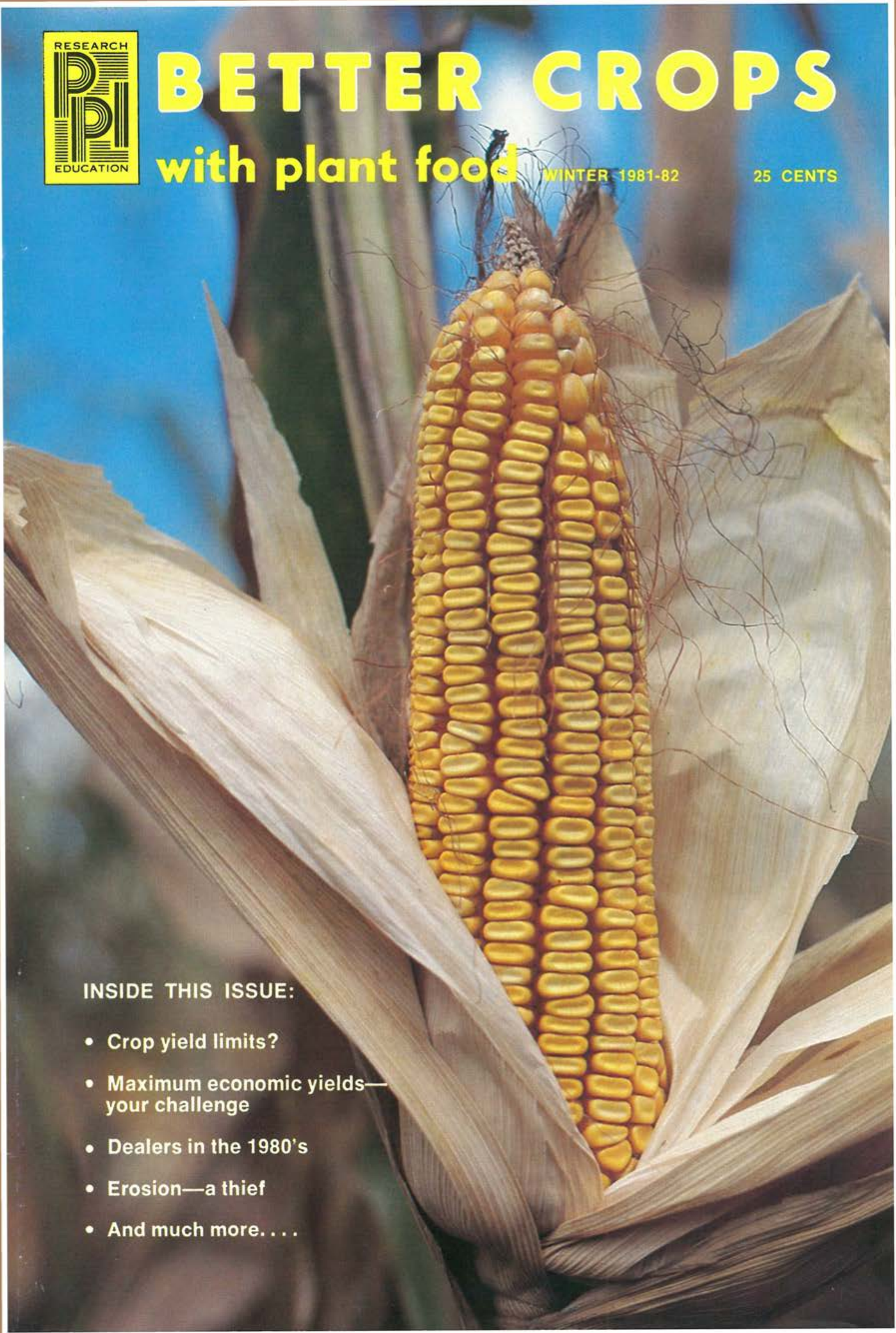
BETTER CROPS with plant food

WINTER 1981-82 25 CENTS



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How High Can Crop Yields Go?

By Richard R. Johnson
Deere and Company

FOR THE PAST FEW YEARS it's been popular to proclaim that yields are beginning to plateau and that advances in yield per acre will soon cease. This scenario has been cited by non-scientists, as well as some research administrators of universities and USDA.

It's appropriate to ask if we are really approaching maximum possible crop yields. Many of us believe that increasing corn and soybean yields can be a realistic objective. First, let's review where we are and where we have been.

Figures 1 and 2 show U.S. yields for corn and soybeans since the USDA began collecting data. When viewed in the long term, there is no apparent yield plateau in either crop. During the past 25 years, soybean yields have been increasing at the rate of about 0.3 bu/A/year; corn yields have increased at the rate of about 2.1 bu/A/year.

Illinois Crop Reporting Service data show a similar trend. Illinois

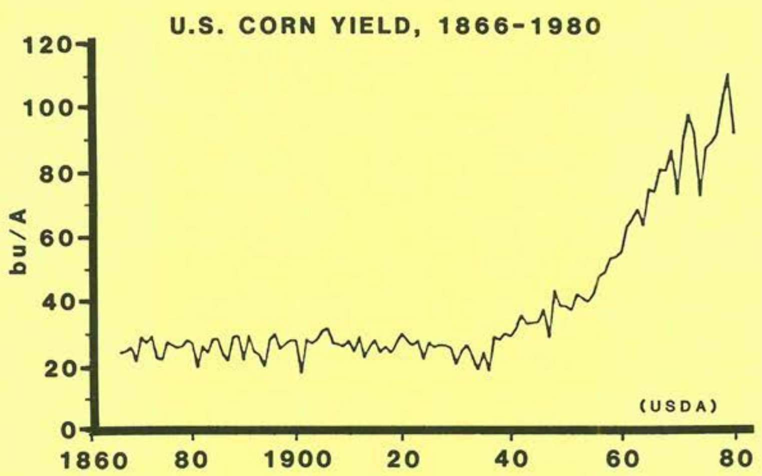


Figure 1

Richard R. Johnson is Staff Agronomist at Deere and Company Technical Center, Moline, IL. He is a former associate professor of agronomy at the University of Illinois.

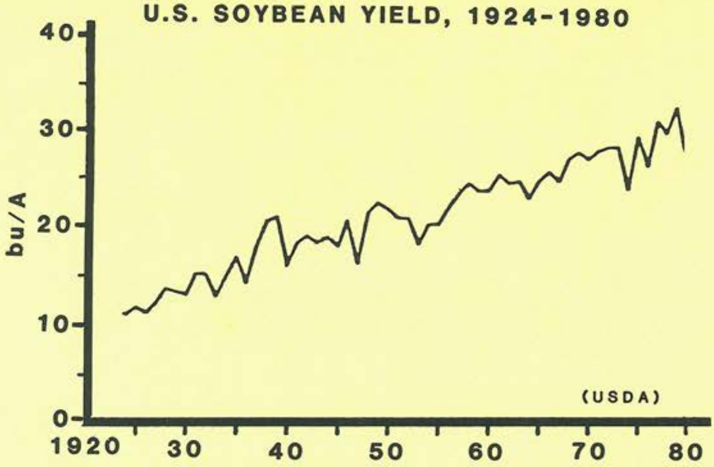


Figure 2

soybean yields are increasing at about 0.3 bu/A/year, and corn yields at 1.8 bu/A/year. Cotton is the only major U.S. crop which has not increased yields in recent years.

YIELD LIMITATIONS

"What limits crop yields?" This is an ancient question, but it's as interesting today as when the first seed was planted. The answer involves soil fertility, variety, pest control, and a host of other management variables.

Yet one factor sets the upper limit on potential yield: the quantity of energy that crop tissue captures from the sun. Without energy, the factory does not operate.

Solar energy is different from many other production inputs. A farmer at a given location can do little to change the amount of energy that an acre of his ground receives. With other inputs such as fertilizer, pesticide, water, and crop varieties a farmer can purchase and apply at different levels.

A producer must accept his level of solar energy input, and manage it in the most efficient manner possible. For example, narrow rows, early planting and other practices permit more efficient use of seasonal sunlight. Disease and insect control are often aimed at maintaining leaf tissue in a healthy condition during the growing season.

THEORETICAL MAXIMUM YIELD FOR CORN

In its simplest form, crop yield is a function of seasonal photosynthesis and the distribution of the photosynthate into crop yield. The carbon dioxide (CO_2), water and sunlight used in photosynthesis provide 90 to 95% of a crop's dry matter. The balance is composed of mineral elements. Corn is one of the highest yielding crops—with one of the most efficient photosynthetic systems. So we can calculate a theoretical yield based on physiological limitations and average local growing conditions.

A full season corn hybrid in central Illinois or Iowa grows for about 120 to 130 days before reaching maturity. It takes several weeks to develop enough leaf tissue to intercept a majority of the sunlight. Leaf tissue begins to die before maturity. We might assume that the crop could photosynthesize at near maximum rates for the 90-day period between early June and early September.

During this 90-day period, each acre in the central U.S. Cornbelt receives an average of about 20 billion calories from the sun each day. At maximum photosynthesis, this energy could produce 625 lb/A of dry matter per day. This assumes an average temperature of 68° F and an average CO_2 concentration, with about one-third of the newly formed sugars being used in respiration.

Respiration is necessary to maintain the plant in a living condition. It also provides building blocks and energy to build more complex products such as protein, oil and cellulose.

Currently, a high yielding corn crop allocates about 25% of that dry matter production to root formation. About 55% of the remaining above ground dry weight is in the grain. Using these percentages, a corn crop producing 625 lb/A daily for 90 days would yield 490 bu/A of #2 shelled corn.

Several variables could change this yield estimate. For example, the yield level would increase if greater amounts of sunlight were available. Reduced cloud cover in many areas of the western U.S. results in 25 to 30% greater daily energy from the sun than is attained in the central Cornbelt.

Latitude and altitude also affect quantity of incoming sunlight. It's possible that a crop producing nearly 500 bu/A would not require a root system much greater than used to produce a 200 bu/A crop. A lower proportion of plant dry matter in roots would free more dry matter for grain production.

Many factors could also reduce the yield estimate. Maximum photosynthetic efficiency is rarely attained—even under carefully controlled conditions. At higher light levels, photosynthetic efficiency declines because of limiting CO_2 concentration. Also, as plant tissue ages, its photosynthetic output usually decreases.

Under field conditions, factors such as water supply, temperature, mineral nutrition, and leaf arrangement are often less than optimum. For example, areas having more sunlight often average lower amounts of rainfall.

The highest daily experimental corn growth rates that have been measured in the field are about 450 lb/A. These growth rates have persisted for only a few weeks at a time. Nevertheless, record reported corn yields have been surprisingly high.

In 1979, state average yield in Illinois was 128 bu/A; in 1981 it reached 129 bu/A.

The highest recorded yield on the Agronomy Farm in central Illinois was 285 bu/A. An Illinois farmer reported a yield of 338 bu/A in 1975. Thus, even if the theoretical maximum is not attained, there appears to be a great deal of room to improve overall productivity.

THEORETICAL MAXIMUM YIELD FOR SOYBEANS

It's common in the Cornbelt to see soybeans and corn growing side-by-side for much of the growing season. Yet, soybeans often yield only about one-third that of corn. If we compare physiological differences of these two crops, we can calculate theoretical soybean yield.

When water is eliminated, a bushel of dry soybeans weighs 52.2 lb; a

Table 1—Energy Requirements to Produce Carbohydrates, Protein and Oil, and Energy Stored.

Final Product	Pounds of Glucose to Produce One Pound	Energy Stored in Product Million Calories
Carbohydrate	1.2	1.8
Protein	2.2	2.2
Oil	2.8	4.3

bushel of dry corn weighs 47.3 lb. Thus, a bushel of soybeans weighs about 10% more. However, energy content of the grain and the energy cost of producing it are more important. Corn grain is high in starch, while soybeans are much higher in protein and oil.

A unit weight of protein contains more calories of energy than starch. Oil contains almost twice the energy contained in protein, as shown in **Table 1.** The higher energy proteins and oils, in turn, require more of the plant's energy for production. The reason: more of the original photosynthate is used in respiration during the synthesis of protein and oil. But the final weight yield is less.

Glucose is one of the products of photosynthesis. It can serve as an energy and carbon source in the fabrication of carbohydrate (i.e. starches), proteins and oils.

Plant biochemists estimate that it takes the equivalent of about 1.2 lb of glucose to fabricate one pound of starch. However, about 2.2 lb of glucose are needed to produce one pound of protein. And 2.8 lb of glucose are required to produce one pound of oil. Thus, crops high in protein and oil require greater rates of respiration to produce the high energy product.

Using average carbohydrate, protein, and oil percentages in corn and soybeans, we can calculate about 97 lb of glucose are required to produce one bushel of soybeans. About 63 lb of glucose are needed to produce a bushel of corn, shown in **Table 2.**

Table 2—Plant Glucose Required to Produce a Bushel of Corn and Soybeans and Final Energy Stored in Grain.

Grain Product	Percent of Dry Weight	Dry Weight lb/bu	Glucose Required to Produce, lb/bu	Stored Energy Million Calories/bu
Corn:				
Carbohydrate	84	39.7	47.8	71.6
Protein	10	4.7	10.3	10.3
Oil	4	1.9	5.3	8.2
			63.4	90.1
Soybeans:				
Carbohydrate	33	17.2	20.7	30.9
Protein	40	20.9	46.0	46.0
Oil	21	11.0	30.8	47.3
			97.5	124.2

A bushel of soybeans has about 124 million calories stored in the grain. Only about 90 million calories are stored in a bushel of corn. So, compared to corn, it takes about 1.5 times as much glucose to produce a bushel of soybeans. But 1.4 times as much energy is stored in soybeans.

A major reason for soybean yields being lower than corn is the energy intensive process of producing a high protein and oil grain.

A second reason for lower soybean yields is the different biochemical pathway associated with photosynthesis. Besides the normal respiration found in corn, soybeans have photorespiration. It is an enhanced rate of respiration that occurs in the light and consumes about 30% of the products of photosynthesis.

Unlike normal respiration, there is no known benefit of photorespiration. Scientists are exploring possibilities of reducing or eliminating it. Many of the crop and weed species producing the highest tonnages of dry matter lack photorespiration. Of the grain crops only corn, sorghum and millet function without photorespiration.

Respiratory needs of soybeans are greatly different from corn. The photorespiration will reduce soybean output to 70% that of corn. And the additional respiratory needs to produce the bushel of high protein and oil soybeans will reduce yields by an additional factor of 0.65.

The capability of the two crops is theoretically similar, although soybeans often are a bit less efficient than corn. Their quantum requirements for photosynthesis are the same.

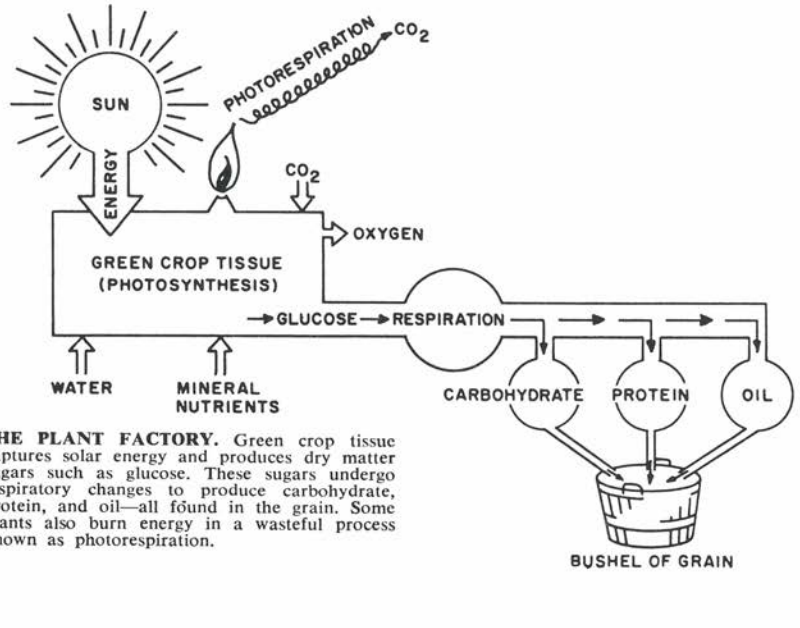
On the basis of energy requirement alone, we might expect soybean yields to be 46% that of corn ($0.7 \times 0.65 = 0.46$). This would place **a theoretical maximum soybean yield at about 225 bu/A in the central Cornbelt.**

If we refer to yields in the mid-1920's, before modern breeding methods, soybean yields were about half as much as corn yields—11 bu/A vs. 24 bu/A. That's very close to my theoretical calculation.

Since then, the gap has widened. Soybean yields are about one-third the level of corn yields. Annual yield increases have been less in soybeans.

One explanation might be the lack of hybridization in soybeans. Other reasons could include failure to understand the needs of the soybean plant, or simply an error in calculation.

Both crops have substantial room to improve productivity. Increasing crop yields can be a realistic goal for many years to come. ■



THE PLANT FACTORY. Green crop tissue captures solar energy and produces dry matter sugars such as glucose. These sugars undergo respiratory changes to produce carbohydrate, protein, and oil—all found in the grain. Some plants also burn energy in a wasteful process known as photorespiration.

New Chairman and Vice Chairman of PPI Board of Directors

DAVID S. DOMBOWSKY, president of the Potash Corporation of Saskatchewan, has been elected chairman of the board of the Potash & Phosphate Institute (PPI). He will also serve as board chairman of the Foundation for Agronomic Research (FAR), an affiliated organization.

Dr. Gino P. Giusti, president and chief operating officer of Texasgulf Inc., succeeds Mr. Dombowsky as vice chairman of the PPI and FAR boards.

Boyd R. Willett, who was vice president of PPG Industries, Inc. and general manager of Kalium Chemicals before retiring recently, had served as chairman of the PPI and FAR boards the past two years.

In welcoming the new leaders, Dr. R. E. Wagner, president of PPI and FAR, expressed deep appreciation for Mr. Willett's years of dedicated service.

PPI is the research and education arm of the potash and phosphate industries. FAR includes other agricultural industries which support agronomic research. The chairman and vice chairman are elected by boards of directors composed of executives representing member companies.

"The missions of PPI and FAR continue to fulfill vital needs," Mr. Dombowsky noted. "Industry recognizes the problems farmer face today. We can help meet these challenges through the support of PPI and FAR programs in agronomic research and education, especially the maximum economic yield approach which means so much to agriculture."

The new chairman is a native of Avonlea, Saskatchewan. He earned a bachelor of commerce degree from the University of Saskatchewan and a diploma in public administration from Carleton University.

Since beginning his professional career in 1958 with the Saskatchewan provincial treasury department, Mr. Dombowsky has held senior positions including Deputy Provincial

David S. Dombowsky
Potash Corporation of Saskatchewan

Chairman, Board of Directors
Potash & Phosphate Institute and
Foundation for Agronomic Research

Dr. Gino P. Giusti
Texasgulf Inc.

Vice Chairman, Board of Directors
Potash & Phosphate Institute and
Foundation for Agronomic Research

Treasurer and Deputy Minister of Industry and Commerce. He was named Managing Director of the Saskatchewan Economic Development Corporation (SEDCO) in 1973.

In 1975 he became president of the Potash Corporation of Saskatchewan, the largest producer of potash in North America.

Dr. Giusti, the new vice chairman for PPI and FAR, has a career spanning more than 33 years with Texasgulf Inc.

He was elected president in 1979 and was appointed chief operating officer in 1981. Texasgulf Inc., with headquarters at Stamford, Connecticut, is a major U.S. producer of phosphate and potash.

In addition to B.S. and M.S. degrees in chemical engineering, Dr. Giusti earned a Ph.D. degree in business and economics at the University of Pittsburgh.

As a recognized leader in the fertilizer industry, he is also serving as chairman of the board of The Fertilizer Institute, located in Washington, D.C.

"In difficult times as we are facing, the programs of the Potash & Phosphate Institute and the Foundation for Agronomic Research are needed more than ever," Dr. Giusti commented. "The maximum economic yield approach offers great opportunities for agriculture." ■

Maximum Economic Yields—Your Challenge in the 1980's

PROFITABLE FARMING in the 1980's will depend heavily on maximum economic yields. Production is back in style and yields continue to trend upward.

And this higher production can mean higher profits for those who find ways to **reduce cost per bushel,** says John F. Marten, Staff Economist of **Farm Journal.**

Dr. Marten and Dr. Werner Nelson, Senior Vice President of the Potash & Phosphate Institute, encourage maximum economic yield clubs for producers. In this article, they discuss questions farmers ask about the approach on 10- to 20-acre fields.

1. Is this just another deal to sell fertilizer? No. But you're partly right. We are definitely selling—selling a complete management program to move producers up the yield ladder. Even more important—to shift growers UP to a new yield curve, one that reduces cost **per bushel,** not cost per acre.

It is true you may purchase more and better seed, plant food, pesticides, drainage/irrigation equipment, etc. . . . expected if more output is to result. Realistic producers know you don't get something for nothing in farming.

2. What if I'm already up against the yield limit for my farm? Scientists tell us we use only about 10% of our brainpower. But farmers continue to amaze us with their ingenuity.

The top profit yield will vary among areas. It may be 250 bu corn in one area and 150 in another . . . 75 bu soybeans in one area and 45 in another . . . 100 bu wheat in one and 60 in another . . . 10 ton alfalfa in one and 6 in another. **BUT** almost invariably the maximum economic yield is much higher than we now think. Aren't you producing more today than you dreamed was possible 10 years ago? Of course you are. Expect the same pattern now. Your own ability will amaze you!

3. Do these higher yields pay? Yes. A University of Illinois study showed that by increasing corn yields from 100 to 175 bu/A, production costs dropped by one-third. And a substantial loss became a profit, even at $2.75 corn.

Corn Yield	Production Costs		Net Profit
bu/A	$/A	$/bu	$/A
175	383	2.18	98
150	359	2.39	54
125	343	2.74	1
100	331	3.31	-56

Let's look at an example on soybeans. Phosphate did nothing by itself. Potash alone added 14 bu. **TOGETHER** they increased yield 27 bu. We call this a **positive interaction** . . . a striking profit.

P_2O_5	K_2O	Soybean Yield	Prod. Cost	Net Profit
lb/A		bu/A	$/bu	$/A
0	0	31	6.45	17
120	0	30	7.86	−26
0	120	45	4.88	95
120	120	58	4.48	146
Soil medium in P and low in K.				

Soybeans in the U.S. received an average of only 17 lb/A P_2O_5 and 25 lb/A K_2O in 1980. Much higher levels of phosphate and potash will pay dividends if a complete management package is used. Try it under your conditions.

Let's look at an example on wheat. On this Kansas soil, 40 lb P_2O_5 increased yield and net profit substantially. Wheat farmers applied an average of only 17 lb/A P_2O_5 in 1980. A key to profitable P response is **first applying adequate N.** Again, we see the importance of **interactions** . . . and the "package" concept.

P_2O_5	Yield	Prod. Cost	Net Profit
lb/A	bu/A	$/A	$/A
0	35	129	−6
20	44	137	17
30	49	142	30
40	57	147	53
75 lb N, low P, high K soil			

(Turn to page 12)

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4. Has anyone ever produced 300 bu corn? Dr. Roy Flannery, a university researcher in New Jersey, produced 312 bu/A of corn in 1980. We weren't surprised. We've had farmers claim such success. The stunning part was that it could be produced PROFITABLY, with $2.75 corn! The net return was $349/A with the 312 bu yield, even with very high production costs.

	Fertilizer use* High	Fertilizer use* Medium	Response to fertility
Yield—bu/A	312	218	94 bu more
Gross—$/A	858	600	—
Est. cost—$/A	509	377	—
Est. cost—$/bu	1.63	1.72	9¢ less
Net $/A	349	223	$126 more

*High 500+300+300 ($N+P_2O_5+K_2O$), medium 250+125+125

Soil test pH 6.5, very high in P and K.

Note the considerable response beyond rates currently recommended—**and on a soil testing very high in P and K!** Such research establishes potential for profitable corn production within an environment of rising production costs.

5. How can I have confidence in my management ability? Don't sell yourself short. Some farmers may not have the ability to produce higher yields. Others do. But those with ability can push back the yield frontier—**and make a profit.** It takes commitment and an open mind.

6. How can I learn from my on-farm test fields? Form a maximum economic yield club in your area. Share approaches, ideas, and results with other producers with similar climate and soils. Split the responsibilities for farm tests among members.

7. How do I go about this? One maximum economic yield club has 10 farmers. An interested dealer and a consulting agronomist helped to organize it. Here's their plan.

Plots: Corn-soybean rotation of 10 acres each—20 acre total . . . committed for a 6 year study.

Farmer: Furnishes all material, labor, and scouting . . . monitors the crop and keeps accurate records . . . openly shares plans and results with other farmers in the club.

Dealer: Furnishes technology, coordination, and information . . . holds several diagnostic clinics during the growing season . . . assembles the group after harvest for exchange of results and planning ideas.

A successful club does not have farmers competing. It is a **joint learning experience.** It emphasizes improvement in management and yields . . . and the sharing of new knowledge.

8. Can research results be applied directly to my farm? Yes. Even though your on-farm test results offer great advantage, they should complement rather than replace results by university and agribusiness scientists. We are still formulating specific recommendations for maximum economic yields but can only offer suggestions right now.

9. How can I apply the right amount of fertilizer? It is impossible to apply the exact amount needed. Research results show that if you make a fertility level mistake, you should make it on the high side. Dr. Stan Barber at Purdue University found that one-fourth over, compared to one-fourth under optimum fertility, netted 2.6 bu/A more corn.

Fertilization	Yield bu/A	Net Bushels Minus Fertilizer Cost bu/A
Optimum	151	55.2
¼ less	142	50.4
¼ more	153	53.0
Check	79	—

Adjust soil pH to the 6.0 to 6.5 range for grain crops on your test field. The soil can be built gradually to very high fertility levels and monitored by soil tests. Monitor balance of nutrients in plants by plant analyses each year. Keep a close watch on P and Zn level in corn.

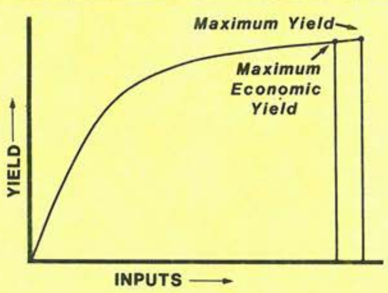
10. What about other management practices—besides fertilizer? Much of your initial yield increase will come from improved management practices, not just extra fertilizer. Many of these practices cost very little.

For example, one hybrid yielded 53 bu/A more corn than another hybrid in **Illinois work** . . . 35,000 plants per acre yielded 43 bu/A more corn than 24,000 plants in **Colorado work** . . . 7-inch soybean rows yielded 19 bu/A more soybeans than 30-inch rows in **Ohio work** . . . planting soybeans May 17 yielded 17 bu/A more soybeans than beans planted June 15 in **Louisiana work.**

Timeliness is important with all crops. All this is combined under the term "management ability." Make sure all controllable factors are taken care of.

11. Are we out just for the yield? No. The idea is to find the maximum economic or top profit yield. **Figure 1** shows that the maximum economic yield is slightly below the maximum yield. It varies among years and farms.

Figure 1



The key is to find **today's limitations,** not some leftover idea from 10 to 20 years ago. This requires persistent attempts to see just what our limitations really are. Then you can transfer key practices to the rest of your farm. ■

Cracks in the Wheat Yield Barrier

By Lowell Burchette
Kansas Crop Improvement Association

WHY HAVE SOME FARMERS produced such extremely high wheat yields in recent years?

There are many reasons. They are usually explained as favorable weather acting on improved varieties with good cultural practices.

But how do we explain great yield differences in adjacent fields which apparently receive the same treatments?

Seed Quality

One factor is generally ignored or taken for granted by most farmers. It may provide many answers to such questions. That factor is overall seed quality.

For this report, overall seed quality means all the genetic, physiological, and mechanical factors that contribute to the successful production of a new crop.

Before discussing some of these qualities, we must remember an important fact. As yields go up, yield responses to some production factors become increasingly important.

For example, a practice giving a 2% increase at a 15-bu/A yield level with $2/bu grain is worth only 60¢/A. The same 2% increase is worth $4.80/A with 60 bu/A wheat at $4/bu.

It can be expressed another way. Some 2% responses at 15 bu/A may be 4% or 10% response at higher yield levels. Some data and experience suggest that responses from excellent seed fall in this category.

Let's look at some ingredients of good quality seed that should give maximum yields and reduce production risks.

1. Genetically Pure Seed Of Adapted Variety. We have long known the need for using adapted varieties. The genetically pure aspect now requires more attention.

Three factors make some mixing almost inevitable: (a) Greatly increased numbers of varieties available. (b) More varieties planted per farm. (c) Shorter life cycles for varieties. Experience shows that all semi-dwarf varieties will outcross. They are difficult to maintain with high genetic purity.

Recommendation: Plant only certified generation seed, especially for semidwarfs. Plant no seed more than two years from certification.

2. Large Seed. The road to higher yields is with larger seed. Research has consistently shown that large seeds produce more vigorous seedlings, frequently leading to higher yields.

Kiesselbach (1924) summarized several years of results with winter and spring wheat and oats. Small seed yielded 18% less than large seed at low seeding rates . . . 10% less when equal numbers of seeds were used at optimum rates for the large seed . . . and 5% less when equal weights of seeds were used at optimum rates.

Taylor (1928), Waldron (1941), Austenson and Walton (1970), and Grabe (1976) conducted wheat research with similar results.

Recommendation: Use at least a 5/64-inch wide slotted-bottom screen (with 6/64-inch wide slot preferred) to clean the seed. This will commonly sieve out 15% of the seed. With winter wheat varieties such as Newton and Centurk, up to 50% of some seed lots will be sieved out.

3. High Protein Seed. A direct relationship between seed protein and plant growth was apparently first established by Schwiger and Ries in 1969.

Later field tests showed a correlation of +0.96 between spring wheat seed protein content and yields produced by that seed. With winter wheat, grain yields were increased 12% by fertilizing the previous seed crop with 80 lb/A of nitrogen.

Lowe and Ries (1971) found that seedlings from high protein seeds were taller, had more leaf area, and produced more total growth. Lowe, Ayers, and Ries (1972) suggested that reports of varieties deteriorating or "running out" might be caused by seed production under low nitrogen conditions.

Recommendation: Select seed from fields that have been adequately fertilized to produce maximum protein content. Ideally, protein level can be determined on various seed lots. Generally large, plump, dark, hard vitreous seed will come nearest to meeting this standard and the large-seed qualification discussed earlier.

4. Seed Treatment. Perhaps the biggest problem in maintaining seed quality is proper seed treatment.

There are challenges in selecting appropriate materials and applying them properly. Even so, calculated benefits outweigh the costs and hazards by large margins. Don't take the risk of not treating seed.

Recommendation: Select treatment material from extension and industry recommendations according to your needs. Then apply at approved rates. Be sure to get complete coverage with treatment on each kernel.

Yield data from Kansas (Jacques et. al. 1975) research strongly suggest that farmers can easily increase both quality and quantity of wheat produced by improving the quality of the seed planted. ■

Problems or Opportunities for Fertilizer Dealers in the 1980's?

By W. David Downey
Purdue University

RETAILING FERTILIZER is a very competitive market. Yet many dealers have been successful and grew much larger in the past 10 years. Their dollar volume has increased. Their business has grown in physical size, in tonnage, in number of employees, in investment, and most important, *in profits.*

DO DEALERS CHANGE AS CUSTOMERS CHANGE? Management has not always grown enough to meet the unprecedented economic pressures of the 1980's. Some dealers may be comfortable with their past successes. They may be reluctant to make the sometimes-drastic changes that are needed.

Their management style may be similar to when they were a much smaller business. This means many dealers today face severe time-management problems. Some have personnel who cannot satisfy the highly technical needs of large progressive growers.

Dealers also face cash flow restrictions that severely limit their flexibility. Too often, inadequate records don't give sufficient information for management decisions.

In short, many managers must make important changes in their organizations, *IF* they are to continue to be successful and grow.

THERE'S ANOTHER SIGNIFICANT CHALLENGE facing fertilizer dealers: the trend toward larger, more specialized farm operations. These farmers are better educated. They travel extensively and adopt new technology quickly to increase the efficiency of their huge investment. They are professional, demanding, and tough negotiators.

MANY DEALERS HAVE inadequate record systems to make critical management decisions. Financial statements arriving weeks or even months after the season has ended help little in adjusting the operation.

With insufficient detail to determine profitable or unprofitable areas, it's hard to determine an adequate price.

The fertilizer market has begun to mature. No longer is abundant growth possible just because the dealer is there. There is still opportunity for selling much more fertilizer. But it seems increasingly clear that additional growth must come from changes in market share.

Yet, there are big opportunities for growth and profit in distributing fertilizers to farmers, if dealers do two things:

1. Objectively examine their changing environment.

Dr. Downey is Prof. of Agri-Business Management, Agricultural Economics Department, Purdue University, West Lafayette, IN.

2. Make significant adjustments in their operations.

SUCCESSFUL DEALERS MUST become more business-like. They must recognize that they are no longer small businesses. They must begin to create their organization structure.

Agronomists and outside salesmen are becoming valuable to larger dealers. Larger retailers must work closely with their accountants, bankers, and lawyers. Business activities must be planned more thoroughly—and communicated to everyone who must execute the plan.

COMPUTER APPLICATION. Computers will play a big role in success over the next 10 years. Retailers will rely on computers for accounting chores and for instant communication with suppliers.

Dealers will also use this information to bring their customers sound agronomic and economic advice.

Detailed cost analysis will help each service become a profit center in its own right. And each piece of equipment will have its own cost analysis records.

MARKET PLANNING AND UPGRADING. Successful retailers will create their market plans early—and rely heavily on these plans as they move through the year.

Establishing specific marketing goals, selecting target markets, and laying out timely action plans will become standard procedure for profitable dealers.

And, perhaps most important, successful dealers will move to upgrade their business. They will recognize the importance of their image in the market place. They will watch their physical appearance, their customer relations, and their billing practices.

Progressive dealers will allocate resources to upgrade their people with technical skills and selling skills. They will improve human relations with customers.

HIGH PROFITS REQUIRED. Successful dealers will recognize that profit levels adequate for the 1970's are inadequate for the 1980's. Inflation has greatly increased the costs of equipment and facilities.

A self-propelled custom applicator selling for $100,000 today may cost $200,000 when it must be replaced in 5 to 7 years at current inflation rates.

The first $100,000 to replace the equipment can be covered by depreciation expense charged to the business. But the remaining $100,000 must come from additional profits.

Dealers must recognize that their profit rates must keep pace with inflation rates. They must **plan for profits** as they establish gross margins and prices for their products and services.

CHANGES ARE REALLY NECESSARY. Fertilizer dealers face unprecedented challenges in the 1980's. They can be summed up in one thought—record interest rates combined with double digit inflation to double costs in 5 to 7 years.

Limited energy resources greatly influence this energy-intense industry. Rapidly growing farm operations demand more from their dealers. These farmers drive harder bargains.

Dealers cannot rest on their past success and laurels. If they try to, the pressures may cause serious problems. Optimistic and progressive dealers will adopt appropriate changes in their management practices. Their future is filled with opportunity. **Their key is professional management.** ■

EROSION — A Thief of Productivity

By D. W. Dibb

FOR DECADES, erosion has been recognized as a serious cause of depletion of productivity in agricultural soils. Recently, this concern for erosion losses has increased. The reasons include: (1) potential effect on water quality from nutrients associated with the lost soil; (2) effect of reduced soil productivity; (3) a perceived incease in rate of erosion.

A DUAL PROCESS

Erosion is both a physical and chemical process that can result in lower productivity.

Physical erosion, related to agriculture, refers to actual movement or loss of soil particles from a field. The consequence is shallower soil and exposed soil horizons or layers, usually less suitable for crop production. **Sedimentation** occurs as these soil particles are deposited in surface water.

Chemical erosion results from the loss of nutrients associated with the physically-removed soil particles. It also reduces productivity. Any process that would remove nutrients and reduce soil productivity might be called chemical erosion.

MAGNITUDE OF LOSSES

Soil scientists estimate the "equilibrium rate" of physical erosion is about 5 tons/A/year. That is, natural soil forming processes would replenish that much soil annually. Any sustained physical erosion much more than this would severely limit productivity in a few years.

Let's take a physical erosion rate of 20 tons/A/year (a very high rate) and evaluate the chemical erosion process. We will use P and K as examples since they are the crop nutrients required in the largest amounts. They are essentially immobile in most soils and not subject to loss mechanisms associated with N.

Assume a P_1 test of 80 lb/A of P and a K test of 500 lb/A—both would be considered in the "very high" soil test range. The "chemical erosion" loss at the 20 tons/A/year soil loss rate would be about 12 lb/A of available K_2O and 3.6 lb/A of available P_2O_5 lost each year. This would be in addition to the soil-associated "fixed" phosphorus and potassium fractions.

Dr. Dibb is Southcentral Director for the Potash & Phosphate Institute.

A substantial loss

This 12 lb of potash and 3.6 lb of phosphate per year may not appear too great initially. But if a farmer allows this erosion to occur on 100 acres, his losses quickly multiply to 1200 lb of K_2O and 360 lb of P_2O_5 per year on his farm. That's a substantial economic and productivity loss.

CHEMICAL EROSION

A farmer who harvests his crop without replacing the nutrients removed allows chemical erosion of his soils. For example, a 50 bu/A soybean yield would remove about 40 lb/A of P_2O_5 and 70 lb/A of K_2O in the grain. If these nutrients are not returned in the fertilization program, the chemical erosion rate is 11 times higher for P and 6 times higher for K than the level of these nutrients that are lost in the 20 tons/A/year soil erosion rate. This will result in somewhat lower available P and K soil tests.

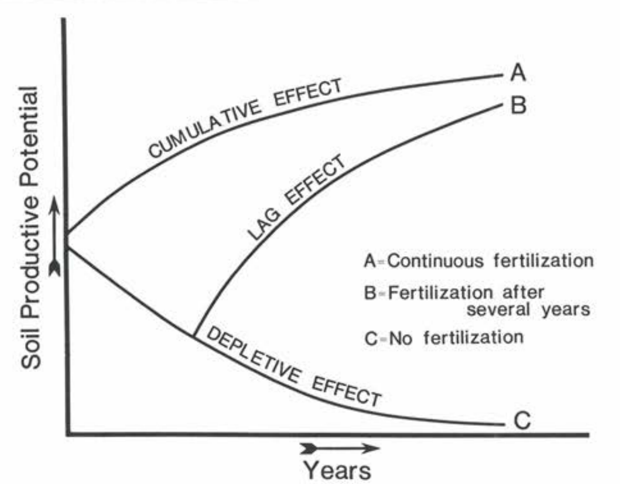
Where soil nutrient levels have been depleted only a few years, large applications of the nutrients may re-establish productivity in one or two years. But where neglect has been more extensive, it might require several years and substantial nutrient additions to rebuild fertility and productivity.

REBUILDING SOIL PRODUCTIVITY

Through soil development, it takes nature many years to replenish the soil losses which have occurred through years of excessive physical erosion. Similarly it takes a good fertility program several years to replenish the productivity lost through years of chemical erosion.

Figure 1 illustrates this time component required for rebuilding productivity of chemically eroded soils.

Figure 1



Where chemical erosion has been allowed for a number of years (C), it takes several years of adequate fertilization (B) to return the soil to a point approaching the productivity level of the soil where chemical erosion was not allowed (A).

(Continued on page 20)

A long term fertility trial in Tennessee illustrates this concept in **Table 1.**

Table 1. Effect of K_2O depletion.

TN

K_2O applied	Corn yields (Hartsells loam) Low-K soil	Med-K soil	Increase
lb/A	bu/A		bu/A
0	59	136	77
30	95	158	63
60	128	153	25
90	119	162	43

Where K was depleted to a lower level, extra increments of K_2O did not return soil in a single year to the productivity level of the soil maintained at a higher nutrient level.

Similarly, a Rothamstead, England, experiment shows that it will require time and care to remedy more than 50 years of nutrient depletion.

Table 2. Effect of P_2O_5 depletion.

England

P_2O_5 rates First 57 yrs	Next 3 yrs	Oat yields	Wheat yields
lb/A		bu/A	
0	0	21	6
	50	41	22
33	0	103	41
	50	110	45

EROSION AND HIGH YIELD AGRICULTURE

Erosion is an enemy of sustained high yield production. If erosion continues, long term yields and productivity potential will suffer.

Let's look at the reverse of this situation—where long term maximum economic yield production is the objective.

Research shows that increasing yields on a long term, sustained basis requires certain steps: earlier planting, higher plant populations, narrower rows, more adequate fertility and replacement of nutrients as they are removed by the crop, timeliness of operations, etc.

Increasing corn yields can decrease erosion potential—if top management is applied.

A corn crop has a harvest ratio of about 50%. That is, 50% of the weight is in the grain and 50% in the stover. So, if we can increase grain yield by about 50 bu/A (about 2366 lb/A of dry matter), we will also be adding over a ton more organic matter back to the soil surface as residue.

Handled properly, this residue can decrease wind erosion, improve the moisture holding capacity and soil infiltration rate, and improve the water stability of soil aggregates as it is decomposed. These effects can improve water infiltration while decreasing surface water movement and sedimentation potential.

Also, high yield management causes greater root proliferation. Researchers estimate that about 30% of total dry matter produced by the plant is below ground. A profuse root network decreases erosion potential by anchoring the soil particles. Too, aggregate stability is improved during root decomposition.

The earlier planting, higher plant population and narrower rows suggested by research for higher yields mean much earlier canopy closure. So surface soils are less susceptible to beating rains. There is less potential for raindrop impact erosion and displacement.

Research shows that inputs applied for **sustained maximum economic yield production can decrease erosion potential.** Indeed, where sustained maximum crop yields are **not** the objective, there is increased erosion potential.

OUR MOST LIMITING NATURAL RESOURCE

Highly productive agricultural land is our most limiting natural resource for food production.

Recently, concern has been mounting for the millions of acres of our best farmland lost annually beneath highways, homes and shopping centers. This concern is highly justified and should be resolved.

There is also mounting concern for the destruction of productivity through physical erosion and loss of our productive topsoils.

The loss of productivity caused by chemical erosion or depletion of fertility should be of equal concern. If allowed to occur due to ignorance, neglect, or calculated "mining" of this resource, it could take years to restore soil to its former level of productivity.

These chemically eroded soils that continue in production without corrective changes are more susceptible to physical erosion because of slower crop growth and less plant residue returned to the soil.

We need a concerted effort to maintain the fertility level and productivity of our soils.

Safeguarding this productive land—the greatest of all our natural resources—requires a four-pronged effort:

1. **Preserve its use for agricultural production.**
2. **Keep it in place by essentially stopping physical erosion—physical removal of soil particles.**
3. **Maintain its productivity by stopping chemical erosion—the depletion of soil fertility.**
4. **Enhance its long term productivity by managing for sustained maximum economic yield.** ■

Effects of Fertilizer P and S on Sugarcane Yields and Leaf Content

By Laron E. Golden
Louisiana State University

SIX FERTILIZER experiments were conducted in Louisiana to measure the effect of fertilizer phosphorus and sulfur on sugarcane yields and P and S content in the leaf blade of sugarcane. The experiments were located on selected commercial plantation sites in the sugarcane growing areas.

In each experiment nitrogen was applied at a constant rate of 160 lb/A. The N only treatment served as a check. Three experiments were conducted to study S. Another three were to study S and P treatments. S was applied at rates of 0 and 24 lb/A. P was applied at 0 and 17.4 lb/A.

The data in **Table 1** show results of soil analyses from the test sites. **Tables 2** and **3** give sugarcane and sugar yield data and leaf blade P and S concentrations. **Table 2** reflects only sulfur experiments while **Table 3** reports on the P and S experiments.

S Experiments. Yield differences obtained in experiments 1 and 2 were not significant. In experiment 3, sulfur increased yields by 1.67 tons/A of cane and 570 pounds of sugar. Applied sulfur increased S content of leaf blades and significantly decreased P content of leaf blades in experiments 2 and 3.

P-S Experiments. Fertilizer P and S interactions of the nutrients showed no significant effect on cane and sugar yields. The PxS interactions reflect a tendency for response to fertilizer P to be greater when fertilizer S was applied and conversely, for response to fertilizer S to be greater when P fertilizer was applied. The average yield for the NPS treatments in the three experiments was 376 lb/A higher than the average yield from the N control treatment.

The leaf blade P was generally increased with the use of fertilizer P and decreased with sulfur applications.

The effect of fertilizer P on leaf blade P content generally was positive. It was not as great as the positive effect of fertilizer S on leaf blade S content.

The effect of fertilizer P on leaf blade S content was inconsistent, and the effect of fertilizer S on leaf blade P content was generally negative.

There were significant correlations between total P in soils and leaf blade P content; between extractable soil P and leaf blade P content; and between soil S and leaf blade S content. ■

Table 1. Chemical Properties of Topsoil Samples from Experimental Sites.

Experiment Number	Soil Type	Variety and Age Class of Cane	Organic Matter, %	P (ppm) Total	P (ppm) Extractable	S (ppm) Soil	S (ppm) Extractable	pH
1	Mhoon silt	CP52-68 2nd ratoon	1.37	619	233	148	4.8	6.7
2	Mhoon silt cl	CP52-68 1st ratoon	1.85	724	278	122	3.4	6.1
3	Mhoon silt cl	CP52-68 2nd ratoon	2.10	751	271	124	3.6	6.2
4	Baldwin silt cl	CP52-68 1st ratoon	2.03	445	25	174	9.8	5.1
5	Sharkey Clay	N Co 310 2nd ratoon	3.62	847	368	376	7.8	6.6
6	Jeanerette silt	N Co 310 1st ratoon	1.84	473	99	173	4.9	5.8

Table 2. Yield and Leaf Blade Data from S Experiments

Experiment Number	Fertilizer Treatment	Yield		Leaf Blade	
		Sugarcane	Sugar	P	S
		T/A	lb/A	%	%
1	N	31.71	5245	0.19	0.10**
	NS	31.86	5378	0.18	0.15
2	N	31.56	5154	0.22*	0.07**
	NS	32.13	5452	0.20	0.12
3	N	34.41*	6354*	0.22*	0.10**
	NS	36.08	6924	0.19	0.19

*significant at 5% level
**significant at 1% level

Table 3. Yields and Leaf Blade Data from P-S Experiments

Experiment Number	Fertilizer Treatment	Yield		Leaf Blade	
		Sugarcane	Sugar	P	S
		T/A	lb/A	%	%
4	N	33.55	6215	0.15	0.12
	NP	33.75	5936	0.16	0.11
	NS	33.77	6087	0.15	0.15
	NPS	35.38	6651	0.16	0.13
5	N	33.56	7034	0.23	0.23
	NP	33.90	7136	0.26	0.19
	NS	34.86	6973	0.22	0.28
	NPS	34.86	7313	0.24	0.27
6	N	25.55	4456	0.19	0.10
	NP	26.01	4487	0.20	0.11
	NS	25.66	4613	0.17	0.13
	NPS	28.41	4869	0.19	0.15

Using Phosphate Sorption Curves To Determine P Fertilizer Requirements

By Robert L. Fox
University of Hawaii

WHY RELIABLE P SOIL TESTS ARE NEEDED. Suppose that identical but small quantities of phosphate are extracted from two soils that will be growing the same crop.

One soil is a sand with a small capacity for phosphate sorption. The other is a clay with a large capacity for phosphate sorption. Will the recommended quantities of phosphate fertilizer be identical for these two soils?

Suppose that different crops are growing in the same kind of soil having identical P test values. Will P fertilizer recommendations be identical for both crops?

Suppose that a soil testing low in available P were fertilized liberally with P at recommended rates. Later, a soil test did not show a significant increase in available P.

A second application of P was recommended as generous as the first. What happened to the first application? Did the lab err? Was the fertilizer worthless? Were the lab, the farm advisor, and the fertilizer dealer conspiring to sell fertilizer?

THESE ARE SERIOUS QUESTIONS. Inappropriate soil tests or incorrect interpretations of valid soil tests result in lost production worth millions of dollars, thousands of tons of squandered fertilizer, untold wasted effort, and lost confidence among members of the agricultural community.

I don't wish to imply that soil testing fails to provide reasonable answers to questions about soil fertility or about the requirements of soils for fertilizer, lime or other amendments.

But it is true that much of the soil testing practiced today is an inadequate, if not inappropriate, basis for making the precise recommendations needed by modern agriculture.

NEED FOR UNIVERSAL P SOIL TEST. Soil testing programs grew out of government subsidies for certain conservation programs and were greatly encouraged by the advent of inexpensive fertilizers.

Farmers were urged to initiate fertilizer programs. Those early testing methods answered the question about soil needing fertilizer. They did not show how much fertilizer was needed and how long it would last.

Today the need for fertilizers is generally appreciated. So fertilizer recommendations should be more quantitative. Now that diversity among individual fields has been magnified by non-uniform management, fertilizer recommendations should be more site-specific.

Such needs prompted a search for soil extractants that would do two things: (1) Evaluate the phosphorus status of the soils, and (2) Serve as a basis for making quantitative fertilizer recommendations across a wide spectrum of soils.

The search continues today indicating that the quest has failed. Many extractants can provide reasonably accurate information about soil deficiency in a particular nutrient. However, all of them fail to show exactly how much fertilizer is required for a given crop.

Calibration experiments have provided some help by showing the fertilizer needs of similar soils in relation to soil test values.

SOIL TEST CALIBRATIONS MUST BE ADEQUATE. Difficulties arose when soil test calibrations were applied beyond the conditions encountered during calibration. For example, calibrations developed for the Mollisols of the prairies do not hold for the Oxisols of the tropics. A more universal basis for making P fertilizer recommendations was needed.

THE P ADSORPTION SOIL TEST. This method has been developed for phosphorus. The principle is simple. Phosphorus needs of soils are based on the adsorption of phosphate by soils from phosphate that is added in solution. Aliquots of soil are placed in solutions containing graded quantities of phosphate. Depending on the P status of the soils and the P concentration of the solution, P may be taken up through adsorption by the soil, released through desorption, or there may be no change in the solution concentration. In the latter case, an equilibrium condition exists.

The initial concentration of P in each solution is known and the concentration of P in solution is determined after the reaction has subsided. Phosphorus removed from solution represents adsorption and can be calculated by multiplying the decrease in concentration by the volume of solution.

An increase in P concentration in solution represents P desorption and can be calculated by multiplying the increased concentration by the solution volume.

If a large number of different concentration solutions are employed, one concentration can be found that is not altered by contact with the soil. This concentration represents the short-term (instant) P supply (intensity) of which the soil is capable.

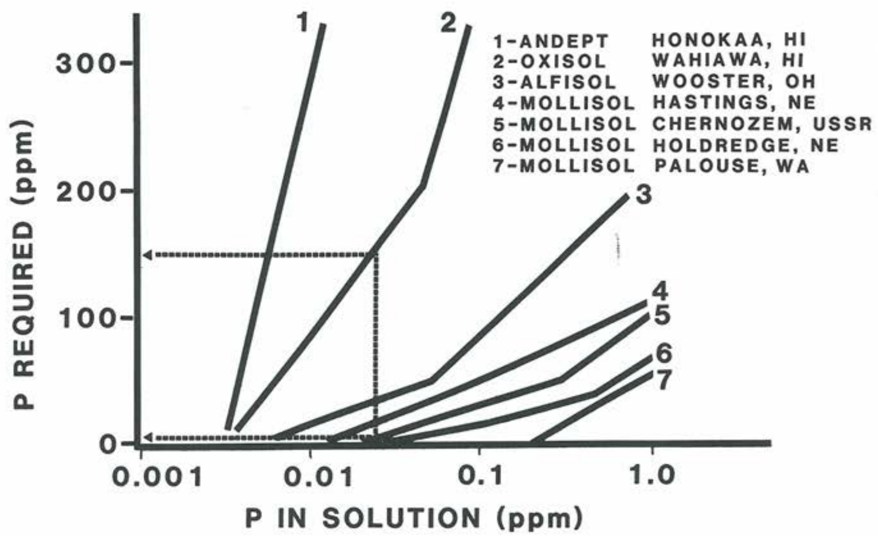


Figure 1. The Phosphorus sorption curves for these seven soils differ greatly in their mineralogies. Characteristics of the Mollisols are typical of much of the corn and wheat growing areas of North America and Central Asia. The Wahaiwa soil is a Hawaiian Oxisol. They occur only in the Tropics. The Honokaa soil from Hawaii is an extreme example of high P sorption. This soil developed from weathered volcanic ash and sorbs great quantities of phosphate.

In actual practice, the results of two or more soil-P solution combinations may be used to construct curves, shown in **Figure 1.**

Note how increasing concentrations of P in solution correspond with increasing P sorption. Phosphate sorption is concentration dependent. These sorption curves can be used as a basis for calculating P fertilizer requirements of soils for any particular concentration of P.

P ADSORPTION SOIL TEST LEVELS. What concentration is needed? That depends primarily on crop species being grown and the desired production level. The requirements are determined by field experiments using plots specially designed for that purpose as **Figure 2** shows. Or they may be based on composite curves constructed from yield observations of plots or fields designed for other purposes.

Near maximum lettuce yields are attained when soil solution concentrations are 0.2 to 0.4 parts per million (ppm) P in solution. Chinese cabbage requires less P in solution as shown in **Figure 3.** The concentration should be greater if the soil is cold.

Maximum corn grain yields may be obtained when solution concentrations are as low as 0.01 ppm if the yield potential is low. But high yield potential is associated with concentration in the 0.025 ppm range. Wheat requirements average slightly more than corn. A tentative conclu-

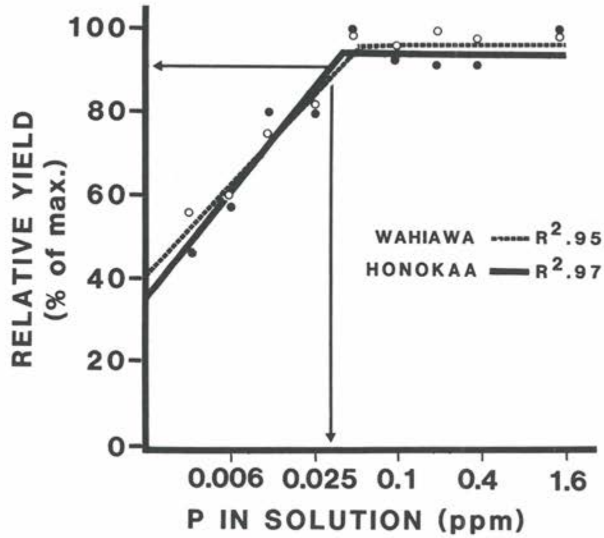


Figure 2. These two soils are dissimilar. Yet look at the relative yields of corn in relation to levels of P established in solution by fertilization. The vertical arrow represents the external P requirements for near maximum yield attained (95 percent of the yield plateau).

sion based on Hawaii data is that corn and grain sorghum require about the same.

Some crops, such as the sweet potato, make acceptable yields at very low concentrations of P in solution. **Table 1** lists the external P requirements of several crops.

DETERMINATION OF FERTILIZER REQUIREMENT. Phosphorus fertilizer requirements are estimated from the adsorption curves, shown in **Figure 1.** The curves represent many soils, from the P-fertile Palouse soil of Washington to the extremely P-deficient Andept soil of Hawaii.

The vertical dashed line represents the external P requirements appropriate for corn. The horizontal arrows represent P fertilizer requirements, expressed in ppm of P in the soil.

The curves predict the phosphorus-deficient Oxisol of Hawaii will require about 150 ppm of P (690 lb/A of P_2O_5, assuming 2,000,000 pounds of soil is being fertilized). The nominally deficient Mollisol of Nebraska requires only 27.6 lb/A of P_2O_5.

LONG-TERM VALUE OF P SORPTION CURVES. The P status of soils changes continuously because of (1) the reaction of P with inor-

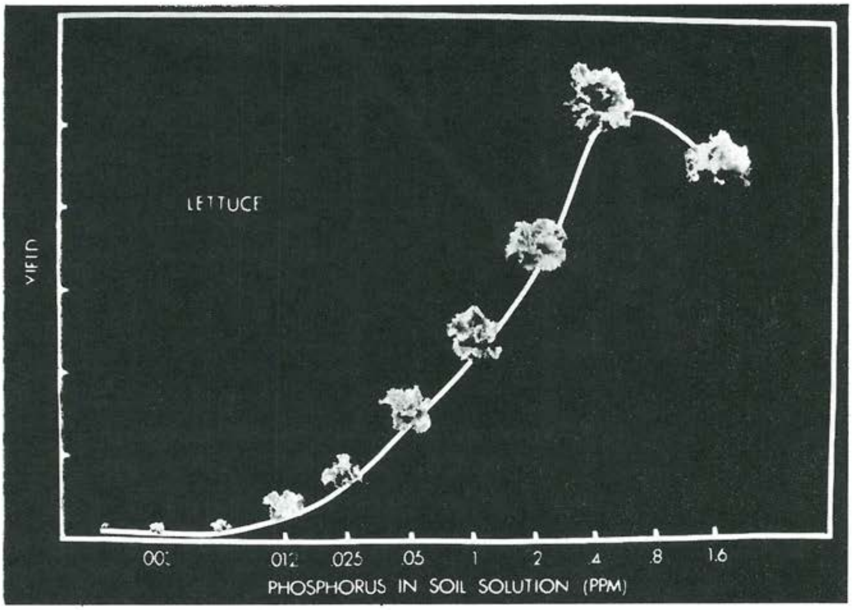


Figure 3. Compare the yield curves for lettuce and Chinese cabbage in relation to the concentration of P in solution. The crops were grown on a Wahiawa series Oxisol in Hawaii.

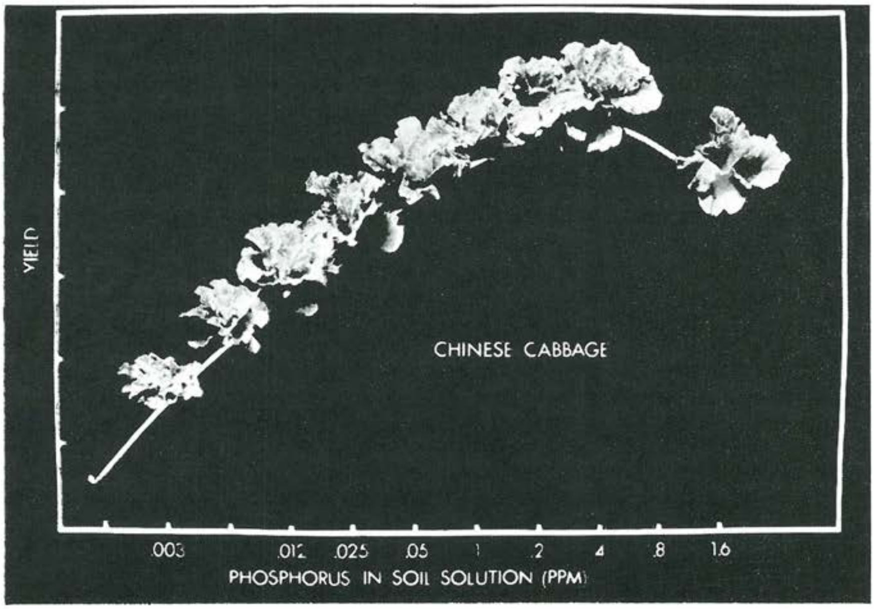


Table 1. Estimated concentration of P in soil solution associated with 75% and 95% of maximum yields of selected crops.

Crop	Location(s)	Approximate P in soil solution for yield indicated	
		75% of max.	95% of max.
Cassava	Hawaii (Halii)	0.003	0.005
Peanuts	Hawaii (Halii)	0.003	0.01
Corn	Hawaii (Honokaa, Wahiawa) Nigeria (Ikenne) S.E. U.S.A. (Various)	0.008	0.025
Wheat*	India, Nebraska, Pakistan	0.009	0.028
Cabbage	Hawaii (Kula)	0.012	0.04
Potato	Bangladesh, Idaho, Hawaii (Kula) Ontario, Peru	0.02	0.18
Soybean	Hawaii (Honokaa, Wahiawa)	0.025	0.20
Tomato	Hawaii (Kula)	0.05	0.20
Head Lettuce	Hawaii (Kula, Wahiawa)	0.10	0.30

*Unpublished data of K. S. Memon, University of Hawaii.

ganic components of the soil and (2) management practices. These practices include fertilization, nutrient removal by cropping, organic matter decomposition (P mineralization), and erosion.

The P sorption curve usually shifts to the right when P is added to the soil. The curve shifts to the left when P is withdrawn. But the curve slope (semilog plot) is not easily changed.

Once the slope of the sorption curve is determined, only one point is needed to plot a new curve. The new P status of the soil and the revised fertilizer requirements can be predicted from this. Thus P sorption curves have long-term value.

Preparing phosphate sorption curves requires more lab time than current tests of extractable phosphorus made by most labs.

But if precise fertilizer recommendations are required and especially if the properties of the soil being tested are unknown, the phosphate sorption curve method may be the answer for making fertilizer recommendations.

The more efficient fertilizer use may repay many times the added costs of the tests. ■

For Soybeans

Benefit from Applying K to a Compacted Soil

W. B. Hallmark and S. A. Barber
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SOIL COMPACTION cuts soybean yields. This is well known. Increasing soil K frequently increases yields.

Lower yields in compacted soil are associated with reduced root weight and coarser roots. Increasing soil K stimulates root growth of some crops.

This raises a question: How do soil compaction and soil K level interact to influence the growth, nutrition, and yield of soybeans?

The data in this report show that increasing soil K helped to overcome many of the detrimental effects of compacted soil.

Table 1 shows that increasing soil bulk density reduced both root and shoot weight. Bulk density is a measure of soil compaction. Increasing soil K caused more root and shoot weight at both soil bulk densities.

Added K increased root weight more in compacted soil than in non-compacted. Thus, soil compaction had less influence on root weight in high K soils than in low K soils. Potassium level had the greatest effect in compacted soil.

TABLE 1. EFFECT OF INCREASING SOIL BULK DENSITY AND ADDING K TO SOIL ON PLANT WEIGHT OF SOYBEAN SEEDLINGS.

Treatment		Plant Weight		
Soil Bulk Density	K Added	Roots	Shoots	Total
g/cm^3	lb/A		g/pot	
1.25	0	1.02	2.43	3.45
1.25	200	1.08	2.62	3.70
1.45	0	0.86	2.29	3.15
1.45	200	0.96	2.48	3.44

SECONDARY ROOT RADIUS was increased when soybeans were grown in compacted low K soil. See **Table 2.** But secondary root radius was not increased when the high K soil was compacted.

An increase of root radius causes less root surface per gram of root (area/g) for absorbing nutrients. **So an increase of root radius is undesirable.**

Soil compaction did not affect the primary root radius of low-K plants. But with high-K plants, the primary radius was reduced.

Soil compaction reduced secondary root weight. But increasing soil K

TABLE 2. EFFECT OF SOIL BULK DENSITY AND ADDING K TO SOIL ON ROOT RADIUS AND WEIGHT.

Soil Bulk Density	K Added	Radius: Secondary Roots[1]	Radius: Primary Roots	Weight: Secondary Roots	Weight: Primary Roots
g/cm^3	lb/A	mm		g/pot	
1.25	0	0.092	0.71	0.835	0.178
1.25	200	0.095	0.92	0.900	0.180
1.45	0	0.101	0.70	0.680	0.174
1.45	200	0.097	0.63	0.770	0.187

[1]Bulk density × K interaction: Secondary root radius $p = 0.041$.
(The "p" value indicates how confident you can be that there is a significant difference. For example, $p = 0.05$ means there is 95% chance of obtaining the same response.)

increased secondary and primary root weight. See **Table 2.** Soil compaction reduced secondary root weight more at low K than at high K.

These results for root weight and root radius document how high soil K helped overcome the detrimental effects of soil compaction on root growth.

INCREASING SOIL K caused significant soil bulk density × K interactions for root surface area per plant, per gram of root (g root), and per gram of shoot (g shoot). See **Table 3.**

TABLE 3. EFFECT OF INCREASING SOIL BULK DENSITY AND ADDING K TO SOIL ON ROOT SURFACE AREA MEASUREMENTS OF SOYBEAN SEEDLINGS.

Treatment: Soil Bulk Density	Treatment: K Added	Root Surface Area: /pot[1]	Root Surface Area: /g root	Root Surface Area: /g shoot
g/cm^3	lb/A	cm^2		
1.25	0	550	550	225
1.25	200	540	500	205
1.45	0	370	430	160
1.45	200	420	440	170

[1]Bulk density × K interactions: Root surface Area/Plant $p = 0.027$; Root Surface Area/g root $p = 0.071$; Root Surface Area/g shoot $p = 0.015$.

The decreases for the above parameters due to soil compaction were less for high K than for low K plants. Increasing K in the compacted soil caused more root surface area per plant.

These results show again that increasing soil K benefitted root growth and helped to overcome restrictions soil compaction placed on plant growth.

COMPACTING SOIL reduced the P, K, Ca, and Mg concentrations of

TABLE 4. EFFECT OF INCREASING SOIL BULK DENSITY AND ADDING K TO SOIL ON P, K, Ca, AND Mg CONCENTRATION OF SOYBEAN SEEDLINGS.

Soil Bulk Density	K Added	P	K[1]	Ca	Mg
g/cm³	lb/A	ppm			
1.25	0	47	430	510	345
1.25	200	44	490	485	300
1.45	0	38	380	495	340
1.45	200	37	460	465	280

[1]Bulk density × K interaction: $p = 0.001$ for K concentration of shoots.

soybean shoots. See **Table 4.** Increasing soil K increased K concentration of shoots more in the compacted than in the non-compacted soil. See **Tables 1, 2, and 3.**

Also, increasing soil bulk density for high K soil caused less reduction of K in shoots than when the low K soil was compacted. See **Table 4.**

This coincided with the tendency of high K soil to overcome the detrimental effects of soil compaction on root weight and radius and root surface area per plant, per g root, and per g shoot. See **Tables 1, 2, and 3.**

IN SUMMARY. Increasing soil bulk density reduced soybean growth and nutrient concentration of shoots.

Increasing soil K increased plant growth and helped overcome the detrimental effects of soil compaction on many plant parameters measured. This suggests high K fertility of soil may help reduce soybean yield losses caused by soil compaction. ■

Long-Term Benefits from a Single Application of P

By A. D. Halvorson and A. L. Black
USDA-SEA, Agricultural Research

LOW LEVELS of plant-available phosphorus in soils of the northern Great Plains hold wheat yields below the climatic potential in many years. That is, unless producers add sufficient P fertilizer to correct the deficiency.

Phosphorus can be banded either away from or with the seed. Or it can be broadcast and incorporated before seeding. When the amounts of fertilizer P are inadequate to correct a deficiency, banding P with the seed may be the most efficient method of application.

The crop's P requirements vary under dryland conditions from year to year. This depends on climatic conditions and the amounts of water available to the plant.

BROADCAST APPLICATION. A single high rate of P fertilizer could show profitable returns on the investment within a short time. Reducing the need for annual application would mean savings in fuel and other costs.

Added savings might come from favorable fertilizer prices, income tax deductions, and reduced workload. Building the available soil P up to or above maximum yield level would assure enough plant-available P to cope with variable precipitation patterns.

EXPERIMENTS. Duplicate studies were conducted on a Williams loam soil near Culbertson in northeastern Montana. The purpose: to determine long-term response of spring wheat to a single broadcast application of P fertilizer (concentrated superphosphate).

Phosphorus rates of 0, 20, 40, 80, and 160 lb/A of P were applied at seeding in 1967 in one study and in 1968 in another study. In both studies, crop-fallow rotation was followed for six crops. Then, all of the plots were cropped annually.

The 1967 plots generally were in crop during years of low-precipitation during the growing season. The 1968 plots were in crop during years of normal to above-normal growing season precipitation. The initial level of sodium bicarbonate-extractable P in the soil was very low (6 ppm) at both sites.

INCREASING AVAILABLE SOIL P. The level of bicarbonate-extractable P in the soil increased similarly for both sites following the initial

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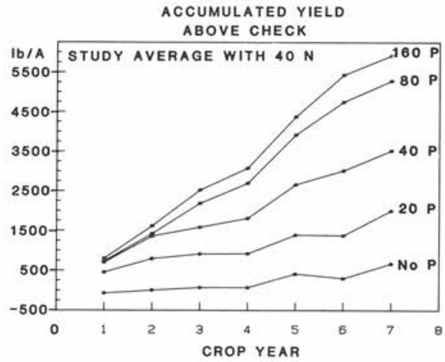

Figure 1

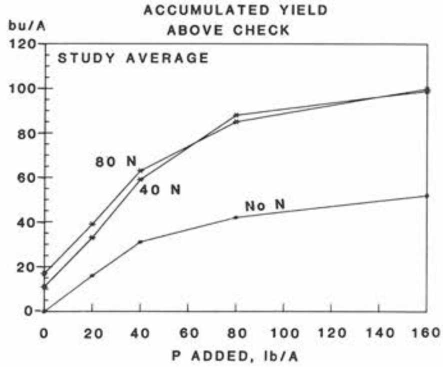

Figure 2

application of P fertilizer.

A bicarbonate P level of about 16 ppm in the 0- to 6-inch soil depth is considered adequate to reach optimum grain yields. The 40 lb/A rate raised the bicarbonate P level to only 13 ppm. The 80 lb/A treatment raised the bicarbonate P level to 27 ppm.

Application of 40 lb/A of P was not enough to reach maximum yield. But it did increase yield to 70 or 80% of maximum for the first two crops.

YIELD RESPONSE TO P and N-P INTERACTION. Figure 1 shows the accumulated yield increases for each P treatment with 40 lb/A of N over the check plot yield. Grain yields were near maximum with the 80 or 160 lb/A rates of P through seven crops.

Figure 2 shows that applying 40 or 80 lb/A of N nearly doubled actual yield from P fertilizer over the 12 years of alternate crop-fallow. This indicates the need for a balanced soil fertility program to get maximum return on dollars invested in fertilizer.

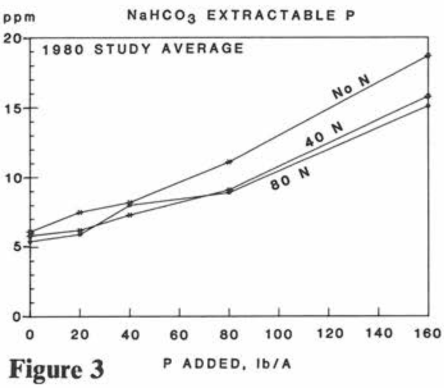

Figure 3

Figure 3 illustrates the 1980 bicarbonate P level after seven crops. It is still above 16 ppm for the 160 lb/A of P treatment.

The increased yields from adding N fertilizer accelerated the decline in soil P levels. We expect to harvest several more crops before additional P fertilizer is needed.

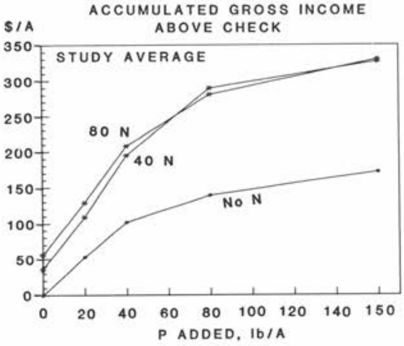

Figure 4

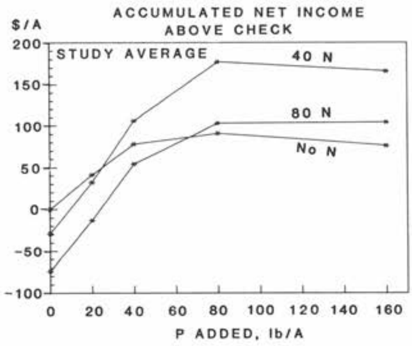

Figure 5

When the bicarbonate soil-P level nears 16 ppm, a maintenance program would be advisable to maintain available P near that level. Except for the 20 lb/A P application, the residual effects of all other P treatments can be measured by the soil test. And they are still showing up in crop yield responses after seven crops have been harvested. **See Figures 1 and 3.**

ECONOMICS OF N AND P FERTILIZATION. We assumed a spring wheat price of $3.30 per bushel and a fertilizer cost of 60¢/lb for P (25¢/lb of P_2O_5) and 27¢/lb for N. **Figure 4** compares accumulated gross income (after 7 crops) above that of the check.

Applying 80 lb/A of N on summer fallow did not increase spring wheat yields enough to justify additional expense. **Figure 5** shows that net income (gross income less fertilizer costs) was negative from applying 80 lb/A of N and 20 lb/A or less P after seven crop years.

The most economical N-P combination was 40 lb/A N plus 80 lb/A of P after seven crop years. This treatment returned an estimated average net income of $25/A per year above the check treatment.

Higher wheat prices would increase net return per acre even more. The above economic analysis does not consider the interest on borrowed money or savings from income tax deduction.

SUMMARY. This study shows how a single high rate broadcast application of high P fertilizer can increase wheat yields in the northern Great Plains.

If a producer can afford to invest in P fertilizer for his land, the returns per dollar could be surprisingly high. Potential would be greatest on the medium-and-coarse-textured soils of the northern Great Plains that are very low in available P.

The data show that additional N may also be needed to get the full benefits of the P applied. Too much N applied to summer fallow may be costly. So a good soil testing program for N is highly recommended to avoid unnecessary nitrogen in these growing conditions.

Nitrogen needs should be based on yield potential governed by water supplies available to the plant. For maximum wheat yields, annual cropping will require more N fertilizer than a summer fallow system. ■

Effects of P and K On Cereal Crop Diseases

By L. J. Piening
Research Branch, Agriculture Canada
Lacombe, Alberta

POOR SOIL FERTILITY is just one of many factors that make plants more susceptible to attack by disease pathogens.

The big challenge in fertilizing soils is to use materials in combination with suitable rotations and other soil management practices that promote maximum plant productivity and economic yields.

Disease control is usually a secondary consideration. However, we must avoid conditions such as an excess of nitrogen (N) or other nutrients that may result in an imbalance.

BROWNING ROOT ROT. Mineral deficiencies can increase some plant diseases markedly. Yield loss from such diseases can frequently be avoided by applying proper fertilizers.

For example, phosphorus applied to wheat in Saskatchewan reduced browning root rot. The disease is frequently seen on wheat grown in low P soils.

COMMON ROOT ROT. Another disease, common root rot, may be the most serious barley and wheat disease in western Canada today. It causes estimated annual yield losses of 10% in barley and 6% in wheat.

Field studies at Lacombe, Alberta, have shown how phosphorus fertilizer can reduce yield losses. Application rates of 100 lb/A P_2O_5 cut disease damage on four barley varieties on low P soil. Yield loss was 15% without P and only 9% with P application.

Another test added 30 lb/A of P_2O_5 to the soil. This phosphorus treatment reduced the percentage of barley plants infected with root rot from 42% **without** phosphorus to 21% **with** P.

Research at Saskatoon showed that root rot lesions developed more rapidly on the sub-crown internodes of Manitou wheat in a soil with a low level of available P.

Researchers also noted that phosphorus suppressed root rot the most during mid-season. That's when plants experience maximum phosphorus uptake.

TAKE-ALL ROOT ROT. Wheat fields in Australia, England, and the U.S. have long been ravished by another root rot fungus which causes the disease called "take-all".

When researchers found this disease was frequently associated with soils low in P, they found that phosphorus fertilization would reduce the harmful effects. Because of phosphorus fertilization, take-all has less impact on wheat in these three nations.

Applying chloride-containing fertilizer materials greatly reduced take-all infection of winter wheat in Oregon State University research supported by the Potash & Phosphate Institute.

EXTENT OF LOW P SOILS in western Canada with potential root rot problems. An estimated 60% of the cultivated soils in western Canada contain inadequate available P for optimum crop growth. Without added P fertilization, potential yield losses from root rots would be very great.

P AND K combinations also help control foliar pathogens.

Adding phosphorus and potassium to deficient soil significantly reduced net-blotch on Gateway barley leaves in greenhouse studies at Lacombe.

POTASSIUM DEFICIENCY AND ROOT ROT. Potassium deficiency in the soil may also increase root rot of cereal crops. But potassium deficiency is not as common as phosphorus deficiency in western Canada—possibly 10% of agricultural soils in the area have less than optimum K.

Yet, it's estimated that K application has reduced plant disease losses world-wide more than any other added nutrient.

At Lacombe, researchers added 30 lb/A of K_2O to five barley varieties growing on a soil very low in available K. Root rot decreased from 91% **without** K to 40% **with** K.

Potassium reduced root rot most in the Bonanza variety and least in the Gateway variety. **Table 1** shows these results.

ACTION OF P IN CONTROLLING DISEASES. The required nutrient may enhance plant disease resistance through two processes: (1) Changes in soil microflora, and/or (2) altered physiological processes in the host plant.

Table 1. Percent of barley plants infected with common root rot in soil with and without potash

Barley Variety	Fertilizer*	
	60-30-0	60-30-30
Bonanza	74%	16%
Centennial	96	30
Conquest	86	35
Galt	100	35
Gateway	100	86

*lb/A N-P_2O_5-K_2O

Phosphorus also promotes root growth and hastens maturity. So it is logical to conclude that well nourished cereal plants can produce new root growth fast enough to compensate for the damage done by disease pathogens.

A shorter growing period to maturity also increases chances of plants escaping serious infection.

Increasing P or K relative to N increases phenolic compounds in some plants. Phenolic compounds, when they become oxidized in the plant, can inhibit many pathogenic microorganisms. This confers disease resistance on the host plant.

Adding P has reduced snow mold injury in winter rye. The snow mold pathogens were inhibited by the large number of actinomycetes which developed when the phosphate was added.

Russian scientists have associated a decline in common root rot of wheat grown on phosphate-fertilized soils with the large increase in microorganisms. This decreases the saprophytic development of the root rot pathogens in such soils.

ACTION OF POTASSIUM IN CONTROL OF DISEASES. Potash, unlike phosphorus, doesn't become a structural part of the plant

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Potatoes Respond to Fertilizer and Lime

By James W. Paterson
Rutgers Research and Development Center

ADEQUATE, BALANCED FERTILITY has a tremendous effect on potato yields and production profits.

A 1980 study at the Rutgers Research and Development Center at Bridgeton, N.J., shows why.

Superior white potatoes were planted on long-term fertility plots. Lime, first level nitrogen (N), first level K_2O, and P_2O_5 increased yields, as shown in **Table 1.**

Table 1. Potato yields across all treatments.

Treatment		Yield	Soil test levels after harvest, 1980			
Main effect		cwt/A	pH	Mg (lb/A)	P (lb/A)	K (lb/A)
Lime	no	143	5.3	78	135	168
	yes	190	6.4	140	158	178
N (lb/A)	0	127	6.1	120	152	205
	75	179	5.9	112	149	174
	150	188	5.7	103	144	157
	225	173	5.6	99	141	154
P_2O_5 (lb/A)	0	145	5.9	108	119	179
	100	188	5.8	110	174	166
K_2O (lb/A)	0	118	5.9	113	148	73
	150	192	5.8	108	146	165
	300	190	5.9	105	146	281

Phosphate produced the most dramatic increase. It boosted yields even on soils which tested high before the experiment. The pH and K_2O soil test ranges were established by treatments in previous years.

Table 2 shows how balanced fertility can increase potato yields. Top yields reached more than 300 cwt/A—about 150 cwt/A higher than the yields averaged across all treatments.

Look at the optimum treatment in **Table 2.** It was 150 lb/A N, top P_2O_5 rate on **high P soils,** top K_2O rate on **high K soils,** and the highest pH level.

Table 2: Influence of lime and fertilizer on potato yields and returns

Selected Treatment	lb/A N	P_2O_5	K_2O	Lime	Marketable yield cwt/A	Return over lime & fertilizer cost ($/A)*
Optimum	150	100	300	yes	320	1,627
Omit P	150	0	300	yes	239	1,210
Omit K	150	100	0	yes	159	787
Omit lime	150	100	300	no	233	1,167
Increase N	225	100	300	yes	304	1,518
Decrease N	75	100	300	yes	214	1,065
Omit P, K + lime	150	0	0	no	87	437

***Prices and costs used: N—28¢/lb; P_2O_5—28¢/lb; K_2O—15¢/lb; lime—$18/year. Potato price—$5.50/cwt (about average for 1979 and 1980 seasons).**

This treatment returned $1627/A above lime and fertilizer costs, shown in **Table 2.** When P_2O_5 was omitted, yields declined more than 80 cwt/A. A farmer trying to save $28 on his phosphate bill would have lost $417 in return.

Note how the most profitable returns came from adding P_2O_5 and K_2O to plots already testing high in these nutrients. This spotlights the importance of adequate and balanced nutrition for intensive potato production.

Look at what happened when K was omitted from the top treatment. Yields and returns declined drastically. But the zero K_2O treatment was on soils already testing low in K.

There is another consequence of unbalanced fertility, especially low K. The plots show "early dying disease", where vines die prematurely as they approach maturity.

We did not determine the effect of this disease (stress) on the yield and quality of white potatoes. **But the disease always occurred on plots stressed with low K_2O levels. ■**

(Continued from page 37)

cell. Potassium regulates cell metabolic activity and photosynthesis.

Adequate K insures an optimum functioning metabolic system. This helps insure maximum health of the plant.

Potash also promotes thicker outer walls in the epidermis. This may help physically exclude pathogens. Moderate potash also increases the resistance of cereals to leaf rusts.

Moderately resistant varieties can be made susceptible by depriving them of K. Increasing N, relative to available P and K, often increases damage from several foliage diseases.

The reasons may be a more favorable micro-environment because of increased foliage or thinner cell walls and delayed maturity due to N.

CONCLUSIONS. No general rules can be laid down for fertilizing soils to avoid disease in plants. Each disease must be considered by itself.

Recommendations must be based on soil type, nutrient need of the plant, availability of essential nutrients in the soil, and the type of disease pathogens we want to reduce.

Conspicuous soil deficiencies, especially potash and phosphorus, should be corrected. ■

Foundation for Agronomic Research Receives New Funding Support

FRIT INDUSTRIES, INC., a leading supplier of micronutrients in the fertilizer industry, recently announced a $50,000 contribution to the Foundation for Agronomic Research (FAR).

The Foundation is a tax-free organization which sponsors research in total crop production systems. It is affiliated with the Potash & Phosphate Institute (PPI) with headquarters in Atlanta, Georgia.

"Our contribution to FAR will be $10,000 annually for a five-year period," said S. E. "Gene" Allred, president of Frit Industries. The company has headquarters at Ozark, Alabama and facilities in the U.S. and Brazil for manufacturing and marketing micronutrients.

Other contributors with concern for current challenges in crop research have previously announced their support of FAR. They include: Agrico Chemical Company; Chemical Enterprises, Inc.; International Minerals & Chemical Corporation; Kalium Chemicals — PPG Industries, Inc.; Potash Corporation of Saskatchewan; The Sulphur Institute; Texasgulf Inc.; and DeKalb AgResearch, Inc.

The new contribution increases total FAR funding to $1,210,000. All of the pledges are for periods of three to five years.

FAR was launched in 1980 to strengthen support for crop research. The Foundation now sponsors 36 different research projects in the U.S. and other countries.

"There is a real need to continue encouraging research efforts that encompass all disciplines related to maximum economic yields," emphasizes Dr. Robert E. Wagner, president of FAR and PPI. "Through the Foundation for Agronomic Research, all segments of the fertilizer industry as well as seed, pesticide, and farm equipment companies and other industries can focus their support toward these important goals." ■

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