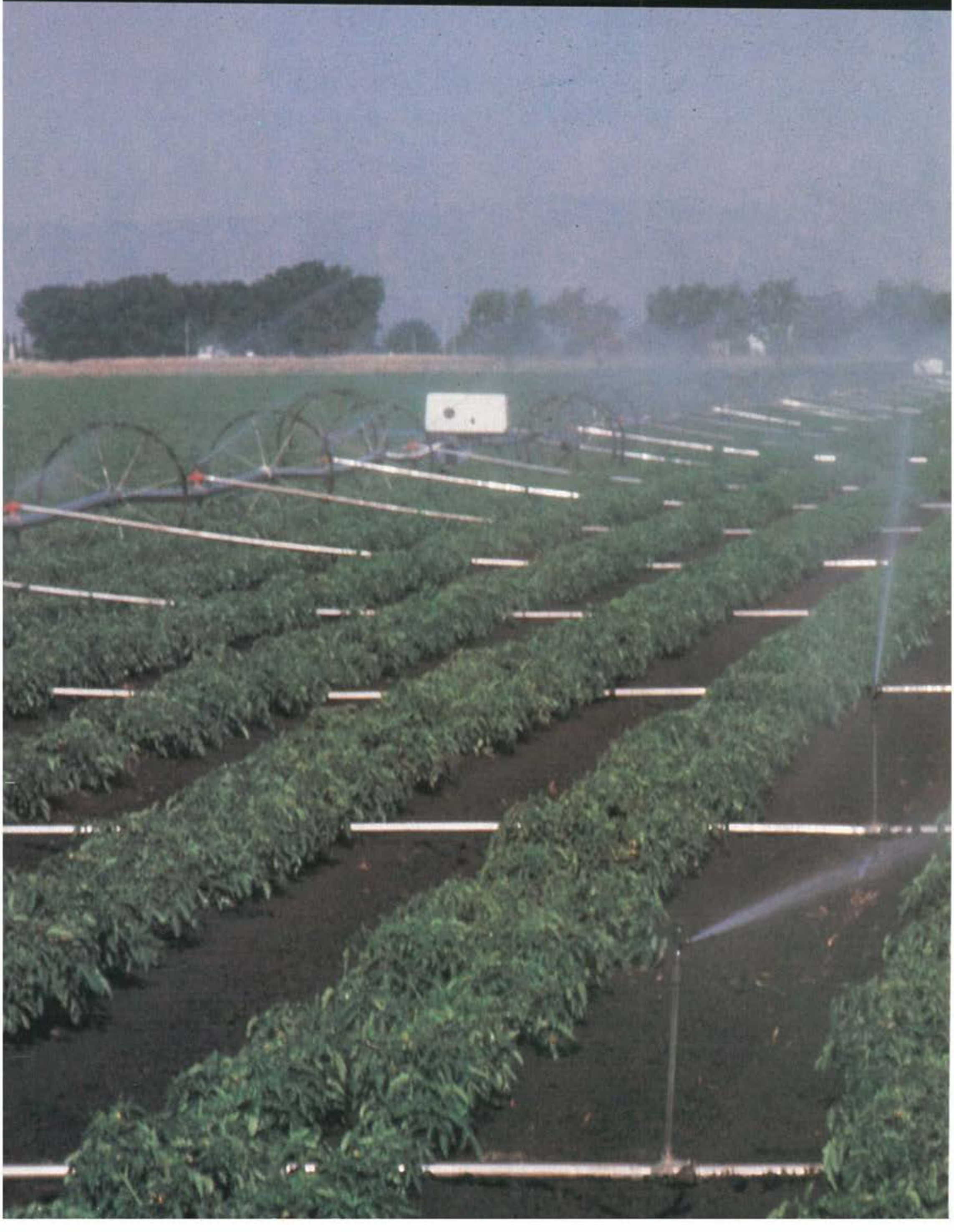
BETTER CROPS

WITH PLANT FOOD

Summer 1989



BETTER CROPS With Plant Food

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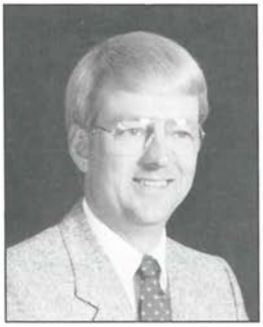
Contents

Our Cover: Irrigating processing tomatoes near Woodland, California. Nearly 90 percent of all tomatoes produced in the U.S. for catsup, paste, sauce and other processing, are grown in California.

Photo by Dr. A.E. Ludwick

J. Larry Sanders Relocates as Great Plains Director for PPI



J.L. Sanders

DR. J. LARRY SANDERS has been appointed to the position of Great Plains Director for the Potash & Phosphate Institute (PPI). Dr. Sanders moves from his former role as Eastern Canada Director and Coordinator, Asia Programs, with the Institute. He joined the staff in 1981 and has been located in Ontario, Canada. In his new position, Dr. Sanders will be located near Kansas City.

Announcement of the assignment came from Dr. David W. Dibb, President of PPI, in Atlanta, and Dr. Larry S. Murphy, Vice President, located in Manhattan, Kansas. "We are very pleased to have Dr. Sanders in this new assignment. The Great Plains Region is a vital agricultural area and has many opportunities for the agronomic research and education program of the Institute," noted Dr. Dibb.

Dr. Sanders will have responsibility for six states: Kansas, Missouri, Nebraska, Oklahoma, Colorado and Wyoming. A native of Shreveport, Louisiana, he earned his B.S. degree from Northeast Louisiana State University and his M.S. and Ph.D. degrees from the University of Arkansas. The main emphasis of his research involved characterzing the soybean root system in ion uptake, growth, and effect on yield.

He is the author and co-author of several published papers and articles in his scientific field. Dr. Sanders is a member of the American Society of Agronomy, Crop Science Society of America, and the American Society of Farm Managers and Rural Appraisers.

Dr. Sanders may be contacted at the following office address: Suite 250, 7721 West 151st Street, Stanley, KS 66223; phone (913) 681-3998.■

Mark D. Stauffer Appointed as Eastern Canada Director for PPI

M.D. Stauffer

DR. MARK D. STAUFFER has been named Eastern Canada Director for the Potash & Phosphate Institute (PPI). Dr. Stauffer transfers from his previous position as Western Canada Director. He joined the staff in May 1988 and has worked from the office of the Potash & Phosphate Institute of Canada (PPIC) in Saskatoon, Saskatchewan. Dr. Stauffer will move to Ontario to serve his new region.

Dr. Stauffer will direct the Institute's programs in the Eastern Canada provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, Newfoundland, and Nova Scotia. In addition, his region will include the states of Michigan and New York.

A native of Ontario, Dr. Stauffer took his undergraduate training at the University of Guelph and earned his Doctorate in Agronomy at the Virginia Polytechnic Institute and State University. He has worked in agricultural research, sales and management in the United States and Canada. He was a research scientist with a major agricultural chemical company in Regina, Saskatchewan, before joining the PPI staff.

Dr. Stauffer succeeds Dr. J. Larry Sanders as Eastern Canada Director. Dr. Stauffer's former position as Western Canada Director was funded by a grant from the Government of Canada through the Western Diversification Program (WDP). A replacement is being sought for appointment as Western Canada Director. ■

A Love Affair with LISA

By Don Holt

A movement which has become identified as "LISA" continues to spark interest, concern and dialogue among diverse agricultural and environmental groups. A university administrator offers some thought-provoking observations in this article.

LISA, an acronym for "low-input, sustainable agriculture" is a buzzword in agricultural and environmental circles. In addition to representing a general farming systems concept, the term LISA is used to describe a specific, federally-supported research and education program. The program, administered as a regional competitive grants program, is focused on developing and promoting low-input, sustainable farming systems.

Background

Interest in LISA was stimulated in the mid-1980s by the emergence of some major public concerns about agriculture. During this period the general public was sensitized to water quality, soil conservation, and other environmental issues. Also, the public became concerned about the fate of one of the nation's most treasured institutions, the family farm.

Legislation was introduced in 1983 by Senator Patrick Leahy that would have mandated national demonstrations of low-input systems. After considerable revision and discussion, the current LISA program was funded in 1988.

Supporters and Opponents of LISA

The individuals and groups expressing enthusiasm and soliciting support for LISA state various objectives, such as preserving the family farm, conserving soil and other natural resources, and improving environmental quality. In general, private firms that manufacture and market inputs for agriculture have not been enthusiastic about LISA, for both technical and economic reasons.

When we develop and implement technological changes in agriculture to enhance productivity, we need to consider the potential impact of such changes on our ability to achieve other important objectives. In my opinion the overriding consideration must be profitability. In almost every case it is farmers who must implement LISA systems. If farmers cannot implement these systems as part of profitable farming enterprises, the changes will not be implemented.

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The U.S. capacity for production systems research, decision support, and education is inadequate to support major farming systems changes, some of which are mandated by current legislation. Hopefully, LISA systems will never be mandated, but will be carefully studied and developed to the point that they represent economically viable farming systems alternatives.

Dr. Holt is Director, Illinois Agricultural Experiment Station, Champaign-Urbana. This article is adapted from a presentation to the staff and Advisory Council of the Potash & Phosphate Institute (PPI), in April 1989.

Positive Impacts of LISA

The LISA movement sensitized many people to important environmental, conservation, technical, and social concerns associated with agriculture. It alerted universities and other public agencies to new constituencies, some of which are outside traditional agricultural groups but very concerned about the impact of agricultural practices on the environment and on society.

The LISA issue clearly revealed the need for a major infusion of systems science and systems perspective into agricultural teaching, research, and extension and for an increase in institutional capacity for production and marketing systems research. A systems approach is required to investigate the complex interactions that occur within and among agricultural systems and to predict the effects of these interactions. There is increased awareness of the need for improved field experimentation techniques and a wave of interest in on-farm research.

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The LISA movement stimulated a great deal of ingenuity on the part of farmers, agribusiness people, and researchers toward finding more productive, cost-efficient, environmentally safe, and resource-conserving methods of producing crops. The LISA movement created a great opportunity for education, not only of farmers, agribusiness people, and scientists, but also of the general public.

Farm business management, which has received relatively little research attention in the past decade or so, is enjoying an increase in interest and support. The public interest in LISA has generated more financial support for related research and educational efforts.

Negative Aspects of LISA

In general, people associated with agriculture support the concept of sustainability and recognize that sustainable agriculture is not incompatible with but rather is essential to the welfare of both agriculturalists and the general public. The supporters and critics of LISA disagree considerably on what approaches should be taken to achieve LISA goals.

What is meant by low-input?

Critics of LISA are particularly skeptical of the use of the qualifier "low-input." It is not clear whether the term refers to low input per unit of output or low input per unit of land, two very different concepts. Most LISA enthusiasts seem to promote LISA in the latter context. Some proposed LISA approaches actually represent a substitution of one type of input for another, rather than a reduction in level of inputs.

LISA is being interpreted by many to mean that there is some system of agriculture that is productive and competitive, and, at the same time, requires only low inputs per acre or per farm. I believe there is strong evidence that agricultural systems involving low variable inputs per unit of fixed assets, e.g., land, cannot sustain themselves in a mature agricultural economy.

LISA and profit

Some sobering conclusions can be drawn from economic relationships among productivity goals, fixed costs, variable costs, and prices of farm products. In a mature, highly competitive agriculture, farmers will have to maximize profits to survive without subsidization. If maximizing profit is the goal, the optimum cost per unit of output will be greater than the minimum cost per unit of output; this is also true if minimizing loss is the goal.

(continued on next page)

LISA . . . from page 5

Low-input systems are least appropriate for operations with high fixed costs. A lower price does not result in a proportionately lower cost of the optimum combination of inputs. If low-input systems are those that involve lower levels of inputs than the level leading to minimum cost per unit of output, low input systems cannot be self-sustaining in a mature agricultural industry.

LISA and soil fertility

Some LISA enthusiasts perpetuate misunderstandings about fertility. They do not seem to accept that crops remove essential nutrients, including phosphorus (P) and potassium (K), from soils and that fertilization is necessary to replace those nutrients. Nutrients can be recycled to some extent, by spreading plant and animal wastes back on fields, but not all nutrients removed in crop production are available for recycling.

Extrapolating LISA research findings

Failure to estimate the degree to which alternative systems can be successfully adapted in global agriculture can lead to erroneous conclusions. For example, the proposal that forage-livestock systems should replace grain systems in order to reduce soil erosion and decrease nitrogen (N) inputs fails to take into account the relatively inelastic demand for red meat and other products derived from ruminant animals.

LISA and productivity

Some LISA enthusiasts downplay the need to maintain high levels of agricultural productivity. They argue that even if the LISA approach resulted in higher prices of farm products, the impact on the consuming public would be minimal. After all, they say, U.S. consumers spend only 15 percent of their income for food and only 25 percent of that expenditure reaches the farmers.

When food expenditures are analyzed by income class, however, it is evident that 30 percent of families spend over 50 percent of family income for food and 50 percent of families spend over 30 percent of their income for food. Any policy that results in lower productivity in U.S. agriculture is the equivalent of a particularly regressive tax levied on the consumers of agricultural products.

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LISA and business strategies

LISA enthusiasts often support the strategies of diversification and vertical integration for small farmers. These strategies are not generally successful when used by small private firms. Any new enterprise added to diversify a farm operation or integrate it vertically must achieve enough economy of scale to be competitive. For example, if a livestock operation is added to a grain farm as a means of diversifying and vertically integrating the farm business, the livestock operation must be large enough and efficient enough to be competitive.

LISA and technological solutions to problems

Some LISA enthusiasts, particularly within some environmental groups, reject all technological solutions to problems. For example, they do not accept the possibility that chemical pesticides can be produced that are harmless to all organisms except the target pests. Likewise, they are unwilling to accept any risk associated with pesticide use, nor to recognize that there are great risks involved in not using fertilizers and pesticides.

LISA and international competition

I don't believe that many LISA enthusiasts fully appreciate the economic consequences of failure to address the issue of agricultural competition. If U.S. agricultural producers are unable to compete for global agricultural markets, there will have to be further downsizing of the agricultural infrastructure, with resulting loss of jobs and economic activity. The

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LISA and politics

In my opinion, the political risk associated with supporting LISA is less than that of not supporting it. Many of the LISA support groups represent very large constituencies with great political influence. Our best approach is to join with them in a sincere effort to learn about the potentials of LISA and to help prevent ill-advised policy decisions.

Conclusions

Above all, those of us in the traditional establishment of public and private agricultural research and education must recognize that we are receiving messages from individuals and groups that have legitimate claims on our time and talents. We must not try to "shoot" these messengers. We need to scrutinize carefully each of their concerns, which are also our concerns, and help them find and implement answers.

Our future depends on handling the LISA issue in a scientifically sophisticated, technologically sound, economically realistic, politically sensitive, and socially responsible manner.■

Robert F Barnes Added to Advisory Council

DR. ROBERT F BARNES, Executive Vice President of the American Society of Agronomy (ASA), was recently appointed to the Advisory Council of the Potash & Phosphate Institute (PPI). The announcement came from Dr. David W. Dibb, President of the Institute.

R. F Barnes

Dr. Barnes will serve as Vice Chairman of the Advisory Council until 1991, when he will become Chairman. The Advisory Council consists of 10 individuals appointed to serve on an unpaid, voluntary basis.

During his career with the USDA-ARS, Dr. Barnes became well known for his work in evaluation of forage quality and the development and application of forage evaluation techniques. In September of 1986, Dr. Barnes was appointed to his current position as Executive Vice President of ASA, Crop Science Society of America (CSSA) and Soil Science Society of America (SSSA).■

Research for a Sustainable Agriculture

By E.T. York, Jr.

Sound programs of agricultural research are essential to maintaining the productivity and sustainability of agricultural systems.

"THE NEXT FEW DECADES present a greater challenge to the world food systems than they may ever face again. The effort needed to increase production in pace with unprecedented increase in demand, while retaining the essential ecological integrity of food systems, is colossal, both in its magnitude and complexity. Given the obstacles to be overcome, most of them man-made, it can fail more easily than it can succeed."

This statement by a special panel of the World Commission on Environment and Development presents a sobering but realistic appraisal of the challenge facing global food systems.

This challenge has contributed very directly to the great interest in the sustainability of agricultural systems around the globe. Such interest is well placed.

E.T. York, Jr.

Progress in Food Production

There has been phenomenal progress in food production since the middle of this century. In fact, from 1950 to 1984, global food production went up 2.6-fold, making possible a 40 percent increase in per capita cereal production — despite rapid population growth during that period.

Today, many are questioning our ability to sustain such increases in food production — or even maintain current levels. Since 1984, per capita production of cereals, worldwide, has declined each year — for a total of 14 percent over the 4-year period. Global grain reserves are projected to be at the lowest level this year since immediately after World War II.

It is still uncertain whether the drop in agricultural output in the last four years is a short-term aberration due, primarily, to unfavorable weather or whether it is the beginning of a long-term trend which

Dr. York is Chancellor Emeritus of the State University System of Florida and Distinguished Service Professor of the University of Florida. He was formerly Administrator of the Federal Extension Service, USDA.

could have some disastrous consequences, particularly to many parts of the developing world already suffering from inadequate levels of nutrition.

The World Bank estimates that over 700 million people, about one-third of the developing world population, do not have enough calories for an active working life. Moreover, approximately one-fourth of the populations of both Africa and South Asia do not receive enough calories to prevent stunted growth and serious health risks, according to United Nations agencies.

It is obvious that there must be significant increases in food availability throughout much of the developing world, merely to meet the needs of current population levels. But there is little hope of meeting the growing need of future generations unless significant progress is made in limiting rates of population growth. This is at the heart of current global hunger and malnutrition problems.

Population Growth

Global populations continue to grow at a rate of 1.6 to 1.7 percent, resulting in almost 90 million more consumers of agricultural products annually. More than 90 percent of this growth is occurring in the developing world, many parts of which are already suffering from inadequate food.

Such growth in population not only substantially increases the demand for food year after year, these greater numbers of people contribute to environmental and natural resource degradation problems in ways that threaten the continued productivity of many agricultural areas.

For example, growing needs have forced Third World farmers to clear and cultivate hillsides and other fragile lands. This, along with an intensification of traditional cropping cycles, has resulted in greatly accelerated rates of erosion and loss of soil productivity. The forage needs of livestock in many developing countries now exceeds the carrying capacity of grasslands — by as much as 50 to 100 percent in some areas — leading to severe deterioration and often to desertification. In industrial regions such as North America and Western Europe, increased export demand in the 1970s and crop subsidies more recently have resulted in the cultivation of marginal lands, highly subject to erosion and other forms of degradation. Water resources are being depleted, and air, soil and water are being contaminated by waste products of industry, urban development and some agricultural practices.

These are some of the circumstances that have led many government entities as well as private organizations and groups all over the world to become seriously concerned about the ability of our planet to achieve and maintain sustainable levels of agricultural production.

There have been many definitions or characterizations of agricultural sustainability. However, most emphasize a dynamic concept of accommodating growing needs for agricultural products without degrading the natural resource base on which agriculture depends.

In the U.S., a number of groups are advocating various approaches to achieving sustainable agricultural systems. These include those proposing "alternative," "regenerative," or "organic"

(continued on next page)

farming systems. Most of these approaches emphasize a number of practices, including:

- More extensive use of longer cycle crop rotations — in contrast to monoculture or short-term rotations;
- More extensive use of leguminous green manure crops to add nitrogen (N) and organic matter to the soil;
- The use of animal manures to provide both organic matter and nutrients to the soil;
- Less use — or in some cases, no use — of commercial fertilizers, relying on plant and animal residues to supply plant nutrients;
- Less use — or in some cases, no use — of pesticides, relying upon "natural" systems including predators and parasites and upon crop rotations to help keep pests under control.

The Big Question

There is obvious merit in some of these approaches. The value of green manure crops and animal manures have long been recognized. Similarly, crop rotation practices offer many benefits. **The big question is the extent to which such practices can substitute for, or replace, commercial fertilizers and pesticides.**

Leguminous green manure crops may supply N but not other forms of plant nutrients. Even the levels of N supplied by such crops are likely to be inadequate to assure most efficient levels of production and desirable economic returns. Large amounts of animal manures are required to provide needed plant nutrients in many cropping systems, but manures in such quantities are not available to most farmers. While crop rotations may help in the control of some pests, serious pest problems can develop despite the use of sound rotation practices. Many farming systems may not lend themselves to the types of rotations that might offer the greatest advantages from the standpoint of pest control. Perennial fruit crops, for example, pose special problems in this regard.

Inputs

These and other circumstances have led many to question the extent to which certain commercial inputs can be reduced and still maintain a viable and economically sound farming program. Indeed, one of the most controversial issues pertaining to agricultural sustainability relates to the use of inputs — especially pesticides and fertilizers. Some believe that high levels of such inputs threaten sustainability; others suggest that without greater input use, sustainability objectives cannot be achieved. For example, without adequate inputs, many believe it would be impossible to meet the food needs of increasing world populations unless additional land that is less sustainable is brought into cultivation, thereby damaging or destroying natural ecosystems. Organic gardening enthusiasts advocate the use of no commercial chemical inputs — a philosophy sharply in contrast to the type of intensive farming found throughout much of the U.S. and western Europe.

LISA

The level of input usage has been tied directly to the sustainability issue by the U.S. Department of Agriculture (USDA) through its "Low-Input Sustainable Agriculture" (LISA) program. Many (including this writer) believe it is a serious mistake to link low inputs directly with sustainability. Certainly, the two are not synonymous; one is not a corollary to the other. Moreover, "low inputs" is a very imprecise term. How low? Low in relation to what? What inputs? Systems involving reduced levels of some inputs, such as herbicides, may actually require higher levels of other inputs, such as labor. It is regrettable that the USDA with its long history of leadership in developing scientific approaches to agricultural improvement would adopt such an unscientific approach to a major problem.

More intensive production systems, involving the use of commercial inputs, have been the product of decades of research by both public and private institutions including land grant universities

". . . It should be recognized that there is no adequate substitute for the use of commercial fertilizers if agricultural systems, worldwide, are to satisfy the food needs of steadily increasing numbers of people at prices which most can afford to pay. . .

"Where fertilizers are contributing to environmental problems (such as nitrate pollution of groundwater), research should be accelerated to develop means of overcoming these problems. There is little doubt that this can be done, given the great accomplishments of such research in the past."

and USDA. Farmers, over the years, have followed the advice and recommendations of these organizations. If problems, relating to such usage, have developed, there is need for **scientifically-based** corrective action. Labels such as "LISA" serve no useful purpose and, indeed, do a disservice to efforts to achieve sustainable agricultural systems.

Research Needs

Research should be organized and carried out to optimize returns from inputs while avoiding undesirable consequences, if any, from such usage. Pesticides and fertilizers have undoubtedly been misused by some in the past. Every effort should be made to avoid such misuse in the future.

Research can undoubtedly lead to a reduction in the need for some pesticides — for example, by developing genetic resistance to many plant diseases and insects. Research can also develop more effective biological approaches to pest control as well as improve systems of integrated pest management. Such research needs to be expanded so that pesticide usage can, indeed, be lowered in a meaningful and cost-effective manner.

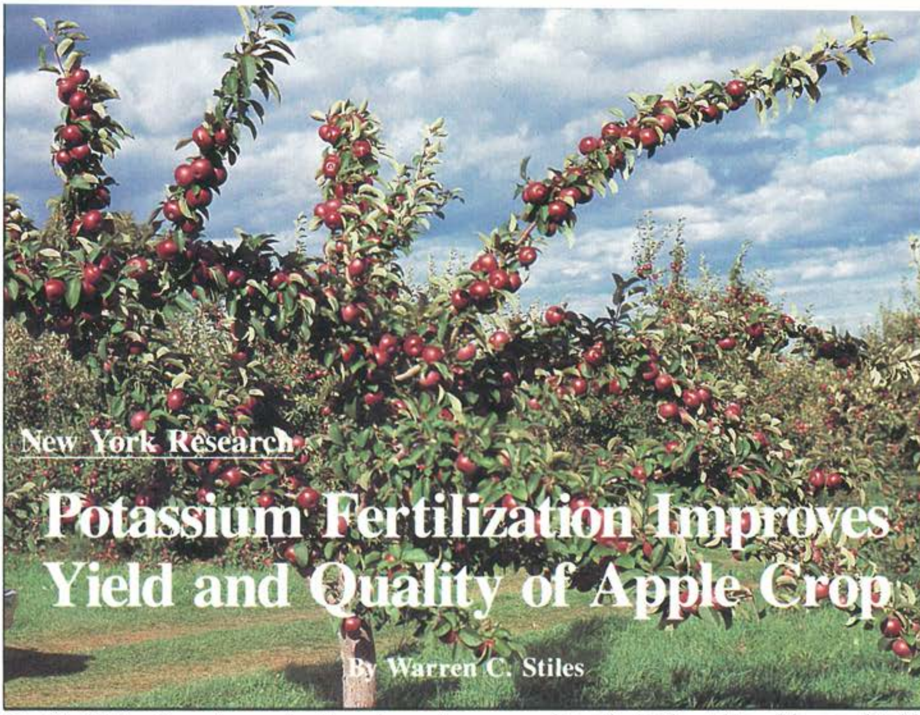
Fertilizers

The situation with fertilizers is somewhat different. Chemical nutrients are essential for plant growth. While some of these nutrients can be supplied by soils, nutrient levels in soils are usually inadequate for optimum crop performance. Some nutrients, particularly N, may be provided by plant and animal residues. However, such residues are usually not available to most farmers in amounts needed for optimum crop performance. It should be noted that less than one percent of U.S. food is estimated to be produced organically — that is, without the use of chemical inputs. However, the cost of such food is usually substantially higher because of lower production levels and, at times, greater costs of other inputs such as labor.

It should be recognized that there is no adequate substitute for the use of commercial fertilizers if agricultural systems, worldwide, are to satisfy the food needs of steadily increasing numbers of people at prices which most can afford to pay. Research must continue to determine what levels of fertilizers should be used to meet the demand for agricultural products and give the producer an adequate economic return. Where fertilizers are contributing to environmental problems (such as nitrate pollution of groundwater), research should be accelerated to develop means of overcoming these problems. There is little doubt that this can be done, given the great accomplishments of such research in the past.

Summing Up

Sound programs of agricultural research have provided the technology to enable U.S. agriculture to become the most productive and efficient of any in the world. If some agricultural practices are contributing to environmental or human health problems, our research institutions must address and solve these problems. This is essential to maintaining the productivity and sustainability of agricultural systems so that they can meet the needs of current and future generations — while at the same time the producer is assured of a fair and equitable return for his investment and efforts.■



New York Research

Potassium Fertilization Improves Yield and Quality of Apple Crop

By Warren C. Stiles

Profitability of apple production depends on consistently high yields of large, highly colored fruit. And high yields of quality fruit require availability of adequate amounts of potassium (K). This article reports results of a recent study at Cornell University.

RESPONSES of Empire apple trees to K were evaluated in a five-year trial initiated in a three-year-old orchard in 1983. Soil at the site is a Knickerbocker fine sandy loam. Initial soil and leaf sample analyses indicated the K supply to be very low.

Treatments consisted of annual applications of sulfate of potash-magnesia (0-0-22-11) at rates up to 775 lb/A (170 lb K_2O). These treatments were broadcast over a 6-foot wide weed-free row-strip each year in late fall. Since leaf analysis showed boron (B) to be lower than desired, it was applied in all treatments, either to the soil or in foliar sprays. Nitrogen (N) and phosphorus (P) levels were considered to be adequate and those nutrients were not applied during the study.

Yield Responses to K

Over the range of K_2O rates applied, the combined yields for 1986 and 1987 increased by 65 percent, from 750 to 1,243 bu/A **(Table 1)**.

Table 1. Effect of K_2O on yields of Empire apples.

K_2O, lb/A/year	bu/A
0	750
45	877
90	1,030
170	1,243

1986 and 1987

These responses to K were obtained with treatments that included soil-applied B (2.5 lb/A/year). The importance of an adequate supply of B in obtaining yield response to K applications should not be overlooked. In contrast to the 65 percent yield increase with soil-applied B, K applications increased yield only 9 percent when B was supplied as foliar sprays (data not shown).

Leaf and Soil Tests

Leaf and soil samples collected during 1988 indicate that 90 lb/A/year of K_2O approximates the optimal rate of application for this soil. With lower rates, leaf K

The author is Professor of Pomology, Cornell University, Ithaca, New York.

TYPICAL symptoms of K deficiency in young apple trees include browning of leaf tips and margins. Empire apple tree is shown on facing page.

was below desired levels (1.35 to 1.8 percent), and subsoil K (8-16 inch depth) did not differ from the zero K treatment **(Table 2)**. Unfortunately, 1988 yields were lost to freeze damage.

Table 2. Potassium in leaf and soil samples.

K_2O rate, lb/A/year	Leaf K, %	Soil K 0-8 inches	Soil K 8-16 inches
		lb/A	
0	0.92	148	75
45	1.19	289	76
90	1.38	407	144
170	1.41	559	169

1988

The subsoil (0-8 inch) samples showed a relatively slow rate of movement of K through this soil profile from surface applications. At the same time, it indicates the need to place greater emphasis on preplant incorporation of K before new orchards are planted.

Potassium and Nutrient Interactions

Analysis of the data from this experiment indicates that maximum benefit from K fertilization may frequently be limited by shortages of other elements.

Although magnesium (Mg) was applied as a component of the K treatments, leaf Mg levels declined and were below acceptable levels with the higher rates of application.

Yield, fruit size and fruit color were found to be highly correlated with both leaf K and leaf copper (Cu) levels. In this case, the effects of these elements were apparently independent and additive over the ranges of concentrations found.

Tables 3 and 4 demonstrate the K-Cu relationship. Yields of Empire apples **(Table 3)** that were at least 3 inches in diameter and with at least 65 percent red color were dramatically affected by both leaf K and leaf Cu. This shows the general relationship between K, Cu and yield over the range of Cu and K values found in these samples.

Table 3. Higher leaf K and Cu levels increased yields of Empire apples with at least 3-inch diameter and 65% color.

Leaf K, %	Leaf Cu, ppm 5.5	Leaf Cu, ppm 6.5	Leaf Cu, ppm 7.5
		Yield, bu/A	
0.59	38	81	124
0.93	79	122	165
1.27	121	164	207

1986 **$R^2 = .663$**

Similar relationships of total yields to leaf K and Cu for the 1986 season are shown in **Table 4**.

Table 4. Total yields of Empire apples as influenced by leaf K and Cu.

Leaf K, %	Leaf Cu, ppm 5.5	Leaf Cu, ppm 6.5	Leaf Cu, ppm 7.5
		Yield, bu/A	
0.59	68	268	427
0.93	191	391	590
1.27	314	514	713

1986 **$R^2 = .673$**

The results of this experiment emphasize the importance of adequate nutrition for high yields of quality fruit and the need to consider not only the direct effects of the nutrient element being applied, but also its interactions with other nutrients in the orchard fertilizer program.■

This project received funding from Hatch Project NYC 155414.

Why Spring Barley Matures Earlier Than Spring Wheat

By Armand Bauer, A.L. Black and A.B. Frank

Understanding the reasons for the maturity differences between wheat and barley can help growers widen the "window" of opportunity between harvest of the stubble-source crop and winter wheat planting in the Great Plains. Researchers offer some management suggestions.

IN THE NORTHERN GREAT PLAINS, it is common knowledge that spring barley matures earlier than spring wheat. Planted on the same day, the maturity difference can be as much as 14 days.

Observations made on currently available cultivars grown in the field over several years at the USDA/ARS Northern Great Plains Research Laboratory point to the reason for the maturity difference. In this comparison, wheat cultivars grown differed in maturity class, and both two- and six-row barley cultivars were included.

Here are reasons for the maturity differences:

1. Planted at the same depth, barley emerges about one day earlier than wheat.
2. Barley requires fewer growing degree-days (GDD) than most wheat cultivars to develop each leaf and other morphological units through the heading stage **(Table 1)**. Almost all cultivars of spring wheat and spring barley produce eight leaves on the main stem. (We compared only those that did.) The difference between "typical maturing" wheat and barley in accumulated growing-degree days from emergence to heading—about 65 GDD—translates into 4 calendar days under "normal" temperatures in the northern Great Plains.

Table 1. Growing-degree days (GDD) per plant development stage (Haun scale), emergence through heading of spring wheat and spring barley.

Crop	GDD/ Haun stage[1]	GDD through heading[2]
Wheat (early maturing)	73	765
Wheat (typical maturing)	81	850
Barley	75	785

[1] Based on Celsius degrees.
[2] These are accumulated from emergence, which is about stage 0.5.

3. Onset of flowering in barley grown in the northern Great Plains precedes flowering in wheat by about two Haun development stages. The difference **(Figure 1)**, translates into about eight to nine calendar days under "normal" conditions.

Barley begins flowering when the awns have emerged about an inch (2 cm) from the collar.[1] Flowering usually is completed before the head has fully appeared. Heading "normally" requires about five days to complete from first appearance of the tip of the head until it has cleared the collar. Wheat doesn't begin flowering until about three to four days after the head has cleared the collar, during the stem elongation stage.

The number of calendar days from onset of flowering to maximum dry mat-

[1] Private communication, Dr. Earl Foster, Crop & Weed Science, North Dakota State University.

Armand Bauer and A.L. Black are Soil Scientists, and A.B. Frank is Plant Physiologist, USDA/ARS, Northern Great Plains Research Laboratory, Mandan, North Dakota.

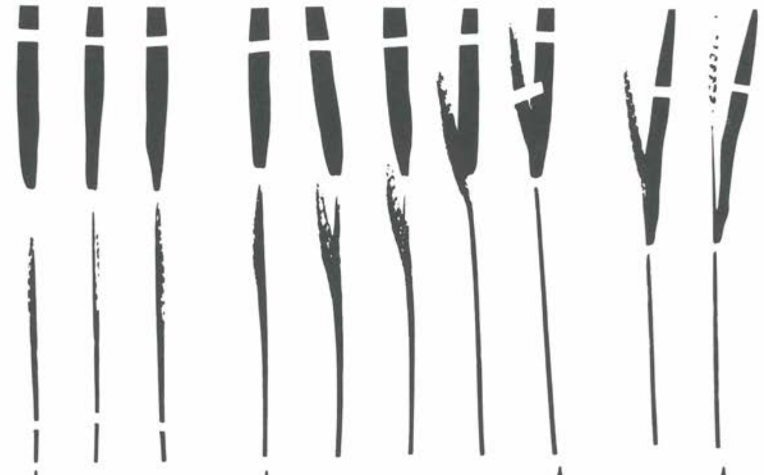


Figure 1. Boot, heading, and stem elongation stages of cereal crops (illustrated with wheat).

ter accumulation in the grain is essentially the same for the two crops (**Figure 2**). The daily dry matter accumulation rate during the linear phase of grain filling averages about one milligram per kernel of wheat and 1.4 milligrams per kernel of barley. A barley kernel normally is heavier than a wheat kernel.

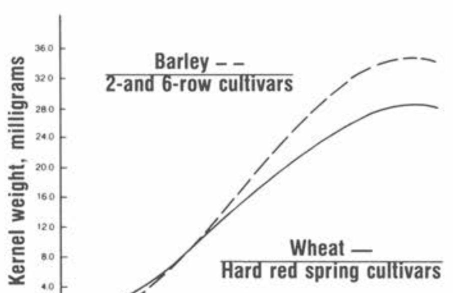


Figure 2. Kernel dry matter accumulation in spring wheat and spring barley in relation to days after flowering begins.

Maturity differences between these two crops have implications for management. In the northern Great Plains, success in winter wheat production is enhanced by planting no-till into erect cereal stubble. This practice traps snow to provide insulation against winterkill soil temperatures and an additional source of stored soil water for growing season use.

SEEDING winter wheat into cereal crop stubble with no-till system.

The period between the harvest of the stubble-source crop and winter wheat planting is relatively short for enough water to accumulate from rain for germination and autumn growth of the winter wheat. Taking advantages of the maturity difference between wheat and barley can widen the "window" between harvest of the stubble-source crop and winter wheat planting.■

Eight Graduate Students Receive "J. Fielding Reed PPI Fellowships"

EIGHT OUTSTANDING graduate students have been selected as 1989 winners of the "J. Fielding Reed PPI Fellowships" by the Potash & Phosphate Institute (PPI). Grants of $2,000 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D) degree in soil fertility and related sciences. The eight are:

- **Ezio M. Buselli, Louisiana State University,** Baton Rouge, Louisiana;
- **Zhengqi Chen, Macdonald College,** Ste. Anne de Bellevue, Quebec;
- **Michele Cheslock, University of Manitoba,** Winnipeg, Manitoba;
- **Newell R. Kitchen, Colorado State University,** Ft. Collins, Colorado;
- **Jeffery Lynn Nagel, Purdue University,** West Lafayette, Indiana;
- **Daniel C. Olk, University of California-Davis,** Davis, California;
- **Jinshu Qiu, North Carolina State University,** Raleigh, North Carolina;
- **Bryan L. Unruh, Oklahoma State University,** Stillwater, Oklahoma.

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

Ezio M. Buselli, a native of Miraflores, Lima, Peru, is a candidate for the Ph.D. degree in soil chemistry/fertility at Louisiana State University. Mr. Buselli earned both his B.S. (1983) and his M.S. (1988) degrees at Louisiana State. His research is designed to develop a soil test method based on ion adsorption by resins. The research will be conducted in four consecutive steps, beginning with laboratory tests to establish relationships among resins and multiple ion species. It will culminate with greenhouse and field studies to correlate plant uptake, predicted availability from the resins method and current soil tests.

Zhengqi Chen is completing his M.Sc. degree at Macdonald College, McGill University, in soil fertility and crop production. He plans to carry out a Ph.D. program in the same field. Mr. Chen was born in Chengdu, Sichuan, P.R. China and obtained his B. Sc. degree at Southwest China Agricultural University. The objective of his current research project is to determine the effects of nitrogen fertilizer on grain production, nodulation and growth of selected early soybean cultivars in southern Quebec. He plans to study the phosphorus-molybdenum interaction as it influences legume nitrogen fixation.

Michele Cheslock was born in Selkirk, Manitoba, and graduated with honors and distinction from the University of Manitoba in 1987. She is currently working toward her M.Sc. degree in soil science, also at the University of Manitoba. She plans to pursue the Ph.D. degree with a long-term goal of employment in research and teaching at the

Ezio M. Buselli

Zhengqi Chen

Michele Cheslock

Newell R. Kitchen

university level in the field of soil physical chemistry. Ms. Cheslock is investigating chromium dynamics in fertilizer-soil-plant systems. So far, results of her research have shown that the increase in soil chromium levels from fertilizer sources is negligible.

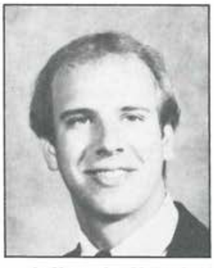
Newell R. Kitchen attended Snow College, received his B.S. degree from Brigham Young University in 1984 and his M.S. degree in agronomy from the University of Missouri in 1986. He is currently working toward his Ph.D. degree in soil fertility at Colorado State University, with expected graduation in the spring of 1990. Mr. Kitchen is a native of American Fork, Utah. His research project is designed to evaluate nitrogen requirements, nitrogen fertilizer sources and fertilizer placement methods in dryland, no-till cropping rotations. He is also assessing residue accumulation and the long-term effects of fertility on the success of no-till cropping.

Jeffrey Lynn Nagel was born in Rensselaer, Indiana. He earned his B.S. degree at Purdue University in 1987 and completed his M.S. degree in agronomy-soil fertility during 1989, also at Purdue. Mr. Nagel's research has shown that predictable soil color-organic matter relationships exist within landscapes. This research has led to the development of a prototype sensor calibrated to measure soil organic matter levels through color changes in a landscape (field). Such a sensor, properly calibrated, can have tremendous impact on fertilizer, pesticide, and seeding rates, as determined by the productivity potential in a given soil.

Daniel C. Olk is a native of Clintonville, Wisconsin, and attended the University of Wisconsin, 1975-77 and again, 1981-83, when he received B.S. degrees in geography and German. He also studied at Albert-Ludwig Universitat in Freiburg, W. Germany, 1977-78. He earned his M.S. degree in geography in 1986 from the University of California-Davis where he is presently pursuing a Ph.D. in soil science. Mr. Olk plans to research factors influencing potassium availability in vermiculitic soils of California's San Joaquin Valley, especially as related to potassium nutrition of cotton.

Jinshu Qui was born in rural China. He worked on a farm for four years following graduation from high school and at China National Rice Research Institute for three years after receiving his B.S. degree. He obtained his B. S. degree in agronomy from Zhejiang Agricultural University in 1982. He completed his M.S. degree in agronomy-crop physiology and production at Mississippi State University in 1986. He is currently working toward his Ph.D. degree at North Carolina State University. His research deals with the influence of phosphorus stress on carbohydrate accumulation and utilization, and nitrogen assimilation and utilization in soybeans.

Bryan L. Unruh is from Newton, Kansas, and attended Hutchinson Community College before receiving his B.S. degree in agriculture, Cum Laude, at Kansas State University in 1985. He earned his M.S. degree at Oklahoma State University in 1987 and is currently working toward his Ph.D. degree in soil science with emphasis in soil fertility-chemistry, also at Oklahoma State. His research program is designed to study ways to improve fertilizer nitrogen use efficiency while protecting the environment. Mr. Unruh is also developing computer software to assist in teaching economic fertilizer use.■



Jeffrey L. Nagel

Daniel C. Olk

Jinshu Qiu

Bryan L. Unruh

Canada Research

Fertilizers Can Reduce Plant Diseases

By L.J. Piening

The capacity of plants to be protected from diseases is influenced by the health of the plant and its stage of phenological development. A severely nutrient stressed plant is often more susceptible to disease than one at a nutritional optimum; yet plants receiving a large excess of a required mineral may become predisposed to disease.

THERE are many factors that contribute to the good health of plants, which is achieved, in part, through a balanced supply of essential minerals. The availability of adequate minerals is dependent upon good weed control, moisture, crop rotation, planting density, and most important upon a balanced and adequate external supply of minerals.

Potash (K) as a fertilizer has been recognized, on a global basis, to have retarded more plant diseases than any other substance. Potash is essential in catalyzing a variety of cell activities. In a test at Lacombe, Alberta, barley had significantly less common root rot (*Cochliobolus sativus)* when grown on a K deficient soil receiving K than on soil with no fertilizer K **(Figure 1)**.

While soil fertility does affect the prevalence and severity of some plant diseases, it is but one of several factors that predispose plants to infection by pathogens. Although the mechanisms of how host-pathogen-nutrient interactions affect plant resistance to diseases are not clearly understood, it is known that specific minerals and the application of plant nutrients in fertilizers can reduce disease severity in plants by one or more of four different mechanisms. An explanation of these mechanisms follows.

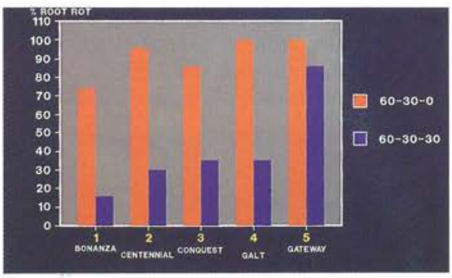


Figure 1. Added K fertilizer reduced the incidence of common root rot on five barley cultivars.

Increasing Disease Tolerance in Plants

Well-nourished plants produce new roots more readily to replace those destroyed by soil-borne pathogens. Good root growth requires adequate levels of all nutrients, but especially phosphorus (P) and K. Browning root rot of cereals caused by *Pythium* spp was a major disease in the Canadian prairies during the period 1920-1940. The increased use of P fertilizer during the 1940s eliminated this disease. In another test at Lacombe, barley had significantly less common root rot (*C. sativus*) on soil where P was applied than on soil without added P **(Figure 2).**

Whenever root growth is restricted, plant growth and yield suffer. Foliar diseases may retard root growth by reducing the movement of photosynthates to the root. The addition of higher levels of fertilizer can help the plant compensate for the smaller soil volume explored by

Dr. Piening is with Agricultural Canada Research Station, Lacombe, Alberta.

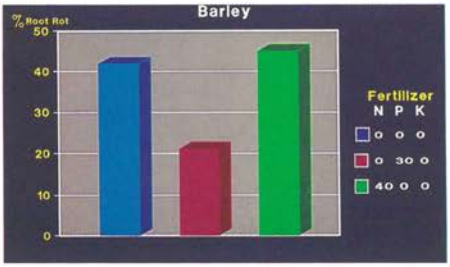


Figure 2. Added P fertilizer reduced the incidence of common root rot of Galt barley.

the diseased root system. Also, the still-healthy root or leaf tissue in a well nourished but diseased plant becomes increasingly more efficient at mineral gathering and food production. Consequently, yields are not greatly depressed.

Enhance Escape or Avoidance from Disease

Added P, K and nitrogen (N) stimulate the production of roots so they outgrow attacking pathogens. This is especially important for seedlings where P encourages early growth. Phosphorus also hastens plant maturity so the plant may produce its full yield potential before the disease has progressed to damaging proportions. The reverse to this phenomenon is the excess effect which increases vegetative growth for a prolonged period. The associated disease-favouring microenvironment encourages foliar diseases such as rusts and mildews.

Phosphorus and K nutrition together help develop strong mechanical tissues in contrast to the succulent tissue produced by high levels of N. Phosphorus and K also promote thicker cuticles and cell walls making it more difficult for fungi such as *Puccinia graminis,* the cause of rust, to penetrate plant cells. Also, thickened cell walls can limit fungal growth once inside the host.

Enhanced Physiologic Resistance

Disease resistance can be increased by creating an unfavourable environment for the pathogen within the plant. One way is through altered metabolic pathways which can produce anti-pathogenic substances. This dynamic process may be hastened in response to disease invasion. Another is by reducing the availability of nutrients essential for the growth of the pathogen. Potash deficient plants accummulate simple N compounds, like amides, and as well limit protein synthesis. Amides, etc., are good nutrient sources for invading pathogens. Balanced mineral nutrition helps reduce disease proliferation by avoiding excesses of nutrients which may encourage growth of the disease organism. The nutritional environment in the host is especially critical for obligate parasites, such as rusts, mildews and viruses. All aspects of physiological resistance are intimately interrelated with the nutritional status of the plant.

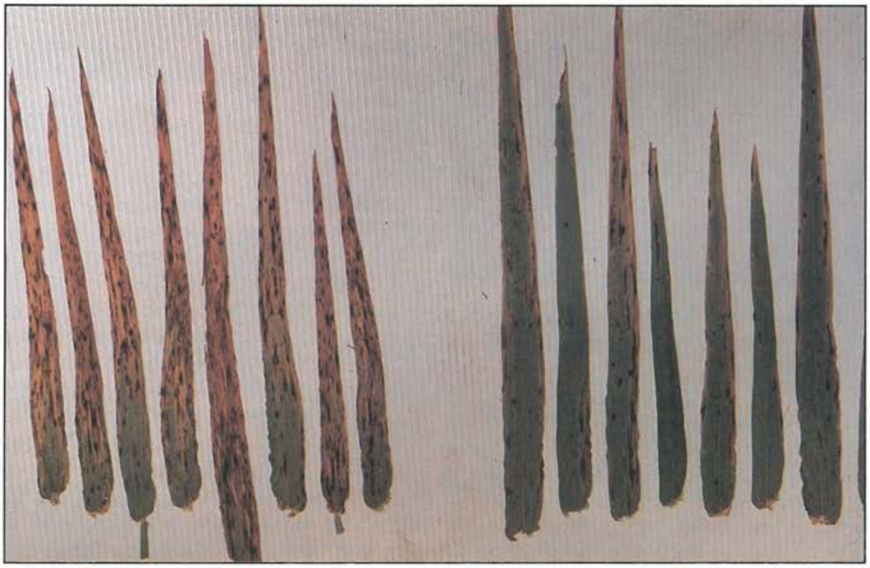
Reducing Pathogen Virulence

Mineral nutrients may reduce the ability of the pathogen to cause disease by inhibiting germination, growth, penetration or enzymatic activity. Pathogen survival in the soil may be profoundly affected *per se* by added fertilizers and lime. These can modify the physical and chemical environment as well as affect the availability of substrates. In some cases, as with lime or different N sources (nitrate versus ammonium), the altered pH affects the growth (parasitic activities) of soil inhabiting pathogens. Fertilizers may also alter the composition and pH of host plant exudates or leachates which can affect the invading pathogen.

Research has shown less incidence of some common root and foliar diseases of cereals supplied with needed N, P or K. Supplying K to barley in K deficient soils in northeastern Alberta caused significantly fewer and smaller lesions of net blotch *(Pyrenopthora teres)* on the flag and penultimate leaves of barley (see photo, next page).

Supplying N up to 120 lb/A to Oslo and Neepawa wheat significantly reduced the root disease, take-all (*Gaeumannomyces graminis*), only in Oslo and Septoria leaf

(continued on next page)



FERTILIZATION with K reduced the incidence of net blotch on the flag leaves of Galt barley (right side). At left are leaves from barley without K added.

blotch (*Septoria tritici*) in both Oslo and Neepawa wheat **(Table 1).** These data suggest that the disease-suppressing effects of fertilizers are generally more greatly effective on susceptible plants. The resistance of Neepawa wheat, which is relatively resistant to take-all when compared with Oslo, was not affected by the extra N.

Table 1. Added N reduced percent of Oslo wheat plants with take-all and the percent of flag leaf area of Oslo and Neepawa wheat infected with Septoria.

N Rate, lb/A	Oslo		Neepawa
	Take-all	Septoria	Septoria
	----------percent infected----------		
0	4.1 a*	4.5 a	5.6 a
20	2.1 b	3.4 ab	3.6 b
120	0.2 c	2.4 c	1.6 c

* The means in each column followed by the same letter do not differ significantly at P=0.05 using Duncan's multiple range test.

Summing Up

In summary, although few diseases can be totally eliminated by a specific fertilizer, the severity of most diseases can be reduced by proper nutrition. Balanced mineral nutrition enhances the chemical, genetic and biological control of many crop pathogens.■

Phosphorus Cycles in Terrestrial and Aquatic Ecosystems Proceedings Available for Regional Workshop 1: Europe

PROCEEDINGS of "Phosphorus Cycles in Terrestrial and Aquatic Ecosystems, Regional Workshop 1: Europe" have been published. Dr. Holm Tiessen, Saskatchewan Institute of Pedology, University of Saskatchewan, served as Editor.

The Proceedings are from the May 1988 workshop in Czerniejewo, Poland, arranged by the Scientific Committee on Problems of the Environment (SCOPE) and the United Nations Environmental Programme (UNEP); organized by the Department of Agrobiology and Forestry of the Polish Academy of Sciences.

The Proceedings are available, at a price of Cdn $15.00, from the Department of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0.■

Alberta Research

Copper Reduces Stem Disease of Some Wheat Varieties

By L.J. Piening, S.S. Malhi and D.J. MacPherson

A study in Canada shows that copper (Cu) applied as fertilizer can help control stem melanosis disease and increase grain yield of wheat.

ALTHOUGH Park is the most suitable wheat cultivar for the short growing season areas of the "parklands" region of Canada's prairie, it is highly susceptible to the bacterial disease known as stem melanosis. The disease shows up as dark brown patches in the field ranging from a few square yards to several acres in size. Symptoms first appear in early August at the milky ripe stage of growth.

Diseased wheat generally occurs on sandy soils which are low in copper (Cu). This disease has discouraged producers in Central Alberta from growing Park.

The association of low levels of Cu in the soil with stem melanosis stimulated research to determine the role of Cu in this disease on wheat, barley and oats. Field experiments were conducted at Lacombe on a Black Chernozemic sandy loam soil containing 0.2 ppm Cu. Copper chelate was applied to the soil surface as a solution and incorporated prior to seeding. A blanket application of nitrogen (N), phosphorus (P) and potassium (K) was added to the soil to supply adequate amounts of these nutrients.

The results of the first experiment showed that wheat plants without added Cu were diseased and produced low grain yields. All wheat plants grown on soil without added Cu showed typical deficiency symptoms of leaf tip die back, lack of plant vigor, stunted pale vegetative growth, delayed maturity, aborted or shrivelled grains and head bending. Adding Cu at a rate of 2.5 lb/A controlled stem melanosis and increased grain yield by more than sixfold. Other nutrients, such as N, P, K, and zinc (Zn) applied without Cu did not reduce the disease or increase the yield. The results also indicated that an application of Cu controlled the disease and increased grain yield for three consecutive years.

In another experiment in 1985, six wheat cultivars were compared for susceptibility to stem melanosis on soil treated with or without added Cu. On the test strip all cultivars had stem melanosis, but Park was the most diseased and had the lowest yield. When Cu was applied at 3.5 lb/A all wheat cultivars were less diseased and had substantially higher grain yields. In the following year, on the same test site two wheat, four barley and four oat cultivars were grown on plots with or without added Cu. Only wheat showed stem melanosis and Park had more disease than Neepawa. Wheat yields were very low on land without added Cu, but increased dramatically with Cu application (2.75 lb Cu/A). Barley and oat cultivars also grew poorly and were stunted when Cu was deficient; although yields were somewhat lower, they were not as low as those of wheat. The yields of barley and oat cultivars increased when Cu was applied.

In conclusion, all wheat cultivars had disease symptoms, but Park was the most susceptible cultivar to stem melanosis when grown on Cu deficient soil. The application of a Cu fertilizer controlled the disease and increased grain yield. Barley and oats showed no disease, but grain yield was increased by the application of Cu. To determine if a soil is Cu deficient and to obtain proper fertilizer recommendations, soil testing is advised.■

The authors are with Agriculture Canada Research Station, Lacombe, Alberta.

Interpreting Interactions Between K and P Responses When Applied to Vegetable Crops

By Arthur Wallace

An article in the Winter 1988-89 issue of this publication discussed responses of seven different vegetable crops to potash (K) and phosphorus (P) fertilization in studies at Geneva, New York. This article presents further discussion of nutrient interactions from the study.

THERE are actually three different types of interactions in the data from the New York study of vegetable crop fertilization described by Dr. Nathan H. Peck in the Winter 1988-89 issue of *Better Crops With Plant Food*.

Table 1 shows a summary of the interactions. They do not easily separate into groups for vegetative growth versus groups for reproductive growth.

The cabbage heads, the snap bean pods, and the brussels sprouts each exhibited a sequentially additive interaction. In this case the per cent response to either P or K was unchanged, whether applied alone or with the other. Both P and K then comply with the Mitscherlich version of the "Law of the Minimum," which states that the decrease in yield is proportional to the degree of supply in relationship to the need. Simply stated, the responses can be predicted and easily computerized for projections of maximum economic yields (MEY).

The broccoli heads showed a clear-cut synergistic response. The per cent response to either P or K alone was substantial, but response to P was greater when applied with K than when used alone. The same occurred for K with P. Although it is nice to see synergistic responses to combinations of fertilizers, it does not mean that it is the more ideal condition. It means that the background level of both P and K are severely limiting and that full response to the other cannot be obtained until the deficiency of the other is first corrected.

In this case, both P and K are described as being Liebig-type limiting factors. Their limitation can prevent substantial responses to other inputs of any kind until they are corrected. Maximum economic yield forecasts may not be accurate if there are any Liebig-type limiting factors remaining.

The interaction for the sweet corn ears is called slightly synergistic in that there is slightly more per cent response to both P and K when used together than when used alone.

The table beet roots and cauliflower heads both represent an antagonism which is corrected and described as a Liebig-synergistic interaction. In both cases P resulted in a yield decrease when used alone. When combined with K, P gave a modest yield increase with table beet roots. With cauliflower heads, there was neither yield loss nor yield gain for P when used with K. When K was added with P on table beet roots, there was a large synergistic response to the K; the antagonism to P had disappeared. With cauliflower heads, P really did not give a yield response with or without K, but the

The author is Professor, Laboratory of Biomedical and Environmental Sciences, University of California, Los Angeles.

Table. 1 Interactions of P and K fertilizers on vegetables.

Annual Rate P_2O_5	Annual Rate K_2O	Table beet roots	Cab-bage heads	Sweet corn ears	Snap bean pods	Broc-coli heads	Cauli-flower heads	Brus-sels sprouts
--------lb/A--------		----------Relative yields----------						
0	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
140	0	0.64	1.65	1.26	1.31	1.48	0.82	1.13
0	140	1.21	1.82	1.17	1.41	1.86	2.71	1.35
140	140	1.55	2.94	1.57	1.80	3.86	2.71	1.46
		Predicted by sequential additivity						
140	140	0.77	3.00	1.47	1.85	2.75	2.22	1.53
		Ratio of actual to predicted						
140	140	2.01	0.98	1.07	0.97	1.40	1.22	0.95
		Type of interaction[2]						
140	140	S or LS	SA	SS	SA	S	S or LS	SA
		Per cent response						
P alone		-36	65	26	31	48	-18	13
P with K		28	62	34	28	108	0	8
K alone		21	82	17	41	86	171	35
K with P		142	78	25	37	161	230	29
More K and P		39	4	-4	-14	-14	20	-18

Calculated from data of Dr. Nathan H. Peck, New York State Agricultural Experiment Station.
[1]The predicted relative yield if sequential additivity is operating is equal to the individual relative yields multiplied together.
[2]For sequential additivity (SA), the ratio is 1.00 or near it. Values well over 1.00 represent various kinds of synergism (S). Some are slightly synergistic (SS) and others Liebig synergistic (LS). None of the interactions are antagonistic where the ratio would be considerably less than 1.00.

K did overcome the antagonism of P used alone. There was large response to K.

For at least 80 years the agricultural community has been evaluating the two different versions of the "Law of the Minimum." Full understanding of the interacting nature of nutrients and other inputs should lead to the positive approach for a "Law of the Maximum," rather than the negative "Law of the Minimum."■

For More Information

Better Crops With Plant Food is published by the Potash & Phosphate Institute (PPI). Some of the articles published in the magazine are also available as reprints. PPI offers a variety of agronomic education information, including printed materials, color slide sets, and other media. For more details and a current catalog, contact: Circulation Department, PPI, 2801 Buford Hwy., NE, Suite 401, Atlanta, GA 30329; phone (404) 634-4274.■

MAFES Study

Soybeans Respond to Potash Fertilization, But No Interaction Found with Fungicide

By N.W. Buehring, W.F. Jones and K.W. Roy

Soybeans have the reputation of responding to residual soil fertility rather than direct application of plant nutrients. Mississippi research shows that soybeans do, indeed, respond to direct application of potassium (K) fertilizer. However, no synergistic interaction was identified for K with benomyl fungicide.

ONE OF THE ORIGINAL objectives of this study was to determine the independent and interactive effects of Benlate (benomyl fungicide) and potassium (K) for reducing several pod, leaf, stem and seed diseases of soybeans. However, results indicate that the effects of Benlate and K, for the most part, were independent. That is, combinations of Benlate and K offered no better control than if each was used alone.

After seven years, there was a good response to K fertilization, as shown in **Table 1.** The response at 40 lb/A K_2O averaged 3 bu/A, while an 80 lb/A treatment resulted in an average response of 6 bu/A. The 160 lb/A treatment resulted in no additional yield increase.

Table 2 shows the influence of K_2O rate and soybean yield on soil test K levels during the course of the study. At the zero rate of K_2O the soil was being "mined." There was also a drop in soil test K at the 40 lb/A K_2O rate.

Table 2. Influence of fertilization on soil K levels, seven-year study.[1]

K_2O Rate,	Soil Test K, lb/A						
lb/A/year	1979	1980	1981	1982	1983	1984	1985
0	170	143	153	105	125	117	154
40	178	158	182	120	144	135	163
80	197	155	222	138	170	178	217
160	217	216	272	211	259	258	280

[1]Soil test K determined each fall after harvest.

There was some increase in soil test K at the 80 lb/A rate, which also produced the best yield response. The 160 lb/A K_2O rate was well above the level removed by the crop and would not be considered as a sound economic practice.

It should be pointed out that growing conditions over the term of this study were not always satisfactory for optimum yields. Had production levels been higher, response to K fertilization could have been greater. The drawdown in soil test K would probably have been more severe at the zero and 40 lb/A K_2O fertilization rates.■

Table 1. Potash increased soybean yields in a seven-year study.

K_2O Rate,	Yield, bu/A							
lb/A/year	1979	1980	1981	1982	1983	1984	1985	Average
0	43	34	28	41	27	28	27	33
40	43	36	33	43	32	34	32	36
80	42	41	36	43	39	37	33	39
160	38	41	39	42	40	40	33	39

Dr. Buehring is Assistant Superintendent, Mississippi Agricultural and Forestry Experiment Station (MAFES), Northeast Branch Station, Verona, Mississippi. Dr. Jones is Professor of Agronomy, Mississippi State University, Department of Agronomy. Dr. Roy is Professor of Plant Pathology, Mississippi State University, Department of Plant Pathology and Weed Science.

How to Improve Accuracy of DRIS Analysis for P and K Deficiency in Soybeans

By W.B. Hallmark

The Diagnosis and Recommendation Integrated System (DRIS) is used to detect plant nutrient deficiencies and is based on nutrient ratios. DRIS diagnoses have been shown to be less affected than diagnoses by the "sufficiency range" or "critical value" methods when nutrient concentrations vary due to plant maturity. However, recent data indicate that the most accurate soybean diagnoses made by DRIS occur when plant analyses are taken at, or near, the same growth stage as the DRIS data base.

THE Diagnosis and Recommendation Integrated System (DRIS) is a diagnostic method used to detect plant deficiencies of phosphorus (P), potassium (K) and other nutrients from analyses of leaves. A proposed advantage of DRIS is that since it is based on nutrient balance (ratios), its diagnostic accuracy is less affected by variations in nutrient concentrations as plants mature. However, recent research indicates that inaccurate DRIS diagnoses may result from ignoring the effects of plant age on nutrient analyses.

Development of DRIS Data Bases

Two soybean DRIS data bases were developed from plant analysis samples taken at the R1 (initial-bloom) and R5 (initial pod-fill) growth stages of 10 high-yielding (55+ bu/A) cultivars. Although these data bases would not normally be used to diagnose nutrient deficiencies (because they were derived from a limited number of samples for one site-year), they do allow a comparison of the effects of plant age on nutrient diagnoses.

P- and K-Deficient Soybeans

Two soybean cultivars grown in an Iowa P-K-lime soil fertility study were used to test the ability of the R1 and R5 DRIS data bases to detect eight P and 20 K deficiencies. Leaf samples were taken at the R2 (full-bloom) growth stage and analyzed for nitrogen (N), P, K, calcium (Ca), and magnesium (Mg). These concentrations were used in the R1 and R5 DRIS data bases to diagnose P and K deficiencies in the R2 plants.

Comparison of DRIS Diagnoses

The results showed that the R1 data base was more accurate than the R5 data base in detecting P deficiencies. Differences in diagnoses were attributed to the large decrease (-59%) of P and the large increase (178%) of Ca in the data bases from the R1 to R5 growth stage (data not shown). This resulted in Ca being misdiagnosed as deficient (data not shown), and the failure to diagnose P as deficient by the R5 data base.

Although the data bases differed in P diagnoses, there was no appreciable difference in detecting K deficiencies. However, in six of the nine situations where the R5 data base failed to diagnose K as most limiting, it also failed to diagnose K as second most limiting. This differed with the R1 data base, which diagnosed K as second most limiting for all 10 situations where it failed to diagnose K as most limiting. Consequently, plant growth stage also affected K diagnoses.

In summary, the R1 DRIS data base was superior to the R5 DRIS data base in diagnosing the P and Ca status of R2 soybeans. Consequently, to obtain the most accurate nutrient diagnoses by DRIS, plant tissue should be taken at or near the same growth stage as the DRIS data base.■

Dr. Hallmark is Associate Professor, Iberia Research Station, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, P.O. Box 466, Jeanerette, LA 70544. Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 88-70-2591.

Soil Fertility and the Transition from Low-Input to High-Input Agriculture

By Lin Bao, Jin Ji-yun and S.F. Dowdle

There are important lessons to be learned from China's experience, particularly for those in developed countries who are advocating reduced inputs or the low-input approach to sustainable agriculture.

CHINA is a vast country where land has been cultivated continuously for centuries. It is mountainous, with only about 10 percent of the land area suitable for cultivation. Yet China's agricultural systems have been providing sufficient food and resources for a large population, and a stable foundation for China's old and rich culture. From a historical perspective, China's agriculture has been enormously successful. In searching for the underlying reasons for this record, one might argue that the basis of success has been the intricate and complex systems for the collection, composting, and recycling of organic materials.

In China, organic fertilizers are composed of farmyard manure and green manure. Farmyard manure is the product of agricultural activities and domestic wastes. The manure mainly includes stalk, straw, municipal wastes, animal and human excrements. Animal excrements account for about 60 percent of the total quantity of nutrients supplied by farmyard manure, while stalk and straw account for about 20 percent. The area sown to green manure has decreased sharply in recent years, falling from a peak of 12 million ha in the 1970s to around 6 million ha today.

However, it is not always fully understood that the maintenance of fertility of lowlands with organic fertilizers was obtained at considerable cost to the nation and the environment. Nutrient losses in the cycle were historically compensated for—organic matter and plant nutrients from the uplands that were not used for agriculture were transferred to the lowlands. Over centuries, this practice has shaped China's landscape—fertile lowlands surrounded by deforested, depleted uplands.

In the past four decades, however, China's agriculture has undergone a massive transformation. From reliance solely on organic sources of nutrients, China is now the world's third largest consumer of manufactured fertilizers and the world's largest user of manufactured nitrogen (N) fertilizers. The transformation has profound agronomic, social, and economic implications. This change was brought about by the need to increase yields to keep pace with the rapid growth of population which increased from about 600 million in 1953 to 1.05 billion in 1986.

The purpose of this article is to examine some of the developments which led to the transformation, and some of the implications referred to above.

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ORGANIC MATERIAL collected in the upland hills has been transferred for centuries to lowland areas for livestock bedding and feed or for fuel. This process has resulted in fertile lowlands and depleted uplands in China.

Encouraging farmers to maintain and improve soil fertility through the use of manure is recorded from as early as 3,000 B.C., in records from the Shang dynasty. There are several detailed descriptions of manure preparation, application, variety, quality and effectiveness that have survived more than two thousand years. Concepts such as "the more manure input, the more fertile is the soil", and "soil fertility could be sustained by means of manure incorporation and intensive farming" are deeply ingrained in the collective Chinese consciousness. In fact, these concepts are so much a part of the system they are hindering the development of a proper balanced use of nutrients in today's more modern Chinese agriculture.

It is important to note that the benefits of cycling and utilization of organic nutrient sources have been largely confined to the irrigated highly productive lowlands. Nutrient losses in the cycle were historically replaced by transfer of nutrients from the uplands.

Grain Yields

To gain an appreciation of the transition from traditional to modern agriculture, it is interesting to look at the historical trends of wheat and rice yields in China **(Table 1)**. Prior to the 1950s, virtually no chemical fertilizers were used in China, as production was sustained for more than two thousand years using organic fertilizer alone. However, yields were relatively low, as was the improvement of soil fertility, especially in dryland farming. The increase in wheat yields from 793 kg/ha to 1,465 kg/ha covered a time span of more than 2,000 years, an average increase of 17 kg **every 50 years.** From 1952 to 1986, wheat yields increased from 735 kg/ha to 3,040 kg/ha, an average increase of 68 kg **every year.** For rice, the increase from 603 kg/ha to 1,560 kg/ha occurred over a time span of 1,200 years, an average increase of 40 kg every 50 years. From

Table 1. Average yields (kg/ha) of wheat and rice in China from 221 BC-present.

Dynasty	Year	Yield, kg/ha Wheat	Rice
Qin	(221-206BC)	793	—
W. Han	(206BC-AD24)	904	603
Song	(960-1279)	780	1,560
Ming-Qing	(1368-1911)	1,465	2,930
	1952	735	2,408
	1965	1,020	2,940
	1980	1,890	4,133
	1986	3,040	5,338

Adapted from Liu Geng-Lin (1988) and China Agricultural Yearbooks.

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1952 to 1986, rice yields increased from 2,408 kg/ha to 5,338 kg/ha, an average increase of 86 kg **every year.** Between 1950 and 1987, total grain production increased threefold, peaking at a record 407 million tons in 1984.

This historical perspective demonstrates that since 1952 the increase in grain yields exceeds anything seen before in China's long history. There are many factors responsible for the accelerated growth of the agricultural production, including: improvements in water control; development and dissemination of high yielding crop varieties; improved agricultural education, research, and extension services; and, perhaps most importantly, increased supplies of manufactured fertilizers. The close relationship between grain production and commercial fertilizer consumption is shown in **Figure 1.**

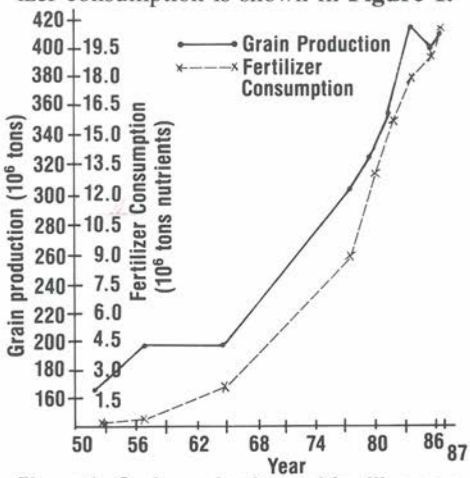

Figure 1. Grain production and fertilizer consumption in China from 1952 to 1987.

Use of Manufactured Fertilizer

The huge growth in use of manufactured fertilizers in China since 1952 is unprecedented **(Table 2)**. Perhaps the most striking feature of the data in **Table 2,** aside from the overall high growth rate, is the predominance of N, relative to phosphorus (P) and potassium (K). Why has the use of commercial fertilizer advanced in such an unbalanced manner?

Table 2. Consumption of chemical fertilizers in China for selected years, 1952-1987.[1]

Year	Total N, P_2O_5, K_2O	N	P_2O_5	K_2O
	--------thousand tons--------			
1952	78	78	—	—
1957	373	320	53	—
1965	1,942	1,331	608	3
1972	4,559	3,228	1,304	27
1980	12,694	10,180	2,386	128
1984	16,133	12,153	3,286	694
1987	17,906	13,268	3,719	919

Data from State Statistical Yearbook and China Agricultural Yearbooks.

[1]Data do not include complex fertilizers. In 1984 and 1987 complex fertilizers accounted for 7.3% and 11.6% of total nutrients applied.

The introduction and acceptance of manufactured fertilizers in China have followed a pattern: a large scale introduction of N fertilizers, followed by P and then K fertilizers. During the long history of China's agriculture and ending only in the early 1950s, nutrient supply depended solely on organic fertilizers, which normally supplied more P and K than N, to sustain the low input and low output agriculture system. As a result, soil organic N was severely depleted. During the 1960s, when high-yielding, fertilizer-responsive varieties of rice, wheat, and corn were released, N was by far the most limiting nutrient. As a result, N use soared far ahead of P and K use. The heavy application of N fertilizers, in turn, stimulated the depletion of soil P and K.

With the increase in use of chemical fertilizers, there has been a decrease in the use of organic fertilizers **(Table 3).**

Table 3. Amount of inorganic and organic fertilizer applied in China.

Year	Total	Source of Nutrient: Inorganic	Source of Nutrient: Organic
	N, P_2O_5, K_2O (million tons)	% of total	
1949	4.34	1.4	98.6
1965	9.13	19.3	80.7
1975	16.03	33.6	66.4
1983	28.62	58.0	42.0

Adapted from Chen Li-zhi et al., 1988.

IMPROVED BALANCE in plant nutrient application rates can increase fertilizer efficiency over time. Shown here is rice response to potash in Hunan province. The field on the right received potash, the field at left did not.

Although data for organic fertilizers in China are variable and inconsistent, the declining trend is incontestable. There are many factors responsible for the decline in the use of organic fertilizers. The rural economy has been particularly buoyant since economic reforms were introduced in 1978. Farmers now have other money earning opportunities besides farming. Thus, there exists a premium on labor in the countryside which never existed before. The time and labor-consuming practices for the collection, preparation, and application of organic fertilizers are out of step with the rapid development of the rural economy.

With increased supplies of chemical fertilizers, and the proliferation of high-yielding, fertilizer-responsive varieties, farmers eagerly buy the limited supplies of chemical fertilizers.

Increases in Production

Since rapid increases in production began in the 1950s, the development of the fertilizer industry and fertilizer practices has not kept pace with the changing needs of China's agriculture. The traditional practices of using balanced, organic fertilizers have been replaced by use of inorganic fertilizers in an unbalanced ratio of nutrients. This change was required in order to supply the increased demand of nutrients by high yielding crops. One effect of such one-sided use of manufactured N fertilizers has been a decline in the efficiency of N fertilizer, and an increase in the effect of P and K fertilizers. Data from the National Network on Chemical Fertilizer Experiments (NNCFE) clearly show these trends **(Table 4)**.

Table 4. Changes of chemical fertilizer efficiency with time.

		Yield increase in kg/kg of nutrient	
Nutrient	Crop	in 1958-1963	in 1981-1983
N	Rice	15-20	9.1
	Wheat	10-15	10.0
	Corn	20-30	13.4
P_2O_5	Rice	8-12	4.7
	Wheat	5-10	8.1
	Corn	5-10	9.7
K_2O	Rice	2-4	4.9 (6.6 in South China)
	Wheat	ns[1]	2.1
	Corn	ns	1.6

[1]ns indicates no significant difference was found.

Source: Lin Bao

(continued on next page)

Table 5. Phosphorus balance in China's agriculture prior to widespread use of manufactured P fertilizer.

Year	P input: Total	P input: Contribution of organic amendments	P output in harvest	P recycling	P Balance
	(10^3 tons)	(%)	(10^3 tons)	(%)	(10^3 tons)
1949	348	100	607	57	-259
1957	562	96	1038	52	-476
1965	850	72	1043	58	-193

Adapted from Zhu and Xi, 1988.

Prior to the wide availability of manufactured P fertilizers, more P was being removed in the harvests than was being returned to the soil (**Table 5**). Thus, P deficient areas in China have been increasing. A similar situation exists in the case of K. In large areas across south China, soil K levels have been extremely depleted through greater removal of K by intensive cropping than K input rates with organic and inorganic fertilizers. This situation with K depletion is not confined to south China, however. **Table 6** shows data from a detailed study of K input and output on a soil in north China, an area previously thought to be well supplied with K.

Perhaps the best documentation of the decline in soil fertility comes from data from the Chinese Academy of Agricultural Sciences. According to results from China's first nationwide chemical fertilizer trials conducted in 14 provinces during 1936-40, it was estimated that about 80 percent of the agricultural land was deficient in N, about 40 percent was deficient in P, and about 10 percent was deficient in K. More recent results from field trials conducted during 1981-1983 by the NNCFE, established in 1957, revealed that about 74 percent of the cultivated land in China was deficient in P (available P less than 10 ppm), about 40 percent was severely deficient in P (available P less than 5 ppm), and about 23 percent was deficient in K (available K less than 70 ppm). It should be noted that these estimates are based on average results from a large number of field experiments and most probably underestimate the deficient areas when high yielding crops are being grown.

Table 6. Yield response and K balance in corn-wheat-corn cropping system.

Year	Crop	Treatment[1]	Yield	Increase	K (Applied)	K (Removal)	Balance
			kg/ha	%	kg K/ha	kg K/ha	kg K/ha
1st Crop 1987	Spring Corn	NP	4,546	—	0	32.4	−32.4
		NPK	7,588	66.9	93.4	69.9	+23.5
		NPM	6,235	37.1	21.0	42.7	−21.7
		NPKM	7,921	74.2	114.4	72.1	+42.3
2nd Crop 1987/88	Winter Wheat	NP	2,665	—	0	49.5	−49.5
		NPK	3,466	30.1	93.4	79.5	+13.9
		NPM	2,799	5.0	14.4	54.4	−40.0
		NPKM	3,750	40.7	107.8	86.7	+21.1
3rd Crop 1988	Summer Corn	NP	1,948	—	0	24.0	−24.0
		NPK	4,471	129.5	93.4	95.1	− 1.7
		NPM	3,154	61.9	0	34.9	−34.9
		NPKM[2]	5,179	165.8	93.4	89.3	+ 4.1

Data adapted from Jin Ji-yun, 1989.
[1]For NPM, NPKM treatment, cattle compost manure (M) was applied at rate of 13.5 t/ha dry weight.
[2]No manure applied for this crop.

AFTER a continuous cycle of nutrient transfer in organic material, upland areas have become barren while lowlands maintained fertility. Now in China and other Asian countries, crop residues from productive lowlands are often removed for fuel, livestock fodder, and industrial uses. For sustainable, regenerative systems of food and fiber production, crop residues should be returned to the soil.

A debate has developed in China, similar to the debate in some developed countries, as to whether organic or inorganic fertilizers are better. The debate is unfortunate in that it draws attention away from the best management practice, which is to use both types of fertilizer whenever possible and practical (i.e. economical). As shown in **Table 6,** when both types of fertilizers are used together under certain conditions, greater benefit can be obtained than when either one of the fertilizers is used alone.

Proponents of strictly organic farming systems tend to overlook two important factors: (a) the adequacy of supply of organic materials, and (b) the high labor costs of collection and application of organic fertilizer sources. Also, little attention is given to the lack of proper soil conservation in the areas supplying organic fertilizer sources for maintenance and improvement of productivity in more suitable agricultural areas.

Whether with organic or inorganic fertilizers, if there is concern as to the effect of cropping on soil fertility, attention must be paid to quantities of nutrients being removed, and quantities of nutrients provided with fertilizers. Organic fertilizers can supply a portion of the P and K required by crops, and therefore slow down P and K depletion processes to some extent. However, with repeated cropping, the amount of P and K supplied in organic fertilizers can hardly meet the requirements of crops.

The unbalanced use of nutrients in China has resulted in severe adverse effects on agricultural production, including increasing incidences of certain diseases, crops of poor quality, declining fertility of soils, and most importantly, stagnation in the increase of agricultural production. Therefore, it will be important to readjust the ratio of N, P, and K fertilizers both in production and in importation so that adequate P and K fertilizers are available for farmers and balanced use of N, P, and K necessary for sustainable increases in agricultural production can be practiced by China's farmers.

For sustainable agriculture, whether it is in China, the U.S.A. or any other country, soil fertility must be preserved through balanced fertilization. Anything less results in declining soil fertility and theft from the most precious natural resource of future generations—the soil.■

Hard Work

Soul, thou hast much goods laid up for many years;
take thine ease, eat, drink, and be merry. — *Luke 12:19*

In the "good old days" man often worked 72 hours a week. The shifts at the factory near my home were 12 hours, six days a week. Farmers worked from daylight to dark. Housekeepers toiled seven full days a week.

Many high school students worked after school, worked a year or so to earn money for college,and then worked their way through college. There were no government loan funds.

Should anyone work that hard today? What for? A bigger house? Fancier cars? Is hard work really sensible? Can't we get all we need and want without hard work today?

We think of medicine and farming as professions requiring long hours and exacting duties. Today medicine is likely to be the more rewarding financially (farming was 100 years ago).

But, did you know that medical schools are resorting to **advertising** for students? Medical school enrollments **declined** 37 percent nationally between 1974 and 1988! Why — for such a prestigious and lucrative profession? Too long and too expensive an education, followed by tough hours and work. Not worth it!

Likewise, agriculture college enrollments have been declining. Not many young people consider farming a glamorous or enticing profession. More appealing is life in the suburbs with luxury homes, country clubs, swimming pools and golf courses.

Studies suggest that too many idle hours contribute to our problems with drugs and crime. Were our youth better off on the farm, despite the long hours and hard work?

— *J. Fielding Reed*

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