RESEARCH PPI EDUCATION

BETTER CROPS WITH PLANT FOOD

Winter 1989-90

BETTER CROPS With Plant Food

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Our Cover: Soil organic matter can be maintained and increased with proper management practices. This issue highlights results from several research projects.

A Timely View of Soil Productivity, Organic Matter and Commercial Fertilizers

"I SEND YOU a brief memoranda of a series of experiments undertaken by Prof. Miles of the Illinois Industrial University. It is not expected that should extraordinary results follow use of most of the articles in the way of increasing the crop, it would be found profitable to employ them. But the thing to be learned is, and it is a great matter, what commercial fertilizers, or what combination of them, will increase corn yield; and that being settled, it will be for chemical manufacturing skill to produce them at a price so low they can be profitably used. The fact cannot be much longer ignored, that as rich as the prairie soils originally were, they are slowly being impoverished and exhausted and the time is not far off when the fact will be generally acknowledged and acted on. From that hour, the manufacture of commercial fertilizers of every kind will be a very important and lucrative business, and their use as general as the necessity for them is imperative. It is not claimed or expected that they will take the place of or do away with the ordinary manures of the farm, but supplement them, and in that way restore to the soil many of those elements of fertility a long course of unscientific farming has impoverished it of. Perhaps some may sneer at the phrase "unscientific farming," and perhaps many others may laugh at the idea that the soil needs to be enriched in any other than the old way of green and stable manure; but I beg to say to those gentlemen, that science will yet do for farming what it has done for nearly all other arts—that is revolutionize it and save our agriculture, and in that way arrest soil exhaustion and that which inevitably follows, natural decadence."

— Editor's note introducing an article by Professor Manley Miles outlining the establishment of a series of plots at the Illinois Industrial University (now known as the University of Illinois), *Prairie Farmer,* June 10, 1876.

Soil Organic Matter: An Integral Ingredient in Crop Production

By B.C. Darst and L.S. Murphy

Organic matter contributes to a soil's productivity. It acts as a storehouse for nutrients, increases the soil's cation exchange capacity (CEC) and reduces the effects of compaction. It builds soil structure and increases the infiltration rate of water. It helps to buffer the soil against rapid changes in pH and is an energy source for soil microorganisms.

ORGANIC MATTER is not easily characterized. It is made up of a wide array of substances, its specific nature being determined by the plant and animal residues that are added and decomposed in a continuous cycle. It consists of proteins and their decomposition products, carbohydrates, organic acids, fats, resins and other complexes. Management of organic matter, including the use of crop residues and animal manures, is a key factor in building soil fertility and sustaining productivity.

A Storehouse for Plant Nutrients

Soil organic matter makes an important contribution to plant nutrition in most soils. It is a storehouse of major nutrients, secondary nutrients and micronutrients. The approximate percentages of total nitrogen (N), organic phosphorus (P) and organic sulphur (S) in organic matter . . . in fine-textured, cultivated, humid region soils . . . is as follows.

• Total N	5.0
• Organic P	0.5
• Organic S	0.5

The National Research Council has estimated N availability from organic matter in the U.S. at about 3.4 million tons per year, approximately 15 percent of the total annual N input to soil (**Table 1**). In comparison, 1988 fertilizer N use in the U.S. was 10.5 million tons. Similarly, organic matter supplies important amounts of other nutrients for plants. Phosphorus in organic matter has been estimated to represent up to 75 percent of the soil's available P. Sulphur availability is closely associated with soil organic matter content as is the availability of micronutrients, particularly zinc (Zn) and iron (Fe).

Organic matter also contains approximately 50 percent carbon (C). This C can serve as an important energy source to sustain microorganisms, crucial in the decomposition of plant and animal residues.

Organic Matter and CEC

Organic matter, depending on its level in the soil, can make a significant contribution to the soil's CEC. Stable organic matter can have CEC values as high as 600 milliequivalents/100 g of soil, the usual range being 150 to 200. Clay minerals, on the other hand, have CECs that range from 10 to 150 milliequivalents/100 g, while sands have no CEC. Organic matter content is a yardstick by which the reactivity (and potential productivity) of a soil can be measured. Its concentration influences the management of many production inputs. The following are some examples.

- **Fertilizer management, particularly N.** Organic matter levels influence decisions on rates, timing, source and placement of fertilizer N. Higher organic matter levels improve

Dr. Darst is Vice President, Potash & Phosphate Institute (PPI), and President, Foundation for Agronomic Research, Atlanta, GA. Dr. Murphy is Senior Vice President and Director of Research, PPI, Manhattan, KS.

Table 1. Estimated annual N input to soil in the U.S. in 1970.

Source	Total N Input, mill. tons	N Input, lb/A All Land	N Input, lb/A Cropland Plus Pastureland
Fertilizers	8.3	7.4	15.5
Precipitation	6.2	5.4	5.4
Symbiotic Fixation	4.0	3.5	7.4
Nonsymbiotic Fixation	1.3	1.2	1.2
Organic Matter	3.4	3.0	3.0
Total	23.2	20.5	32.5

the availability of P, S and micronutrients over a wider pH range.

- **Frequency and rate of liming.** Organic matter helps to buffer the soil against changes in soil pH, but also increases lime requirements under acid conditions due to the large amount of exchangeable acidity it can hold.
- **Water availability and water management.** Irrigation scheduling and rates of water application are influenced by soil organic matter content. Higher organic matter content implies a greater ability for water storage.
- **Application rate of some herbicides.** Application rates of many herbicides are influenced by the percentage of soil organic matter and by soil texture. Because of its high CEC, some herbicide rates must be increased as much as 50 percent with high soil organic matter levels.
- **Planting date.** Higher concentrations of organic matter produce darker soil color causing more heat to be absorbed and soils to warm earlier, allowing earlier spring planting dates.

Influence on Other Soil Characteristics

Organic matter has a dramatic influence on soil structure. Tillage results in more rapid oxidation of organic matter and in reduced soil organic matter levels with time. Loss of organic matter and the natural adhesives it provides results in a breakdown of soil structure. As structure is destroyed, soils become cloddy, hard and compact. Seedbed preparation and subsequent tillage become more difficult. Proper residue management, particularly in a high yield environment, has been demonstrated to increase soil organic matter—and to improve soil structure.

Aeration, water-holding capacity and permeability are all favorably affected by organic matter (humus). The addition of easily decomposable residues to the soil leads to the synthesis of complex organic compounds that bind soil particles into aggregates, helping to maintain a friable, granular condition. The increased soil pore space enhances water infiltration and storage. Loss of organic matter, on the other hand, results in reduced pore space and compaction, restricted movement of oxygen (O) and nitrogen (N) gases, a slower rate of water intake and a higher potential for surface runoff and erosion.

Importance of Organic Matter Recognized

Leading farmers and scientists recognize the importance of soil organic matter in overall soil productivity. Proper management for maintenance and building of organic matter levels is critical to profitable, sustainable, environmentally-friendly agriculture. The contributions of organic matter to plant nutrition are re-emphasized each time a soil sample is analyzed to determine fertilizer and lime requirements. Every field study from which soil test correlation data have been drawn included an accounting of all the soil's nutrient sources . . . organic and mineral. It may not have been spelled out, but it was always there.

The following articles in this publication emphasize how modern, scientific farming practices have contributed to improving organic matter levels and overall soil productivity. Proper management of organic matter, then, is an integral part of soil and water stewardship . . . and of profitable crop production. ■

Terry L. Roberts Appointed Western Canada Director

T.L. Roberts

DR. TERRY ROBERTS was recently named Western Canada Director of the Potash & Phosphate Institute (PPI)/Potash & Phosphate Institute of Canada (PPIC). He will have responsibility for agronomic research and education programs in the Canadian provinces of Alberta, British Columbia, Manitoba and Saskatchewan.

A native of Alberta, Dr. Roberts took his undergraduate training at the University of Saskatchewan, Saskatoon, earning his B.S.A. (Distinction) in crop science in 1981. He continued his graduate training there and completed his Ph.D. in soil science in 1985.

In addition to experience in a family-operated retail fertilizer business, Dr. Roberts taught courses at the University of Saskatchewan and Lethbridge Community College. Also, he has held positions of Research Scientist and Project Manager in both provincial and federal (Agriculture Canada) projects.

Although many soils in the Prairie Provinces are well supplied with available potassium (K), more research is needed on questions about soil and environmental conditions which impair K uptake by crops. More information is also needed on the value of chloride in potash as a plant nutrient and as a plant disease suppressant. These and other aspects of sound agronomic and environmental practices will be in the focus of Dr. Roberts' responsibility.

The Western Canada Director position is made possible through the Government of Canada Western Economic Diversification Program (WDP).

Dr. Roberts may be contacted at this office address: Box 1142, Coaldale, Alberta, Canada T0K 0L0. ■

W.R. Agerton Has New Title as Communications Specialist

Bill Agerton

THE Potash & Phosphate Institute (PPI) has appointed William R. "Bill" Agerton to the new title of Communications Specialist. In recent years, he has had a dual role as Visual Aids Coordinator and Circulation Manager for PPI.

The new role recognizes greater emphasis on visual communications tools, such as color slides, videotape presentations and other methods used by PPI staff and member companies. Mr. Agerton will also provide appropriate support in computer applications for PPI field staff, provide input for some PPI publications, and handle other special assignments.

Mr. Agerton earned B.S. and M.Ed. degrees at Auburn University and worked as Extension Editor of Publications at the University of Georgia before joining the PPI staff in 1979. ■

PPI Appoints Lethia Griffin as Circulation Manager

Lethia Griffin

THE Potash & Phosphate Institute (PPI) has named Lethia Griffin as Circulation Manager in the organization's headquarters office in Atlanta. Her responsibilities include general mailroom operation, maintaining mailing lists, handling requests for PPI information materials and other aspects of circulation and distribution.

Ms. Griffin has previous experience as a personnel assistant, customer service representative and sales representative. Her knowledge of efficient procedures for materials inventory, fulfilling orders and working with the public will be helpful. She is a graduate of Southwest High School (Atlanta), and attended Griffin Community College and the Southern Bell Communication Course. ■

Increasing Soil Organic Matter with Soil/Crop Management

By J.L. Havlin and A.J. Schlegel

Evaluation of soil-forming factors helps explain differences in productivity and organic matter content of various soils. Researchers are investigating soil and crop management systems that can increase organic matter by maintaining surface residues, increasing quantities of residues from crops, and supplying sufficient plant nutrients to optimize grain yields.

NUMEROUS chemical, biological and physical properties contribute to the "productive capacity" of soil. Many of these properties can be used to indicate relative soil productivity. Soil organic matter content has been the most common soil property used for these estimations. Unfortunately, soil cultivation for food and fiber production has resulted in substantial declines in soil organic matter, which can lead to lower productivity if proper management practices are not used to modify the trend.

Long-term tillage studies have quantified soil organic matter losses with cultivation. These studies showed that in most Great Plains soils, organic matter content declined approximately 50 percent after 40 or more years of cultivation. The decline in soil organic matter over time is primarily related to: 1) the "biological oxidation" of soil humus resulting from increased aeration with tillage; and 2) the loss of unprotected, organic matter-rich topsoil by water and wind erosion. Increasing surface residue cover and reducing the cultivation intensity should then slow or reverse the decline in soil organic matter content.

Several studies also have demonstrated beneficial effects of crop rotation on soil organic matter content. Data from the Morrow Plots in Illinois, established in 1876, clearly show that long-term crop rotation practices can increase organic matter content.

Ohio research has demonstrated the effects of tillage management and crop rotation on soil organic carbon (C) and nitrogen (N), the primary components of soil organic matter. After 19 years, organic C and N in the surface soil were 1.5 and 1.3 times greater, respectively, under no-tillage (NT) compared to conventional tillage (CT) management. Organic C and N levels were higher with continuous corn than with corn/soybean rotation.

Kansas Studies

Cultivation/Rotation. Recent studies in Kansas also investigated cultivation and crop rotation effects on soil organic C and N. Long-term tillage/crop rotation studies were initiated in eastern Kansas on two sites in 1974 and 1975. Continuous sorghum, continuous soybean, and sorghum/soybean rotations were grown at each site. No-tillage and CT systems were used with each rotation. Crop residues were kept on the soil surface in the NT system, but were incorporated with the conventional tillage. Soils were sampled prior to planting in 1987 at 0 to 1, 1 to 3, 3 to 6, and 6 to 12 inch depths. Organic C and N were determined in each sample. Soil organic matter percentage was estimated by multiplying organic C percent by 1.8.

(continued on next page)

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Increasing . . . from page 7

At both locations in the Kansas studies, organic C and N and organic matter decreased with soil depth. Tillage/crop rotation effects were primarily concentrated in the 0 to 3 inch zone. The greatest effects were in the 0 to 1 inch zone.

Increasing the frequency of sorghum in the rotation increased soil organic C and N in soils of both sites, although treatment effects were greater on a Muir silt loam (28 percent clay) than on a Grundy silty clay loam (36 percent clay). See **Table 1.** Maintaining crop residues on the soil surface with a no-till system resulted in greater soil organic C and N content, except in the soybean rotations on the Grundy soil. Rotation and tillage effects were greater on the Muir silt loam compared to the Grundy silty clay loam because of differences in soil texture. Similar soil texture differences were noted in the Ohio studies.

Differences in organic matter with tillage and rotations were directly related to the quantity of residue produced and left on the soil surface after harvest (**Figure 1**).

The quantity of residue produced at both sites decreased with increasing frequency of soybeans in the rotation (**Table 2**). This indicates that increasing the quantity of residue returned to the soil by increasing the frequency of high residue-producing crops in the rotation will increase soil organic matter more than including soybeans in the rotation (**Figure 1**). Increasing the frequency of soybeans in the rotation resulted in less organic N, especially with a no-till system. Estimates of soybean grain N removed and soybean residue N returned to the soil showed that each soybean crop depleted soil N 22 lb/A per year.

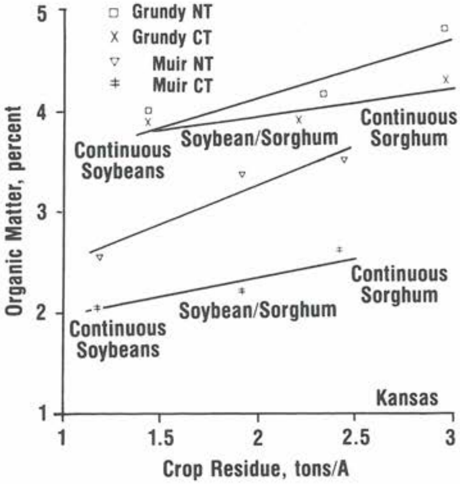

Figure 1. Soil organic matter levels increase as tillage decreases and larger amounts of crop residue are returned to the soil.

Increasing Yields. Since these data demonstrate that rotations which maximize residue production increase soil organic matter, then increasing yields should have a similar effect. Two N rate studies in Kansas illustrate the positive

Table 1. Crop rotation and tillage systems have significant effects on soil organic C and N. Higher amounts of residues and reduced tillage increase soil organic matter.

Rotation	Organic C[1]		Organic N[1]		Organic Matter	
	CT[2]	NT[2]	CT	NT	CT	NT
	Percent					
Muir silt loam—12 crop years						
Soybean - Soybean	1.14	1.43	0.109	0.126	2.05	2.57
Soybean - Sorghum	1.25	1.86	0.114	0.156	2.25	3.35
Sorghum - Sorghum	1.41	1.98	0.120	0.168	2.54	3.56
Grundy silty clay loam—13 crop years						
Soybean - Soybean	2.17	2.13	0.177	0.178	3.91	3.83
Soybean - Sorghum	2.19	2.28	0.176	0.189	3.94	4.10
Sorghum - Sorghum	2.35	2.67	0.186	0.205	4.23	4.81

[1]0 to 1 inch sample depth
[2]CT = Conventional tillage; NT = No-tillage
Organic C × 1.8 = Organic matter

Kansas

RESEARCH shows that high amounts of crop residues associated with better management and higher yields increase soil organic matter.

effects of fertilization on soil organic matter (**Table 3**). At the eastern Kansas site begun in 1978, irrigated continuous corn, continuous soybeans and corn-soybean rotations were grown with N rates of 0, 75, 150, and 225 lb/A. At the western Kansas site begun in 1961, irrigated continuous sorghum was produced with N rates of 0, 40, 80, 120, 160, and 200 lb/A. Soil analyses show that increasing yield and crop residue with fertilizer N increased organic matter content of both soils. At the eastern site after 9 crop years, increasing the frequency of soybeans in the rotation (lower crop residue produced) decreased organic matter content compared to continuous corn. Fertililizer N effects on organic matter would have been even greater if all the residue had been left on the soil surface with NT instead of being incorporated.

These and similar studies demonstrate some important considerations: 1) maintaining surface residues by reducing tillage; 2) increasing the quantity of residues with appropriate cropping systems; and 3) supplying sufficient plant nutrients to optimize grain yield can halt or reverse the decline in soil organic matter content and increase productivity.

Crop rotations that include grain legumes will always be economically viable. However, the importance of maximizing grain yields to produce high residue levels, combined with maintaining surface residue cover, will help sustain the productive capacity of our soils for future generations. ■

Table 2. Grain crops such as sorghum produce larger amounts of residues affecting soil organic matter. Higher yields with larger amounts of residue have a positive affect on soil organic matter.

Crop Rotation	Annual residue production: Muir silt loam	Annual residue production: Grundy silty clay loam
	------ tons/A ------	
Continuous Soybean	1.16	1.44
Sorghum-Soybean	1.91	2.20
Continuous Sorghum	2.41	2.96

Kansas

Table 3. N fertilization influences soil organic matter content. Nitrogen use and larger amounts of crop residue increase organic matter.

Rotation	Organic Matter[1] N Rate, lb/A: 0	Organic Matter[1] N Rate, lb/A: 225/200[2]	Annual Crop Residue N Rate, lb/A: 0	Annual Crop Residue N Rate, lb/A: 225/200[2]
	--Percent--		---tons/A---	
Eastern Kansas, Eudora silt loam—9 Crop Years				
Corn - Corn	1.62	1.73	2.77	5.96
Corn - Soybean	1.49	1.53	2.26	3.81
Soybean - Soybean	1.35	1.39	1.74	1.65
Western Kansas, Ulysses silt loam—28 crop years				
Sorghum - Sorghum	1.69	1.87	3.15	5.08

[1]Organic matter calculated as 1.8 × organic C percent, 0-6 inch sample depth.
[2]200 lb N/A at Western site, 225 lb N/A at Eastern location.

An Economist's View

Is Sustainability Enough?

By Ross C. Korves

Economic policy debates often result in "bumper sticker" descriptions of policy positions. "Save the family farm," "export competitive price support loans," "no to more taxes" and "balanced budget amendment" are recent examples. The newest one in agriculture is "sustainable agriculture", couched in terms such as low-input sustainable agriculture (LISA). Like most bumper sticker descriptions, while simply stated, the issue of sustainable agriculture is complex and has far reaching implications.

THE STARTING POINT is this: What does sustainable agriculture mean?

Two meanings related to farm production systems are relatively easy to see. One would be to maintain the current yield levels for an indefinite period into the future. The other is to maintain the natural resource base so the yield increases of the past century can be sustained into the indefinite future.

These two views are very different. One assumes we have reached our limits of productivity growth for land and must now focus on environmental concerns. The other view assumes that increased productivity and environmental quality are not mutually exclusive goals.

These two views of sustainable agriculture are complicated by a third meaning related to the sustainability of the human population. The purpose of agriculture is the production of food and fiber for the preservation of people and some type of society. Food and fiber production is not an end in and of itself and must be considered in relation to the "quality of life" issue that has become popular over the past 20 years.

It has been 200 years since Thomas Malthus postulated that population would always grow faster than food production, and starvation would be the recurring sorry lot of mankind. Since that time, starvation has been much more a political decision and the lack of income to draw food resources to the right locations than the total lack of food at any price.

To these views of sustainability has to be added a fourth, the economic sustainability of U.S. farmers. Farmers, like all producers of economic goods and services, have an ongoing need to increase productivity by producing more and/or finding ways to produce the same amount while using less resources. That is the only way their standard of living can be improved.

If the idea that yields per acre cannot be increased becomes accepted as public policy, and reflected in regulations and research efforts, consumer food costs would begin to rise and farmers would lose an important source of productivity increase. If the rest of the world does not pursue similar policies, U.S. producers would eventually become economic cripples, vis-a-vis the rest of the world.

These various views on sustainability clearly present the policy options and consequences. If sustainability means the maintenance of the current yields, the goal will be easy to achieve, but the economic and social consequences are

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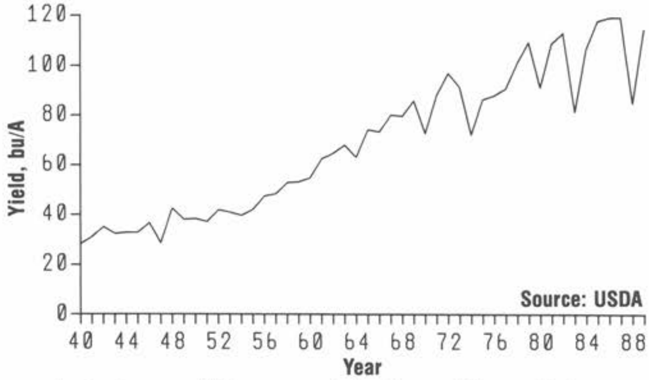
The author is with the Economic Research Division of the American Farm Bureau Federation (AFBF). This article is adapted with permission from the AFBF *Farm Bureau News*, November 13, 1989 issue.

U.S. average corn (grain) yields since 1940.



monumental and grow increasingly large as the years go by. If sustainability means maintaining our natural resource base so that yield increases can be sustained indefinitely, then the ecnomic outlook for U.S. farmers and the outlook for the quality of life for a significant portion of the world's population is encouraging.

However, the modern day challenge is to continue to enhance both quantity and quality without degrading the physical environment. The linchpin for this challenge is an old friend, or foe, depending on your view: technology. Agriculture cannot get from its current state to natural resource sustainability that is consistent with a higher quality of life for the world and improved farm income without a continued development of new technology.

The debate over what is sustainable agriculture and where do we go from here is at the heart of two radically different views of where we as human beings are now and where we will go over the next 50 or 100 years. One view is that much of what is labeled "progress" over the last 300-400 years is wrong. There is plenty of pollution, depravation and population crowding to "prove" that view. The doom and gloom that became popular in the 1970s reflected the idea that the world was running out of resources and we had to accept a lower standard of living. Technology is considered part of the problem, not part of the solution.

The other view is that the "progress" of the last century has, on balance, been good. Living in a brick house is better than living in a mud hut, refrigerated meat is better than dried meat hung in a well and modern false teeth beat gumming your way through life. This approach to the world sees that an evolutionary shift in current production practices combined with a better understanding of the impact of production processes on the environment can lead to a higher quality of life in the future. The issue is not humanity vs. the environment, but how can humanity better live in harmony with the environment and at the same time actually improve the standard of living.

While we argue over the definition of sustainable agriculture, the evolution in agricultural production continues. In the U.S., lower dosage crop protection products replace higher dosage products and reduced tillage systems become more commonplace. Outside the U.S., more policy analysts are realizing the increased use of fertilizer on highly productive soils is one way to increase food supplies and reduce the amount of land of marginal productivity that is needed to meet food demands.

The answers to the public policy issues are radically different, depending on what definition of sustainable agriculture is used and how the "progress" of the last century is viewed. As is often true in the public policy debate over agriculture, the question is **not** what is the answer to the question. The question is: What is the question?

Is sustainability enough? If it means sustaining current yields, the answer is an unequivocal no. If it means sustaining the ability to continue to increase yields and improve farm income and the quality of life of both consumers and farmers, the answer is an unqualified yes. ■

Coastal Plain Example

Proper Management of Soils Can Increase Organic Matter

By D.L. Karlen

Recent research on Coastal Plain soils indicates that conservation tillage with high levels of management can produce good crop yields while increasing organic matter concentrations.

SOILS with good tilth are usually loose, friable, well-granulated, and have higher organic matter content than soils with poor tilth. However, in the southeastern Coastal Plain, where intensive cultivation has been practiced for more than 200 years, organic matter concentrations are often very low.

One result of low organic matter is that many Coastal Plain soils have dense hardpans that severely restrict plant root growth unless they are fractured each year with deep-tillage or subsoiling. Other effects of low organic matter include reduced water retention, reduced infiltration rates, and tendencies for the soils to form crusts or lose seedbed water so quickly that plant emergence is reduced.

Soil and Crop Management Effects on Organic Matter

Implementing soil and crop management practices that increase and/or conserve soil organic matter is one method for improving Coastal Plain soils. To increase soil organic matter, any organic amendment, including animal manures, plant residues, food processing wastes, sewage sludges, compost and mulches, or synthetic polymers, can be added to the soil. These materials stimulate microbial activity and production of natural polymers which can stabilize soil structure. Improved tilth conditions often improve water retention capacity, decrease bulk density, and increase water infiltration rates.

The most effective method for conserving soil organic matter is reducing the number of tillage operations. An increase in organic matter occurs because aggregates that protect unoxidized organic matter are not disrupted as frequently and rates of bio-oxidation are reduced.

The most abundant and least expensive organic inputs are plant residues and root exudates. For most crop production systems, the amount of fresh organic matter needed to maintain steady-state conditions often exceeds the supply of available plant residues. A recent Coastal Plain study, however, has shown that by combining conservation tillage with high levels of management to produce good crop yields, soil organic matter concentrations can be increased.

Research Methods

A 7-acre study that compared conventional tillage, which consisted of the minimum number of diskings needed to incorporate crop residues, fertilizer, and lime, with conservation tillage (disking eliminated) was conducted on a Norfolk loamy sand. Both tillage treatments received deep, in-row subsoiling (strip-tillage) at planting.

Dr. Karlen is with USDA-Agricultural Research Service, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011. At the time of the research reported in this article, he was located at the Coastal Plain Soil and Water Research Center, Florence, South Carolina.

THE two photos above show a conservation tillage seedbed before planting (left) and after planting (right).

Continuous corn was grown with and without irrigation from 1979 through 1982. This was followed by four years of a two-year rotation that consisted of a wheat-soybean double crop followed by corn. Corn and soybean were planted in 30-inch rows, wheat in 7-inch rows. The fertilizer program for corn averaged 200-60-160 lb/A N-P_2O_5-K_2O, while average fertilizer rates for wheat were 116-66-66, respectively. Nitrogen for both crops was applied using split application techniques. Soybeans did not receive additional fertilizer. Soil pH was maintained at approximately 6.0 with periodic dolomitic lime applications. Herbicides and insecticides were applied for weed and insect control using Clemson University recommendations. One set of plots was irrigated. But since irrigation did not influence soil organic matter concentrations, the data are averaged for irrigated and non-irrigated treatments. Soil samples were collected from the top 8 inches and analyzed using dry combustion to determine organic matter concentrations.

Table 1. Soil organic matter concentrations measured after 1-, 3-, and 6-years of good crop management on a Coastal Plain soil.

Tillage system	1980	1982	1986
	----------	%	----------
Conservation	1.2	1.3	2.5
Conventional	1.0	1.2	2.0
Avg.	1.1	1.2	2.2
LSD (0.05) System	ns	ns	ns

Research Results

Soil organic matter concentrations in the surface soil increased from 1.1 percent in the spring of 1979 to 2.2 percent in fall of 1986 **(Table 1).** The tillage treatments effects were not significantly different, but organic matter concentrations ranged from 0.1 to 0.5 percent higher for conservation tillage compared to conventional tillage treatments. Soluble organic carbon from decomposing corn stover may account for part of the carbon increase measured in the fall of 1986. However, analysis of soil samples collected from the 0- to 6-inch depth in November 1987, after 14 months of chemical fallow, confirmed that high levels of crop management had increased soil organic matter concentrations to at least 1.8 and 1.5 percent for the two tillage treatments.

Soil organic matter presumably increased because most crop residues were returned and good management produced yields averaging 130, 40, and 35 bu/acre for corn, wheat, and soybean, respectively **(Table 2).** Organic matter levels for

IN THIS SOIL PROFILE, the restricted rooting common to many Coastal Plain soils is illustrated. Many conventional fields have crop rooting restricted to the mechanically disrupted portion of the surface soil and hardpan (Ap and E horizon) because low organic matter contributes to high soil strength. This condition can reduce fertilizer and water use efficiencies.

conventional tillage plots were slightly higher than expected, but seedbed preparation required fewer tillage operations than most farmers use. In the Coastal Plain, winter tillage is frequently used to maintain weed-free surface conditions, but excessive pulverization of the soil is not necessary and can result in a more rapid degradation of aggregates and tilth. However, if winter rainfall is limiting, surface tillage approximately two weeks before planting is beneficial and can prevent weeds from depleting seedbed water.

The soil organic matter concentrations with conservation tillage were increased somewhat. Without surface disking, soil aeration would be decreased, microbial populations would be altered, and rates of crop residue oxidation would be decreased.

Table 2. Crop yield levels which resulted in increased Coastal Plain soil organic matter concentrations.

Tillage system	Corn 1979-86	Wheat 1983-86	Soybean 1983-85
	------- bu/A -------		
Conservation	127	39	34
Conventional	132	42	36
Avg.	130	40	35
LSD (0.05) System	ns	2	ns

Decreases in soil organic matter during a period of chemical fallow emphasize that crop residues should be added each year to maintain or improve Coastal Plain soils. This can be done most efficiently by using soil and crop management practices that produce good crop yields and then managing the residues by eliminating unneeded tillage operations.

Demonstrating an increase in soil organic matter after only eight years was very important because Coastal Plain soils often have low organic matter content, and small changes can substantially alter tilth and soil properties such as nutrient and water retention. Decomposing organic matter can also combine with subsoil aluminum which can be a root-limiting factor in Coastal Plain soils. This benefit of soil organic matter may extend the depth to which plant roots can penetrate to extract water and to recover mobile nutrients such as nitrate.

Summary and Conclusion

Organic matter is very important for maintaining or improving soil tilth and developing sustainable crop productivity. This study demonstrates that soil organic matter can be increased by using best management practices (BMPs) and striving for good yields on Coastal Plain soils. ■

California

Cotton Cultivars Differ in Response to Fertilizer and Soil Potassium

SCIENTISTS are exploring the reasons for large differences in potassium (K) use efficiency of cotton varieties (cultivars). The cotton plant is apparently more sensitive to K limitation than most other crops.

Late season K deficiency reduces cotton yield by an estimated 15 to 20 percent on more than 200,000 acres in the San Joaquin Valley of California. A recent study in the area compared cotton yields and K use efficiency, using two varieties. Both the higher and lower yielding varieties showed excellent responses to K in 1986 and 1987 . . . even at very high rates of K. Response of the lower yielding variety exceeded 1,000 lb/A seed cotton in 1987.

The researchers say more study is needed to clarify whether a plant disease may be involved and to compare root development and K uptake under other conditions. ■

Source: K.G. Cassman, T.A. Kerby, D.C. Bryant, and S.M. Brouder, Dep. of Agronomy and Range Science, Univ. of California, Davis, CA 95616; B.A. Roberts, Univ. of California Agric. Extension, Kings County, Hanford, CA 93230.
Published in Agron. J. 81:870–876 (1989).

International Canola Conference April 2-5

AN INTERNATIONAL Canola Conference is scheduled for April 2-5, 1990, in Atlanta, Georgia. The program will feature international experts on canola as invited speakers, presentation of volunteer scientific papers, educational exhibits, and tours of research plots and canola production fields.

Sponsors include the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR). For more information, contact: Dr. Noble Usherwood, Vice President, PPI, Suite 401, 2801 Buford Hwy., NE, Atlanta, GA 30329; phone (404) 634-4274; FAX (404) 636-8733. ■

North Central Soil Fertility Conference Proceedings Available

COPIES of the Proceedings of the 19th North Central Extension-Industry Soil Fertility Conference are available from the Potash & Phosphate Institute (PPI), 2805 Claflin Road, Suite 200, Manhattan, KS 66502.

The Conference is an annual opportunity for researchers, extension workers, and agricultural industry personnel to be updated on the latest soil fertility research from the North Central region of the United States and Canada. The area represented in the meeting includes North Dakota, South Dakota, Nebraska, Kansas, Missouri, Iowa, Minnesota, Wisconsin, Illinois, Indiana, Kentucky, Ohio, Michigan and Ontario.

Program presentations included: sample variability in nitrate soil testing; correlation and calibration of nitrate soil testing; MAP vs DAP, agronomics implications; MAP vs DAP, manufacturing implications; phosphorus management for wheat; site specific fertilizer applications; and university and industry perspectives on fertilizer use in the future.

Copies of the Proceedings in the U.S. and Canada are $8.00 each, including postage and handling. In other countries the cost is $11.00. Checks should be made payable to: "NC Ext-Ind Conference." ■

Arkansas Research

Nitrogen Can Increase Cotton Yield and Soil Organic Matter

By Richard L. Maples

Cotton has a reputation of depleting the soil of its fertility and overall productivity when grown without rotating with other crops. Cotton can be a soil builder when adequate nitrogen (N), phosphorus (P) and potassium (K) are applied to maintain soil nutrient balance. Over the period of the 17-year study, both lint yields and organic matter were increased by fertilization.

THE PRIMARY OBJECTIVES of this research were to 1) measure cotton yield responses to N fertilization, 2) determine the long-term effects of annual N fertilization on the organic matter content of a loessial soil, and 3) develop soil test and plant analysis data for N fertilizer recommendations on cotton.

The study was conducted at the Cotton Branch Experiment Station on a Loring silt loam soil. Annual N fertilizer rates were 0, 25, 50, 75, 100, 125 and 150 lb/A. There were nine replications in a randomized complete block design. The N source each year was either ammonium nitrate or 32 percent UAN solution. Phosphate (P_2O_5) and potash (K_2O) were applied annually at rates of 60 and 90 lb/A, respectively.

Data in **Table 1** compare organic matter concentrations of soil samples collected in March of 1973 with those taken in March of 1984 and 1989. Samples were taken from the same plots at depths of zero to six inches. Organic matter concentrations were determined by University of Arkansas soil testing procedures. (Note: Testing procedures were unchanged between 1973 and 1984. The 0.10-0.20 average increase in the 1989 readings partly reflect a modification in soil testing procedures made in 1986.)

Table 1. Influence of N fertilization on soil organic matter concentrations, zero to six-inch depth, after 17 years of continuous cotton.

N rate, lb/A	Organic Matter Level, %		
	1973	1984	1989
0	0.66a	0.69a	0.9c
25	0.69a	0.76cd	1.0bc
50	0.66a	0.89bc	1.1b
75	0.69a	0.89bc	1.1ab
100	0.67a	0.91ab	1.1ab
125	0.68a	1.02a	1.2a
150	0.68a	0.93a	1.2a

Values in a column followed by different letters and not the same letters are significantly different at the 0.05 probability level by Duncan's new multiple range test.

After 17 years, significantly different levels of organic matter had developed that were positively related to the rates of N that had been applied. All rates of N from 50 to 150 lb/A increased organic matter concentrations over the check plot.

Figure 1 shows 1988 cotton lint yields. After 17 years, the response to N fertilization was still striking, but cotton has a high requirement for N. The impact N had on soil organic matter shows that relatively short-term employment of sound management practices can favorably alter soil properties. The combination of high yield production and improved soil organic matter content strengthens the argument that following

Now working quarter time, Professor Maples was former Director of the Arkansas Soil Testing and Research Laboratory at Marianna. He is a recognized world authority on cotton production.

scientifically-based management is environment friendly . . . and provides economic advantage to the grower.

The University of Arkansas recommendation for N on cotton is 80 lb/A. Under irrigation and when conditions are favorable for high yields, an additional 30 lb/A N as side dress is recommended. As can be seen in **Figure 1**, these rates fit well on the Loring soil.

Assuming that one percent organic matter equals about 20,000 lb/A of topsoil, the Loring silt loam contained about 13,500 lb when the study was initiated in 1973. On those plots receiving the higher N rates, as much as 6,000 lb/A of organic matter were added to the soil over the 17-year period.

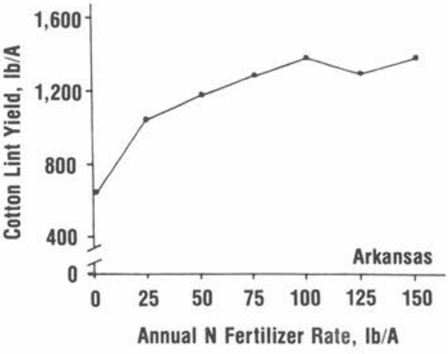


Figure 1. 1988 lint cotton yield as influenced by N rate.

Most farmers apply N primarily to produce profitable cotton yields. An important by-product of those yields . . . as shown in this study . . . is a beneficial effect on long-term soil productivity. **In other words, best management practices (BMPs) such as sound N fertilizer management, give an added bonus of sustainability as well as short-term profit advantage.■**

NITROGEN rates of 50 lb/A (left) and 100 lb/A are compared here. Note the darker color and heavier foliage with the higher rate. Some of the most productive fields in Arkansas have been in continuous cotton for 50 years or more.

Long-term Evidence for Sound Fertility Management

By Harold F. Reetz, Jr., Ted R. Peck and M. Gene Oldham

The oldest crop management experiment in America, the Morrow Plots at the University of Illinois, continues to provide valuable information on the long-term benefits of crop rotation and fertilization practices. The insights provided by data from these plots are useful today in understanding soil fertility and best management practices (BMPs).

THE MORROW PLOTS are the oldest research plots in the United States and include the oldest continuous corn plot in the world. The plots provide a continuous source of data from the late 1800s to the present. Continuous corn is compared with corn-soybean rotations (since 1967 only) and with a 3-year rotation of corn-oats-clover.

The main objective in establishing the plots was to help settle the controversy regarding whether the rich prairie soils of central Illinois could be depleted. By 1904 it had been determined that continuous cropping without supplemental fertilizer was significantly reducing corn yield potential. Crop rotation was helping to maintain productivity. At that point, manure, lime, and phosphate (rock or bone) were added to half of each plot to determine whether productivity could be improved.

Over the years, the size of the Morrow Plots has been reduced due to needs for campus building expansion, but in 1968 the Morrow Plots were named a National Historic Landmark by the U.S. Department of the Interior.

Morrow Plot Treatments

None	= No fertilizer materials added since 1876
LNPK	= Lime + NPK fertilizer since 1955; Untreated 1876-1904
MLP	= Manure + Lime + Phosphate fertilizer 1904-Present
MLP + LNPK	= MLP 1904-1954; LNPK 1955-Present

Treatment Descriptions

No treatment	Nothing applied since 1876
MLP	Manure, 2 tons/A/year limestone, none since 1956 Unprocessed phosphate applied 1904-1919 only; none since
LNPK	Started before 1955 growing season L = maintain pH>6.5 N = 200 lb/A/year P = maintain P-1>40 lb/A K = maintain K>300 lb/A
MLP + LNPK	MLP thru 1966; LNPK 1967-present
MLP + High LNPK	Similar to MLP + LNPK, N = 300 lb/A P = maintain P-1>100 lb/A K = maintain K>500 lb/A

Actual K soil test levels have not yet reached the goals (300 and 500 lb/A) on all of the plots so designated.

Harold F. Reetz, Jr. is Westcentral Director, Potash & Phosphate Institute (PPI). M. Gene Oldham and Ted R. Peck are with the Department of Agronomy, University of Illinois.

Management Effects on Yields

In 1955, nitrogen (N), phosphorus (P), and potassium (K) fertilizers were added to some of the previously untreated plots and to some MLP plots to determine whether depleted soils could be re-built and how long the process would take. The results were dramatic the first two years of the treatment (**Table 1**).

Table 1. Corn yields in 1955 and 1956 showing the effects of the first two years of complete chemical fertilizer treatment (Plot 3, Continuous Corn).

Treatment	Yield, bu/A 1955	1956
No treatment	36	29
LNPK	86	113
MLP	79	96
MLP + LNPK	98	128

L = 5 tons/A limestone; N = 200 lb/A; P_2O_5 = 150 lb/A; K_2O = 100 lb/A. Applied in both 1955 and 1956.

In the years since the fertilizer treatments were initiated, the MLP + LNPK treatment has continued to produce higher yields than the former no treatment plot now receiving LNPK. Also, the corn in rotation consistently outyields the continuous corn plots. Fertilizer addition has not completely offset the effects of crop rotation. The highest yield produced to date (215 bu/A in 1982) was on the corn-oats-clover rotation plot with LNPK since 1955 (untreated 1876-1904).

Part of each of the three cropping systems has been maintained with no fertilizer or manure applied since 1876. Since 1904 some subplots have had various fertilizer and manure treatments in a continuous plan to maintain or build soil fertility levels.

Figure 1 shows the yields for various treatments in recent years.

Fertilizer Effects on Organic Matter

The organic matter changes in the Morrow Plots tell an interesting story. In general, cropping of heavy textured soils naturally high in organic matter leads to the accelerated decomposition of organic matter. This trend has been noted on the Flanagan silt loam of the Morrow Plots. **Figure 2** shows the effects of fertilizer added since 1955 on the percent organic matter in the surface soil of the Morrow Plots. When adequate plant nutrients are applied, organic matter decline can be reversed.

Summary

The long-term studies of the Morrow Plots provide some important insights into the best management practices (BMPs) for the productive prairie soils of the Midwest. The lessons learned from these plots include the following:

- **Without soil fertility treatments, crop production reduces the productivity of these soils.**

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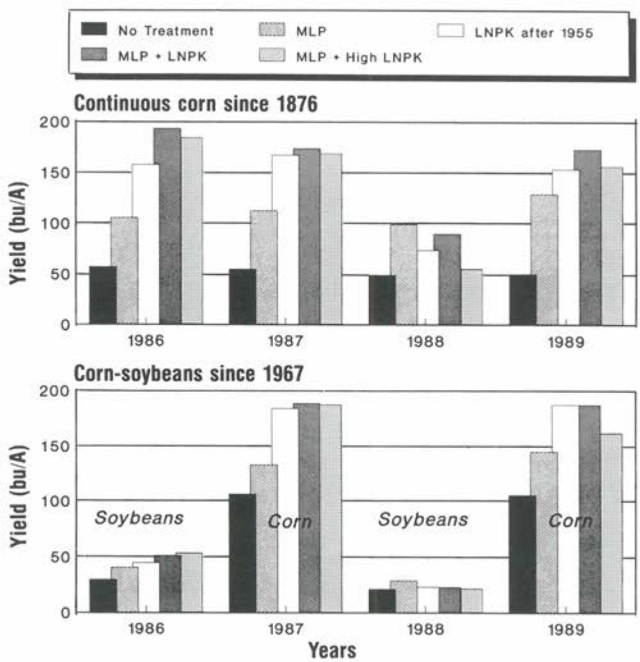

Figure 1. Corn and soybean yields in the Morrow Plots for different rotation and fertilizer treatments.

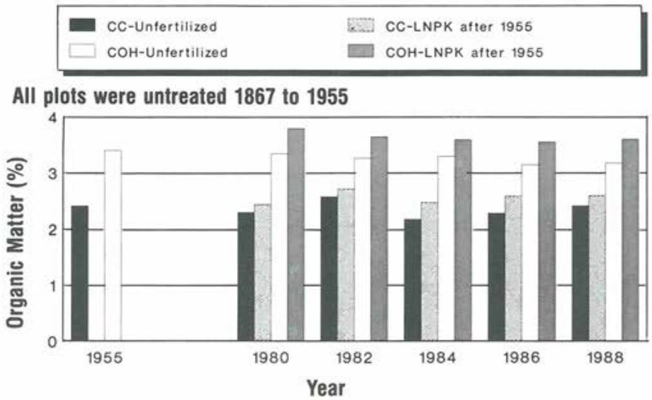

Figure 2. Organic matter content in various treatments of Morrow Plots, as affected by fertilizer added since 1955.

- **Crop rotations without addition of fertilizers helped maintain organic carbon and N levels in the soil, but did not maintain high productivity levels.**
- **Treatments of manure, lime, N, P, and K are necessary to maintain nutrient levels and productivity of the soil.**
- **When nutrients have been depleted, addition of adequate fertilizers can reverse the trend of organic matter depletion.**
- **A combination of crop rotation and fertilizer addition supports the highest corn yield levels. Fertilizer addition has not completely offset the effect of crop rotation.**
- **Crop rotation plus fertilizer addition produced the highest crop yields and maintained the highest soil N and organic matter levels.**

As recognized by Professor Manley Miles 125 years ago, we must continue the quest for economical methods of maintaining and improving the productivity of our soil resources. Science has helped to revolutionize agriculture and ''arrest soil exhaustion''.

Research programs such as the Morrow Plots studies provide conclusive evidence of the long-term value of sound fertilizer management as part of a BMP system for maintaining the productivity and profitability of crop production. ■

E.H. Vasey Named First Winner of Robert E. Wagner Award for Efficient Agriculture

THE American Society of Agronomy (ASA) recently announced Dr. E.H. ''Ed'' Vasey as the first recipient of the Robert E. Wagner Award for Efficient Agriculture. The award is named in honor of Dr. R.E. Wagner, who retired as President of the Potash & Phosphate Institute (PPI) in 1988.

Dr. Vasey is a soils specialist with the North Dakota State University Extension Service at Fargo. He formulated a very successful educational program in North Dakota based on the concept of maximum economic yield (MEY). The core of the program emphasizes economically efficient crop production.

Dr. Vasey holds advanced degrees from North Dakota State University and Purdue University.

The award, to be presented each year by ASA, is supported by PPI. Nomination forms are available from ASA headquarters; deadline for receipt of nominations is March 1. ■

Sanborn Field

Long-term Studies Indicate Differences in Stability of Soil Organic Matter

By G.H. Wagner

Sanborn Field, located on the University of Missouri campus at Columbia, is the oldest experimental field west of the Mississippi River. Historical records indicate that the area was originally a native prairie with warm season grasses predominating. Some important conclusions about soil organic matter and productivity can be determined after the first 100 years.

SOME PLOTS of Sanborn Field have been under continuous cultivation of the same crops for nearly 100 years. Soil samples collected from the plots since 1915 have been preserved and provide a special resource for assessing changes in organic matter content and cycling brought about by soil management and cultivation of several different crops.

The effects of wheat, red clover and timothy on soil organic matter turnover have recently been studied using a new stable isotope technique based on the different degree to which these crops become labelled by carbon-13 fixed during photosynthesis.

Stability of Organic Matter

Wheat and Timothy. Using soil samples collected from 1915 to 1986, the progressive turnover of soil organic carbon (C) from native prairie to that produced from cultivated crops was evaluated for wheat (**Figure 1**) and timothy (**Figure 2**). Total soil C levels at each sampling were measured directly and the C of prairie origin calculated from measurements of the carbon-13 isotope.

A marked decrease in total soil C or organic matter occurred when the prairie was brought under cultivation. This was most pronounced from 1888 to 1915 and was followed by a further decrease to 1938 which was more significant under wheat than under timothy. After 1950, wheat received a more liberal annual fertilizer treatment and wheat crop residues were incorporated into the soil. This change in management approximately doubled the annual C input to the soil and resulted in a subsequent increase in soil organic C (organic matter). Soil organic C under timothy was variable after the 1915 sampling but data suggest a general equilibrium level was maintained.

The quantity of native prairie C under wheat declined rapidly from 1888 to 1928 then became nearly stable (**Figure 1**).

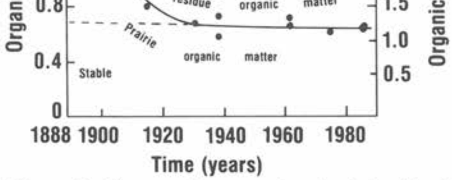

Figure 1. Changes in amount and origin of soil organic carbon (organic matter) with long-term wheat production on formerly virgin prairie soil. Open circles indicate total soil carbon (C), closed circles that from prairie vegetation. Two sets of symbols at each date indicate 0-4 and 4-8 inch sampling depths. Area between the two curves represents the C or organic matter from wheat residue.

(continued on next page)

The author is Professor of Soil Microbiology, University of Missouri-Columbia.

Sanborn Field . . . from page 21

SANBORN FIELD is located on the campus of the University of Missouri-Columbia. By measuring the carbon dioxide evolved from soils in these plots over time, Dr. George Wagner determined the rate of breakdown of soil organic matter and the contribution of cropping systems to soil organic matter levels.

Data indicate a stable pool of prairie origin amounting to 0.64 percent C (approximately 1.18 percent organic matter) in this soil (Putnam silt loam). Under timothy without annual cultivation, however, the quantity of stable prairie organic C present was 1.0 percent (approximately 1.85 percent organic matter) and that level was reached by 1915 (**Figure 2**).

In both systems, the easily mineralized C was essentially exhausted during the first 30 to 40 years. The mean half-life for this fraction was estimated to be 10 to 15 years. Continued turnover of soil organic matter after 1915 or 1928 was primarily that which originated from the cultivated crop.

Data suggest a very slow mineralization of the stable portion of soil organic matter under the cultivated crop. From the slope of this curve for residual prairie C under wheat between 1928 and 1986 (**Figure 1**), it was determined that complete turnover would require more than 600 years. In the case of timothy, data between 1915 and 1986 suggested complete turnover of prairie C would require 1,400 years or longer (**Figure 2**).

After nearly 100 years, the original native C of prairie origin was 71 percent of total soil C under timothy and 49 percent under wheat. The higher level under grass suggests that some organic matter is structurally labile but physically protected. This protection does not exist with wheat because of annual tillage.

Corn. In 1950, corn was introduced on plots that had grown forage crops for 61 years. That provided an opportunity to determine the contribution of organic matter from forage crops compared with that from

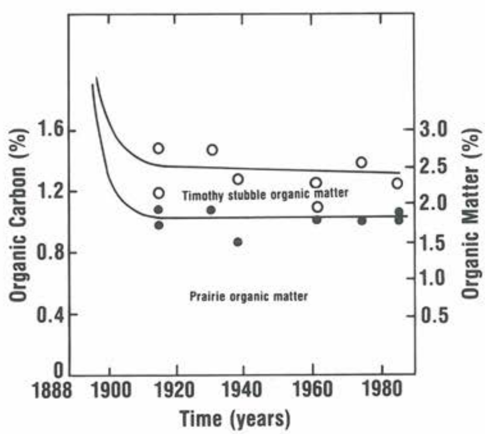

Figure 2. Sources of soil organic C associated with the long-term culture of timothy on formerly virgin prairie soil. The area between the two curves represents the C or organic matter from timothy stubble and roots.

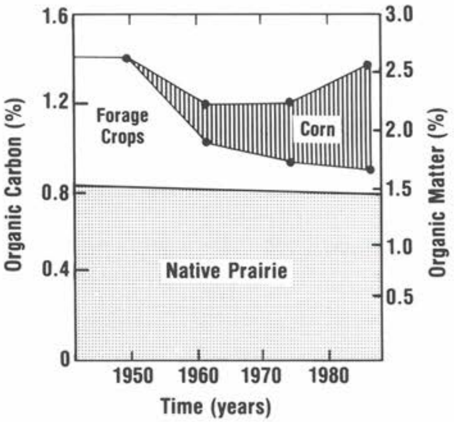

Figure 3. Changes in amount and origin of soil organic matter to a depth of 8 inches related to 36 years of continuous corn on soil formerly used for the production of forages. Note that total soil organic matter was increased by corn production under full fertilizer management.

36 years of continuous corn. The effects of these cropping changes on soil organic matter are shown in **Figure 3.**

Corn residues after 1950 should have provided sufficient replacement C to maintain the organic matter level similar to the equilibrium level established prior to that time. The measured C at samplings in 1962, 1975 and 1986 was partitioned among the three contributing components of prairie, forage, and corn. **Samples taken in 1986 indicate an increase in the level of soil organic matter due to the input of corn residues produced under full fertilizer management (Figure 3)**.

As organic matter from corn residue was added to the soil, it mainly replaced organic matter which had been produced from forages. The greatest decline of forage-origin organic matter occurred in the first 12 years after corn production began. Forage origin organic matter between 1950 and 1986 had a half life of 10 years. By 1986, 34 percent of the total soil C was from corn, 9 percent from forages, and 57 percent from native prairie.

Conclusions

After 100 years of cultivation, the proportion of soil organic matter in the soil of Sanborn Field originating from native prairie species was no less than 50 percent, indicating the presence of a large pool of stable organic matter.

Rapid loss of soil organic matter that occurred when the prairie was first brought under cultivation represented loss from the labile pool. Loss was greater with cultivated crops.

Mechanical separation of soil sand, silt, and clay showed the clay fraction included the most stable organic matter.

Improved crop management including the use of adequate fertilizer for wheat and corn had positive effects on soil organic matter content and tended to reverse the long-term decline in organic matter levels. ■

Some Lessons from Sanborn Field

SANBORN FIELD at the University of Missouri has yielded countless bits of valuable information. George Smith, professor emeritus of soils, watched over the experimental field during his tenure at the University of Missouri. James R. Brown is currently the director.

Here is a list of some important conclusions from the plots.

- **The negative effects of continuous cropping.** Sanborn research points out that continuous clover or other legume crops deplete the soil. Legumes can take nitrogen from the air only if adequate minerals are present in the soil. Animal manure alone will not maintain soil productivity.

(continued on page 25)

Stem Canker in Soybeans Related to Organic Matter, K Fertility and pH

By Fred E. Rhoton

A greater incidence of stem canker infection of soybean was associated with less eroded soil. Higher levels of organic matter, soil water and pH were responsible for more stem canker occurring on the more fertile sites. Organic matter content proved to be the most important of these properties. Greater stem canker levels on low fertility plots were attributed to lower concentrations of potassium (K) in soybean plants.

STEM CANKER is a destructive disease of soybeans. This disease can unpredictably increase from negligible amounts to near total infection within a year. Most stem canker research in the South has been concerned with determining soybean cultivar responses to the disease. An understanding of the soil environment's contribution to these outbreaks is essential to a comprehensive stem canker research program.

Stem canker disease of soybeans was first recognized in the Midwest in 1947 and since has spread over much of the soybean production area of the U.S. It appeared in Mississippi in 1975. The southern strain of this organism is distinctly different from northern strains. Yields are reduced by an amount that depends on the time and extent of the infection. Generally, losses will be greatest when infection occurs soon after pod

Table 1. Soybean stem canker infection levels associated with different soil properties and fertility levels.

Site	Avg. Depth to Fragipan	Fertility Levels[1] P	K	pH	Soil Organic Matter	Stem Canker Infection Level Min.	Max.	Mean
	Inches	lb/A			%	%		
1A[2]	23	125	250	6.9	1.50	50	85	72
1B		32	166	7.1	1.47	75	90	86
2A	21	125	250	7.2	1.32	25	50	41
2B		52	153	7.2	1.33	55	75	64
3A	17	125	250	6.7	1.24	30	55	45
3B		79	143	6.0	1.21	60	85	68
4A	16	125	250	6.8	1.18	13	30	22
4B		65	165	6.7	1.17	15	35	28
5A	7	125	250	6.9	0.95	5	8	6
5B		32	145	6.2	0.96	8	18	11
6A	6	125	250	6.5	0.99	1	4	3
6B		21	174	5.1	0.97	1	4	2

[1]P and K levels were adjusted to these levels immediately prior to planting.
[2]Sites A had high fertility treatment; Sites B were left unamended.

Dr. Rhoton is Soil Scientist with the National Sedimentation Lab, USDA-ARS, Oxford, Mississippi.

development. Yield losses in the Midwest range from 13 to 60 percent. But in the South, losses up to 80 percent have been reported.

This study was designed to assess the relationships among several soil properties and different disease levels occurring over a range of soil conditions. Experimental plots were established at six sites that differed due to depth of past erosion. High fertility status, with soil phosphorus (P) at 125 lb/A and soil K at 250 lb/A, was maintained on one-half of the plots at each site. The remaining plots were left unamended. Visual estimates of stem canker infection levels in 1986 equalled 72 and 86 percent for the fertilized and unfertilized treatments, respectively, at the slightly eroded site (**Table 1**).

Soil organic matter content, pH and soil water accounted for 66 percent of the variability in infection levels among the different eroded sites, but plant residues from the previous crop year had no influence. Higher infection levels associated with the unfertilized plots were significantly correlated with lower concentration of K in the soybean plants (**Table 2**).

Table 2. The relationship between higher soybean stem canker infection levels and lower K concentrations in plants grown on low fertility plots.

Site	Depth to Fragipan	Infection Level Increase—in Low Fertility Plots	K Concentration Decrease—in Low Fertility Plots
	Inches	%	%
1	23	16.6	23.0
2	21	36.5	33.0
3	17	34.1	33.1
4	16	20.7	15.6
5	7	41.1	37.8
6	6	0	11.8

These results indicate that greater stem canker infection levels can be expected on soils with higher organic matter, pH and soil water content, and on soils that contain lower amounts of K.■

Sanborn Field . . . from page 23

- **Organic systems of farming—adding only crop residue or manure that the land produces—will not keep soil productive.** Organic materials must be supplemented and balanced with elements not present in residues and manures.
- **Crop rotation, without balanced fertility, only slows the soil deterioration associated with continuous cropping.**
- **Additional lime is essential for legume growth and nitrogen fixation.**
- **Adequate humus and available phosphate levels not only furnish nutrients to a growing crop but also "tie up" elements toxic to plants.**
- **Proper use of chemical fertilizers is essential to keep soil productive.** Good yields of nutritious crops can be produced only where proper amounts of essential elements are available at critical stages of plant growth.
- **A vigorous growing crop provides a soil-conserving ground cover.** Growing plants break the force of raindrops and reduce soil erosion and runoff sediment.
- **Cropping systems and soil treatments influence the composition of soil humus.**
- **Fertilizers can replace nutrients removed by crops.** However, where top soil has eroded and remaining soils has a lower water-holding capacity, added nutrients have a limited influence on crop yields.
- **Soil changes that have developed under known treatments through the years made it possible to develop soil-testing procedures now in use throughout Missouri and other states.** ■

Wheat Productivity Has Improved, Even in Adverse Environments

By Fred Cholick

In many high-yield environments, dramatic increases in wheat yields have been documented, with yields surpassing 150 bu/A. However, some believe that only limited progress has been achieved in adverse or marginal production areas. This article presents data from South Dakota to illustrate that agriculture technology has greatly improved productivity in adverse as well as favorable environments.

FIRST, one must understand that the environmental conditions in South Dakota are truly marginal for spring wheat growth and development. This is illustrated by the record average yield of 34 bu/A in 1984. This record culminated a period of consistent increases beginning in the late 1970s. Those yields are a far cry from the 100 bu/A plus yields reported in western Europe and many areas of North America. The drought of 1988 in the northern Great Plains reduced spring wheat yield in South Dakota by slightly more than 60 percent.

The average spring wheat yield in 1988 was estimated by the state Agricultural Statistics Service to be only 12 bu/A. Compared to the drought in 1934 and 1956 where yields were 4 and 9 bu/A, yields in 1988 were nearly 1.5 to 3 times greater.

Yield data in **Table 1** are from statewide trials conducted by the spring wheat breeding project. All varieties (except Chris) were released during the late 1970s or 1980s. As new varieties were released, older varieties were replaced. For example, Prospect replaced Marshall in 1986. Chris was used for comparison because it was the leading spring wheat variety in South Dakota during the late 1960s and early 1970s, and because it represented a major improvement when compared to

Table 1. New spring wheat varieties out-yield old varieties in good years and bad years.

Variety	Origin, year released	Years 1984 8*	1985 8	1986 7	1987 8	1988 7
		bu/A				
Chris (old)	MN 65	37.9	39.4	29.1	32.4	14.0
Butte	ND 77	50.9	—	—	—	—
Marshall	MN 82	48.0	47.1	—	—	—
Guard	SD 83	48.7	48.6	39.0	39.2	18.5
Stoa	ND 84	53.7	49.2	42.6	43.8	19.3
Butte 86	ND 86	—	51.6	44.0	44.2	19.1
Prospect	SD 88	—	—	42.4	44.2	18.2
Average of new varieties	bu/A	50.3	49.1	42.0	42.8	18.8
Improvement	bu/A	12.4	9.7	12.9	10.4	4.6
	%	32.7	24.7	44.3	32.2	34.3

* Number of locations.

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CONTINUED improvement in wheat genetics, coupled with better management, has improved wheat productivity even in adverse environments.

the other varieties available in the late 1960s. In every year, all improved varieties yielded greater than Chris, with yield improvement ranging from 25 to 44 percent, and averaging nearly 34 percent. On a percentage basis, this yield improvement was approximately the same in the drought year (1988) and the record year (1984). The percent improvement was relatively constant even though the actual yield varied greatly. These results demonstrate that the relative magnitude of increased yields was similar in "good" and "poor" years in South Dakota and that production is strongly influenced by environmental factors beyond our control.

In similar comparisons of new semidwarf and old varieties in Great Britain, the yield improvement was found to be about 40 percent with yields approaching 100 bu/A (Austin et al. 1980). These experiments were conducted using netting to minimize lodging, fungicide to minimize disease and both low and high fertility. Schmidt (1984) using nine regional nurseries in the U.S., found that the average increase in yield from 1958-1980 was 32 percent. There was some variation from region to region, but given the differences in controls and locations where these nurseries were grown, the differences between regions were surprisingly small. Therefore, the rate of yield improvements appear to be similar, even though there were large differences in yield potential among years in South Dakota, and among regions of wheat production.

A number of publications have partitioned these increases in yield and attributed given percentages to different segments of agricultural research. However, these increases are the result of an interactive system with each component making a contribution. The system will only be optimized when all components are used and used properly. The individual components can be divided into two general categories: (1) improvement of conditions for plant growth and development, and (2) improved varieties. The data presented here use varieties for comparisons, but the varieties are only one component. They integrate all of the other components.

A partial list of the factors which have improved conditions for plant growth and development include: 1) weed control—which primarily removes competition factors (light, moisture and nutrients); 2) soil fertility—which increases plant productivity and the plant's ability to withstand stresses; 3) equipment—for timely and efficient field operations and reduced harvest loss; and 4) producer abilities—result in increased soil moisture conservation and improved application of technology.

Environmental conditions in total determine the growth and development of every crop in every environment. The goal of agricultural research is to increase the utilization efficiency of all inputs and improve the environmental conditions for growth and development. The management practices that incorporate the results of this research are referred to as best management practices (BMPs). These practices will continue to increase productivity under both marginal **and** optimum conditions. ■

Ending Hunger and Protecting Environment Are Equally Important, Challenging Goals

By Orville Freeman

If the framework between producing food and preserving the environment is a hostile relationship, it can only be counterproductive. Technology, including the measured and careful application of fertilizer and crop protection chemicals, represents hope for the future.

THE ESTIMATED POPULATION GROWTH for the next quarter century is so enormous that warning bells should be sounding in every quadrant of the globe. Feeding this population may well be the greatest challenge we have ever faced—one that will test the world's productive and technological capabilities to their very limits.

I am not an alarmist by nature, but over 40 years experience in both the public and private sectors, including eight years as United States Secretary of Agriculture, have made me an unabashed realist.

From this perspective I say it will take total mobilization of all global productive resources—including land, infrastructure, people skills and technology—to prevent massive famine in the decade of the 1990s and beyond.

Even conservative projections call for a population increase of over one billion people—bringing the world's population to 6.2 billion by the year 2000. These same projections predict a population of nearly 11 billion by the year 2050.

This increase will take place in a world where already over 75 percent of the population can barely feed themselves; almost 500 million people are severely malnourished; where 15 million children worldwide die each year from starvation—that is over 41,000 every day.

In this regard, many people—particularly those in the relatively well-fed industrialized world—simply cannot relate to the concept of subsistence, where securing enough food to sustain life is the focal point of each day's activities.

In the United States—for all but a relatively small segment of the population—the task of securing food means no more than a trip to the nearby supermarket where we choose from over 8,000 items to meet our needs. In fact, one of our major food related concerns is how to eat less!

For that reason, I sometimes think we are ill-prepared to wrestle with the realities of what it will take to feed the kind of population increases we will experience. In fact, there is no precedent in our history that even comes close to approximating the population and food-supply pressures we will experience in the next ten to twenty years.

To give some definition to the magnitude of the challenge this presents, let me cite one statistic that drives this point home more clearly than any other I have encountered: **In the next two to four generations, world agriculture will be called on to produce as much food as has been produced in the entire 12,000 year history of agriculture.** A very

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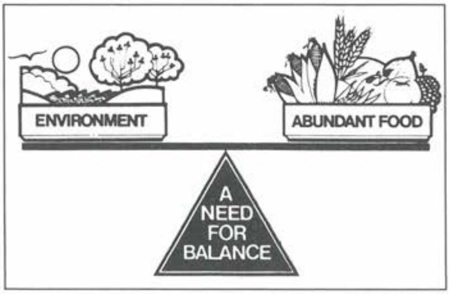

sobering prospect indeed—and a challenge of unprecedented magnitude.

To meet this challenge, difficult and delicate choices will have to be made—probably none of which will emerge without heated debate.

A Balancing Act

Choosing alternatives or making tradeoffs is most difficult when each is desirable and moral imperatives for each are both clear and compelling.

Nowhere is this dilemma more apparent than in the current debate over protecting our planet's increasingly fragile environment and feeding its growing hungry population.

To say "humanity **versus** the environment" suggests irreconcilable conflict. And yet, here we have goals that should be compatible. After all, the earth's resources were put in place to meet mankind's needs, the most basic of which is feeding himself.

Unfortunately, the balancing act between producing food and preserving the environment appears cast in an increasingly hostile framework—almost on a collision course, that in the end can only be counterproductive. We must exercise every caution to guard against the tyranny of a single issue dominating what must by definition be a very complex balancing act, frequently calling for difficult tradeoffs.

In order of priority then, the first challenge we must address is how to bring these goals—feeding the world's population and protecting the world's environment—into harmony. They need not and must not be mutually exclusive.

To maximize our productive capabilities and minimize the effect this production has on the environment, the vital connective tissue is technology—fostering and harnessing the technological means through which both goals can be served—applying science to meet the objectives of both man and his environment.

Unfortunately, this does not seem to be the direction we are headed. From what I read and hear of late, technology is being cast in an increasingly dim light—a scapegoat for a host of environmental ills man has inflicted on his planet.

Certainly, application of agricultural technology has not been without its missteps over the years. But, fortunately, the industrial world is demonstrating a growing understanding that the price of environmental abuse is high and can be irreversible. This realization must strengthen.

At the same time, however, we also have to acknowledge that without sophisticated food production technology, we wouldn't have the food supply we enjoy today—and certainly could never meet the needs of the population realities nearly upon us.

In the three decades since the early 1950s, the world—led by Europe and the United States, followed by many Third World countries—witnessed unprecedented advances in the development and application of agricultural and food-related technology. The resulting increases in production and delivery of food—the so-called Green Revolution in which world grain output multiplied 2.6 times—has been truly phenomenal. However, since the early 1980s, a gradual tightening of the world food situation on the production side is taking place- . . .with little corresponding leveling on the population side of the equation.

(continued on next page)

Ending Hunger...from page 29

What Caused the "Green Revolution"?

We need to examine what caused the so-called Green Revolution—because that type of production surge is exactly what has to be repeated in the decades ahead if we are to avoid mass starvation among the exploding populations in Third World countries.

We also need to look at the factors that caused the slow-down in productivity to see what can be done to return to previous growth levels.

There seems to be general agreement on five major forces behind the Green Revolution: (1) the hybridization of corn; (2) the nine-fold increase in fertilizer use between 1950 and 1984; (3) the near tripling of irrigated areas in the same period; (4) the rapid spread of new high yielding wheat and rice seeds in Third World Countries; and (5) the use of chemical insecticides, herbicides, rodenticides and fungicides.

Crop protection chemicals and nitrogen (N) fertilizer are often targets in the environmental debate. But all of us would do well to remember—particularly in light of the anticipated population/food pressures—that these chemicals currently account for as much as 40 to 50 percent of the world agricultural production.

Regarding the causes of the slowdown in productivity growth, there is less solid agreement, but certainly we have to recognize: (1) shortage of land, with millions of acres withdrawn from production because of erosion; (2) scarcity of water from drought and as heavy irrigation has drawn down water tables rapidly in many places in the world; and (3) despite the predicted potential of coming biotechnology, at present there is an absence of dramatic new technology that will match that which was so instrumental in stimulating productivity between 1960 and 1984.

Whatever the causes, it is clear that world grain carryover has dropped to an alarmingly low level—a 16 year low with only a 17 percent reserve—less than two month's supply. To put this in perspective—this is very close to the 1973/74 picture when the U.S. became so concerned about tight supplies that it embargoed soybeans.

In the face of reduced number of acres planted worldwide and rising global demand, this trend likely will continue unless returning the world to a high rate of food productivity commands a high priority as we look to the future.

Why Technology Is Vital

To do this there is no question that technology must play a major role. Any effective blueprint for increasing agricultural productivity worldwide must incorporate development and application of crop and food-related technology. To suggest that agricultural technology is the enemy of man or the environment is to ignore the realities of food production and population trends.

Of course, there are potential risks in agricultural and food-related technology that should keep us ever vigilant. We must constantly strive for smart use and avoid misuse.

At the same time as we measure the impact of technology, we must take into account the effect of advances in scientific techniques that are taking place with breathtaking speed. Current scientific capabilities are measuring elements in parts per trillion—pushing the concept of absolute zero existence of chemical traces that many environmentalists demand, further and further from our reach. In fact, we may face the possibility that there is no zero anymore—or that the meaning of zero may have changed completely. Given the current capability to measure infinitesimal amounts of substances that are deemed "harmful"—it is entirely possible that the term "harmful" is no longer an absolute concept. More likely, "harmful"—like "zero"—is moving away from us. The concept is mind-boggling, but it should remind us of the need for balance and sensible trade-offs. In seeking solutions to complex questions, we have to exercise an abundance

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of caution to avoid tossing the baby and bathwater out together.

In light of new scientific capabilities to identify heretofore undetectable quantities of substances—dangerous perhaps in larger quantities but harmless or even beneficial in smaller amounts—we have to recognize the wisdom of trade-offs and not pay an unwarranted price by continued pursuit of zero risk—an increasingly elusive goal.

The Good Old Days

As attractive as some would make it sound, a return to the "good old days" and a pristine environment simply is not feasible.

I remember unpasteurized milk, no penicillin, wormy apples, shocking grain in the hot sun, and fresh fruit and vegetables only in the summer months. A return to that would represent a giant step backward—and one that ignores the needs of our growing world population.

Technology—intelligently conceived and carefully implemented—including the measured and careful application of fertilizer and crop protection chemicals—represents the hope for the future and, as such, should be a cornerstone of food and agricultural policy for the coming decades. In this regard, the way must be paved for coming biotechnology and the fantastic possibilities this whole area of science opens up regarding both crop and livestock production and uses of agricultural products.

Agricultural technology can be the tool that brings humanity and the environment into harmony and productive coexistence. For that reason it should be embraced, not rejected, both in its conception and its application.

As I said at the outset, I think we make a potentially dangerous mistake when we frame the question in an adversarial light—to serve humanity or the environment.

The needs are not mutually exclusive. In fact, they are totally interdependent. My caution is this: In our haste to atone for environmental "sins" of the past, we must not delude ourselves about the realities of the future. What we have to do is measure and manage carefully how we apply technology today and how we oversee the evolution from one type of technological solution to another. We must guide the world to technology that meets the needs of both humanity and the environment.

Admittedly, this is a complex and difficult assignment. Without question, opinions as to the "right" answer will differ markedly and sharply. However, in this regard, I urge all parties to the debate to identify wherever possible their commonality of interest, rather than exacerbate their differences. Effective resolution of these issues simply cannot be accomplished in a circus-like atmosphere that features emotional charges rather than solid scientific evidence.

The Need for Cooperation

The greater the degree of cooperation among those affected—the greater the chances for real accomplishment and progress.

There is no question that meeting the food needs of the coming decades will exert increasing pressure on an already strained environment. However, no matter how compelling the case for reducing these environmental pressures is, we simply cannot turn our backs on the needs of the hungry. ■

LIES (A Fairy Tale)

Once upon a time, a fine young man lived on a beautiful farm. He was ambitious, worked hard, and wanted to succeed.

One day his father called him in and said, "Son, you're working too hard. You're out of date. There is a new philosophy—a new approach to life today. It is known as **Low Input Ensures Success,** or **LIES.** Try less input."

The young man went off to college. He decided to try "low input". He studied a little, but less than his classmates. It was great; but to his amazement he flunked out of school!

He got a job as a salesman. Again, "low input" was his creed. He became the poorest salesman in the company. So, he quit and decided to go back to the farm.

There he followed the "low input" philosophy completely. He reduced all his inputs—lime, fertilizer, pesticides and, finally, labor—and waited for the success he had been promised.

As he sat and pondered his fate, he said to himself, "Is it possible that my own father misunderstood the new approach? Perhaps it was '**Proper** Input Ensures Success (PIES).' "

This fairy tale might have a happier ending if it had been **PIES** instead of **LIES.**

—J. Fielding Reed


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