in soil and colonize plant roots. The mycorrhizal fungi grow in the root cells (endo-mycorrhiza) or as a root sheath (ecto-mycorrhiza) and the hyphae (filaments) of these organisms grow out into the soil pores. In general, the normal plant root system is colonized with mycorrhiza, as shown in the photo. Mycorrhizal fungi colonize the root and then grow into surrounding soil to act very much like an extension of the plant root system. Hyphae or filaments of these fungi can be 100 times longer than the entire plant root system.

Mycorrhizal fungi are important in crop production, and coarse rooted plants such as peppers and onions are quite dependent upon nutrients supplied by mycorrhizal fungi. Terminology relative to these organisms includes mycorrhiza, endo-mycorrhiza, VA mycorrhiza, vesicular-arbuscular mycorrhiza or VAM. All refer to the same group of fungi which are important in maintaining healthy, vigorous plants during normal growth and plant stress conditions.



PLANT ROOT filled with the blue stained mycorrhizal fungi.

Symbiotic Association

The symbiotic plant-mycorrhizal relationship is dependent upon the plant supplying the carbon (C) necessary for fungal growth and reproduction in exchange for nutrients transported into the plant by the fungus. Mycorrhiza (the term means root fungus) have been found to affect uptake of nitrogen (N), P, potassium (K), sulfur (S), magnesium (Mg), manganese (Mn), copper (Cu), calcium (Ca), iron (Fe), silicon (Si), aluminum (Al), zinc (Zn) and water by the plant. Positive effects of mycorrhiza also include decreased plant water stress and altered plant transpiration.

Negative Effects of Mycorrhizal Loss in the Field

Plants can be negatively affected when mycorrhizal colonization potential is reduced in soils due to conditions such as long periods of fallow, fumigation, flooding, or severe soil erosion. In Australia, researchers found a problem of P and Zn deficiencies after long fallow (long-fallow

Dr. Ellis is Microbiologist with USDA-ARS, University of Nebraska-Lincoln, NE 68583-0915.

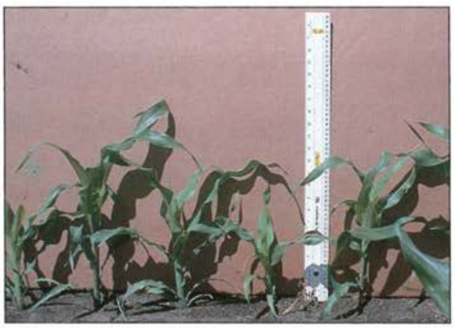
disorder) in the Darling Downs area of Queensland. The condition was due to the absence of a mycorrhizal plant host during the fallow period and subsequent loss of mycorrhizal inoculation potential for the succeeding crop.

In a fumigation study in Nebraska involving corn, plants were stunted and showed severe P deficiency symptoms (shown in photo) after fumigation. When mycorrhizal fungi were reintroduced into the soil at the time of planting, plant growth and yields were comparable to that for the non-fumigated plot area. In a current research study, we are finding that in fields where crops were killed by flooding in Iowa and Missouri in 1993, there is a low mycorrhizal fungi colonization potential. Where starter fertilizer was not applied, corn in many of these fields had P deficiency symptoms and was stunted, as shown in photo. This type of problem is not exhibited in all soils. It is affected by nutrient availability and the degree of crop dependency on mycorrhiza for nutrient uptake.

THIS SOIL-FUMIGATED area planted to corn was surrounded by plants growing in non-fumigated soil. Plants in the fumigated area showed pronounced symptoms of P deficiency. (Nebraska)

Culturing Problems

Scientists have been able to culture inoculum of ecto-mycorrhizal fungi, which are commonly found on woody plant roots. A host is not necessary for growth and reproduction of this fungal group. The endo-mycorrhiza, which are important for most agricultural plants, cannot be propagated in the absence of growing plant roots. These fungi have great potential benefit to agriculture if isolates could be economically mass produced and introduced into the soil. However, unlike symbiotic N fixers for legumes and ecto-mycorrhiza, we have been unable to unlock the key to growing endo-mycorrhizal fungus without the host plant. If we could economically mass produce endo-mycorrhiza, we could introduce into the soil isolated strains which are more efficient in taking up nutrients, producing soil aggregates and reducing plant stress. Unlike the symbiotic N fixers which have a limited host range, mycorrhizal fungi affect a wide range of crops. Thus they have great potential to significantly affect crop production and soil sustainability. We are fortunate in that most soils have a ready supply of these fungi. But there is a premium for using farming practices that are favorable to mycorrhizal production and that maintain mycorrhizal fungal populations. ■



CORN PLANTS shown at left were growing in a field in Polk county, Iowa, which had flooded the previous year, killing crop plants. Plants on the right were growing in an area of the same field which was not flooded.

Plant Potassium Partitioning During Progression of Deficiency Symptoms in Cotton

By C.W. Bednarz and D.M. Oosterhuis

The progression of potassium (K) deficiency in cotton at mid-maturity is accompanied by declining K levels in all plant organs beginning at the shoot apex and progressing downward. Stored K from apparent luxury consumption may serve as a reservoir during a K shortage and boll filling.

THE USE of faster-fruiting and higher-yielding cotton varieties has resulted in the widespread occurrence of K deficiency across the U.S. Cotton Belt. However, the onset of K deficiency has been difficult to predict from soil and tissue tests. Furthermore, the response to soil or foliar K applications has been variable.

Potassium in Cotton

Potassium deficiency symptoms in modern, high-yielding cotton varieties first appear on leaves of the upper canopy. This is not consistent with characteristics of a nutrient which is highly mobile in the plant. It is the mobility of K that creates a problem in attempting to predict the tissue deficiency threshold. If a plant organ that is highly sensitive to K availability is approaching a deficiency, the remainder of the plant may still contain adequate K. A decline in petiole K may only indicate a shift in the K source:sink ratio, not the beginning of a deficiency.

Potassium is an essential nutrient with numerous important roles in plant growth and development. It is not a constituent of any structural component, which may allow it to be stored in apparent luxury amounts and remobilized during a period of reduced availability or increased demand. This is not considered in current plant growth models, but is reflected in the season-long decline of petiole K from the uppermost fully expanded leaf.

Procedures

A study was initiated to determine how K is distributed throughout the cotton plant during the progression of K deficiency and to improve our understanding of the onset of K deficiency in cotton and of K limitation.

Cotton (variety DP 20) was germinated in approximately 2 gallon pots of sand in a growth chamber with a photoperiod of 12 hours, adequate light, photosynthetic day/night temperature of 86/77 F°, and day/night relative humidity of 50/80 percent. Plant nutrients were provided by solution. When the main-stem leaf at main-stem node 12 was the size of a quarter dollar (almost one inch), K was withheld from the nutrient solution given to half the plants.

Plants in each treatment were harvested 2, 7, 12, 16 and 21 days after K was withheld and grouped into (1) main-stem and sympodial leaves, (2) main-stem and sympodial petioles, (3) main-stem and sympodial branches, (4) fruit, and also into (5) lateral roots, and (6) tap roots. Plant components were dried, ground, and assayed for K.

Study Results

Lateral root K of the no-K plants declined sharply immediately after K was withheld. After 12 days the K level in these plants had declined from 4.5 percent to less than 1 percent. Tap root K declined more slowly in the no-K plants and never dropped below 1 percent (**Figure 1**).

Mr. Bednarz is Graduate Assistant and Dr. Oosterhuis is Professor, Department of Crop Physiology, University of Arkansas, Fayetteville.

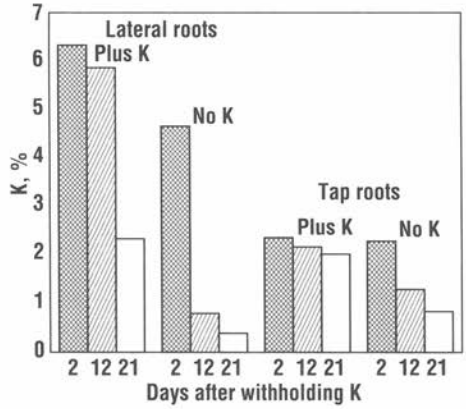


Figure 1. Root K concentration at 2, 12, and 21 days of treatment.

Leaf K concentration was highest in the lower plant canopy and declined as main-stem nodal position increased. Two days after withholding K, apical leaf K was lower in the no-K plants. Leaf K declined first in the upper leaves and then in leaves lower in the plant canopy. For example, after 12 days all leaves above main-stem node 8 contained less than 2 percent K, but at 21 days all leaves above main-stem node 6 had fallen to this level (**Figure 2**).

Petiole K exhibited trends similar to leaf K. The only observed difference was that petiole K did not begin dropping in the no-K plants until after 2 days of withholding K (data not shown).

Interestingly, stem K was highest in the uppermost main-stem nodal regions and declined in a downward direction. Stem K was also unaffected after 2 days in the no-K plants. Similar to the leaf and petiole K, treatment differences in stem K appeared greater in the apical regions after 12 and 21 days (**Figure 3**).

Fruit (bolls) K exhibited no clear trends with main-stem nodal position. After 2 days of withholding K, all fruit in both treatments contained approximately 2.5 percent K. Fruit K did not appear to decline in the no-K plants until after 7 days (data not shown). After 21 days of no K, the K content of the oldest fruit in the

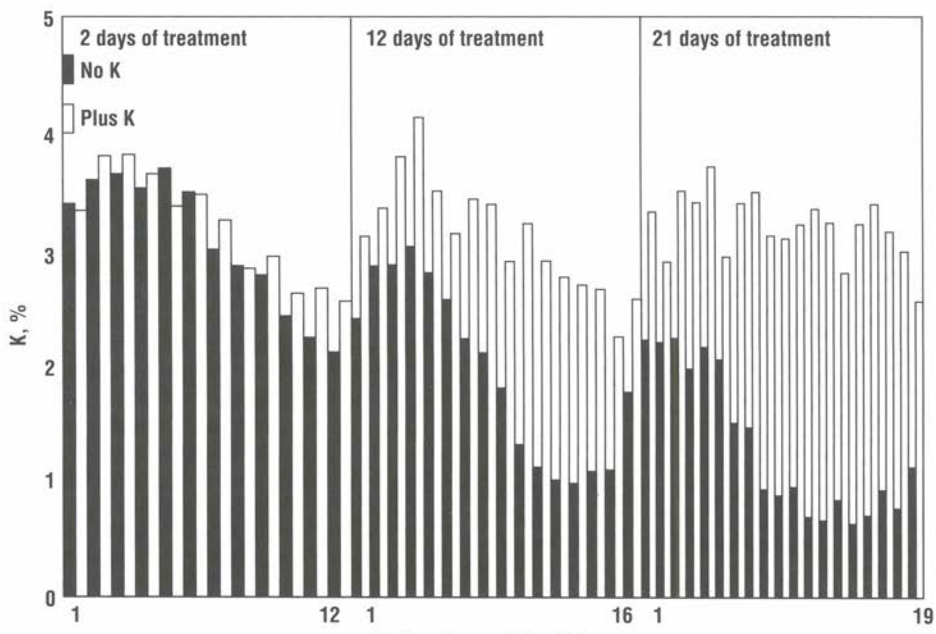


Figure 2. Leaf K concentration at each main-stem location at 2, 12, and 21 days of treatment.

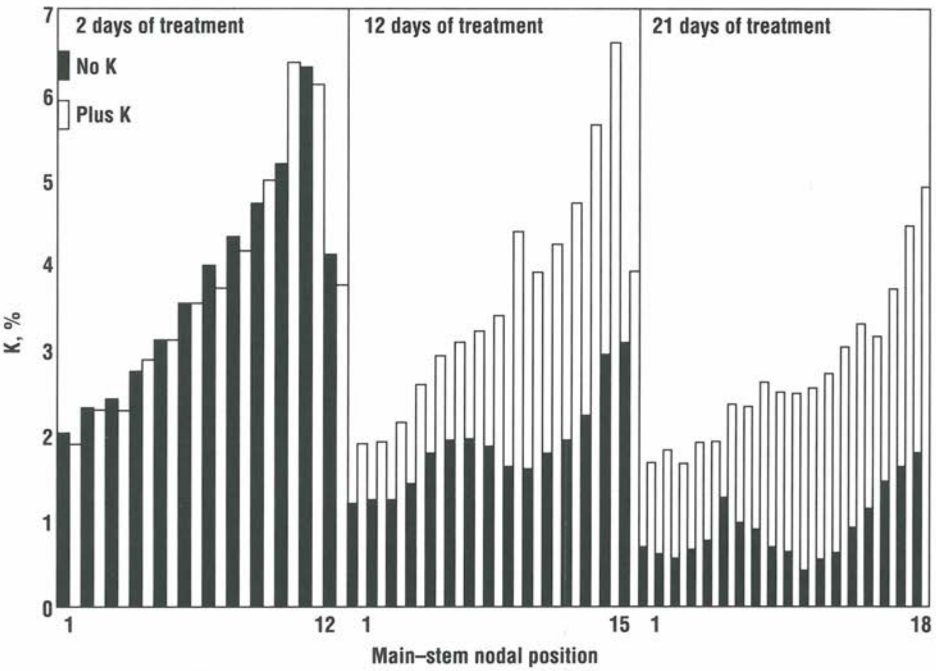


Figure 3. Stem K concentration at each main-stem location at 2, 12, and 21 days of treatment.

no-K plants seemed lower than that of the younger fruit (**Figure 4**).

Results of this study indicate that cotton roots and leaves are the most sensitive organs to K limitations, while bolls are the least sensitive, and stems and petioles are intermediate. When petiole test results indicate a K shortage, boll K may continue to be sufficient due to K movement from excessive storage in other plant organs.

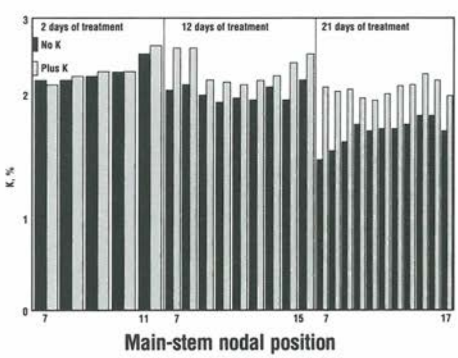


Figure 4. Fruit K concentration at each main-stem location at 2, 12, and 21 days of treatment.

Conclusions

From these results it is evident that the K status of a cotton plant cannot be accurately predicted using diagnostic tissue test results of the petioles from a single main-stem location. Also, it is our conviction that a cotton plant can store excess K in apparent luxury amounts, which can serve as a reservoir during times of K shortage and boll filling.

In order to more fully understand the severity of a pending K shortage, we believe that petioles from mid-canopy main-stem nodes should be compared with those of the upper canopy.

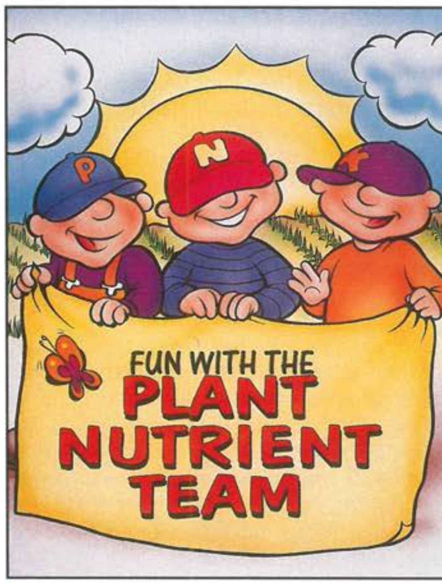
Other researchers (Rosolem and Mikkelsen) reported a sequence of increasing sensitivity to K deficiency among cotton plant parts (leaves<bolls<roots<stems) such that when K deficiency symptoms are clearly visible in the leaves, all other plant parts are already affected. However, our data show the progression of sensitivity to K deficiency to be bolls<stems<leaves <roots. When K deficiency symptoms are visible in the leaves, boll development will continue due to remobilization from other organs. ■

FUN WITH THE PLANT NUTRIENT TEAM

AN EDUCATIONAL activity book for use in kindergarten through third grade is now available. The book, a project of PPI and FAR, encompasses information about the importance of plant nutrients and basic concepts of food and fiber production.

"Because so many children today don't grow up on farms, they may not realize how plants grow and where food and fiber products originate," said Dr. David W. Dibb, President of PPI. "Our challenge was to produce an activity book that will be entertaining but also educational for young children. We believe we have met the challenge with *Fun with the Plant Nutrient Team*."

The 24-page book features nitrogen (N), phosphorus (P) and potassium (K) as characters in a variety of activities such as dot-to-dot, word puzzles, coloring, mazes, matching pictures and experiments. Principles such as soil conservation and science as part of modern agriculture are included.



A sample copy of *Fun with the Plant Nutrient Team* can be purchased for $3.00. Additional copies are $1.00 each, plus shipping/handling. A teacher's guide with additional information, experiments, facts and resources is also available on request.

Send orders to: Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Phone 404-447-0335, ext. 213 or 214; fax 404-448-0439. ■

Global Potassium Trade

By T.L. Roberts

EXPORTS AND IMPORTS of agricultural produce can have large effects on the transfer of plant nutrients from one region of the world to another. The potassium (K) in food products that are exported is completely lost from the agricultural system of that country. These losses are largely offset by K fertilizer inputs. Imported foodstuffs can also return K to the agricultural system, depending on the social living conditions of the country and the methods of waste disposal.

Little K is retained in the human body. In areas where sewage is utilized for land application, some K is returned to the soil. However, sewage discharged to rivers will never enhance soil fertility unless this water is used for irrigation. In contrast, most of the K originating in animal feeds will benefit agriculture if the animal wastes are applied to the soil.

Regardless of the source, K inputs must balance K outputs or productivity will suffer. Whether it's a field, farm or country, removed plant nutrients must be replaced. The net balance of nutrient imports and exports plays a role in determining the long-term soil fertility and long-term sustainability of the farm or country that depends on it.

K Trade in Crop Products

Worldwide K trade in crop products has increased more than 30 percent since 1976. During the five years from 1986 to 1990, total K imports in crop commodities averaged 3.65 million tons. This included K found in fruits, vegetables, cereals, oilseeds, oilseed cake, fibers, pulses, coffee and tea, cocoa and coconut products, bran and sugar. As shown in **Figure 1**, cereals, oilseed cake, oilseeds, and coffee and tea dominate, accounting for 85 percent of all world K trade.

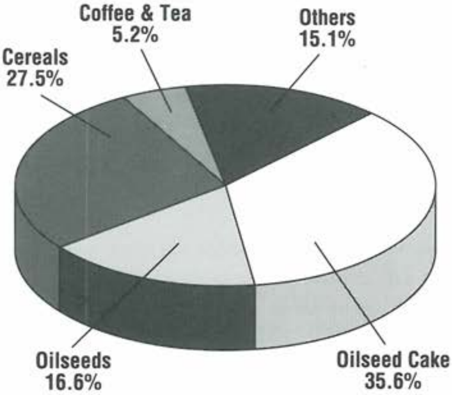


Figure 1. Four major crops dominate world K trade (1986-1990 average).

Although cereal grains are usually low in K, they are important to crop commodity K trade due to the large volume. In contrast, oilseed cake, oilseeds, coffee and tea are important due to their high K content.

K Trade in Livestock Products

Livestock commodities represent a relatively minor component of world K trade compared to crop commodities. From 1986 to 1990, K trade in livestock products was only 3 percent of K trade in crop products. However, like crop commodities, K trade in animal products steadily increased from an average of 85 thousand tons (1976 to 1980) to more than 119 thousand tons in the 1986 to 1990 time period.

Milk accounts for 42.8 percent of world animal commodity K trade, followed by fresh meat at 31.2 percent, and cheese and dried whey at 11.3 percent. Other animal

Dr. Roberts is PPI Western Canada Director located in Saskatoon, SK.

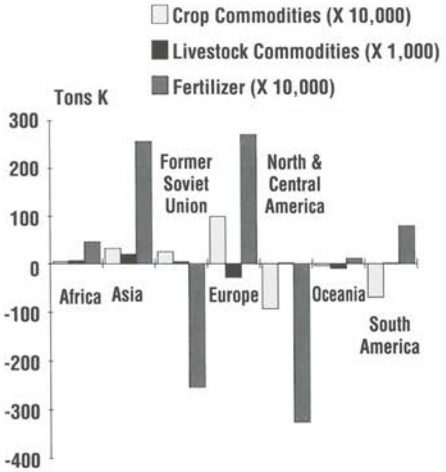


Figure 2. World balance (total K in imports minus total K in exports) of K in crop and livestock commodities, and in fertilizer averaged for the years 1986-1990.

products in order of decreasing importance are: meat meal and fat (5.8 percent), live cattle (4.2 percent), live pigs (1.8 percent), live sheep (1.2 percent), and eggs (1.3 percent).

K Trade in Fertilizers

World production of K in fertilizers averaged 26.0 million tons from 1986 to 1990, up from 23.9 million tons in 1976 to 1980. Three regions accounted for more than 90 percent of K production: the Former Soviet Union (FSU), 37 percent; Europe, 26 percent; and North and Central America, 30 percent. These three regions are also the world's largest exporters, being led by North and Central America, 42 percent, followed by Europe, 28 percent, and then the FSU, 19 percent. Only North and Central America and the FSU export more K than they import.

World K Trade Balance

Figure 2 shows the net balance (total K in imports minus total K in exports) for world trade of K in crop and livestock commodities, and in fertilizers.

Fertilizers dominate, accounting for more than 80 percent of K movement worldwide. Crop commodities represent 18 percent of global K trade and livestock less than 1 percent. Africa, Asia, Europe, Oceania, and South America are net sinks for K. The FSU and North and Central America are net exporters of K. The Americas as a whole are the only net exporters of commodity K.

While exports and imports of crop, livestock and fertilizer commodities depict gross movements of K on a global basis, they do not accurately reflect regional K balances. That is, they don't account for the K required to grow a crop, nor any K that may be lost through waste disposal, surface runoff, or other non-agricultural commodities. This explains why many soils throughout the world are deficient in K and require fertilization.

Table 1 compares K removed from the soil in crop and animal production to K fertilizer consumption for each of the major world regions during 1986-1990.

Worldwide, 99 percent of K removal is offset by K fertilization. Only the FSU and Europe have exceeded K removal with fertilizer addition. Fertilization balances K removal in North and Central America and Oceania, while the remaining regions have a net negative balance. Africa, Asia, and South America are only replacing an estimated 25, 46 and 60 percent of the K

(continued on page 19)

Table 1. Average K (000 tons) removed in crop and animal production compared to fertilizer consumption during 1986-1990.

	Africa	Asia	Former Soviet Union	Europe	North & Central America	Oceania	South America
Crop K	1,641	8,521	2,104	3,530	4,475	266	2,412
Livestock K	65	342	264	532	301	19	105
Total K removed	1,706	8,863	2,368	4,062	4,776	285	2,517
Fertilizer K consumption	430	4,038	5,921	7,246	4,873	226	1,501

Maximum Corn Yield Research Evaluates Chloride Fertilization

By J.R. Heckman

Chloride (Cl) supply is not generally considered to be a limiting factor for corn production in most field environments. However, the adoption of more intensive production practices and higher yield levels may increase the need of corn for Cl.

EXCEPTIONALLY high yielding environments provide ideal conditions for the study of the agronomic importance of Cl nutrition of corn. Experiments with Cl fertilization of corn were conducted in New Jersey using maximum corn yield research methods similar to those developed by Dr. Roy Flannery during the 1980s.

The experiment attempted to achieve a minimum stress field environment by use of irrigation and effective control of insects, diseases and weeds. Pioneer Hybrid 3245 at 43,560 plants per acre was established using an equidistant 12 by 12 inch spacing pattern. Applications of nitrogen (N), phosphorus (P) and potassium (K) fertilizer were made at planting and were also sidedressed during the growing season. The total N, P_2O_5 and K_2O applications were 500, 268 and 405 lb/A for the season, respectively. Boron (B), copper (Cu), manganese (Mn) and zinc (Zn) were also applied at planting to ensure that these micronutrients were not limiting. Chloride treatments were 0, 45, 90, 180, and 360 lb Cl/A. The Cl source was potassium chloride (KCl). Combinations of KCl, potassium hydroxide (KOH), and potassium sulfate (K_2SO_4) were used to apply equal amounts of K to all plots.

Table 1. Corn grain yield, stover yield and ear size as affected by Cl fertilization.

Cl, lb/A	Grain, bu/A	Stover, tons/A	Ear size, lb
	1990		
0	180	4.73	0.27
45	194	5.00	0.27
90	205	4.87	0.31
180	189	4.87	0.28
360	200	5.14	0.30
	1991		
0	302	5.31	0.42
45	310	5.00	0.45
90	308	4.60	0.45
180	316	4.91	0.45
360	328	4.82	0.46
	1992		
0	231	5.05	0.29
45	232	5.05	0.30
90	242	5.22	0.30
180	238	5.05	0.30
360	240	5.27	0.31

Grain and Stover Yield Response

Grain yield and ear size were generally increased by Cl fertilization, as presented in **Table 1**. In 1990, yield of Cl-fertilized treatments averaged 17 bu/A more grain than the check yield of 180 bu/A. In 1991, the check yield was 302 bu/A and yields increased with each rate of added Cl up to 360 lb/A . . . a yield of 328 bu/A. In 1992, Cl-fertilized treatments averaged 8 bu/A more grain than the check yield of 231 bu/A. Yield levels in this experiment were 2 to 3 fold higher than previous studies that did not report yield increases from Cl fertilization of corn.

Chloride fertilization did not increase stover yield. In 1991, when grain yield

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showed the largest increases from Cl fertilization, stover yield was decreased. This suggests that the grain yields were improved by partitioning a higher proportion of the plant's total dry matter to the grain.

Plant Nutrient Concentrations

Large increases in Cl concentration of the ear-leaf were produced by increasing rates of Cl fertilization. Although leaf tissue Cl concentrations were strongly influenced by Cl fertilization, there was no change in Cl concentration in the grain. Grain yield was positively correlated with ear-leaf Cl concentrations, shown in **Figure 1**. The relationship was strongest in 1991 when the higher grain yield was produced. There was no effect of Cl rate on the concentration of other nutrients in the ear-leaf (data not shown). In 1991, when grain yield was greater than 300 bu/A, the ear-leaf nutrient concentrations were 2.83 percent N, 0.29 percent P, 2.34 percent K, 0.48 percent Ca, 0.20 percent Mg, 0.22 percent sulfur (S), 8 ppm B, 9 ppm Cu, 31 ppm Mn, and 23 ppm Zn.

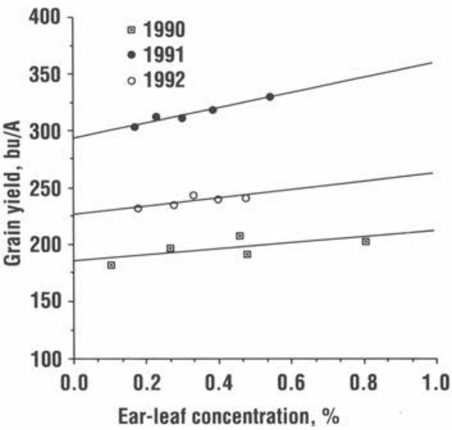

Figure 1. The relation of corn grain yield and Cl concentration in ear-leaf tissue.

Stalk Rot and Lodging

The incidence of stalk rot was not influenced by applied Cl in 1991, but there was a linear decrease in lodging with increasing Cl rates, **Table 2**. In 1992, increasing Cl rates resulted in a linear decrease in incidence of stalk rot. Retention of water in the plant and delayed maturity may be reasons for such a response.

Table 2. Chloride effects on incidence of stalk rot and lodging in corn.

Treatment, lb Cl/A	Stalk rot,% 1991	Stalk rot,% 1992	Lodging, % 1991
0	6.8	10.9	12.7
45	7.2	9.4	12.3
90	7.3	4.7	11.8
180	8.0	4.2	9.3
360	6.2	4.2	7.0

Summary

Maximum yield experiments suggest that Cl supply may be an important yield limiting factor for high yield corn. Fertilization of corn with Cl in an intense cropping system may increase grain yield and reduce stalk rot and lodging. Results also suggest that corn may benefit from both the Cl and the K that are present in the most common K fertilizer, KCl. ■

Global Potassium Trade . . . from page 17

removed by agricultural production, respectively.

Even in regions where replacement apparently balances removal, there will undoubtedly be large areas where removal exceeds fertilizer replacement. For example, the prairies of western Canada remove about 10 times as much K in crops as is returned in K fertilizers. However, many of their soils are rich in K and do not, as a rule, require K fertilization. In areas where K deficiency is severe, removal will often exceed replacement unless good fertilization practices are followed.

Summary

In summary, nutrient balances can be a valuable tool to focus attention in areas where possible nutrient deficiencies are developing. Building and maintaining soil nutrient reserves at levels sufficient to support optimum plant growth are essential to offset the net losses in plant available nutrients that can occur in the normal course of agricultural production. ■

Alabama

Calcium, Magnesium and Sulfur Uptake by Cotton

By G.L. Mullins and C.H. Burmester

Four modern varieties of cotton accumulated similar amounts of secondary nutrients in a recent study. Distribution in various plant parts and rate of accumulation during the season were also similar.

THE MOST RECENT intensive study of the calcium (Ca) and magnesium (Mg) nutrition of cotton grown in the U.S. was published in the early 1940s. For sulfur (S), there has never been an intensive study on cotton. A lack of attention to the needs for these nutrients is probably due to the infrequent reports of Ca, Mg and S deficiencies in cotton. Since the early 1940s, cotton varieties and cultural practices in the U.S. have changed. Due to genetic diversity, modern cultivars may differ from one another in their ability to accumulate Ca, Mg and S.

Non-irrigated field studies were conducted for two years in Alabama to evaluate nutrient uptake by different cotton varieties. The study was conducted on a fertile Decatur silt loam in north Alabama and a Norfolk sandy loam soil in central Alabama. Soil pH was approximately 6.0 at both locations as a result of previous additions of dolomitic limestone. No further applications of Ca, Mg or S were made during the two years of this study.

Four genetically varied cotton varieties were compared at each location: (1) Deltapine 90 (an Acala cotton); (2) Coker 315 (a Midsouth cotton resulting from Carolina breeding); (3) Stoneville 825 (a Midsouth cotton from Delta breeding); and (4) Paymaster 145 (developed for the High Plains of Texas). Nutrient uptake was evaluated by harvesting whole plants at two-week intervals throughout the season, beginning approximately 15 days after

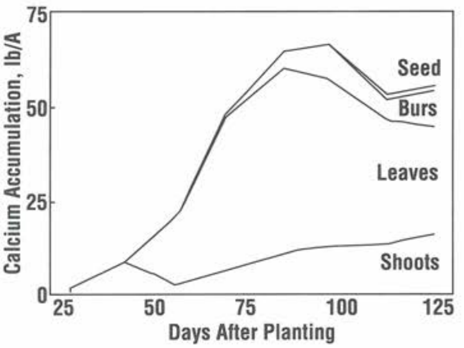

Figure 1. Average uptake of Ca by four cotton varieties grown on a Decatur soil in 1987. Sampling was initiated 30 days after planting and continued at 14-day intervals throughout the growing season. Reprinted by permission of the American Society of Agronomy.

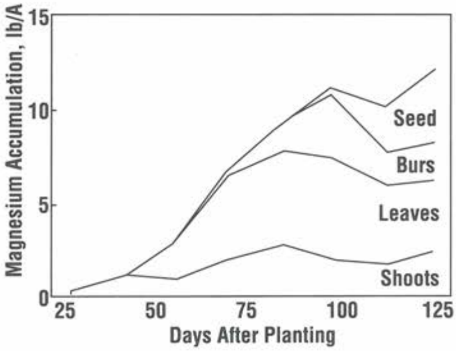

Figure 2. Average uptake of Mg by four cotton varieties grown on a Decatur soil in 1987. Sampling was initiated 30 days after planting and continued at 14-day intervals throughout the growing season. Reprinted by permission of the American Society of Agronomy.

Dr. Mullins is Associate Professor and Mr. Burmester is Extension Agronomist in the Department of Agronomy and Soils and Alabama Agricultural Experiment Station, Auburn University, AL 36849-5412.

Table 1. Accumulation of Ca, Mg and S by mature cotton plants (average of four varieties) on two soils.

Plant part	Ca	Mg	S
	------------- lb/A -------------		
Stems	10.9	2.7	2.6
Leaves	37.3	6.1	7.5
Burs	7.8	2.3	4.2
Seed	1.6	5.0	3.9
Total uptake	57.3	16.1	18.2

Table 2. Distribution of Ca, Mg and S in mature cotton plants (average of four varieties) on two soils.

Plant part	Ca	Mg	S
	----- % of total uptake -----		
Stems	19	17	14
Leaves	64	38	39
Burs	14	14	22
Seed	3	31	25

emergence. Harvested plants were separated into stems, leaves and fruit for dry matter and nutrient analysis. Bolls were further separated into seed, burs and lint. The bur fraction included squares, flowers and immature bolls. All plant parts except lint were analyzed for Ca, Mg and S. See **Figures 1, 2 and 3.**

Total Nutrient Accumulation

The four varieties were very similar in their ability to accumulate Ca, Mg and S. There were no consistent differences among the four varieties in total Ca, Mg and S uptake or uptake by a given plant part. At the last sampling for each year, total Ca, Mg and S averaged over varieties and soils were 57.3, 16.1 and 18.2 lb/A, respectively, shown in **Table 1**. Magnesium uptake was similar for the two soils, but total Ca and S uptake was lower on the Norfolk soil compared to the Decatur soil. The Norfolk soil has a lower clay content and lower levels of extractable Ca and S as compared to the Decatur soil. Total nutrient uptake values were similar compared to older cultivars used in previous studies.

Figure 3. Average uptake of S by four cotton varieties grown on a Decatur soil in 1986. Sampling was initiated 36 days after planting and continued at 14-day intervals throughout the growing season. Reprinted from J. Plant Nutr. 16(6), p. 1077, by courtesy of Marcel Dekker Inc.

Nutrient removal by the seed represented 3 percent of the total plant Ca, 31 percent of the Mg and 25 percent of the total S, listed in **Table 2**. Yield of seed cotton averaged 1,874 lb/A. Combining yield data, available ginning data and total uptake data showed that an average of 7.6 lb of Ca, 2.1 lb of Mg and 2.4 lb of S were accumulated for every 100 lb of lint produced.

Maximum Daily Nutrient Uptake

Maximum daily uptake rates for Ca and Mg occurred at 58 to 98 days after planting (first to fourth week of bloom) which was close to the period of maximum dry matter production. The maximum accumulation period for S was different since S uptake reached a peak during the last sampling interval. Peak uptake rates ranged from 1.4 to 2.1 lb/A/day for Ca, 0.3 to 0.7 lb/A/day for Mg and 0.3 to 0.4 lb/A/day for S. During the peak two-week intervals, an average of 48 percent of the total Ca, 39 percent of the total Mg and 30 percent of the total S was accumulated.

Summary

In this non-irrigated field study, four modern varieties of cotton accumulated similar amounts of Ca, Mg and S. The varieties tested were also similar in how Ca, Mg and S were distributed within the cotton plant and the rate that these nutrients were accumulated during the season. Levels of available Ca, Mg and S did not limit the growth of the cotton plants. Under these non-limiting conditions, an average of 7.6 lb of Ca, 2.1 lb of Mg and 2.4 lb of S was accumulated for every 100 lb of lint produced. ■

Dr. W.R. Thompson, Jr. Honored as Fellow of American Society of Agronomy

Dr. W.R. Thompson, Jr.

DR. W.R. THOMPSON, JR., Mid-south Director of PPI, has been elected as a Fellow of the American Society of Agronomy (ASA). The award was presented at the ASA's 1994 annual meeting recently in Seattle.

Dr. Thompson earned degrees from Mississippi State University. He is located at Starkville, MS, and directs the agronomic research and education programs of PPI in several southern states. He also serves as a Vice President of the Foundation for Agronomic Research (FAR). Dr. Thompson has worked to establish the ASA's Certified Crop Adviser (CCA) program in Mississippi and other southern states and he will be serving as Chair of the Mississippi CCA Board.

ASA has been electing outstanding members to the position of Fellow since 1924. Colleagues within the Society nominate worthy members and the ASA Committee on the Nomination of Fellows, with the ASA Past President acting as nonvoting chair, rank the nominees. Final election is made by the ASA Executive Committee. ■

Dr. D.W. Dibb Elected as Fellow of Soil Science Society of America

Dr. D.W. Dibb

DR. DAVID W. DIBB, President of PPI, has been elected a Fellow of the Soil Science Society of America (SSSA). He was honored at the 1994 annual meeting of the Society recently in Seattle.

Dr. Dibb earned degrees from Brigham Young University and the University of Illinois. Prior to his election as President of PPI in 1988, he served as Regional Director, Latin American Coordinator, Vice President for North American programs and Senior Vice President.

While living in West Lafayette, IN, and serving as PPI's North American program coordinator, Dr. Dibb was appointed an Adjunct Professor at Purdue University. He is listed in Who's Who in America and is a Fellow of the American Society of Agronomy.

The SSSA Fellows program was initiated in 1976. Fellows are active members of the Society who have been nominated by other active members, recommended by the Fellows Committee, and elected by the SSSA Executive Committee. Up to 0.3 percent of the active members may be elected Fellow of SSSA. ■

Site-Specific Nutrient Management Brochure and Fall *Better Crops* Issue Are Available

THE FALL 1994 edition of *Better Crops with Plant Food* featured several articles related to site-specific nutrient management. Additional copies are available. The cost is $2.00 each, plus a nominal shipping/handling charge.

Also, a brochure titled "Site-Specific Nutrient Management Systems for the 1990s" is available in quantity. The colorful eight-panel publication highlights some of the developing technology for more precise management in crop production. It emphasizes the need for soil testing and record-keeping. The brochure is 60¢ per copy with a discount for PPI member companies, schools and government agencies.

Order from Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821; phone (404) 447-0335, ext. 213 or 214; fax (404) 448-0439. ■

Conversion Factors for Metric and U.S. Units

To convert column 1 into column 2, multiply by	Column 1	Column 2	To convert column 2 into column 1, multiply by
		Length	
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in	2.54
		Area	
0.386	kilometer^2, km^2	mile^2, mi^2	2.590
247.1	kilometer^2, km^2	acre, acre	0.00405
2.471	hectare, ha	acre, acre	0.405
		Volume	
0.00973	cubic meter, m^3	acre-inch	102.8
3.532	hectoliter, hl	cubic foot, ft^3	0.2832
2.838	hectoliter, hl	bushel, bu	0.352
0.0284	liter, l	bushel, bu	35.24
1.057	liter, l	quart (liquid), qt.	0.946
		Mass	
1.102	tonne (metric)	ton (short)	0.9072
2.205	quintal, q	hundredweight, cwt (short)	0.454
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp), oz	28.35
		Yield or Rate	
0.446	tonne (metric)/hectare	ton (short)/acre	2.240
0.891	kg/ha	lb/acre	1.12
0.891	quintal/hectare	hundredweight/acre	1.12
1.15	hectoliter/hectare, hl/ha	bu/acre	0.87
		Temperature	
(1.8 x C) + 32	Celsius, C	Fahrenheit, F	0.56 x (F-32)
	-17.8°	0°F	
	0°C	32°F	
	20°C	68°F	
	100°C	212°F	

Metric Prefix Definitions

mega	1,000,000	deca	10	centi	0.01
kilo	1,000	basic metric unit	1	milli	0.001
hecto	100	deci	0.1	micro	0.000001

To convert U.S. crop yields from bushels per acre (bu/A) to metrics:

Corn — bu/A x 0.063 = tonnes/ha
Soybeans — bu/A x 0.067 = tonnes/ha
Wheat — bu/A x 0.067 = tonnes/ha
Grain Sorghum — bu/A x 0.056 = tonnes/ha

Note: International articles which appear in *Better Crops with Plant Food* use metric units of measure, such as kilograms and hectares. In general, articles from the U.S. and Canada appearing in this publication use U.S. (formerly called English) units, such as pounds and acres. The units can be converted from one system to the other using multiplication factors provided in the publication. See page 23.

China

Effects of Magnesium Fertilizer on Crops in South China

By Xie Jian-chang, Du Cheng-lin and Ma Mao-tong

BECAUSE OF STRONG WEATHERING, primary minerals containing magnesium (Mg) in most soils of south China have almost completely decomposed, and dominant clay minerals contain no Mg. As a consequence, total Mg content in the soil is very low, only 0.33 percent on average.

In soils derived from neritic deposits, granitic gneiss and granite, it is even lower . . . commonly below 0.05 percent. The non-exchangeable Mg in the soil usually accounts for less than 10 percent of total Mg. Non-exchangeable Mg of more than 200 soil groups averaged less than 10 mg/100g soil, with many of them containing less than 4 mg/100g. Thus, in general, the Mg-supplying potential is rather low in most soils of south China.

Table 1. Area under fruit and economic crops in south China.

Crop	Total area, 1,000 ha	Crop	Total area, 1,000 ha
Sugarcane	1,164	Rapeseed	3,710
Citrus	1,123	Soybean	1,200
Tea	1,060	Peanut	992
Rubber	616	Tobacco	986
Banana	133		

The southern parts of China are important production areas for cash crops, economic forests and fruit trees, **Table 1**. Some crops require relatively high Mg levels, while others are less sensitive to Mg applications. Traditionally Chinese farmers have not used Mg fertilizer. Calcium carbonate added to farm land for liming purposes contains very little Mg. Calcium-magnesium phosphate applied as fertilizer (about 14 percent of phosphate fertilizer used in the whole country) provides only a small quantity of Mg in the soil. As a result, Mg has become deficient in many soils of south China.

In the Taihu lake region the yearly deficit of MgO is 63 kg/ha. Magnesium deficiencies often develop in crops, as illustrated in the photos. In four plantations in Guangdong province, Mg fertilization markedly alleviated Mg deficiency in rubber trees, as shown in **Figure 1**.

Since 1985, over 70 experiments have

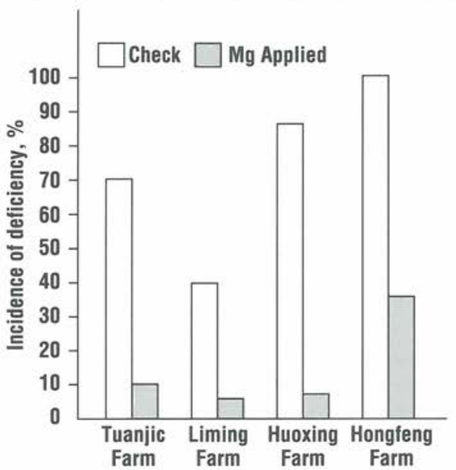

Figure 1. Effect of Mg application on controlling Mg deficiency in rubber trees. (Rate of magnesium sulfate: 0.05-0.25 kg/tree. Investigation made one year after fertilizer added).

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MAGNESIUM-deficient rubber plant in western Guangdong province.

MAGNESIUM-deficient mango plant in western Guangdong province.

Table 2. Effect of Mg fertilizer on crops in south China.

Crop	No. of experiments	Yield, kg/ha		Yield increase	
		NPK	NPKMg	kg/ha	%
Tobacco	8	3,630	4,095	465	12.8
Sugarcane	4	68,100	83,445	15,345	22.5
Peanut	7	3,405	3,570	165	4.9
Rapeseed	3	1,035	1,140	105	10.1
Soybean	2	1,155	1,275	120	10.4
Sweet orange	1	16,155	17,055	900	5.6
Litchi	1	7,905	8,475	570	7.2
Pineapple	3	11,325	12,875	1,550	13.7
Mango	1	3,435	4,035	600	17.5
Banana	1	27,420	29,085	1,665	6.1
Jute	5	1,665	1,950	285	17.1
Chili pepper	1	22,665	27,150	4,485	19.8
Tomato	1	67,365	72,510	5,145	7.6
Cassava	4	17,730	19,845	2,115	11.9
Sweet potato	7	11,535	12,570	1,035	9.0
Corn	3	4,680	4,950	270	5.8

been conducted with related organizations on more than 20 crops grown on different soils. **Table 2** summarizes some of the results. In general, most crops responded favorably to Mg applications. However, little or no effect was shown from Mg application in eight rice experiments.

Magnesium fertilizer application not only increased crop yield but also improved quality on many crops. For example, application of Mg fertilizer significantly improved quality and price of tobacco and had beneficial effects on banana quality and flavor (data not shown).

In southern China, K fertilization has received considerable public attention and promotion. As may be expected, with increased use of K fertilizer, incidences of Mg deficiency have increased.

For example, as shown in **Table 3**, K reduced Mg concentration in rubber saplings. Demand for Mg fertilizer will undoubtedly increase. Research into the correct ratios of K and Mg for specific crops and soil conditions is urgently needed in south China. It is almost certain that the combined use of K and Mg fertilizers will become one of the important issues in balanced fertilization for China in the future. ■

Table 3. Effect of K application on Mg content in different plant parts of rubber saplings.

Rate of K_2O[1] application, g/pot	Mg content, % Leaf	Mg content, % Stem	Mg content, % Root	Incidence of Mg deficiency, %
0	0.25	0.14	0.25	0
3	0.14	0.06	0.21	83.3
9	0.17	0.06	0.18	66.7
18	0.14	0.11	0.19	100.0

[1]As K_2SO_4

India

Long-Term Field Trials Reveal Importance of Plant Nutrients in Sustaining Productivity

By K.K.M. Nambiar

TO EVALUATE the long-term sustainability in intensive farming, the Indian Council of Agricultural Research (ICAR) initiated the All India Coordinated Research Project on Long-Term Fertilizer Experiments in 1970 at 11 selected centres representing the major soil-climate regions of the Indian Subcontinent. The experiments have been in progress since then.

During the period 1971-1988, grain yield responses of rice and wheat to nitrogen (N) averaged 1.45 and 2.09 tonnes/ha, respectively, on Hapludolls at Pantnagar (Uttar Pradesh). Responses to potassium (K) were also obtained for rice, **Table 1**. However, **Table 1** shows responses to applied phosphorus (P) have been small in the case of both crops, consistent with its high native availability in the soil.

Grain yield responses of corn and wheat to N on Ustochrepts at Ludhiana (Punjab) were also high–1.01 t/ha for corn and 1.83 t/ha for wheat. Yield responses of wheat to P and K were 1.38 t/ha and 0.74 t/ha, respectively. Similarly, the average grain yield responses of corn to P and K were 0.46 t/ha and 0.56 t/ha, respectively.

Although the balanced use of NPK fertilizers could maintain productivity over an extended period of time in comparison to individual nutrients (N, P or K), it was not adequate to sustain long-term productivity in intensive farming systems. Integrated use of chemical NPK fertilizers and farmyard manure enhanced and stabilized productivity over a considerable period of time. Similarly, amendment of acid soils with lime along with recommended doses of NPK fertilizers maintained higher productivity.

Usefulness of Zinc in Long-Term Productivity

Significant loss in grain productivity was noticed for corn at Ludhiana and

Table 1. Average grain yield response to NPK fertilizers, organics and lime under long-term fertilizer use (1971-89).

Location	Crops/ Cropping systems	No manure	N	NP	NPK	NPKM[1]	NPKL[2]
		Mean grain yield over the years, t/ha Treatment (1971-88)					
Ludhiana	Corn*	0.41	1.42	1.88	2.44	3.24	–
	Wheat	0.91	2.74	4.02	4.76	4.87	–
Jabalpur	Soybean**	1.08	1.36	2.16	2.29	2.51	–
	Wheat	1.16	1.64	3.87	4.02	4.48	–
Bhubaneswar	Rice*	1.67	2.29	2.36	2.90	3.48	3.59
	Rice	1.51	2.37	2.81	3.06	3.71	3.83
Palampur	Corn**	0.25	0.88	2.37	3.27	4.75	4.12
	Wheat	0.37	0.59	1.99	2.59	3.27	3.10
Pantnagar	Rice	4.08	5.53	5.49	5.95	6.67	–
	Wheat**	1.79	3.88	3.90	3.96	4.56	–

[1]M = Manure, farmyard at 10 t/ha (*) and 15 t/ha (**)
[2]L = Lime

Dr. Nambiar is Project Coordinator, All India Coordinated Research Project on Long-Term Fertilizer Experiments, IARI, New Delhi-110012, India.

Table 2. Mean grain yield response to Zn addition under long-term fertilizer use.

Location	Crop	Period	No. of Crops	Mean grain yield, t/ha Treatment NPK	NPKZn
Ludhiana	Corn	1971-78	8	2.74	2.75
		1979-88	9	2.17	2.63
Pantnagar	Rice	1972-82	11	6.35	6.27
		1983-88	6	5.37	6.01
	Wheat	1972-75	3	4.42	4.46
		1975-89	14	3.86	4.15

Pantnagar after eight annual cropping cycles. This yield loss was probably due to depletion of available soil zinc (Zn), **Table 2**. Corn grain yields declined by 21.2 percent over the period 1979-88. Loss of rice and wheat yields was also observed after 11 annual cropping cycles in the absence of Zn fertilization. The reduction was of the order of 11.9 percent and 7.5 percent, respectively. The initial productivity of both the crops was almost restored with the application of Zn.

Usefulness of Sulfur in Long-Term Productivity

As shown in **Table 3**, sulfur (S) had a pronounced effect on the productivity of kharif (monsoon) rice at Barrackpore (West Bengal) and at Bhubaneswar (Orissa) after three annual cropping cycles. Average reduction in kharif rice production in the absence of S addition amounted to 35.4 and 33.7 percent, respectively. However, its effect on the productivity of rice (kharif) and wheat on an initially producive Hapludoll soil at Pantnagar became evident only after 13 annual cropping cycles. The average reduction in rice productivity was 11.9 percent over the last four-year period (1985-89). The effect of S was also marked on the productivity of wheat and soybean at Jabalpur after 9 to 11 annual cropping cycles. The average loss in productivity of both the crops was 12.4-12.7 percent. Similar effects were also noticed with respect to a corn-wheat rotation at Palampur after seven annual cropping cycles.

Long-term experiments showed that deterioration in productivity was often encountered after 3 to 11 annual cropping cycles in intensive farming systems with the drawdown in readily available soil plant nutrients, including secondary and micronutrients. Nonetheless, sustained productivity could be maintained through application of adequate quantities of NPK along with the proper rates of secondary and micronutrients. ■

Table 3. Mean grain yield response to S addition under long-term fertilizer use.

Location	Crops	Period	No. of Crops	Mean grain yield, t/ha Treatment NPK	NPKS
Barrackpore	Rice, kharif	1971-73	3	4.59	4.90
		1974-88	15	2.91	3.94
Jabalpur	Soybean	1972-83	11	2.06	2.15
		1984-88	4	2.36	2.66
	Wheat	1973-82	9	3.69	3.73
		1983-89	6	3.79	4.26
Bhubaneswar	Rice, kharif	1972-75	3	2.55	2.59
		1976-88	14	2.58	3.45
Palampur	Corn	1981-88	8	2.84	3.31
	Wheat	1981-89	8	2.35	2.60
Pantnagar	Rice	1972-84	13	6.09	6.28
		1985-88	4	4.36	4.88

New Video–Precision: At the Point of Revolution

A NEW 27-minute video highlighting site-specific or "precision" management for crop production is now available from PPI. Released in January 1995, the program offers an inside look at new developments such as the use of Global Positioning System (GPS) satellites, computer field mapping, and variable rate application. Through interviews with fertilizer dealers, industry representatives, farmers, consultants, university specialists and others, the video takes a conversational approach to technology now emerging. Cost of the video is $15.00 ($10.00 for member companies), plus $3.00 shipping.

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Australia

Long-Term Trials Show Sugarcane Needs Potassium

By L.S. Chapman

THE Bureau of Sugar Experiment Stations conducts field research on sugarcane and provides technical advice to growers. Current advice on potassium (K) fertilizer recommendations is based on the calibration of soil tests for exchangeable and nitric acid extractable K with cane yield responses. Recommended K application rates for "plant" crops following a six-month fallow receive approximately 100 kg/ha of K. Ratoons and replant crops with no fallow period receive approximately 120 kg/ha of K.

A long-term K trial has been conducted at Mackay Sugar Experiment Station since 1967. The aim of this research is to monitor the effects of K fertilizer on cane yields and levels of selected soil analytical values.

Experimental Procedure

The trial site belongs to the non-calcic brown great soil group and has a brownish black sandy clay loam top-soil overlying a brown medium clay sub-soil. X-ray diffraction patterns indicate kaolinite and illite to be the major crystalline constituents of the clay fraction of this soil, similar to soils in the district.

Eight levels of K fertilizer, ranging from a control to 196 kg/ha of K, were banded into the soil each crop year in a mixture with nitrogen (N) and phosphorus (P). Only the results of the control and the 112 kg/ha of K treatment, which gave the optimum economic response, are reported here.

Three crop cycles of plant cane and four or five ratoons, plus the plant and two ratoons of a fourth cycle have been harvested. Cane yields were measured by a sampling method or by weighing 10 m plot lengths of mechanically harvested cane from the center three rows of five-row plots.

Ten soil cores were sampled per plot to a depth of 25 cm before fertilizer application, prior to planting or after each harvest. Cores were collected from the inter-rows, thereby avoiding previous fertilizer bands. After drying at 30°C, the soil samples were ground to less than 2 mm and analyzed for exchangeable K in a 0.02 M HCl extract and for nitric K in a boiling 1 M HNO_3 extract. Non-exchangeable available potassium (NEAK) was calculated as nitric K minus exchangeable K. In 1989, soil samples were analyzed for exchangeable Ca and Mg in a 0.02 M HCl extract and pH in a 1:5 soil:water extract. The K removed in the 1982 crop was measured in cane samples taken from each plot and analyzed for total K.

Yield data were analyzed for variance. Soil analysis data for exchangeable K, nitric K and NEAK were also analyzed for co-variance using the preplanting data in 1967 as a variable.

Results and Discussion

Cane yields of the controls for the four cycles averaged 77, 76, 61 and 78 tonnes/ha cane. The low yield in the third cycle was associated with lower rainfall. See **Figure 1**.

Yields increased significantly in each crop from the application of K fertilizer, the mean response from 112 kg/ha being 12, 15 and 113 tonnes/ha for the first three

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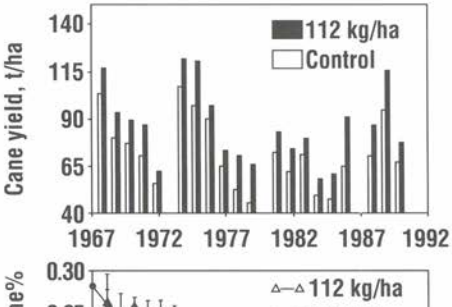


Figure 1. Effect of fertilizer K on cane yield and exchangeable K over four crop cycles involving 20 harvests, including rainfall totals for each crop.

crop cycles, respectively. The largest relative responses, measured as percent yield, were in the fourth and fifth ratoons of the second and third crop cycles. Yields of older ratoons progressively declined in most cases, the exceptions being due to favorable weather conditions.

Exchangeable K levels in soil decreased progressively for both the 112 kg/ha and unfertilized plots. However, there was a small but significant increase from K applications after the first ratoon of the first crop cycle.

Variation in the levels of exchangeable K from year to year could not be related to the rainfall received for each crop. After each fallow period of approximately six months, there was a small increase in exchangeable K compared to the level at the previous harvest. This was attributed to the continued mineralization of K in the soil and to a lack of uptake by plants, as the fallows were generally weed free. During the fallow, a mixing of the fertilizer enriched bands with the plow layer could also be a contributing factor, but this effect was not measured.

The nitric K level was 1.57 me% at the commencement of the trial, an indication of high reserves of K in the soil, typical of illitic clays. NEAK levels were also high, with no trend for increased levels as a result of fertilization, except in 1987 at the beginning of the fourth crop cycle. In the control plots, there was a linear decline in NEAK and exchangeable K levels of 0.0058 and .0072 me% per year, respectively. This represents a total loss of 18 kg/ha/year of K in the topsoil, much less than the 69 kg/ha of K removed by the crop in 1982 for the unfertilized plots. By comparison, the plots fertilized with 112 kg/ha of K lost considerably more K, with 148 kg/ha of K removed by the crop.

Obviously, the total K removed by the crop cannot be estimated directly by soil analyses. This evidence supports the view that equilibria exist among exchangeable K, NEAK and lattice K. Therefore, as K is used by the crop, a considerable amount of K must be released from the lattice K fraction of the soil.

Soil analysis data for 1989 showed a non-significant trend for plots fertilized with K to have higher levels of exchangeable calcium (Ca) and magnesium (Mg) than the control plots. Exchangeable Ca levels were 2.41 and 2.96 me%, and exchangeable Mg levels were 0.66 and 0.80 me% for the control and 112 kg/ha of K treatments, respectively. These data indicate that it may be possible for cane plants to substitute other cations for K ions if the latter are in short supply. It appears that exchange sites on the soil were occupied by hydrogen (H) ions as Ca and Mg ions were taken up by plants, since the plots receiving 112 kg/ha of K had a pH of 5.13, significantly higher than the pH of 4.90 in the unfertilized plots.

(continued on page 31)

Brazil

Soybean Response to Potassium Is Similar for Various Sources

By H.A.A. Mascarenhas, R.T. Tanaka, P.B. Gallo and J.C.V.N.A. Pereira

THE PRINCIPLE SOURCE of potassium (K) fertilizer used on most crops in the State of São Paulo, Brazil, is potassium chloride (KCl). On the other hand, potassium sulfate (K_2SO_4) is used on crops such as potatoes, beetroot, pineapples, some deciduous fruits and vegetables. In the sugarcane growing area, vinasse is a K source for the sugarcane and soybeans grown in rotation. About 20 years ago, potassium-magnesium sulfate ($K_2SO_4 \cdot 2MgSO_4$) was introduced from the U.S.; it contains K, magnesium (Mg) and sulfur (S).

Experimental procedures

Experiments were initiated at four locations. The treatments utilized were:

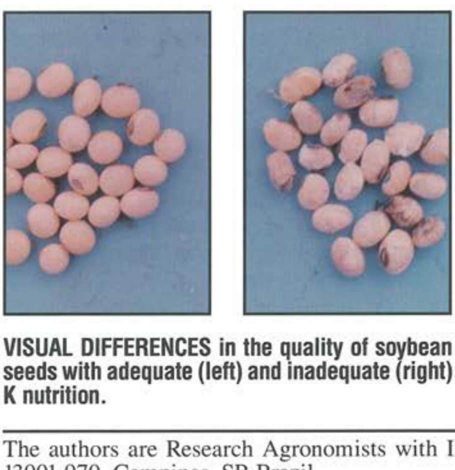
T_1 = Check
T_2 = KCl (60 percent K_2O and 45-48 percent Cl)
T_3 = K_2SO_4 (50 percent K_2O, 18 percent S)
T_4 = $K_2SO_4 \cdot 2MgSO_4$ (22 percent K_2O, 11 percent Mg and 22 percent S)
T_5 = Vinasse.

In treatments T_2 to T_4, K was applied at the rate of 150 kg/ha of K_2O, broadcast before planting. In the second and third year, residual effects were evaluated. For vinasse, 50,000 l/ha was annually applied before planting. The vinasse applied at Mococa and at Paraguaçu Paulista contained an average of 125 and 156 kg/ha of K_2O, respectively. Of the four locations, there was a positive response at only two.

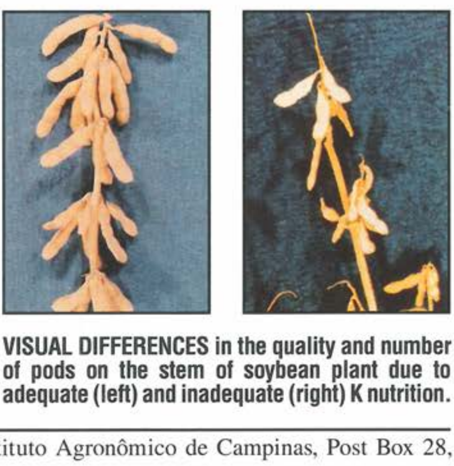
Results

At the Mococa Experimental Station, soybeans did not respond to any source of K in the first two years. Potassium levels in the soil were in adequate supply. In the third year, all K sources out-yielded the check. As shown in **Table 1,** leaf concentration of K decreased from the first to the third year.

At the Paraguaçu Paulista site, the soil is a very low fertility cerrado. There was no response the first year despite low levels of soil K, but there was response the second year as shown in **Table 2**. Appar-



VISUAL DIFFERENCES in the quality of soybean seeds with adequate (left) and inadequate (right) K nutrition.



VISUAL DIFFERENCES in the quality and number of pods on the stem of soybean plant due to adequate (left) and inadequate (right) K nutrition.

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Table 1. Effect of application of different sources of K on soybean yield and leaf K concentration at Mococa.

Treatments	Soybean yield, kg/ha 3rd yr.	K in the leaves, % 1st yr.	2nd yr.	3rd yr.
T_1	2,683	3.0	2.1	1.0
T_2	3,220	3.1	2.6	1.8
T_3	3,087	3.0	2.5	1.3
T_4	2,875	3.0	2.7	1.5
T_5	3,212	2.8	2.8	1.5

Table 2. Effect of application of different sources of K on soybean yield and leaf K concentration at Paraguaçu Paulista.

Treatments	Soybean yield, kg/ha 2nd yr.	K in the leaves, % 1st yr.	2nd yr.
T_1	1,050	2.1	0.74
T_2	1,758	2.8	1.53
T_3	1,722	2.2	1.50
T_4	1,697	2.9	1.50
T_5	1,622	2.2	1.65

ently, decomposition of remaining shrubs and grass released K which satisfied the needs of the soybeans. In the second year, there was a response.

All sources of K produced similar yields and surpassed the yield of the check. In the check plots, there were leaf symptoms of K deficiency. This K deficiency affected seed quality, as shown in the photo. There was a similar decrease in K concentration in the leaves from the first to the second year as observed at Mococa.

It is interesting to note that since vinasse was applied annually, one would expect a higher yield and higher concentration of K in the leaves when compared with other treatments. This did not occur. The results obtained by the research workers of the Pedology Department of IAC showed that due to heavy rains in the summer, more than 60 percent of K is usually leached out. Note in the photo the well developed pods nourished with K fertilization. In the absence of K, the raceme shows the lack of pods, malformation, pods without seeds and white color of young pods.

This study found that all four sources of K had similar effects on soybean response to fertilization. ■

Sugarcane Needs Potassium ... from page 29

Conclusions

The major conclusions that can be drawn from these trial data are:

- Cane yield of unfertilized plots declined with older ratoons. The lower yields in the third crop cycle were largely due to lower rainfall.
- Mean yield responses from K fertilizer were significant and constant from crop cycle to crop cycle.
- Responses were obtained each year, with proportionally larger responses in fourth and fifth ratoons of the second and third crop cycles.
- Exchangeable K in soil gradually declined in fertilized plots, although the decline was greater in the unfertilized plots, particularly in the first crop cycle.
- NEAK levels in soil of the unfertilized plots are also declining, but at a modest rate considering the amount of K removed by each crop.
- Fertilized plots were less acid than the unfertilized plots in 1989.

Industry Significance

The significance of these results is that applications of K fertilizer are necessary to maximize yield, even on this soil type which has high reserves of K. There is little concern at this stage that exchangeable K levels are declining in the fertilized plots, for yield responses appear stable between crop cycles. Higher applications of K fertilizer do not appear to be warranted. ■

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But what is the truth? We hear one side and are convinced until we hear the other. Are farm price supports and conservation reserve good—or bad? Should we spend billions on foreign aid or not?

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