BETTER CROPS
WITH PLANT FOOD

Spring 1988

Maximum Economic Yield (MEY) Management
. . . How It Protects Environmental Quality

BETTER CROPS With Plant Food

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Contents

Our Cover: Many of the management practices recommended for maximum economic yield (MEY) systems are also compatible with environmental quality. This issue features some of the positive benefits.

Fertilizer Use and High Yields Are Compatible with Quality Environment

By M.A. McMahon

Fertilizer and other inputs of modern agriculture have sometimes been considered detriments to environmental quality. However, it is now clear that management practices which favor high crop yields also sustain environmental quality.

MY VIEW of the interaction of agricultural production and the environment is conditioned by my work in helping developing nations and by observing the role of fertilizer in the gigantic increases in food production since the early 1960s. My thinking is also conditioned by a view of the future where increasing population growth and rising incomes will lead to ever-increasing demands for food. This in turn leads us to be concerned with the environment and the sustainability of agricultural systems which will be required to meet that food demand.

Whither Food Production in the Next 20 Years?

As we approach the end of the twentieth century, food surpluses abound in the food exporting countries. Many countries which had serious food deficits 20 years ago are now self-sufficient. However, the panorama is not totally optimistic because many countries are still food-deficient and without the necessary foreign exchange for imports.

Therefore, the poorest segments of the population of these countries and others are still suffering from malnutrition and starvation. It is projected that by the year 2000 we will need nearly 145 million tons more of wheat and 110 million tons more of corn. Since the challenge is to attack both hunger and poverty simultaneously, it is necessary to produce more food and to produce it more efficiently. The key factor in this process is the development of new technology that will produce higher yields per acre or hectare.

M.A. McMahon

It is estimated that in the period from 1975 to 2000 when the global population is estimated to increase 40%, the amount of arable land is expected to increase only 4%. Therefore, we are faced with the task of continuing the increases in yields per acre which we have seen over the past 25 years. Fertilizer will be a key player in this most important task.

We feel that fertilizer will have a major role in this process as it has in the past. While we are faced with this challenge there will be growing concern that increased agricultural production is being achieved at the cost of environmental degradation.

". . . Since the challenge is to attack both hunger and poverty simultaneously, it is necessary to produce more food and to produce it more efficiently."

What Has Happened in the Past 25 Years?

The great advances in the past quarter-century came to be known as the "Green Revolution." Primary components of this

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This article is adapted from a paper presented at the IMC World Food Production Conference, Madrid, Spain, October 1987. Views expressed are those of the author and not necessarily those of CIMMYT. References available on request.

(Compatible . . . from page 3)

technology were:

1. High yielding broadly adapted wheat and rice varieties, with broad based disease resistance.
2. An interdisciplinary approach to production, involving genetics, agronomy and pathology.

This progress in plant breeding and the response to nitrogen (N) fertilizer of old and new varieties is shown in **Figure 1.**

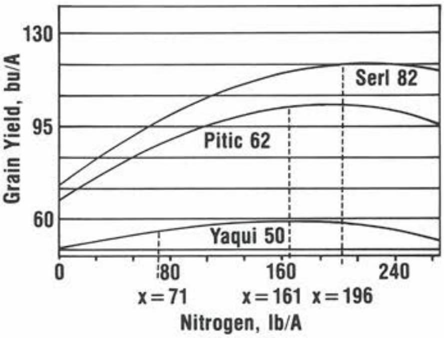

Figure 1. Response of three wheat varieties to increasing levels of N. CIANO, Mexico, CIMMYT, 1987.

These data for irrigated wheat in Mexico show how the *maximum economic* amount of N differs with varieties. Yaqui 50 with 71 lb/A yielded 55 bu/A or 0.77 bu/lb of N applied. At the same level of application (71 lb/A) Seri 82 gave a yield of 98 bu/A or 1.37 bu/lb of N applied. Not only are these semidwarf varieties higher yielding, but they are also more efficient in their use of nutrients such as N.

Another aspect of these semidwarf wheats was that they responded to higher levels of N fertilization. For example, as seen from **Figure 1,** the optimum economic rate of N for Yaqui 50, Pitic 62 and Seri 82 was 71, 161, and 196 lb/A, respectively, giving yields of 55,101 and 118 bu/A, respectively.

" . . . FAO estimates that in Africa some 10 times as many nutrients are being removed in crops as are being put back in the soil through the use of organic manures and fertilizers."

If it weren't for these increases in potential it would be hard to imagine what the world food situation would be today (or, indeed, the fertilizer industry).

The high yields of the semidwarf varieties in India financed tubewells to bring additional lands into irrigated wheat production. Argentina did not follow the typical Green Revolution strategy. Wheat yields did not rise rapidly in Argentina because the country's strategy kept the farm wheat price low and the price of fertilizer high, thus discouraging fertilizer use. From work done in the early 1980s it has been shown that fertilizer can substantially increase wheat yields in Argentina. Thus, changes in policy to favor fertilizer use could significantly increase Argentina's wheat production and fertilizer imports.

Food Needs, Fertilizer and the Environment

One of the principal constraints to yields is the soils' lack of nutrients essential for plant growth and crop production.

FAO estimates that in Africa some 10 times as many nutrients are being removed in crops as are being put back in the soil through the use of organic manures and fertilizers.

Most soils in developing countries are low in phosphorus (P) and N. Under intensive cropping systems, which are forever on the increase, where P and N needs are met, the soil may be gradually depleted of potassium (K), sulphur (S) and certain other nutrients such as zinc (Zn) in the wheat-rice cropping system. These nutrients are all necessary to maintain high levels of production.

As fertilizer use increases so does the concern for its effects on the environment. Therefore, a major question for all of us involved in agriculture is how to achieve increased food production in which we know that fertilizer use will assume an ever-increasing role, and at the same time maintain environmental quality or even increase it?

This discussion will focus on the two major elements, N and P. I should also point out that environmental pollution from fertilizers does not assume the same importance in the developing world because of low fertilizer use and the large yield gap that still exists in all crops due to low fertilizer consumption. Therefore, in a developing world context the concern is less. The main objective is to increase fertilizer use and the target of increased food production is, and will remain, the first priority.

Nitrogen

The concern for fertilizer N becoming a pollution problem is a phenomenon of the last 20 years. It is mainly focused on the nitrate (NO_3^-) content of drinking water. Therefore, the movement of N into water supplies is the primary concern.

Uptake by the plant is the main objective of fertilizer application. Nitrogen that is absorbed and utilized by the crop to provide yield does not cause environmental pollution. Therefore, the best management strategy from an agronomic and environmental standpoint is to apply enough fertilizer N to produce an optimum yield. However, the efficiency of fertilizer N uptake is seldom above 50% when applied to annual cultivated crops. This does not mean that the rest of the fertilizer N makes its way into the drainage water because the N cycle in the soil is a complex one and its various components have not been quantified for many production environments as yet. This is one of the main reasons why there is such diversity in the data available. This variability can be a source of great confusion to people not familiar with agricultural systems.

> *" . . . Much of the data that have been used to build a case against the use of N fertilizer in agriculture is where there is excess and inefficient use of the element."*

It is our opinion that N can be used to produce high crop yields without damaging the environment. The key to this, as stated previously, is the efficient use of N. This principle is adequately shown in **Figure 2.**

These data are based on a five-year field experiment with isotopically labelled N fertilizer applied to corn. High levels of fertilizer N (196 lb/A) coupled with high levels of production (143 bu/A) showed very low po-

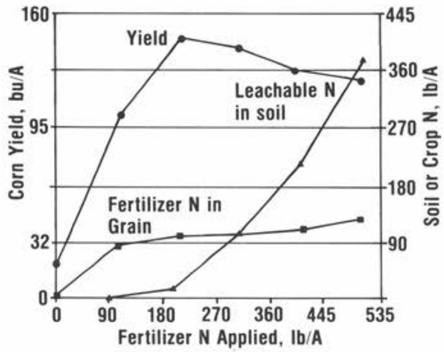

Figure 2. Relationships among corn yield, amount of fertilizer N applied, and N recovered in grain or remaining as leachable N in soil.
Broadbent and Rauschkolb, 1977.

tential for pollution. Fertilization in excess of that needed for maximum yield sharply increased the amount of leachable N in the soil.

Much of the data that have been used to build a case against the use of N fertilizer in agriculture is where there is excess and inefficient use of the element. Research in Minnesota showed that losses of NO_3-N through tile lines after three years of continuous corn were 17, 22, 52 and 107 lb of N/A/year for N application rates of 18, 100, 200, 400 lb/A/year, respectively. However, in this case, the recommended N application rate for corn was 100 lb/A and this rate increased the N loss through the tile lines by only a small amount **(Table 1).**

Table 1. Average NO_3-N loss from tile lines as influenced by N rate, 1973-1975.

Treatment	Avg. NO_3-N loss from tile N, lb/A		
N,lb/A	1973	1974	1975
18	4	15	17
100	5	20	22
200	3.5	27	53
400	5	48	107

Gast et al., Minnesota, 1978

The approach to make high yields, fertilizer use, and the maintenance of environmental quality compatible is to focus on crop management practices that favor high crop yields. Consider the

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(Compatible . . . from page 5)
wheat crop as an example. There are many practices that increase N use efficiency and by doing so decrease the pollution potential of this element.

". . . The approach to make high yields, fertilizer use, and the maintenance of environmental quality compatible is to focus on crop management practices that favor high crop yields."

The interaction of N with other nutrients.
Data on the interaction of N and P from a set of 18 trials on wheat in Argentina are shown in **Tables 2** and **3.** In these examples there is little response to P when applied alone and fairly good response to N. However, when the two are combined the use efficiency markedly increased. Even at high levels of fertilizer use for Argentinian conditions such as 80-53 the response efficiency is still high at 12 lb grain/lb nutrient and at yield level of 71 bu/A. The importance of understanding the interaction of these nutrients is shown by comparing the efficiencies of the treatments 107-0 and 80-18 which are quite similar in the amount of total nutrient applied. The difference in efficiency is 4.45 lb of grain/lb of nutrient **(Table 3).**

Split applications.
The longer applied N is in the soil without being used the more susceptible it is to leaching. The supply of nitrogen must match the uptake needs of the crops. That is why in most conditions split applications are more efficient than applying all of the N at planting.

Interaction with soil moisture.
The relationship among grain yields, amount of N applied and soil moisture conditions is long established. An example of this relationship is shown in **Figure 3.** In treatment B (which was irrigated) when the available soil moisture percentage was reduced to 49, the application of 107 lb N/A increased yields by 60 bu/A. In treatment D (which was not irrigated) until the soil moisture content was reduced to about permanent wilting percentage, the application of 107 lb N/A increased yields by only 28 bu/A. The increase in yield per pound of applied N under optimum soil moisture conditions, was more than double the increase for the driest treatment.

Table 2. Average wheat yields (bu/A) at varying levels of N and P_2O_5 in the Pampa Húmeda, 1982. (18 trials)

N	P_2O_5, lb/A				
lb/A	0	18	36	53	71
0	44		46		46
27		59		63	
53	57		65		67
80		67		71	
107	61		70		71

Source: INTA Pergamino.

Table 3. Average response efficiency (lb grain/lb nutrient) for various combinations of N and P_2O_5. (18 trials)

N	P_2O_5, lb/A				
lb/A	0	18	36	53	71
0			3.08		1.30
27		20.08		14.58	
53	14.78		14.54		11.20
80		14.29		12.00	
107	9.84		10.94		9.13

Pergamino 1982-83

Interactions of fertilizer with weed control.
The interaction of fertilizer response and weed control is shown in an example

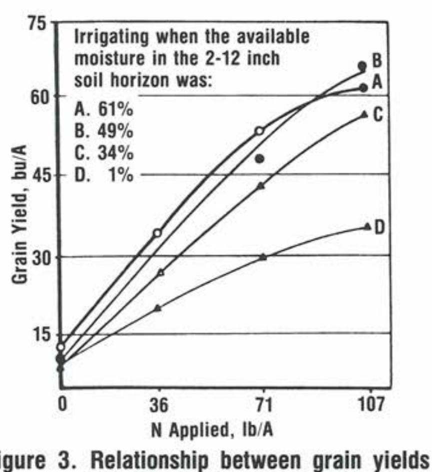

Figure 3. Relationship between grain yields (wheat) and the amount of applied N under different soil moisture conditions.
Fernandez and Laird, 1959

from wheat research in Chile. Without fertilizer and weed control the yield was 25 bu/A. When 114 lb of N/A was added, and without weed control the yield increased to 37 bu/A. However, when adequate weed control was applied at the same level of fertilization the yield increased to 68 bu/A.

Interaction of fertilizer with disease.
Research in Uruguay found an interaction of variety and disease control with fertilizer use. A low potential variety such as Dorado, even with fungicide, will respond to only a low level of N. With fungicide the optimum economic rate was 60 lb/A to give a yield of 28 bu/A. There was a big interaction of fungicide and N in the variety Cardenal which has high yield potential. The maximum yield on this variety without fungicide was 50 bu/A whereas with fungicide it yielded 73 bu/A (44% more, or 250% more than Dorado with fungicide). This increase in yield means increased N uptake and greater N efficiency.

Phosphorus
Most of the P lost from agricultural land is by surface runoff. Because P is strongly retained by the soil, its movement through the profile (except in very few cases) is negligible and its contamination of groundwater poses little or no threat to the environment. Cooke (1967) reported on the classical Rothamstead experiment where P had moved only to a depth of 18 inches after annual applications of manure of 16 tons/A since 1845.

" . . . Because P is strongly retained by the soil, its movement through the profile (except in very few cases) is negligible and its contamination of groundwater poses little or no threat to the environment."

Control of erosion
Therefore, since the greatest threat of P pollution comes from surface runoff, any measures taken to control erosion will also reduce the risk of P pollution from agricultural land. Over the past 20 years great progress has been made in developing technology to grow crops in reduced or no-tillage systems. There have been many reasons for the spread of this technology, both economic and technological, but it is now true to say that there is a worldwide trend toward decreased tillage.

As reduced and no-tillage systems are developed and adopted, it is agreed that one of the main advantages is soil erosion control. The effectiveness of these systems is directly related to the amount of mulch maintained on the soil surface. The effect of increasing rates of mulch for reducing erosion loss is shown in **Table 4.** Even a small rate can decrease erosion greatly. A rate such as 4 tons/A, which can be easily obtained from a reasonable yielding wheat crop reduces erosion 40-fold over that of a bare soil.

Table 4. Effect of straw mulch on soil erosion on a 15% slope.

Mulch (tons/A)	Erosion loss (tons/A)
0	27.8
0.5	8.6
1.0	5.1
2.0	1.1
4.0	0.7

Meyer, Wischmeion and Foster 1970

The effect of different tillage methods on highly erosive soils (red latosols) in Parana, Brazil, is shown in **Figure 4.**

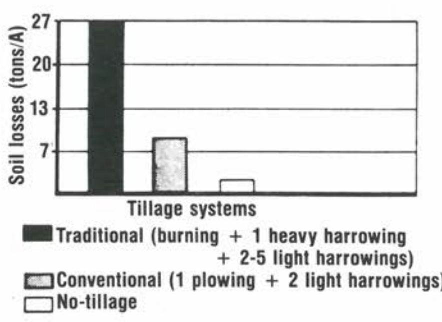

Figure 4. Soil losses by erosion as related to tillage systems in an oxisol (red latosol) soil.
Muzilli, Parana, Brazil, 1984

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Dramatic decreases in erosion of up to 90% can be achieved on these soils using no-tillage.

Therefore, the trend towards reduced tillage should lend itself to increased P use without increasing the risks of environmental pollution from this element.

". . . since the greatest threat of P pollution comes from surface runoff, any measures taken to control erosion will also reduce the risk of P pollution from agricultural land."

These reduced tillage systems will not only reduce environmental hazards but will allow more intensive cultivation for increased food production and prevent soil deterioration from excessive cultivations.

Conclusions

The mandate is clear: More food will be needed because of increasing population and rising incomes. The land resource base is finite and the horizontal expansion of this resource is almost at a standstill. Therefore, increasing food needs have to be met by increasing yields per acre or hectare. Fertilizer will play a key role in producing this food.

Fertilizer use, high yield and a safe environment are compatible through good management of resources. Environmental degradation will not be the result of increasing agricultural production if fertilizer is properly used. In fact, the alternative may have greater detrimental consequences for the environment.■

Maximum Economic Yield (MEY) . . . Sustainable Agriculture at Its Best

MEY is the most profitable yield per acre . . . created by efficient, high volume output at low unit cost. In good times the MEY farmer fully exploits profit opportunities and is sustained at a high income level. In bad times MEY protects him against low prices by the low cost of producing a bushel or a ton of whatever crop he grows.

MEY sustains the agricultural industries that provide services and products to the farmer because his higher profits allow him to reinvest in those vital inputs.

MEY means timely planting, correct populations, balanced fertility, judicious use of crop protection chemicals . . . management of all inputs in a package or systems approach to minimize losses through erosion, runoff and leaching.

MEY controls erosion and sustains groundwater quality by promoting a rapidly growing crop that quickly covers the ground. Greater root proliferation anchors more soil particles and enhances nutrient uptake efficiency. Incorporating more aboveground residue into the soil increases water holding capacity and improves infiltration rate. Root decomposition provides soil aggregate stability.

Yes, MEY protects our priceless soil and water resources, assuring the future of sound, productive agriculture.

In the truest sense, MEY is the best of sustainable agriculture.■

Dr. B.C. Darst,
Potash & Phosphate Institute (PPI) and
Foundation for Agronomic Research (FAR)

Sustainable Agriculture

By R.G. Hoeft and E.D. Nafziger

The definition of "sustainable agriculture" will vary depending on one's viewpoint. This article points out that management systems which achieve the most efficient production and profits, while minimizing adverse effects on the environment, are indeed a form of sustainable agriculture.

THERE IS little evidence to suggest that agriculture as practiced in a variety of ways is not sustainable. We think of sustainable agriculture as a management system that uses inputs . . . both those available as natural resources on the farm and those purchased externally . . . in the most efficient manner possible to obtain productivity and profitability from a farming operation, while minimizing adverse effects on the environment.

Several groups have published materials suggesting techniques that should be used to attain the goals of sustainable agriculture. The University of Nebraska has prepared a list of "Components of a Sustainable System," including:

Cultural practices

- Careful variety/hybrid selection for the system
- Crop rotations with legumes
- Winter cover crops
- Intercropping
- Conservation tillage and residue management

Soil fertility programs ("fertilize the crop, not the soil")

- Precision-calibrated soil test and "accurate" fertilizer recommendations
- Band application of fertilizers
- Planting time and sidedress applications of nitrogen (N) for maximum efficiency
- Use of available manures and wastes
- Allowing N credit for legumes and for nitrate in irrigation water

Pest management

- Selecting pest-resistant cultivars
- Use of pest population dynamics, damage thresholds, and decision aids
- Integration of cultural, mechanical, and chemical control methods
- Use of biocontrol agents when available

Water conservation

- Use of the concepts of irrigation scheduling and limited irrigation
- Use of ecofarming and other moisture-harvesting systems in semi-arid areas
- Crop selection based on the efficiency of water use

This is an excellent list of suggestions and is similar to those given in the *Illinois Agronomy Handbook* for many years. For various reasons, some advisers and farmers have not paid adequate attention to some of these items in the past. The following discussion will focus on the validity of those reasons.

Nitrogen

The use of a legume as a winter cover crop is being promoted as a way to produce "free" N for the following crop. Although the production of "free" N is a commendable benefit, it occurs rarely under Illinois conditions or in most of the Midwest. Fall-seeded legumes tend to

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(Sustainable . . . from page 9)
utilize the residual N from the soil, thus reducing the potential for leaching. But under most Illinois conditions fall-seeded legumes can be shown to fix little additional N for early planted grass crops. Given the severe penalties for delayed planting of corn, delaying planting to allow for N fixation is unacceptable.

Recommendations

Fertilizer is one of the largest single cost items associated with crop production. This factor, combined with the fact that some feel we are "poisoning the soil" with fertilizers, has drawn a lot of attention to fertilizers from the proponents of sustainable agriculture. The Nebraska list suggests that the recommendations for fertilizer use could be more "accurate" and "precise" and that the emphasis should be on fertilizing the crop rather than the soil. Unless followed properly, those recommendations may result in fertilizing the crop by depleting the soil for future generations.

Fertilizer recommendations can be made for the short term, for minimum input, and for maximum profit, or they can be made for a sustainable system. If the amount added is significantly less than the amount removed in harvesting, the soil will eventually be depleted. This situation could hardly be defined as sustainable agriculture.

Soil Tests

Soil tests cannot be calibrated for each particular site (field), so recommendations that are made from a soil test are based on research involving a limited number of soil types. Some recommendations will be above and some below that actually needed for the crop that year. In addition, the vagaries of the weather from year to year make it difficult to be precise in all recommendations. In the long run, the goal of any fertility recommendation based on a soil test should be to obtain a profitable yield while maintaining the fertility status of the soil.

Use Wastes

Animal and other organic wastes have long been applied to the land. Some improvement in utilization of these products might be made, but the impact of such an improvement on U.S. farm input and output figures will be negligible. With current livestock prices and trends in consumer preference, there appears to be little chance that livestock numbers and the waste they produce will increase significantly.

There is ever-increasing interest on the part of the society to recycle and utilize by-products. Some of those products have been shown to be valuable resources for agricultural land under the right circumstances. Because of the cost associated with their disposal, however, manufacturers are usually willing to provide them to agriculture at a reduced cost or, in some cases, at no cost to avoid the disposal fee.

Biological Additives

In addition to utilization of "wastes," some have also suggested the use of biological controls and additives. Commercial agriculture has long used this technique, as evidenced by the continued selection process to achieve disease resistance for many agronomic crops. Similarly, N derived from symbiotic biological fixation by legumes has long been recognized and credited. However, that process is only an economical credit when one grows the legume for the seed or forage produced. It has not been economical to grow the legume just for the N, particularly in areas of the country where growing crops occupy the land during a large part of the growing season, thus leaving little time for legume growth.

New Terms?

A new term proposed along with sustainable agriculture is "thought-intensive agriculture." It means "to think carefully about all available strategies in the farm system that can deal with the problem and create production opportunities." Irrespective of the system selected for the farm operation, one cannot argue with that concept. One method is to plant soybeans within a standing crop of wheat, barley, or other small grain. This is hardly a new concept: it has been evaluated in Illinois research for at least 15 years. Even though the results have shown that given the right year, it will work well, it has not been widely adopted because of the associated high risk.

The term "regenerative agriculture," is frequently used synonymously with sustainable agriculture. This concept means "the capacity of the natural environment to recover from disturbance." As applied in the present sense, this concept seems to propound a return to the "natural" physical, chemical, and biological conditions of the soil. To deplete present soil nutrient levels to their native state, inactivate current drainage systems, and otherwise work toward returning soil conditions to those in Illinois before farming began, would not only take years, it would also be absurd.

According to Robert Rodale (of Rodale Press), farms that have been worn out and abandoned almost always begin to regenerate within a short period of time. Most of these "worn-out" farms have been intensively cropped without replenishing the nutrients, or the productive topsoil has been allowed to erode. While the topsoil cannot be easily replaced, a good fertility management program will rapidly improve the productivity of such land.

Alternative Crops

In order to be economically sustainable, agriculture must produce a marketable product at a lower cost than the market is willing to pay. This idea has prompted many to suggest that we consider producing alternative crops, new crops that can replace those currently grown.

In order for a new crop to provide much relief to the agricultural economy, it must provide a product that will replace a nonrenewable resource. For example, a crop that could replace a substantial amount of imported petroleum would have a tremendous impact on the agricultural economy. Governmental policies and economic realities will determine the extent to which such crops will be grown in the future.

We accept the concept of "sustainable" agriculture to the extent that it calls for reasonable and conservative use of agricultural inputs.We do not agree, however, with some of the undertones of the movement based upon certain interpretations of this concept.

First, the assumption that American agriculture is incapable of far-ranging change is not true; the changes we have seen in tillage and pest control over the past 20 years would have been considered revolutionary in 1960. As markets have tightened, more attention is given to product quality, alternative uses, and value-added technology. Simply put, the idea that agriculture is uncontrollably headed toward disastrous disruption is at odds with the flexibility that the industry has historically shown. Research will continue to guide the necessary changes.

Risk

A second problem with the present "sustainable" approach is the failure to recognize the increase in risk associated with many of the changes being encouraged. Much of the "proof" to indicate that such changes are beneficial is anecdotal in nature and does nothing to assess risks, beyond the occasional admission that a particular practice failed. Farmers have never been, and never will be, well-served by casually generated "technology." This is not to say that such technology will never work, but rather to emphasize that risk aspects are being ignored in the haste to bring change.

Summary

Finally, we reject the anti-science bias that characterizes much of the present "sustainable agriculture" movement. This bias is very clearly seen in its opposition to many new technologies and in its assertions that public researchers do research only to benefit agricultural input suppliers, rather than farmers. It is difficult to imagine how anyone who has had any contact with research and Extension specialists can continue to hold such views, especially, with the present emphasis on the efficiency of production.

In the end, it is only through use of properly conducted and properly interpreted research that an individual producer, when faced with new constraints, will be able to properly adjust his inputs to maximize net income.■

Proper Agronomic Practices Will Reduce Leached Nitrates in Prairie Soils

By C.A. Campbell and R.P. Zentner

Planned management of fertilizers, annual cropping of the land and use of fall seeded crops will significantly reduce nitrates lost by leaching on Prairie soils.

A CONSIDERABLE AMOUNT of nitrogen (N) has been lost from Prairie soils by leaching. This contrasts with the common belief by scientists and the general public who, recognizing that the majority of this land is semi-desert, have assumed that leaching in the area is minimal. However, recent evidence obtained at Swift Current, Saskatchewan, on a loam soil suggests that this is not true.

Analysis of the first 12 years' data from Agriculture Canada Research Station's long-term crop rotation study showed evidence that water and nitrates were being leached below the root zone of cereals in wet years. Thus a more detailed study was made in the 1982 growing season 15 years after the study was initiated. Soil samples were taken at four depth intervals up to a maximum of 8 feet. The 1982 growing season was wet; precipitation of 9.6 inches exceeded the long-term average by 20%. Water and N balance analysis of the results confirmed the movement of considerable nitrates beyond the 48-inch rooting depth of cereals and even beyond the 96-inch depth.

Following is a summary of the main findings from this experiment:

- It was estimated that about 100 lb/A of nitrate-N was lost from the top 96 inches of fallowed land on this loam soil. This is more than the amount of N produced from soil organic matter in an average year (90 lb/A). This loss was valued at about $37/A.
- If we assume that similar losses occurred in all of the 6.24 million acres of fallowed soil in the Brown soil zone of southwestern Saskatchewan, the potential value of leached N in 1982 alone was in excess of $200 million.
- In 30 of the past 96 years the growing season precipitation was equal to or greater than the 9.6 inches received in 1982. Using these data, we estimated that leaching alone could account for about half of the organic N lost from our soils since they were broken out of grassland and cultivated. In fact, this also suggests that leaching has been as much responsible for N losses as has erosion.

Further conclusions, drawn from **Figure 1**, are:

- The crop sequences that have allowed the greatest loss of N were the short 2-year and 3-year wheat-fallow rotations that received no N fertilizer.

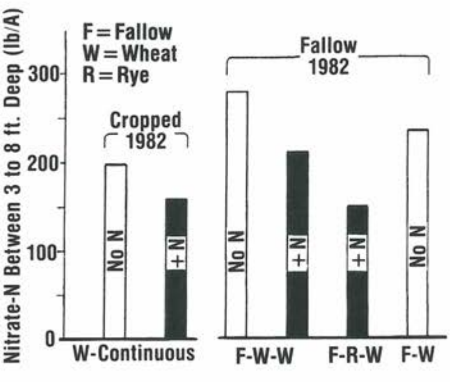

Figure 1. Nitrate-N leaching was reduced by keeping the soil covered and by applying fertilizer for the crop according to soil test.

Dr. Campbell and Dr. Zentner are research scientists at Agriculture Canada Research Station, Swift Current, Saskatchewan, Canada.

• Even when wheat was grown each year, some N was leached from the root zone in wet years.

• The application of fertilizer according to soil test recommendations increased plant growth and thus soil and fertilizer N use and actually reduced the N leached out of the root zone.

• The lowest amount of leaching losses was observed in the 3-year fallow-fall rye-wheat rotation that received fertilizer according to soil test recommendations. The fall rye starts growing in the fall, is off to a fast start the following spring, and thus uses soil mineral N before the June rains arrive to leach it from the soil.

• The value of keeping the soil covered and the dangers of summerfallowing are seen by comparing leaching under continuous wheat versus the fallow treatments.

Conclusions

It is fallacy to believe that because the Prairie region is relatively dry, deep leaching of soluble nutrients does not occur. Because of the increasing use of fertilizers to achieve ever greater grain production, we are obliged to be more conscious of the potential for ground and surface water pollution. These findings are, therefore, significant and timely to society, the producer, and to the scientific community. The agronomic practices that have been identified to reduce leaching will assist producers in planning their rotations and assist those people involved in technology transfer in advising the producer.■

Workshop on Implementing MEY Systems Scheduled August 3-4 in Toledo, Ohio

A WORKSHOP sponsored by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR) will be held August 3-4, 1988, at Holiday Inn Southwest in Toledo, Ohio. The program will provide "hands-on" training in the implementation of maximum economic yield (MEY) production systems for corn, soybeans and other crops.

As a part of a highly successful national and regional series, the workshop will review key management decisions facing farmers and their advisers.

Small workgroups will analyze real farm situations. Using technical information and computer software, detailed management strategies for maximizing profits will be developed. Emphasis will be on the selection of realistic yield goals and the allocation of available resources to achieve those goals.

Attendees are expected from all major farmer support groups: Fertilizer dealers, consultants, farm managers, seed company agronomists, Extension specialists, and lenders. The interaction among individuals from these groups has been one of the most beneficial aspects of the earlier workshops.

A registration fee will be charged for workshop printed materials and meals. The software used in the workshop will be available for purchase.

The workshop is open to anyone who helps farmers develop management plans and has interest in improving skills in recommending practices for greater farming profitability. More information can be obtained by contacting Dr. David Dibb, PPI, 1220 Potter Drive, Suite 108B, West Lafayette, IN 47906. Phone: 317-497-4300.■

In Louisiana

Study Identifies Management for Maximum Economic Yields of Coastal Bermudagrass

By Marcus M. Eichhorn, Jr. and Billy D. Nelson

A multi-year project conducted by Louisiana researchers has revealed potassium (K) fertilization requirements and other management needed for maximum economic yields (MEY) of Coastal bermudagrass based on conditions of the study.

YIELD, crude protein, and digestible dry matter are parameters used for determining the value of Coastal bermudagrass hay produced from a given acreage. Traditionally, the most important of those parameters has been forage yield as hay because the harvested crop is marketed on the basis of price per ton or per bale. Crude protein is normally the most expensive ingredient fed to cattle, while digestible dry matter is the total amount of the feed intake that can be digested by ruminant animals.

A five-year potassium (K) fertilization study was initiated in 1979 to determine the requirements for Coastal bermudagrass hay production on Coastal Plain soil. An existing planting on Mahan fine sandy loam soil was chosen for the experimental site. Hay yield from the site had declined to 60% of yield potential after 11 years of hay cropping. Severe stand loss was evident. Soil K was very low, even though fertilizer K had been applied annually at rates up to 100 lb/A of K_2O.

Objectives of the study were to develop a K fertilization program that would produce maximum economic yields (MEY) of forage, crude protein, and digestible dry matter.

Rates of potash up to 600 lb/A of K_2O were applied annually and in two and four-way split applications. Each year, fertilizer N-P_2O_5-S-B was applied at 400(100/cutting)-150-90-2 lb/A. Dolomitic limestone was applied at 2 ton/A in 1979 and at one ton/A in 1983 to adjust soil acidity to the range of pH 6.5 to 7.0. Forage was managed for four annual hay cuttings, when Coastal bermudagrass was harvested in early seed head growth development.

Yields

Annual K fertilization, with potash rates varying from 0 to 600 lb/A of K_2O, affected forage, crude protein, and digestible dry matter yields **(Table 1).**

Where potash fertilizer was not applied, forage, crude protein, and digestible dry matter yields decreased annually from the initial year level. Forage yields were maximized where 600 lb/A of K_2O was applied annually. Where maximum yields were produced, forage, crude protein, and digestible dry matter yield increased 24.8%, 46.5%, and 24.7%, respectively. Maximum yield response per cutting to potash fertilizer averaged 1,438 lb/A of forage, 177 lb/A of crude protein, and 831 lb/A of digestible dry matter. The effect of application frequency was not significant on yields.

Response data revealed that K fertilization played a vital role in the production of Coastal bermudagrass on this site that

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Table 1. Five-year mean and total forage, crude protein, and digestible dry matter (DM) yields of Coastal bermudagrass as influenced by K fertilization rates.

Annual K_2O Rates	Yield, lb/A (Five-year)					
	Forage Yield		Crude Protein		Digestible DM	
	Mean	Total[1]	Mean	Total[1]	Mean	Total[1]
0	8,919	44,595	1,250	6,250	4,689	23,445
100	12,108	60,540	1,659	8,295	6,538	32,690
200	13,393	66,965	1,801	9,005	7,268	36,340
400	14,208	71,040	1,919	9,595	7,723	38,615
600	14,385	71,925	1,923	9,615	7,847	39,235

[1]Total of 19 cuttings over five years, 1980-84.

was cropped to very low soil K level. Yield of forage, crude protein, and digestible dry matter per cutting was increased annually an average of 1,226, 152, and 699 lb/A, respectively, from application of K fertilizer.

Economics

This study also sought to find what annual rate of K fertilization is required to produce MEY from Coastal bermudagrass fields having very low soil test K level and where stands and yields have declined. Several economic procedures were followed to answer this question.

1. When the value of forage, crude protein, and digestible dry matter was determined, MEY of each occurred where 400 lb/A of K_2O was applied annually.
2. When the value of forage yield and soil K was determined and the Purdue Method followed (based on the value of K_2O removed or added to the soil in the presence of cropping), MEY occurred where 600 lb/A K_2O was applied annually.
3. When all fixed and variable costs were considered for the production of 1,000 lb round bales of hay, MEY yield occurred where 50 lb/A of K_2O/cutting was applied, and hay was sold for \$60/ton. When hay was sold for \$90/ton, MEY occurred where 100 lb/A of K_2O per cutting was applied **(Table 2).**

Economic data revealed that producing Coastal bermudagrass yields approximating 8 ton/A of hay, one ton/A of crude protein, and 4 ton/A of digestible dry protein, and 4 ton/A of digestible dry matter, required 400 lb/A of K_2O (100 lb/A/cutting) when hay was harvested in early-seed head growth stage and K fertility status of soil was low.■

Table 2. Projected cost and net returns per acre of harvested Coastal bermudagrass hay as influenced by potassium fertilizer rates over all application frequencies, 1980-84.

Annual K_2O rate Rate/cut	Total	Mean hay Yield/cut	Cost/ton Harvest[2]	Fertilizer lime, etc.[3]	Total	Net returns/A/cut @\$60/ton	@\$90/ton
lb/A	lb/A	ton/A	\$	\$	\$	\$	\$
0	0	1.32	26.03	36.99	63.02	(3.99)	35.61
25	100	1.79	23.99	29.22	53.21	12.11	65.81
50	200	1.98	23.44	28.16	51.60	16.64	76.04
100	400	2.11	23.12	29.77	52.89	15.01	78.31
150	600	2.13	23.03	32.68	55.71	9.14	73.04

[1]Baler producing 1,000 lb round bales.
[2]Fixed and variable.
[3]Fertilizer annual rate of 400-150-0 to 600-90-2 lb/A of N-P_2O_5-K_2O-S-B. Lime-3 tons/A prorated over 5 years. Herbicide simazine applied annually at 1.2 lb/A (fixed and variable cost included).

Conservation Tillage for Cotton Reduces Runoff and Soil Loss

By K.H. Yoo, J.T. Touchton, and R.H. Walker

Research in Alabama shows that conservation tillage can significantly reduce runoff, erosion, and nutrient losses in cotton production, while producing yields comparable to conventional tillage.

CONSERVATION TILLAGE is the "in thing" as farmers seek production methods that control erosion while maintaining crop yield. It is estimated that over 90% of U.S. farmland will be under conservation tillage by the end of this century. For this to succeed, however, there is a need for information about how such non-inversion tillage systems influence the quantity and quality of surface and subsurface runoffs from fields.

A soil erosion study site at the Alabama Agricultural Experiment Station's Tennessee Valley Substation is being used to evaluate and compare three tillage systems for cotton production. Surface runoff, soil erosion, and plant nutrient and pesticide losses under natural rainfall conditions in the Tennessee Valley region are being determined under tillage systems described in **Table 1.**

There were 15 rains during the 1985 growing season (April 22-November 7) which generated measurable surface runoff. The growing season was divided into two periods for data analysis, before and after the last cultivation of the **conventional tillage (CT)** system (June 21 or 2 months after planting). As shown by data in **Table 2,** there were variations among the tillage systems in surface runoff, soil erosion, and plant nutrient losses. During the early part of the growing season, total surface runoff was about equal from the **no-tillage, no cover crop (NT)** system and the CT system. However, soil loss from the CT system was twice that of the NT system. The early growing period is often called a "critical period" in terms of soil erosion when the crop has not yet developed full canopy.

Table 1. Descriptions of tillage methods in study.

Tillage Systems	Fall Tillage	Spring Tillage	Summer Tillage
No-Tillage With no Cover Crop (NT)	None/Crop Stubble	None/ Plant 4-22-85	None
Reduced-Tillage with Wheat Cover Crop (RTC)	Disk, Chisel Plow/Plant Wheat 11-7-84	None/ Plant 4-22-85	None
Conventional Tillage (CT)	Disk, Chisel Plow/Fallow 11-7-84	Disk/ Plant 4-22-85	3 Cultivations 5-21-85 5-31-85 6-21-85

After the critical period, the soil loss was low from all treatments, with the lowest from the **reduced tillage with cover crop (RTC)** system. More than 85% of the total soil losses from all treatments occurred during the 2-month critical period. There was more rainfall but less surface runoff during the later, noncritical growing period than during the critical period. Sediment concentration during the noncritical period remained relatively low for all treatments even during high runoff events.

Heavy crop coverage during the noncritical period plays a major role in preventing soil erosion by reducing the erosive forces of raindrop impact on the soil surface. The RTC system had the lowest level of surface runoff and soil loss throughout the growing season. This may have been the result of a combination of

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Table 2. Runoff and pollutant losses in runoff-generating storm events during 1985 growing season of cotton.

Tillage Systems	Runoff		Runoff losses/acre				
			Soil	NH_4-N	NO_3-N	N[1]	P[2]
	Inches	% of rainfall	----------	----------	lb	----------	----------
Critical period (8.89 in.rain)							
NT	1.90	21.4	842	0.31	0.92	2.00	0.25
RTC	.81	9.1	203	.16	.42	.56	.14
CT	2.18	24.5	1,877	.38	2.83	2.51	.47
Noncritical period (12.6 in.rain)							
NT	1.68	13.3	110	.22	.25	.63	.23
RTC	.55	4.4	28	.10	.08	.22	.04
CT	1.26	10.0	120	.58	.24	1.02	.10
Total (21.5 in.rain)							
NT	3.58	16.6	952	.54	1.12	2.63	.38
RTC	1.36	6.3	232	.26	.50	.73	.19
CT	3.44	16.0	1,997	.96	3.07	3.53	.57

[1]Total Kjeldahl nitrogen.
[2]Total phosphorus in water and sediment.

the enhanced infiltration and the protection of the soil surface by the wheat stubble against raindrop impact. The summer cultivation in the CT system helped reduce surface runoff during the summer months without increasing soil erosion.

The overall mean concentration of nitrate nitrogen (NO_3-N) in the runoff water from all three tillage systems was well within the 10 ppm upper limit recommended for drinking water (data not shown). However, the concentrations of ammonium nitrogen (NH_4-N) averaged well above the 0.5 ppm standard for public water supplies. There were several runoff occurrences where the NH_4-N concentrations even exceeded the 2 ppm level considered to be toxic to fish.

The percentage of the applied pesticides—pendimethalin (Prowl®) and aldicard (Temik®)—that left the field was lower than 0.5% from all tillage systems. The first runoff after the application of pesticide carried the highest concentration, and the concentration level rapidly decreased thereafter. The pendimethalin was detected throughout most of the growing season.

The CT system gave the highest loss of the plant nutrients and pesticides, whereas the RTC system gave the lowest.

An important concern about conservation tillage is its effects on crop yield. Seed cotton yields from all three tillage systems were comparable for the 1985 season: 3,225 lb/A from the NT system, 2,920 lb/A from the RTC system, and 2,775 lb/A from the CT system.■

New Publications from PPI/FAR

A NEW FOLDER, "Moving Toward MEY Soybeans . . . Supplying Nutrient Needs", emphasizes plant food uptake. "Sulphur—A Plant Nutrient With Growing Importance" is a new brochure by the Foundation for Agronomic Research (FAR). See page 31 for more details.■

Nitrogen Source Influences Nutrient Uptake

By F.E. Below and L.E. Gentry

Illinois research (using controlled conditions) indicates that some crops may respond better when nitrogen (N) is provided in both the nitrate and ammonium forms, rather than nitrate only. Since ammonium N is normally quickly converted to nitrate N after application in the soil, it has been difficult to make use of this information under field conditions. Continuing research has been exploring the role of nitrification inhibitors in influencing the ratio of N forms available later in the season and their effects upon plant growth and yield. There may also be additional environmental benefits from improved N management.

MOST CROPS can utilize either nitrate or ammonium forms of nitrogen (N) but there is increasing evidence that growth is enhanced when a mixture of both forms is available. Since it is difficult to control nitrate/ammonium ratios in the soil under field conditions, such research usually has to be done using hydroponic systems. In the field, ammonium N is rapidly converted to nitrate N through the nitrification process, so the question has generally been considered to be of academic interest only.

The development and use of nitrification inhibitors have renewed interest in gaining a better understanding of the crop's preference for, and response to, different forms of N. These inhibitors offer a possible opportunity for a farmer to influence the nitrate/ammonium ratio. If a mixture of nitrate and ammonium is preferred, the use of a nitrification inhibitor might help to keep a supply of ammonium available for an extended period of time.

These possibilities make the research on crop preference for different N forms of more practical significance.

It has also been determined that the crop's preference for one N form or the other may change at different stages of growth. Since efficient application of ammonium forms late in the season is difficult, if not impossible, there has been little opportunity to take advantage of this research under field conditions. This current research is one of the first attempts to grow corn to maturity in a field environment under carefully controlled mixtures of ammonium N and nitrate N in nutrient solution culture.

While it would be very difficult to duplicate this system in the soil, research is continuing to further study the value of having ammonium N available late in the season. Other studies are exploring the potential for nitrification inhibitors to influence late-season ratios of nitrate N and ammonium N. If using nitrification inhibitors can be shown to increase availability of ammonium N later in the season, this could provide a practical application for the research described here.

Wheat Studies

Growth chamber studies with wheat showed that plants that received a 50/50 mixture of nitrate and ammonium N took up more total N, phosphorus (P) and potassium (K) than plants that received only nitrate N. The plants grown with the mixture of N sources also produced more total dry matter and had 30% higher shoot/root ratios. Most of the dry matter increase was attributed to a greater number of tillers on plants grown with the mixture of N sources **(Table 1).**

This research has also shown the re-

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Table 1. Effect of mixture of nitrate and ammonium versus all nitrate on the accumulation and partitioning of N, P and K for 21-day-old seedlings of two wheat cultivars.

Wheat Cultivar	N Source	Nitrogen Shoot	Nitrogen Root	Phosphorus Shoot	Phosphorus Root	Potassium Shoot	Potassium Root	Dry Matter Shoot	Dry Matter Root
		(mg/plant)						g/plant	
A	All NO_3	28.0	15.1	5.1	2.5	28.8	17.9	.48	.32
	NO_3/NH_4	38.1	16.7	8.9	3.0	35.3	19.1	.62	.33
B	All NO_3	35.8	12.7	12.2	3.5	43.2	17.5	.69	.30
	NO_3/NH_4	62.3	18.3	17.8	5.4	65.5	23.1	1.05	.35
LSD (0.05)		5.2	1.8	1.4	0.5	5.5	1.8	.08	.04

sponse to form of N is genetically dependent. Of the two cultivars used, the increase in dry matter production with mixed N sources was twice as great for B as for A. Cultivar B also had a greater increase in total N and K uptake. The increase in P uptake was approximately the same for both cultivars. Because additional absorption of N with N mixtures appears to be associated with K absorption, adequate levels of K must be available to the plant to realize the full benefit of a mixed N diet.

While this experiment measured only seedling growth and nutrient uptake, other studies support the conclusion that the effects shown here would likely be translated into significant yield advantage for the mixed N treatment.

Corn Studies

A gravel-hydroponic system was used to grow corn plants in the field so that the nitrate/ammonium ratio effects could be studied under near-normal field conditions throughout the growing season. This system is unique because it allows corn

(continued on next page)

Figure 1.
Ears from corn plants grown with all nitrate (100/0, at left) and half ammonium/half nitrate (50/50, at right) sources of N nutrition.

(Nitrogen Source . . . from page 19)

plants to be grown to maturity under defined nutrient regimes.

In 1986, two corn hybrids known to have differing N utilization patterns were grown to maturity at a stand density of 16,000 plants/A. In 1987, four corn hybrids (a widely grown entry of each of the four main heterotic types) were grown to maturity at a stand density of 24,000 plants/A. Although year and stand density affected plant performance over the two years, yields of all hybrids tested in the hydroponic system were increased by 8 to 25% when plants were supplied with the N mixture compared to all nitrate. For the most part, yield increases were due to increased number of kernels per plant rather than individual kernels being heavier, **(Tables 2 and 3).**

As in the wheat experiments, total N, P, and K uptakes were increased when plants were supplied with a 50/50 mixture of nitrate and ammonium N. Because plants grown in hydroponics usually have high levels of N, P and K, it is difficult to implicate enhanced nutrient uptake as the cause for the yield advantage. However, under normal field conditions, the advantage of increased nutrient uptake might more likely be translated into a yield advantage.

Table 2. Corn yield increase produced with a 50/50 mixture of nitrate and ammonium sources of nitrogen versus all nitrate. Corn was grown to maturity in a gravel-hydroponic system under field conditions at the University of Illinois Agronomy-Plant Pathology South Farm.

Year	Hybrid	Plant Density	% Yield Increase
		plants/A	
1986	FS 854		14
	B73 x LH51	16,000	8
1987	B73 x LH51		25
	B73 x LH38	24,000	12
	CB59G x LH38		12
	LH74 x LH51		10

Yield increases based on grain yield per plant.

There might also be an economical as well as an environmental advantage to the mixed N nutrition. If higher amounts of N are accumulated in the plants, less N will be lost to leaching or denitrification. Thus more N will be efficiently used to produce grain and less N in the form of nitrate will end up in the groundwater.■

Table 3. Responses of corn hybrids when supplied with differing N sources. Plants grown under field conditions in a gravel-hydroponic system.

Year	Hybrid	N Source	Grain Yield	Kernel Number	Kernel Weight
			g/plant	no./plant	mg/kernel
1986	B73 x LH51	All NO_3	254	688	369
		NO_3/NH_4	275	764	361
	FS 854	All NO_3	277	818	339
		NO_3/NH_4	315	1,000	315
1987	B73 x LH51	All NO_3	154	540	285
		NO_3/NH_4	193	691	279
	B73 x LH38	All NO_3	161	603	267
		NO_3/NH_4	180	742	243
	CB59G x LH38	All NO_3	137	475	288
		NO_3/NH_4	154	545	283
	LH74 x LH51	All NO_3	181	592	306
		NO_3/NH_4	199	607	328

Maximum Economic Yields (MEY) and the Environment

EFFICIENT agriculture and a clean environment are necessary and compatible. We are faced with the considerable task of producing adequate supplies of food and fiber in the years ahead and, at the same time, preserving the quality of our soil and water resources. Technologies to accomplish both are available today and will be improved through research.

Two management objectives are essential in achieving the goals of a more profitable agriculture and a cleaner environment.

OBJECTIVE 1

Manage crops for optimum efficiency through maximum economic yield (MEY) systems wherein all production inputs are integrated at optimum levels. This will lower the unit cost of production to the point of highest net return for the existing soil and climatic conditions.

OBJECTIVE 2

Within each MEY system and for each field site, utilize conservation farming practices which provide optimum soil retention.

Yield limits are a function of current technology and genetic potential. **A MEY goal must be established** and this is done by first dealing with the uncontrollable soil and climate factors. Soils are classified according to their relative productive capacity. These should be known for each field. When soils information and yield history are combined with length of growing season and water availability, a good estimation of uncontrollable limits to yield can be made.

Maximum yields possible at any one location may be well above a MEY goal. The maximum yield level might be obtained in research, but would be prohibitive under current conditions for producers because some inputs, such as chemicals or equipment, may be unavailable or too expensive. Success in achieving a MEY goal is a product of management ability to integrate available inputs at optimum and balanced levels.

Producers willing and capable of **using precision crop management** and recommended **soil conservation practices** have set the stage for MEY with maximum environmental protection. The adoption of MEY technology decreases erosion potential, which is a major source of nutrient pollution.

For example, a corn crop has a harvest ratio of about one to one (grain to stover). Corn yields increased by 50 bu/A will add back to the soil surface as residue nearly one and one-half tons of additional organic matter. Handled properly, this can decrease wind erosion, increase moisture holding capacity,

(continued on next page)

This article is condensed from the publication titled *Maximum Economic Yields (MEY) and the Environment,* available from the Potash & Phosphate Institute (PPI). See page 31 for details.

(MEY and Environment . . . from page 21)

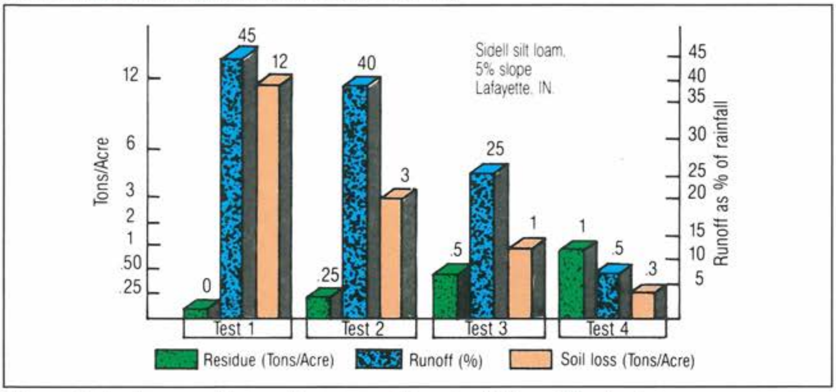

Figure 1. Surface residue reduces runoff and soil loss (Purdue).

and improve water stability of soil aggregates as residue decomposes. These effects can improve water infiltration while decreasing surface water movement and sedimentation potential. MEY corn production generally means earlier planting, higher plant populations, narrower rows, and starter fertilizer, all of which lead to earlier canopy closure and greater protection of surface soils from erosion caused by heavy rains. **Figure 1** shows the relationship between residue amounts and soil erosion.

Table 1. Effects of management on yield of grain and residue.

Crop/ Management	Grain Yield bu/A	Residue Yield tons/A	
Wheat:			
Conventional	81	1.65	(New York)
Good Management	103	2.00	
No P_2O_5	50	2.18	(Nebraska)
58 lb P_2O_5	75	3.61	
Corn:			
Conventional	127	5.00	(New Jersey)
Good Management	299	7.50	

Wheat and corn examples in **Table 1** show that both grain yield and crop residue increase with good management.

Observation of winter wheat under MEY management has shown: (1) faster emergence, (2) quicker early growth, and (3) less winter injury. All these factors reduce erosion and runoff potential and enhance nutrient efficiency.

MEY production and adequate fertility help crops use water more efficiently. Here's how:

- Reducing both evaporation from the soil surface and the erosive energy of raindrops because of an earlier, fuller crop canopy.
- Producing more crop residue, which reduces water loss and soil erosion and increases infiltration.
- Improving soil tilth and water infiltration by building soil organic matter.
- Enlarging root volume and improving exploration of the soil.
- Improving resistance to disease, nematodes, and weed infestations.
- Reducing the length of time to maturity.

Florida scientists found fertilizer helped corn triple its bushel yield per inch of water—from 3.1 to 9.6 bu/inch (**Table 2**).

Table 2. The effect of balanced fertility and corn yields on water use efficiency in Florida.

N	P_2O_5	K_2O	Yield	Water Use Efficiency
--------------lb/A--------------			bu/A	bu/inch
75	50	75	76	3.1
150	100	150	149	6.0
300	200	300	240	9.6

Balancing Other Controllable Inputs for MEY and Nutrient Efficiency

For the greatest benefit from a fertility program with the least negative potential impact on the environment, crop production management should be at MEY levels.

Table 3 summarizes research from several locations for corn. The results show the impact which various growth factors can have on increasing yields and fertilizer efficiency. Only when the whole range of production practices is put together into a MEY system will the highest possible fertilizer efficiency be obtained.

Table 3. The effects of several production inputs on corn yield and fertilizer efficiency from various locations.

Production Factor	Yield	Efficiency P_2O_5	Efficiency N	N Balance Sheet* Soil (–): Unused (+)	State
	bu/A	--bu/lb--		lb/A	
Rotation:					
continuous	105	2.10	0.88	+ 14	North
rotation	120	2.40	0.96	– 6	Carolina
Irrigation:					
without	127	1.02	0.51	+ 85	New
with	214	1.71	0.86	– 28	Jersey
Planting Date:					
late May	132	1.32	0.66	+ 28	
early May	163	1.63	0.86	– 12	Indiana
Hybrid:					
bottom 5	149	0.99	0.60	+106	
top 5	250	1.67	0.83	– 25	Florida
Population:					
low (12,000)	155	1.44	0.52	+ 39	
high (36,000)	231	2.14	0.96	– 60	Florida
Compaction:					
compacted	123	2.46	0.62	+ 33	
not compacted	167	3.34	0.84	– 17	Indiana
pH x P:					
low pH, low P	90	—	0.60	+ 33	
best pH, high P	138	1.97	0.92	– 29	Wisconsin
P Placement (low)					
No P_2O_5	143	—	0.64	+ 39	
35 lb P_2O_5	159	4.54	0.71	+ 18	
70 lb P_2O_5	165	2.36	0.73	+ 11	Wisconsin

*lb of N applied per acre was less than (–), or more than (+), uptake in aboveground portion of crop.

Summary

MEY is achieved through precision management. This includes using the latest agronomic technology for each production input and fitting these components into a productive cropping system. Dedicated production agronomists, during this decade, have put together the kinds of technology that give greater consistency to high yields. This "reproducibility" has given confidence that efficient new MEY systems which lower unit production costs are real today and will be improved tomorrow.

The most striking feature of each MEY system developed is the necessity to integrate all controllable inputs at optimum levels for the crop and site. When using MEY technology, farmers should add soil conservation practices which best fit their particular situation. Together, these two objectives give farmers the best opportunity to increase profits with a minimum negative impact on the environment.■

The Vital Role of Phosphorus in Our Environment

Although phosphorus (P) is sometimes considered a threat to environmental quality, this important nutrient can be properly managed to avoid pollution. Crop production systems which include conservation practices and reduce erosion offer major benefits.

PHOSPHORUS has been associated with environmental pollution, primarily through the eutrophication of lakes, bays and nonflowing water bodies. Eutrophication is the response of a water body (lake, reservoir, slow-flowing river, and certain coastal waters) to overenrichment by nutrients. It may be natural or man-made. The symptoms are algal blooms, heavy growths of certain aquatic plants, algal mats, and deoxygenation.

Sediments comprise the greatest weight of all nonpoint source pollution. Nutrients from croplands can move with this sediment which acts either as a carrier of various nutrient forms or as a sink where nutrients undergo chemical changes into forms which are rather unavailable or slowly available.

Animal wastes, crop residues, percent organic matter, soil type, and the number and intensity of storm events are all factors that affect (1) the degree of nutrient movement, (2) the form of nutrient, and (3) the potential harm this movement may have to water bodies.

It is difficult to draw summary conclusions from environmentally related research on specific cropland sites and extend these findings over wide geographic areas. But certain environmental facts are associated with cropping systems, P use and the management level given to these cropping systems.

Phosphorus Movement in Soils

When a water-soluble P fertilizer is added to a soil, the P portion is rapidly converted into forms having a very low solubility in the soil water unless the soil is almost pure sand or very high in organic matter.

Phosphate is, in fact, an example of a nutrient ion that is extremely immobile in the soil. It is adsorbed very strongly by surfaces of iron, aluminum and manganese oxides and hydroxides. It is adsorbed by clay particles.

Why are P additions to water bodies from farmlands almost wholly associated with erosion? (1) Because P has a very low solubility. (2) Because P moves very little in most soils. (3) Because very low concentrations of P are found in most drainage waters.

Table 1 shows the insidious nature of erosion. The mean composition of surface soil runoff from 12 watersheds had greater concentrations of nutrient material than in the surface soil remaining in place. This is called the enrichment factor and scientists use a nutrient enrichment ratio to characterize soil and site locations.

Table 1. The mean composition of surface soil runoff from 12 watersheds.

Component	Surface Soil	Eroded Material
	----------lb/ton----------	
Organic matter	67.0	83.0
Total N	3.0	5.5
Available P_2O_5	1.0	1.9
Available K_2O	0.2	1.5

The largest percentage of total soil P is associated with **clay-sized soil fractions.**

This article features important points from the publication titled *The Vital Role of Phosphorus in Our Environment,* available from the Potash & Phosphate Institute (PPI). See page 31 for details.

Since the energy required for the movement of clay particles is less than for coarser fractions, this selectivity of movement has led to the concept of enrichment ratios. P is also associated with **organic fractions** in the soil. Manure and crop residues on, or near, the soil surface also contribute to the different movement of P with surface waters. Numerous conservation tillage studies have shown concentration of soluble P in waters from conservation tillage areas is higher than from conventional tillage systems. **Yet, the total amount of P lost is much less because the total runoff is greatly reduced.**

Table 2. A comparison of cropping and tillage systems on soil and P losses.

Crop	System	Runoff in./yr	Soil loss lb/A/yr	P loss lb/A/yr
Corn	P*	5.11	6,300	2.56
	C*	2.25	1,490	0.75
Soybeans	P	5.57	8,430	3.41
	C	3.74	3,340	1.72
Wheat	P	2.67	1,800	0.73
	C	1.57	830	0.43
Hay	P	5.28	190	0.08
	C	2.84	120	0.06

P* prevailing system: plowing, row planting and cultivation
C* Conservation system: contour planting and cultivation, higher fertility, and liming to pH 6.5.

Table 2 shows the conservation system significantly reduced runoff, soil and P losses. Decreases were most substantial for the two row crops, corn and soybeans.

It has been calculated that **more than 50% of the soil loss due to erosion in 1977 occurred on 10% of the nation's cropland.** This suggests big gains could be made in controlling erosion by **stopping agricultural production on these few very erosive acres or by putting intensive erosion control measures in place on them.**

This is in line with the farming approach advocated by the Potash & Phosphate Institute—to **farm the better land more intensively and get the same, or higher production, on fewer acres. This is the maximum economic yield (MEY) approach.**

MEY corn production generally means **earlier planting, higher** plant populations, narrower rows, starter fertilizer—all leading to earlier canopy closure. Surface soils are less susceptible to beating rains. Also, there is less potential for raindrop impact erosion and displacement.

(continued on next page)

(Phosphorus . . . from previous page)

Well fertilized soils, along with other good management practices leading to high crop yields, affect soil erosion directly and indirectly. **The direct effects include the following:**

1. A more rapid crop canopy closure which reduces the erosive energy of raindrops.

2. Higher yields of growing plants both above and below ground which reduce soil detachment, increase infiltration (thus reducing runoff), and anchor more of the soil because of the more vigorous roots.

3. The production of more crop residues, when left on the soil surface, is tremendously effective in controlling erosion.

The indirect effects are residual. The more dry matter produced, the more root growth and the more total plant material turned under or left on the surface, the greater the soil organic matter content. Soil organic matter improves soil tilth through increased soil aggregation. This in turn leads to more water infiltration, thus less runoff as well as increased resistance of soils to detachment. Both factors result in less soil erosion.

Table 3 shows the effect of increasing fertility (threefold) and pH (from 5.4 to 6.8) in a corn, wheat, and forage rotation in a small watershed (Coshocton) in a hilly area of eastern Ohio.

Table 3. Effects of long-term management practices on crop yields, runoff and erosion for Coshocton watershed soils.

	Prevailing Practices	Improved Practices
Corn yield (silage)	5.6 (tons/A)	8.0
Wheat yield	55.0 (bu/A)	84.0
Hay yield	4.7 (tons/A)	8.6
Runoff, growing season	0.7 (in.)	0.4
Peak runoff rate	0.9 (in./hr)	0.6
Erosion, corn	11.7 (tons/A/yr)	3.4

Yields were increased about 50% and runoff and erosion significantly reduced.

Phosphorus Efficiency and MEY

P efficiency is enhanced by any growth factor given optimum management to increase yield. Thus attention must be given to each controllable growth factor to as-

Quotes

"Soil fertility levels have a very significant impact on soil erosion. The impact is greater than often realized. I concluded long ago that no other practice has done more to reduce erosion than an adequate fertilizer program."

—Dr. Billy B. Tucker, (Retired), Oklahoma State University

"Long-term studies in North Dakota have shown beneficial effects of adequate available soil P from onetime high rate broadcast applications of P fertilizer to grain and residue yield. The key to soil resource conservation from the hazards of wind and water erosion is crop residue production and maintenance on the soil surface during fallow or idle periods between crops."

—Dr. A.L. Black, USDA, Northern States Area, Northern Great Plains Res. Lab., Mandan, North Dakota

"If sediment loss is stopped, there is essentially no problem with P and K losses on most soils. Erosion is a culprit, not applied P and K."

—Dr. Jerry Mannering, Purdue University.

sure it is at an optimum level, and in balance with other inputs, for the yield level that can be achieved for the site. The result of this MEY management approach is greater efficiency for all inputs and a reduction in the possibility for unfavorable environmental impact.

One production input in a MEY system is rotation. Long-term research at nine universities has shown that corn grown in rotation averaged from 15 to 30 bu/A more than corn grown continuously. In addition to the obvious benefit to fertilizer efficiency, University of Guelph scientists studied the environmental impact of rotations and found that the average topsoil lost from continuous corn was 3.0 tons/A/year. compared to 1.6 tons for corn grown in rotation.

Research results from several locations for one crop (corn) are compiled in **Table 4.** The results indicate the impact that various growth factors can have on increasing yields and P efficiency.

Summary

Profitable agricultural production must survive and advance to meet our ever increasing needs for food and fiber. And at the same time, this production must be undertaken with the minimum harm to our environment. The key to achieving this goal is for the majority of farmers to adopt the latest crop technology and precision management techniques.

Adequate nutrient use, tramlines, routine scouting for pest control, equidistant planting, computerized fertilizer spreading, accurate fertilizer placement, fertigation, multiple fertilizer applications, and a dedication to timeliness of all operations are just a few of the emerging agronomic practices that must become commonplace for surviving farmers.

Developing and adopting these agronomic practices are not enough. Precision management must include soil conserving techniques which provide optimum soil retention for each field.

Conservation tillage, terraces, contour stripcropping, grass waterways, contour and grass headlands, crop rotations, water sediment control basins, and diversions are examples of practices that must be a part of future cropping systems.

Research must lead the way from **biotechnology and the very basic to applied maximum yield research (MYR) and MEY studies.** Multidisciplinary research teams established to develop MEY cropping systems must include soil conservation expertise.

When combined with conservation practices, all the environmental benefits of MEY production (input efficiency, quicker ground cover, more crop residue, greater root development and freedom to idle more erodible land) will assure future generations can enjoy abundant, high quality food produced with a minimum negative impact on the environment.■

Table 4. Effects of individual management inputs on corn yield and P efficiency.

Management Factor	Yield Increase	Increased Applied P_2O_5 Efficiency		Location
	bu/A	Percent	bu/lb	
Rotation	15	14	0.30	N. Carolina (12)
Population	31	17	0.28	Florida (47)
Hybrid	51	69	0.68	Florida (47)
Within Row Spacing	24	15	0.13	Florida (32)
Planting Date	35	25	0.70	Ohio (45)
Deep Placed P	11	9	0.18	Indiana (5)
Starter P	24	14	0.69	Nebraska (31)
Irrigation	87	71	0.69	New Jersey (28)
Compaction	44	36	0.88	Indiana (38)

Nitrogen Management and the Environment

FERTILIZER NITROGEN (N) use has increased rapidly from 2.7 million tons in 1960 to over 11.4 million tons in 1986 in the U.S. This increase mirrors the equally spectacular rise in agricultural production during that same time.

No one can argue that to put limitations on N application rates will put a ceiling on crop yields and reduce the flexibility farmers have to manage for maximum economic yield (MEY) and increased profit potentials. However, there is a growing concern about fertilizer N as one of the nonpoint sources of nitrate-N which can enter groundwater supplies and become a potential water quality problem.

N Management for Profitable and Efficient Production

Two distinct crop management objectives are needed to assure that adequate amounts of N are used in agriculture for maintenance of profitable production levels, while minimizing any potential negative effect on water quality.

OBJECTIVE 1

Manage crops for optimum N efficiency through MEY systems wherein all production inputs are integrated at optimum levels. This will lower the unit cost of production to the point of highest net return for the existing soil and climatic conditions.

Some N management techniques to consider within a MEY system are:

- Split or multiple applications
- Delayed applications
- Cover crops to take up residual N
- Accurate and efficient application and placement
- Field trials to correlate yield response at MEY levels
- Soil sampling to credit residual N . . . where appropriate
- Tissue sampling and correlation with yield
- Nitrification inhibitors
- Nitrogen form applied and the timing of each form
- Credit for any N from legumes and manures

OBJECTIVE 2

Within each MEY system and for each field site, utilize conservation farming practices which provide optimum soil retention.

Some conservation system choices to use in conjunction with MEY management are:

- Conservation tillage
- Terraces
- Contour stripcropping
- Grass waterways
- Contour and grass headlands
- Crop rotations and cover crops
- Water and sediment control basins
- Diversions

P and K Boost N Efficiency

Tables 1 and 2 show examples from Illinois and Indiana where balancing N applications with adequate phosphorus (P) and potassium (K) results in better yields and more efficient utilization of N. Over 20 to 30% of the N was unused when P and K were not applied. When P and K applications were brought into

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This article is condensed from the publication titled *Nitrogen Management and the Environment,* available from the Potash & Phosphate Institute (PPI). See page 31 for details.

balance with fertilizer N, the growing crop required more N than was applied and a potentially negative environmental impact eliminated. This is shown in both examples.

Table 1. Effects of balancing N with P and K on corn yield and N efficiency in Illinois.

Fertilizer Level	Yield	N Efficiency	N Balance Sheet soil (−): unused (+)	Value unused N
lb/A	bu/A	bu/lb N	lb/A	$/A
180-60-0	96	0.53	+55	11.00
180-0-90	111	0.60	+36	7.20
180-60-90	143	0.79	− 6	—

Table 2. Effects of balancing P and K on corn yields and nitrogen efficiency in Indiana.

Fertilizer Level	Yield	N Efficiency	N Balance Sheet soil (−): unused (+)	Value unused N
lb/A	bu/A	bu/lb N	lb/A	$/A
200-0-0	127	0.64	+35	7.00
200-50-0	139	0.70	+19	3.80
200-0-50	147	0.74	+ 9	1.80
200-50-50	162	0.81	−11	—
200-100-100	167	0.84	−17	—

Similar observations can be cited for cotton, wheat, rice—or any other crop requiring N fertilizer and where a yield response to P and K is expected. In Kansas, for example, a P application almost doubled the number of bushels produced per pound of N **(Table 3).** Each rate of P increased N efficiency. This is very significant in the major wheat states of Colorado, Kansas, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas, where from one-half to three-fourths of the soils test medium or less in P.

Table 3. Adequate P increases wheat yields and improves N use efficiency in Kansas.

N	P_2O_5	Yield	N Efficiency	N Balance Sheet soil (−): unused (+)
---lb/A---		bu/A	bu/lb N	lb/A
75	0	35	0.46	+9
75	20	51	0.68	−21
75	30	56	0.75	−30
75	40	61	0.81	−40
75	50	64	0.85	−45

Average P applications are well below optimum (according to most recent USDA statistics the 51 million planted wheat acres in these states received an average of only 13 lb of P_2O_5/A), which means that quite often the applied N is not being used most efficiently. The result is more N left in the profile as a potential groundwater problem. Nitrogen from the soil to supplement the fertilizer N was needed in increasing amounts as P rates increased. This suggests that a higher N fertilizer application rate, along with adequate P, may have been needed for MEY.

Nitrogen Efficiency at Its Best in MEY Systems

To help assure optimum benefit from N fertilization with the least negative impact on the environment, crop production management should be at MEY levels (OBJECTIVE 1). All the benefits of MEY production, which include quicker ground cover, more crop residue, greater root growth and more leaf area will help improve N efficiency, reduce erosion, and minimize any negative environmental ef-

(continued on next page)

Scientist Comment

"Adequate levels of soil P and/or K are needed to optimize the use of available N supplies by both dryland and irrigated crops. Therefore, maintaining adequate levels of available P and K will improve N use-efficiency by the growing crop and reduce the potential of NO_3 - N loss by leaching, assuming good irrigation and N fertilization management practices are used."

Dr. Ardell D. Halvorson
USDA, Agr. Res. Ser.
Mountain States Area
Akron, Colorado

(Nitrogen . . . from page 29)

fects. Research results show the impact various growth factors have on increasing yields and N efficiency.

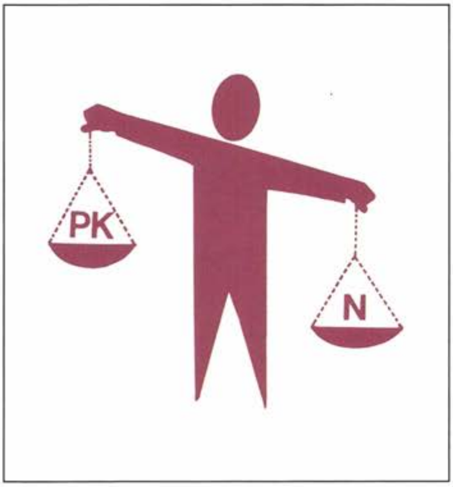
As these production practices are put together to achieve a MEY system, N efficiency improves and the possible detrimental effects on groundwater quality decrease.

Summary

Farmers must retain their freedom to use optimum N rates for each specific crop yield goal. Any mandatory limit on N use will put a ceiling on yield levels, limit the research incentives to develop new crop production technology, and take away from the farmer his management flexibility to produce MEY.

At the same time, it is the responsibility of the farmer and those who serve him to see that N is applied accurately and at rates which fit his yield potential. In doing this, he needs to develop a MEY production management system, using the proper combination of all controllable inputs, which will give the highest level of nitrogen efficiency possible for his soils and climate. Adequate P and K are of particular importance.

When farmers combine OBJECTIVE 1 (MEY) with OBJECTIVE 2 (best soil conservation practices) they can rest assured that fertilizer N will contribute minimal levels of nitrate-N to groundwaters. And, they will benefit from the best of both worlds—a cleaner environment and a more efficient and profitable agriculture.■



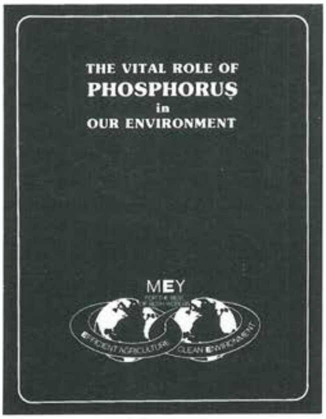
FOR GREATER EFFICIENCY, N rates should be properly balanced with P and K.

NOTE: For calculations in this article the following were used:
1.3 lb/bu N taken up by corn
1.88 lb/bu N taken up by wheat
\$0.20/lb cost for N

Publications on Environmental Concerns

FOR MORE DETAILED information on the environmental topics described in the preceding articles, three publications are available from the Potash & Phosphate Institute (PPI).

See page 31 for request form.



Information Materials from PPI

	Quantity	Cost
Moving Toward MEY Soybeans . . . Supplying Nutrient Needs New folder discusses plant nutrient uptake and the importance of soil fertility for maximum economic yields (MEY) with soybeans. Also notes other management factors. **Cost: 25¢ (15¢ MC*)**	______	$______
Sulphur—A Plant Nutrient With Growing Importance New 12-page brochure describes the reasons for increased attention to sulphur for crops, including yield responses and other benefits. **Cost: 25¢ (15¢ MC*)**	______	$______
The Vital Role of Phosphorus in Our Environment This 20-page booklet discusses the importance of phosphorus as a plant nutrient in our environment, and relationship to crop yield, erosion, and other factors. **Cost: 75¢ (50¢ MC*)**	______	$______
Nitrogen Management and the Environment Brochure outlines management techniques for using nitrogen fertilizer in profitable crop production while reducing any potential negative effect on water quality. **Cost: 25¢ (15¢ MC*)**	______	$______
Maximum Economic Yields (MEY) and the Environment Brochure emphasizes the message that efficient agriculture and clean environment are compatible goals if techniques such as conservation tillage and MEY management are applied. **Cost: 25¢ (15¢ MC*)**	______	$______
MEY . . . Fact and Fallacy Folder features specific statements to clarify what MEY (maximum economic yield) **is**, and **is not.** **Cost: 25¢ (15¢ MC*)**	______	$______
AGRONOMICS for Industry This important booklet states the case for "agronomics" as a marketing tool in modern agriculture. **Free**	______	$______

*The MC symbol indicates Member Cost: For members of PPI, contributors to FAR, to university and government agencies.

Single, sample copies of these publications or script for slide set *free* on request.

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All of Us Are WINNERS

FOR OVER 50 YEARS the Potash & Phosphate Institute (PPI) has provided financial assistance to promising graduate students. The grants-in-aid and the Fellowships enabled many of today's leaders to complete their training. Indeed, the list reads like a Who's Who in Agriculture.

At present, Fellowships are awarded to a number of students each year. Who are the winners? Everyone!

1. **The students receiving the grant.** Invariably they are people of tremendous ability and potential.

2. **The applicants who do not receive the award.** Even so, they have applied and tried and gained the experience of competing. They also are extremely competent and are destined to be leaders. Selection among the applicants is difficult and close.

3. **The student's university**—for encouraging the applicant, for the prestige, and for the information developed through the applicant's research.

4. **The various professors**—whose dedication and devotion to these students are reflected in the quality of the applicants.

5. **The Potash & Phosphate Institute and the industry**—who must look to these students for guidance in the future.

6. **The entire agricultural community**—benefits greatly from the leadership and accomplishments of these talented people.

I have been privileged to assist with the selection of these Fellows for many years. I never cease to be amazed at the quality of the applicants, and wish that every one could be awarded a Fellowship. They all deserve it. There have been no mediocre ones. They strengthen your faith in the future of agriculture.

All applicants over the years who have not received the award should feel very proud of themselves. They are all winners in the long run. Of that I have no doubts whatsoever.

—J. Fielding Reed

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