A History of the Department of Soils and Soil Science at the University of Missouri

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About the author—

C.M. (Woody) Woodruff is Missouri born and Missouri educated. He grew up on a Ray County farm in the Missouri River bottom. Upon graduating from high school he enrolled in the College of Agriculture at the University of Missouri

Thus started an affiliation with the College of Agriculture that started in 1928 when he was a freshman and continues to this day in 1990 as an active and enthusiastic professor emeritus of agronomy. During this 62-year period Woody earned bachelor, masters, and doctoral degrees from the University and he has been a faculty member since 1933.

During his career at Missouri, Woody gained an international reputation for his research aimed at improving crop yields and reducing tillage needs. He was a pioneer in no-till and minimum-tillage research and in developing efficient irrigation systems for upland Missouri soils.

Woody is the author of dozens of research papers, taught both undergraduate and graduate students, and has often been a featured speaker for agricultural groups and at College of Agriculture field days.

As readers turn the pages of this history it will become evident that the writer has been a keen observer of not only the work in this department but of Missouri agriculture in general. His pride and interest in his work, his department, the College of Agriculture, and the state of Missouri shows through. It's particularly evident in those pages devoted to Sanborn Field.

C.M. Woodruff at the entrance to Sanborn Field.

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A HISTORY OF THE DEPARTMENT OF SOILS AND SOIL SCIENCE

Where should one begin?

What should be the focus?

A chronological listing of events, developments, contributions, personnel, operations, purposes? A reference for use by future generations? Accomplishments of the department? If so, why? Why did the department begin? Why has it endured? Was it needed? Is it needed? Will its existence continue to be needed? On what aspects of agriculture do activities of the department impact? A study of what was, what is, what will be, or what ought to be? Is knowledge of the soil and its care sufficient when the concern of the individual is here and now? What motivated the individuals who dedicated their life work to study, teaching, and research in the Department of Soils? Why should we today attempt to document that which has gone on before? Will such a history only occupy space on a library shelf, seldom if ever to be read by the generations to follow?

An answer to all of these questions is more than any reader should expect. But, perhaps the questions can serve to help readers assess their positions in the scheme of things. The following chapters will be used to tell this story.

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IN THE BEGINNING

The midcontinent was a setting of virgin lands, streams, forests, and prairies, peopled sparsely by wandering tribes sustained by hunting, then penetrated slowly by settlers, fur traders, prospectors, and speculators. The evolving establishment was dominated by people clearing and opening new lands, self sufficient as to their needs for food, shelter, and equipment. Concern for the soil was secondary to the paramount need for survival.

An agrarian society developed rapidly. Villages, towns, and cities grew as transportation by streams, road, and railroads brought commerce to the midwest. Within half a century, most of the new land was occupied, used, and depleted with little left to be opened. Concurrently, major developments in farm machinery expanded the operation of farms to larger units of land with a fixed supply of labor provided by the farm family. No longer was new land available to replace that worn out by depletion of fertility and soil erosion.

Soil exploitation of lands along the eastern seaboard during the 17th century focused national attention on the importance of agriculture. This was recognized in the reports of Daniel Lee, MD, to the commissioner of patents in 1850. Lee pointed out that soil elements removed by a harvested crop leave the soil with that much less for future crops. He also stressed the need for educating the public, and especially the farmer, concerning the nourishment of crops. Lee supported the need for colleges and instruction in agriculture. But, in spite of his efforts the response was slow to come.

Although late in the 19th century the University of Missouri had introduced subjects in agriculture taught by one or two individuals, the impetus to agricultural education came with the Hatch Act of 1887 which provided funds for agricultural experiment stations. This act reached all the states and was a turning point in agricultural education. Concurrently, the research arm of the United States Department of Agriculture was funded and assisted in the coordination of work by the experiment stations.

THE LESSONS OF SANBORN FIELD

J. W. Sanborn, chosen as dean of the College of Agriculture in 1882, and later director of the Missouri Agricultural Experiment Station, brought his knowledge and experience from Vermont. He, with the assistance of Cyril G. Hopkins of the University of Illinois, laid out plots in 1888 now known as Sanborn Field. The studies involved crops and crop rotation with and without manure. Fortunately, two plots were included for treatment with chemicals for a full crop based upon the knowledge of the chemical composition of the crops. These plots, with wheat as the first crop seeded in the fall of 1888, makes Sanborn one of the oldest research fields west of the Mississippi River. Later, Dean H. J. Waters questioned the advisability of continuing the plots but M. F. Miller, a recent addition to the staff of the College, supported their continuation as a learning experience for generations of the future.

LESSON NUMBER 1—CHANGES PRODUCED IN THE SOILS

Aside from the information gained pertaining to crops, the value of the plots today and in the future lies in the assessment of the slow changes brought about in the soil (the whole profile) by the crops, management, and treatments imposed upon them. These slow changes, minute as they are from one year to another, are not measurable except over a period of years, long enough to accumulate differences great enough to assess by current techniques.

The principle learned here was that any system of soil or crop management that enhanced yields, without returning to the soil what the plant had removed, eventually leads to depletion of soil fertility. The soil is not a refuge from adversity. In the hands of a disposable society, soils face a rapid demise, and this demise will be followed by the decay of the community, the state, and the nation.

LESSON NUMBER 2—SHORT-TERM BENEFITS VERSUS LONG-TERM FAILURES

One of the early lessons involved in questioning the adoption of improved practices before their time had come was the emphasis placed on crop rotations. They were short (three-year), medium (four-year), and long (six-year) rotations with each of the constituent crops grown in monoculture continually, all both with and without manure. As measured by crop yields, the greater the yield the more rapid the loss of productivity, which in the end, brought the soil of the six-year rotation to the lowest level of productivity. Typical of the times, all crops were removed, not only the grains and hay but also the fodder and straw as well, practices which intensified the drain on potassium. Little potassium is removed when only the grain is harvested.

LESSON NUMBER 3—ROTATING SOILS DOWN THE HILL

Another lesson, one which is presented with tongue in cheek, concerns a comparison of land in a rotation with each of the crops of the rotation also grown separately in monoculture. Any system of cropping that requires tillage of the soil exposes it to erosion. The three-year rotation of corn, small grain, and meadow involved preparing a seedbed for corn and for small grain. Corn was also cultivated three to four times. On rolling hill lands erosion took away top soil exposing nonproductive yellow clay subsoil. The rotated tillage rotated the topsoil off the field. Meanwhile, the monoculture approach left pasture and meadow land surrounding the farm buildings covering the soil as a protective blanket that survived to the mid-20th century. Then this area was also opened to big tractors and plows to produce a surplus that threatened the demise of the family farm. Whereas rotations destroyed all the land, monoculture left some intact.

Sanborn, recognizing the fallacy expressed first by Benjamin Franklin in the quote "lime alone without manure, father rich and soon poor," included plots both with and without manure in both monoculture and rotations. How can we today justify cattle feed lots and swine confinement facilities supported by farm lands now subject to monoculture of tilled seed beds for feed grains? The lesson from Sanborn Field says we cannot.

LESSON NUMBER 4—THE FALLACY OF ACREAGE ALLOTMENTS

The lessons instilled in students of the soils a half century ago first by Sanborn and later by W.A. Albrecht placed the care and maintenance of the soil as the first priority for a stable and prosperous agriculture. Yet, the principles were discarded by U.S. Department of Agriculture economists who injected production controls through acreage allotments, without regard to what happened fo farming systems that were designed and operated to maintain the soil. The welfare of farm land can never be geared to the greed of the profit motive. Only by demand of the people as a nation will the problem be solved.

This we saw in Holland where its people as a nation supported reclamation of land from the North Sea by dikes and retardants that stilled the waters permitting plants and sediments to build the land to a level that permitted agriculture a century later. And this process of reclamation continues today with the full knowledge that no one supporting it will live long enough to benefit personally.

LESSON NUMBER 5—THE DEMISE OF SWEET CLOVER

Some lessons come by surprise and not by plan. One such surprise that found its origin in Sanborn Field came at the close of the 1920s. "Lime and legumes, clover and prosperity," a theme of the day resulting from the observation and fact that sweet clover, as a green manure ahead of corn, provided needed nitrogen for the corn. But, in due time corn yields declined to and then below previous levels. This practice implemented in Sanborn Field in the early 1920s by addition of a series of new plots in the southwest corner of the field was a most revolting and serious development at a time when the practice had been widely accepted over the state. A call to the U.S. Department of Agriculture in Washington brought a representative to assist M.F. Miller with the problem that yielded a grant supporting E.E. Smith as a graduate student. Smith's studies in 1932 revealed a potassium deficiency in corn stalks after sweet clover. This was corrected by applying 0-12-12, and later 0-20-20, fertilizer. The inclusion of phosphorus, based upon Miller's experience with the need for phosphorus as an established fact for Missouri soils from experiments of past decades, was always a point of criticism by W.A. Albrecht in that it confused the solution to the problem as it had been assessed.

As noted the slow changes in soils obscure the consequences of a new practice with promise in the short run that fails in the long run. Until a knowledge and understanding of soils and productive practices are complete, short-term solutions to problems are not adequate for a stable and productive agriculture for the future.

LESSON NUMBER 6—BROOM SEDGE

One fall afternoon as Dean M.F. Miller drove by Sanborn Field on his way home (the Dean 's home was then a two-story cut stone building of an earlier era and which occupied a spot south of Eckles Hall) noted a heavy growth of broom sedge on plot 23 (continuous timothy without treatment). The dean lost no time in calling this to the attention of W.A. Albrecht who, as department chairman, was responsible for Sanborn Field management. Unless taken care of the broom sedge would spread over the whole field. The reprimand was not taken lightly and from it came Albrecht's theory of evolution in reverse, of an ecology of retrogression with legumes, with alfalfa at the top followed by red clover, cow peas, alsike clover, lespedeza, and finally broom sedge so devoid of nutrition that nothing would eat it. Thus, sereceia lespedeza was promoted as a poor-land alfalfa and varieties of crop plants were sought that would do best on poor soils.

Albrecht pointed out that broom sedge grew only on plots devoid of fertility. It grew only where more robust plants could no longer survive.

LESSON NUMBER 7—BROOM SEDGE, ACTINOMYCETES, AND AUREOMYCES

Having dealt with the uniqueness of broom sedge on plot 23, it's appropriate to recognize another of those unanticipated developments that came by virtue of existence, not by plan. In 1945, Dr. B.M. Duggar, formerly with the University of Missouri, came through Columbia on a mission of collecting soil samples seeking to isolate strains of organisms possessing antibiotic properties. Through help from Albrecht samples were collected from the variety of cropping and soil treatments on Sanborn Field plots. Of these, soil from plot 23 yielded the fungus streptomyces now in world-wide production and used by hospitals throughout the country. The discovery of this organism on this plot and on no others asks the question "why here?" What were the circumstances that accounted for its presence? What role did this organism play in the soil of this plot?

Although there are things well known about this situation there is much more that we do not know. We know that the plot, in continuous grass (the plan specifies timothy), was not eroded. The soil was very acid. Phosphorus and potassium had been depleted. Organic matter content was still moderately high, having been maintained from roots, primarily of grasses. The soil as a medium for bacteria and fungi was not the best, reducing the competition that otherwise would have existed for the actinomycetes or thread fungi which included streptomyces aureofaciens. That some organisms prey upon others is not surprising. In this instance the golden colonies of aureofaciens on the plating medium grew outward consuming surrounding colonies of bacteria on the growth medium. Though the usual assumption that the microorganisms of the soil decompose the dead residues of plants, the evidence suggests an ecological balance among organisms that to some extent serve as purifying agents for the percolating waters of many home water supplies. The actinomyces are well known for their ability to destroy cellulose. Was not the observation of Miller pertaining to broom sedge prophetic of the later discovery of aueromycin in plot 23?

LESSON NUMBER 8—LIMITATION OF RAINFALL FOR SUMMER-GROWING CROPS

Long known to Missouri agriculture are the vagaries of the weather—floods, drought, winds, frost, and heat damage. The advent of cheap synthetic nitrogen as fertilizer from the conversion of ammunition plants after World War II, injected new developments in corn production. For many decades corn yields of less than 40 bushels per acre had been common. Applying the knowledge at hand in terms of plant composition, previous corn yields, and size of corn ears with respect to plant populations, a plan for growing 125 bushels of corn per acre was started on the College of Agriculture South Farms and McCredie Field in 1948. The yield that fall was 128 bushels an acre. For five consecutive years, yields in excess of 100 bushels were produced. Fertilizer sales mounted. Farmers rapidly accepted the new technology. Then, a dry summer in 1953 brought corn yields down to 75 bushels an acre. In terms of the future, the question arose concerning how corn would do, within the swings of the weather, using the new fertilizer technology.

Rainfall records since 1890 and corn yield records since 1889 were used to plot yields against maximum estimated water deficits through June, July, and August. The highest yields of corn, regardless of the plot or the treatment from Sanborn Field, were used (there were five sets of data when both fertilizer and rainfall were adequate). The yield line was drawn over the top of all yields ranging linearly from 141 bushels an acre at zero water deficit to zero bushels per acre at eight inches of water deficit. The median deficit was near 3.8 inches giving a median yield of 87 bushels per acre. Twenty years later, the average yield of continuous corn well fertilized was 87 bushels per acre both on plots 6 and 7 of Sanborn Field and on range J of South Farms.

Again, the long records of data from Sanborn Field served a valuable and useful purpose.

LESSON NUMBER 9—PRINCIPLES OF IRRIGATING CLAYPAN SOILS

The consumptive use of water by corn, the plant-available water storage capacity of the soil, the depth of rooting of summer-growing crops, and the distribution of summer rainfall as studied on Sanborn Field was brought together to create a system for irrigated corn production on Missouri upland soils. This system was introduced in 1966 and accepted by farmers where the terrain was suitable for impounding water.

A dry summer in 1947 revealed that roots of corn, soybeans, red clover, and lespedeza moved down through the clay subsoil to a depth of 42 inches. This reduced the water content to near the wilting point behind the advancing root tips of all plants.

The daily consumptive use of water of 0.2 inches from short lespedeza to tall-growing corn focused attention on the calories of energy from the sun impacting on a canopy of green leaves that provided complete shading of the ground as the dominant determinant of water use. In late June, corn after sweet clover, without and with 0-20-20 fertilizer on plots 40 and 41, revealed that without phosphorus leaves rolled at midday, yet there was adequate soil moisture below 30 inches. Unrolled leaves on the adjacent plot that received phosphorus had withdrawn water to a depth of 36 inches. Without adequate phosphorus the roots did not extend downward as fast as water was taken from the soil. At the same time the thin planting of stunted corn on plot 17 (continuous corn with treatment) was supplied with adequate water at a depth of 24 inches.

The 1947 studies, supplemented with measurements of consumptive use of water by corn on McCredie Field plots supported the data derived from Sanborn Field until 1965. Then, William Bohnert, as a special problems student, followed the soil moisture regime of the soil profile under corn, using tensiometers, gypsum blocks, and gravimetric measurements. The rainfall distribution that season was fortunate indeed. It produced the highest yield of fertilized corn on plot 7 ever recorded up to that time. As such, the results implied that if we were to irrigate corn successfully, following Mother Nature's ways of doing it was a good starting point.

Studying the rainfall records and the measurements of soil moisture made two principles evident. First, frequent small rains kept the surface soil of 10 to 12 inches moist enough all summer that the water column in the tensiometers did not break. Second, below that moist surface soil the clay subsoil, swelled shut to air when wet, was subject to dehydration as a drying front moved deeper with the advancing roots tips. By early August the root tips reached 42 inches. The simultaneous removal of water from the surface soil and from the deeper clay by advancing root tips allowed for a longer supply of water at the surface between showers where gaseous exchange was most rapid. Once a sandwich of dry soil existed between the moist surface and the deeper clay, this dry layer withdrew excess water rapidly from the surface during and after rain, thus sustaining good soil aeration around the corn roots.

It was from these principles established on Sanborn Field that a guide for irrigating corn on claypan soils was developed. This guide brought successful irrigation to the prairie soils of northeastern and southwestern Missouri.

LESSON NUMBER 10—LOSS OF TOPSOIL FROM PLOT 17

Soil erosion, the bane of soils opened by tillage which made them vulnerable to catastrophic destruction by torrential rains, was illustrated best by plot 17, in corn continuously with both grain and stalks removed. The native soil, first in corn in 1889, covered the clay to a depth of 16 inches. When these plots were plowed in 1928 to 1932, the plow turned up a smooth silt loan. The next 40 years turned up subsoil clay with none of the original topsoil remaining. Eighty years of experience dissipated 2,600 tons of top soil per acre for an annual average loss of more than 30 tons per year. This was a loss approaching two tons for each bushel of corn produced. And, this happened on a spot 30 feet wide and 100 feet long on the watershed divide without benefit of either steepness of slope nor length of slope. The dispersion of the fine silt by the impact of the rain drop maintained the suspension as the soil was floated off in the water. Only by a continuous cover of protective vegetation can the soil be preserved as a national resource in land from which water flows.

LESSON NUMBER 11—NO-TILLAGE CROP PRODUCTION FOR CONTROL OF SOIL EROSION

Soil erosion from plots 1 to 7 facing east and plots 24 to 28 sloping west, regardless of the rotation, not only removed top soil but in instances washed over and covered new soybean seedings on adjacent plots. No-tillage technology, a development with promise for reducing erosion, was introduced on plot 7 in continuous corn; on plots 40 to 45 in rotation with small grain as a winter cover; and on plots 31 to 33 in a three-year rotation of corn, soybeans, and a cover of small grains. The plots, mowed with a sicklebar after no-tilling corn, provided a straw mulch to prevent erosion, conserve moisture, and eliminated the need for herbicides to control weeds. These were promising sources of information concerning no tillage as a replacement for the plow and as a means of conserving soils. Corn no-tilled into red clover that was later mowed as a mulch resulted in the highest yield of corn from the formerly green-manured plots without exposing the soil to erosion. Supplemental irrigation, to cover the use of water by the clover, would have been a promising contribution. But, the committee appointed to deal with the future of Sanborn Field when C.M. Woodruff retired in 1976 preferred to employ conventional practices accepted by farmers. That is no way to function in research and development.

LESSON NUMBER 12—RELEASE OF NITROGEN FROM ORGANIC MATTER

G.E. Smith published data from Sanborn Field at the end of the first 50 years of study. Using the results of chemical analyses of the soil, the rate of release of nitrogen from soil organic matter was ascertained. This served as a basis for estimating the release of nitrogen when soil testing became accepted as a guide for fertilizer use.

It was this information that suggested the possibilities of growing continuous corn with synthetic nitrogen to both maintain yields and through high-plant populations to increase the return of organic matter to soils. Smith incorporated this concept into plots 6 and 7 beginning in 1950.

He continued the pursuit of this illusive subject based upon the relation that an equilibrium condition required that losses of nitrogen N as a constituent of soil organic matter must be replaced by the amount A added each year such that $Nr = A$ where r denotes the percentage released each year. From this relation the amount of organic matter in the soil as reflected by $N = A/r$ depends upon the amount added each year, the rate r remaining more or less constant depending upon the climate of the region. Twenty years of results substantiated the premise that both yields and soil organic matter content were maintained.

But, a fallacy existed. Organic matter returned to the soil is, in a sense, a source of stored sunshine and corn stover collects sunshine only through June, July, and August. Crops such as alfalfa green up with the first warm days of spring and persist to the first hard frosts in the fall. Small grains, such as wheat and barley, both cool-season crops, collect sunshine from fall through spring. To build soil organic matter with corn requires incorporating a winter cover crop as a collector of sunshine to enhance the quantity A. Because of the added demand for water by the cover crop, irrigation is required to ensure the crop of corn.

That which may not be practical today may become a necessity in the future.

LESSON NUMBER 13—SOIL ACIDITY

W. A. Albrecht, in the early days of testing soils for lime requirement by means of Comber's solution, observed that a county extension agent in Carroll County set up a farm demonstration on river hill soil that tested acid and produced no clover except where lime was applied. River-bottom soil that also tested acid but produced excellent clover without adding lime posed the question that soil acidity was not a sufficient criteria of the need of lime for growing clover.

Years later Albrecht observed the same performance of clover on plot 34 of Sanborn Field. This plot was cropped to a rotation of corn, oats, wheat, and clover, with six tons of manure applied annually. The soil was acid, pH 4.7 to 4.8, but clover grew well. Why?

Today we would ascribe the growth of clover in the acid soil to the chelation of iron and aluminum by the added manure. This formed iron and aluminum humates which without the organic matter would have required lime to eliminate the acidity thereby precipitating the iron and aluminum. The inclusion of a measurement of the organic matter content of soil in the soil-testing program has proved to be a valuable asset in the diagnosis of soil fertilizer needs for producing crops.

Expanding upon this subject on a tour of commercial vegetable production on organic soils in Indiana, we learned that these soils were kept acid because liming them hindered their performance. Then later it was observed that lush green soybeans with well-inoculated roots were growing on sandy loam soil at pH 3.7 both near New Madrid and near the research center at Portageville. Apparently, these soils furnished the needed calcium for the plants but the absence of clay in both the organic and sandy soils removed the deleterious effects from aluminum that becomes active in acid clays.

LESSON NUMBER 14—ROOT PUMPING OF THE SUBSOIL

Root pumping was first observed on the continuous alfalfa and continuous fescue-orchard grass mixture on well-fertilized soil erosion plots, then later on continuous corn plot 7 of Sanborn Field. After some 15 years of heavy production from added lime and fertilizer, production declined on the plots. Originally, the first stand of alfalfa lasted eight years with an annual production of five tons per acre.

Upon re-establishment, stands would last no more than three years. Fertilizer of 0-100-100 on alfalfa and 100-100-100 on the grass mixture was applied each spring and produced a good first cutting. A top dressing of 100 pounds nitrogen per acre on the grass failed to revive it. Analyses of the leaf samples revealed a deficiency of potassium. Taking 2% of K in the leaf tissue as that of a well-nourished plant the removal of potash by five tons of alfalfa would require 200 pounds where only 100 was being added. Then, too, luxury consumption would account for removal of all that added by the first cutting of hay.

Upon top dressing, both the alfalfa and grass responded immediately. Thereafter, a program of adding 40 to 50 pounds of potash per ton of hay after each harvest was adopted. Adding an excess at any one time was avoided because of the likely loss as luxury consumption in the following harvest. The first year of the practice resulted in yields of nine tons per acre of alfalfa and seven tons per acre of the grass hay.

When G.E. Smith revitalized the management of Sanborn Field, plots 6 and 7 had been in continuous corn with ample fertilization since 1950. The new plan called for one of the plots to be irrigated. Not until 1966 was water to the field made available and then pipe had to be laid from the southwest corner to the northeast corner.

Theo Dean, who was taking care of the plots, noted that unirrigated corn on plot 7 was showing a deficiency while irrigated plot 6 was lush and green. Examination revealed burnt edges on the leaves of corn indicative of potassium deficiency. How could this be with the soil testing 300 pounds of K per acre and a pre-plant application of 200 pounds of potash per acre? Drought had left the soil dry so roots were feeding deep in the profile. Over the years potassium from the deeper layers brought up and left in the surface where dryness inactivated the roots left the deeper roots to forage in the depleted subsoil. Irrigated plot 6 kept the surface roots feeding in an abundance of potassium. Soil tests of the soil profile taken initially revealed an ample supply of potassium in the deeper layers of soil but after 16 years the high yields of corn had pumped the subsoil leaving no satisfactory way of moving potash back into the subsoil.

Although somewhat different than the earlier experience with depleting potassium by corn supplied with nitrogen by sweet clover, the final solution for future generations would appear to be use of supplemental irrigation to maintain plant roots in the fertilized zone of soil.

LESSON NUMBER 15—CORN YIELD AS A FUNCTION OF LIGHT

An acre of corn is illuminated by an acre of sunlight. The amount of light allotted to each corn plant is inversely proportional to the plant population. The efficiency of a green leaf in converting a spot of illumination to weight of grain is a property of the genetic potential of the plant. An increment of light added to a plant by a small reduction in the plant population falls upon a mixture of shaded and lit leaves. The fraction of the increment impinging on shaded leaves produces grain. That impinging on functioning lit leaves is not effective.

The genetic potential of a corn plant to produce a full-size ear of corn is determined by the number of rows of kernels, the number of kernels in a row, and the size of the kernels. The area per plant at which competition for light first affects the size of an ear, and the area per plant at which insufficient light does not initiate grain production, established yield parameters by which to determine that population at which changing ear numbers is in equilibrium with changing ear sizes.

It was through experiments on the plots of Sanborn Field that Herschel J. Gaddy, a graduate student, established yield parameters for hybrid corn.

LESSON NUMBER 16—DO ORGANISMS CAUSE ROOT ROT OF CORN OR DOES DEATH CAUSE ROOT ROT?

Herschel J. Gaddy, studying plant populations of corn, noted that at harvest time in September corn plants at populations of 15,000 and less were green and healthy after ears had matured. Plants at populations of 19,000 and more could be lifted out of the soil with the ears, the roots having rotted off. Examination of weather records revealed nine consecutive days of hot cloudy weather with no sunshine in August. Was sugar synthesis by the limited light supply at the higher plant populations insufficient to meet the metabolic requirement of the corn roots at the high soil temperatures through the nine-day period of cloudy weather?

In 1969, the following year, George Gille, a graduate student, followed the concentrations of sugars as measured by a refractometer in the sap of pith from the first internode above the brace roots of corn. At 30,000 plants per acre, percentage of sugars starting at 2% in early July dropped to 1% during a four-day period without sunshine in mid August recovering to 1.5% thereafter until the pith dried out beyond Sept. 2. Simultaneously, sugars in plants growing at 7,500 plants per acre carried 5% of sugars until physiological maturity the third week of August after which the percentages rose rapidly to more than 10%. In another experiment, ears were removed 10 days after silking giving a rise in sugar content from 5% to 15.4% in 30 days. Brace roots remained green and viable in stalks with no ears while brace roots withered and died on stalks containing ears.

The following year Ellis Graham, using a bank of fluorescent lights on both sides of a row of corn with plants spaced two inches apart, produced good ears and green brace roots to maturity.

The lesson from these studies on Sanborn Field explained the root rot at high-plant populations during cloudy weather as being caused by root starvation. Also, as was pointed out by Gillie, failure of the root system brought on by lack of sugars, resulted in drought damage that did not occur with viable root systems.

LESSON NUMBER 17—MORE OBSERVATIONS WITH RESPECT TO LIGHT FOR CORN

Through the years many photographs have been taken of pertinent material on Sanborn Field. However, with some exceptions many have no focus of interest. Eventually, as a point of departure a plan was initiated to photography plot 7 in continuous corn on the first and middle of each month and this plan was executed through four complete years. The result:

1. Corn planted in mid-April provided little if any interception of sunlight before June 1, hence little protection to the soil from impacting rain drops; also it captured little sunlight in useful form.

2. By mid June, in the grand period of growth, corn attained shoulder height and a closed canopy that shaded the soil.

3. By July 1, it had passed the 50% silking stage with all stalks tasseled. At this stage silver dollar-sized spots of sunlight reaching the soil could be observed. Why? An eclipse of the sun at midday revealed quarter-moon patches of light on the soil under the corn. These spots were images of the eclipse brought to focus on the soil by the pin-hole camera effect created by the closed canopy of corn leaves.

4. A hybrid with narrow leaves permitted light to penetrate to the lower leaves producing a higher yield than from a hybrid with wide leaves.

5. Ears reached physiological maturity by Sept. 1 and were harvested by Sept. 15 permitting disking and drilling wheat as a winter cover. The corn was an effective collector of sunshine for no more than 90 days.

The wheat, as a cool-season crop, collected sunshine until corn-planting time when corn was no-tilled into the wheat. The wheat was mowed as a mulch to protect the soil from erosion and eliminated the need for herbicides to control weeds. The three to four tons of oven-dry matter in the wheat returned to the soil aided in the restoration of soil organic matter that had been lost through a century of exploitive cropping.

LESSON NUMBER 18—SALT ACCUMULATION IN IRRIGATED SOILS

The future will bring an expanded use of irrigation because of the vagaries of Missouri weather. Historically, soils irrigated with well water accumulate salts that eventually end their usefulness. This, in due time, gives rise to problems with salt accumulation. Facilities for irrigating the plots in the southwest corner of Sanborn Field using well water from University supplies started in 1966. This should provide a means of following the development and thence lead to a solution to the problems preceding the eventual problems arising on farm fields. Only on a field such as Sanborn, with some promise of perpetuity, may such a study be undertaken.

LESSON NUMBER 19—REPLICATION OF PLOTS

Sanborn Field reviewers often cast a modicum of criticism on the lack of replication. Have they ever given thought that replication of such investigations might be inappropriate or undesirable? Had such an approach been used when the plots of Rothamsted, Morrow, and Sanborn were started these fields would not exist today.

Replications are used to measure small differences of short duration on variable soils such as testing of varieties, hybrids, fertilizers, and herbicides. But small changes in soils that require years to accumulate measurable amounts, and sampling of the vagaries of weather, are not subjects suitable to testing techniques.

The costs, the magnitude of operation, the interests of the investigator, and the turnover of personnel mitigate against large long-term experiments. A growing and expanding University places a premium on space for offices, laboratories, class rooms, dormitories, parking, and fraternity housing. This, surrounding unoccupied agricultural land, requires a perpetual justification for keeping it as each new administration accepts the reins of the University. The College of Agriculture was fortunate that M.F. Miller enjoyed a position of prominence with respect to Sanborn Field from his arrival in 1904 to the publication of his memoirs in Experiment

Station Bulletin 769, July 1961.

One may question whether or not long-term studies of soils and plot investigations should be started today or in the future. Then, too, who knows what questions may arise in the future that will require a long history of soils and their treatments, such as accumulations of pesticides and radioactive fallout?

The application of statistical techniques to plot investigations become prominent in the decade of the 30s through the influence of G.W. Snedecor and his 1937 textbook. As a consequence a statistician was appointed to the research division of the the Soil Conservation Service. For a proposed study of deep shattering and liming of the subsoil involving three treatments and a rotation of three crops—corn, wheat, and clover — a minimum of 27 plots was required. After seven years the maximum yield of corn in any one year was 45 bushels for which the average was only 35 bushels. And this was statistically superior to the yield of the untreated plots. Corn yields at that time were established by the quantities of nitrogen fixed by clover.

The availability of synthetic nitrogen after World War II permitted supplying the nitrogen required to support a plant population of 18,000 per acre with a potential yield of 125 bushels per acre. The yield in 1948 of 130 bushels per acre was heralded by many as a fortuitous occurrence that would not happen again. But, for five consecutive years the yield exceeded 100 bushels per acre and, 40 years later, the average yield of corn for the state of Missouri was 110 bushels an acre.

The lesson gained from this experience suggests that much more may be accomplished by the study and application of fundamental principles than may be learned from a multitude or replicated plots that sap the financial support and the energy of the investigator without contributing much to the advancement of knowledge. There are some investigations for which replication is inappropriate.

SURVEYS OF MISSOURI SOILS: MARBUT AND KRUSEKOPF

The Missouri soils survey was started by Curtis Fletcher Marbut, professor of geology, in 1905. Soil surveys of counties actually began in 1904 although there are references to such work in Howell County in 1901.

The University of Missouri exhibit for the St. Louis World's Fair in 1904 was under the direction of Dean H.J. Waters of the College of Agriculture. For this exhibit, Marbut prepared a large map of Missouri soils made of plaster of paris. This exhibit won a gold medal for its excellence. It is now assembled in Waters Hall.

In 1916 Marbut returned from Washington to Columbia where he was awarded an honorary doctorate by the University of Missouri. In 1934, the year prior to his death enroute to China, the University's Board of Curators appointed him honorary professor of soils.

Of particular interest to Missourians is Marbut's assessment of the Ozarks' soils published as Experiment Station Research Bulletin 3 in 1910. In this bulletin, after dealing with the geology and soils of the region, Marbut digressed to describe the entrance of the pioneers and the development of the agriculture, transportation, and sociology of the region. This is a part of the early history of Missouri that for most is lost in today's concern with the present.

Marbut was followed as chief of the Missouri soil survey by H.H. Krusekopf from the graduating class of 1908. M.F. Miller wrote "Prof. Krusekopf knows more about field soils in Missouri than any other man has ever known."

Through the years of the soil survey there have been many names of party members. The list that follows undoubtedly does not include all even though it is voluminous. In later years the survey of soils administered originally by the Bureau of Soils in the U.S. Department of Agriculture was transferred to the Soil Conservation Service with recent county soil maps surveyed by SCS personnel. The reconnaissance soil erosion survey of Missouri in 1935 was directed by L.D. Baver assisted by Harold Terrill, T.R. Smith, and C.M. Woodruff.

If one who grows up on a farm and knows the soils field by field ever wonders why the government should spend funds to survey soils, that person should realize, as pointed out by Marbut, that our soils are the property of the nation. They are one of many national resources and we, as possessors of the land, are only temporary tenants with a responsibility to the nation to preserve that land for use by future generations.

Individuals associated with the survey of Missouri soils prior to SCS surveys were J.H. Agee, M.W. Beck, J.C. Britton, R.T. Aron Buche, F.S. Bucher, H.I. Cohn, L.V. Davis, C.E. Deardorff, W. DeYoung, R.C. Doneghue, J.E. Dunn, F.V. Emerson, J.B. Fehsenfelt, E.D. Fowler, J. Frieze, F. Gilbert, E.C. Hall, N. Hall, R. Hamby, H.W. Hawker, W.E. Hearn, R. Held, E.Z. Hutton, J.V. Jordan, E.W. Knoble, H.H.Krusekopf, H.B. Lewis, D.D. Long, J.A. Machlis, C.J. Mann, C.F. Marbut, M.M. McCool, M.F. Miller, W. Pettijohn, D.B. Pratapas, L. Ruhlen, H.P. Rusk, C.L. Scrivner, W.D. Shrader, M.E. Springer, A.T. Sweet, W.E. Tharp, B.W. Tillman, E.S. Vanatta, K. Voght, W.I. Watkins, E.B. Watson, R. Wildermuth, and J.F. Williams.

LOCAL AND OUTLYING EXPERIMENTAL FIELDS

Professors in the College of Agriculture, during the early years of its existence, had no research or results of investigation as support for teaching or advice for farmers. Daniel Lee, MD, in his report to the commissioner of patents in 1850 in addition to pointing out the fallacy of depleting soil fertility through removal of crops, published many letters from farmers reporting upon their experiences in growing crops. Of interest to Missourians were the reports on growing hemp (Canabis sativa) which was produced in quantity in northwest Missouri. Bales of hemp were shipped by boat down the Missouri River. These bales were used to advantage by Union forces during the Civil War to rout Confederates entrenched on the hills by rolling water-soaked bales of hemp up the hills in the face of enemy fire at the Battle of Lexington. Today, remnants of these early plants, now growing wild, pose a problem as a source of marijuana.

M.F. Miller, originally a professor of agriculture when he joined the faculty in 1904, in his teaching and experiment station bulletins focused upon the selection and care of seed corn. An appropriation was made in 1905 by the State Legislature for the establishment of outlying experiment station fields to study soil treatments and crop adaptations. Numerous fields of five to 10 acres each were located on various soils over the state. The names of the farmers cooperating in these studies is not recorded, but a few who were effective in the early years included Lewis van Buren, Plattsburg; Eugene Poirot, Golden City; and Paul Veale, Mexico. van Buren, in the era of large mule barns of World War I vintage, cooperated with G.E. Smith in the fertilization of blue grass pastures. Poirot cooperated with W.A. Albrecht from the 20s when sweet clover was introduced, through the decades that followed with artificial manures and fertilizers, and finally into the 60s with irrigation. Veale, at Mexico, was the first to introduce irrigation of soils from surface reservoirs following the irrigation charts developed by the soils department

Among the prominent outlying fields of the early years were the 39 as indicated in Fig. 1. They reflect the statewide distribution and the efforts of Miller in supervising these studies.

OUTLYING EXPERIMENTAL FIELDS

The major conclusions from these early studies were that small grains and legumes responded to phosphate on most upland soils, legumes responded to lime, and it didn't pay to fertilize corn.

1. Maryville
2. Kidder
3. Chillicothe
4. Laclede
5. Unionville
6. Kirksville
7. Hurdland
8. Moberly
9. Monroe City
10. Vandalia
11. Bowling Green
12. Elsberry
13. Fulton
14. Williamsburg
15. High Hill
16. Wentzville
17. Portage des Sioux
18. Marshall
19. Adrain
20. Windsor
21. Green Ridge
22. Jefferson City
23. Union
24. Victoria
25. Lamar
26. Carthage
27. Stark City
28. Eldorado Springs
29. Strafford
30. Billings
31. Willow Springs
32. Elk Creek
33. Salem
34. St. James
35. Cuba
36. Poplar Bluff
37. Morley
38. Sikeston
39. Kennett

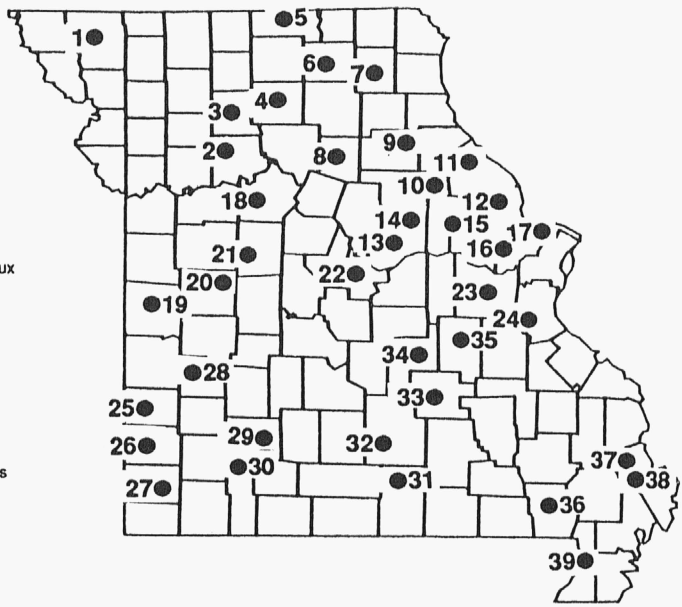


Figure 1

The following excerpt from Miller's report upon the fertilizer opportunities in Missouri at the soil fertility conferences of the northern states in June 1926 reveals much about the understanding of fertilizing crops and soils in the early years of the development of the agricultural experiment stations.

The State of Missouri is in the phosphate stage of fertilizer use. As Missouri is surrounded by cities in which packing houses are located it was but natural that bonemeal should be distributed in this territory, but its use has been important for 25 years. Along with the use of bonemeal there grew up, under the stimulation of the fertilizer manufacturers, the practice of using low-grade and medium-grade mixed fertilizers. For a number of years the principal fertilizers on the market, outside of bonemeal, were such as the 1-8-1 and 2-8-2, along with some fertilizers used for truck crops. Then came the introduction of acid phosphate, which has gradually supplanted bonemeal. Up until 10 or 12 years ago the recommendations of the Experiment Station had little influence on the farmer in regard to his fertilizer purchases. He bought what

his local agent had in stock. However, with the advent of the county agent and later with the adoption of 'Ten Standard Fertilizer Analyses for Missouri,' the recommendations of the Experiment Station began to receive more and more attention. The influence of the Station was strongly toward the use of phosphates, and as these Ten Standard Fertilizer Analyses are commonly published, acid phosphate and bonemeal head the list. As a result of these recommendations, and partly as a result of the low price of acid phosphate, these phosphate fertilizers now represent over half of Missouri's tonnage." (See following table.)

TABLE 1

1925 Use of Missouri's Ten Standard Fertilizers

	Total Tons Used	Percent of Total Tonnage
Acid Phosphate	24,962	47.2
Bonemeal	5,021	8.3
1-12-2	10,226	19.1
2-16-2	1,960	3.6
2-14-2	116	.2
4-12-0	13	.02
0-14-4	407	.7
2-12-6	682	1.2
3-12-4	427	.8
3-8-6	778	1.4
Total of Standard Ten	44,692	82.5

To our early investigators the subject of soil fertility and crop requirements were somewhat of a mystery. They were influenced some by Liebig's law of the minimum seeking to find what element might be in short supply, Mitcherlich's law of diminishing returns, and, lastly, by the economics of providing elements beyond the capacity of the soil to provide them. Only after World War II, with its development of facilities for producing synthetic nitrogen and phosphates, were there fertilizer elements available in quantities at an economically attractive cost. It was then possible to adopt a philosophy of fertilizing the soil rather than the crop as promoted by W.A. Albrecht.

Soil chemistry, as advanced by R. Bradfield, H. Jenny, L. Baver, C.E. Marshall, and E.R. Graham, had reached the stage where Albrecht was able to perceive what a good soil should be chemically and the economics of the time facilitated pursuing this objective. This was in direct contrast to the teachings of economics that sought to maximize profits through applications of lesser amounts of lime and phosphorous.

The culmination of plant tissue testing and soil testing by E.R. Graham and A.W. Klemme and application of the information resulted in the first 100-bushel-per-acre corn on Experiment Station fields in 1948. This opened the door to the widespread adoption of a full fertility program on Missouri soils. The development of the program was initiated by fertilizer studies and demonstrations under G.E. Smith, who had been brought back from the Campbell Soup Company to expedite the work. Whereas corn yields for the state did not exceed 40 bushels per acre in any one year in the decades prior to the 40s, yields of 100 bushels and more statewide in years of adequate rainfall are commonplace.

SOIL EROSION MEASUREMENTS AND CONTROL

The following article "Pioneering Erosion Research that Paid" from the Journal of Soil and Water Conservation (1987), Vol. 42, No. 2, describes the beginning and ultimate use of results of the first erosion measurements at Missouri.

Pioneering erosion research that paid

Whether planned research of accidental inquiry, the Missouri erosion plots provided the first runoff and soil loss data for crops and cropping systems

By C. M. Woodruff

In the 1930s the U.S. Department of Agriculture established 10 erosion experiment stations to evaluate runoff and soil loss from crops and cropping systems on soils subject to severe erosion. Each of these stations used a set of control plots patterned after those used in Missouri two decades earlier.

The Missouri plots provided the first measured runoff and soil loss data from crops and cropping systems in this country. These data served as a reference for later evaluation of results from the East (Piedmont of North Carolina), West (Palouse of Washington), North (Hills of Wisconsin), and South (Plains of Texas).

Today, we consider how such important research resulted. How and where did the idea originate? Was it a planned attack upon a recognized problem? Or was it accidental inquiry? The answer is not simple, but well-documented records offer some explanation.

Resource-prompted questions

Pioneers moving westward to settle Missouri after 1820 encountered the continental climate of the Great Plains. A combination of floods and drought, open and closed winters, and timber and prairie caused these pioneers to focus their attention on water; soil moisture; the water requirements of plants; precipitation; stream gauging; and, farther west, on irrigation.

Beginning about 1880 and advancing rapidly with the evolving agricultural experiment stations, many questions were seriously attacked: How much rain? When does it come? How does it vary? How much runoff soaks into the soil? How much seeps away as groundwater?

An initial test

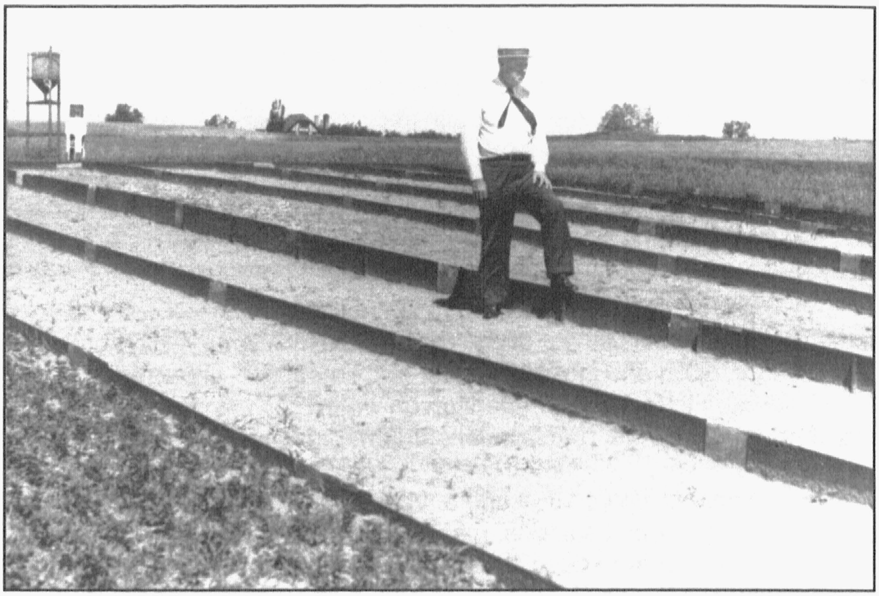
It was the spring of 1915 when a young man, R.W. McClure, went to Professor M.F. Miller at the University of Missouri for a one-hour special problem. McClure was instructed to measure rainfall and runoff over the two-month period until school ended. The result was a diamond-shaped plot at a site on the campus. The plot was surrounded with one-inch boards set in the soil that opened into an oak vinegar barrel.

After the first runoff event, McClure asked what to do with the mud in the barrel (to him an unexpected development). Professor Miller examined the barrel, then suggested weighing the mud and drying a sample. This measurement revealed a loss of soil carrying plant nutrients in excess of that removed by a crop.

The following year, a graduate student R.M. Vifquain was assigned a project that involved the installation of four plots, each 5 1/2 feet wide and 91 feet long. The two center plots occupied the same slope on which the original seven soil erosion plots were installed by F.L. Duley in 1917.

Eleven years later, Hugh Hammond Bennett used the Missouri data to support his request to Congress for funds to establish the nation's first 10 soil erosion experiment stations. The Missouri data showed annual soil losses of 40 tons per acre from uncropped land, 20 tons from corn land, 10 tons from wheat land, and 3 tons from a rotation. Only a trace of soil was lost from bluegrass.

With 1,000 tons of soil in an acre plow depth, the 20 tons lost



Hugh Hammond Bennett surveying the Missouri plots in 1937.

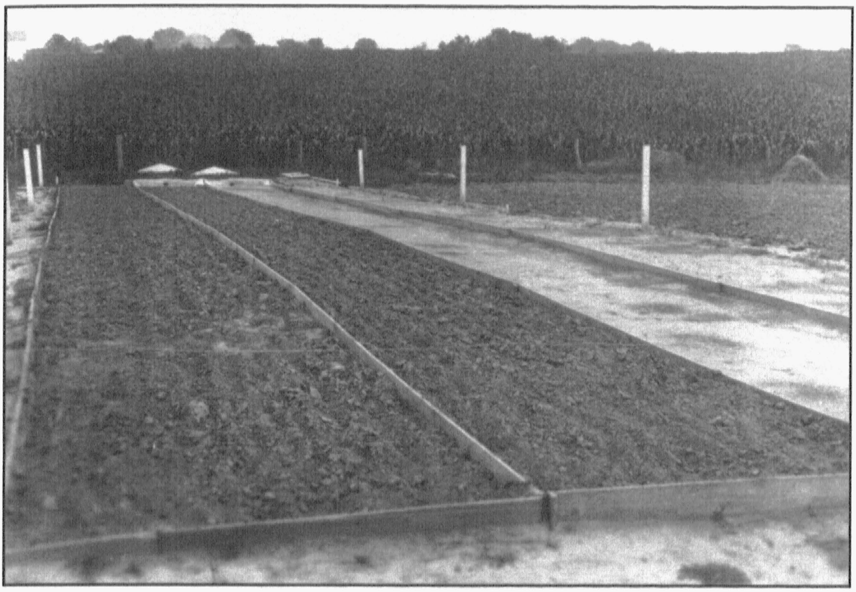
from corn land would remove a plot depth in 50 years on a gentle slope—less than 4 percent. The three-year rotation would extend the life of the land more than 300 years. Many good farms have been ruined because of farmers' inattention to runoff and erosion.

Follow-up studies

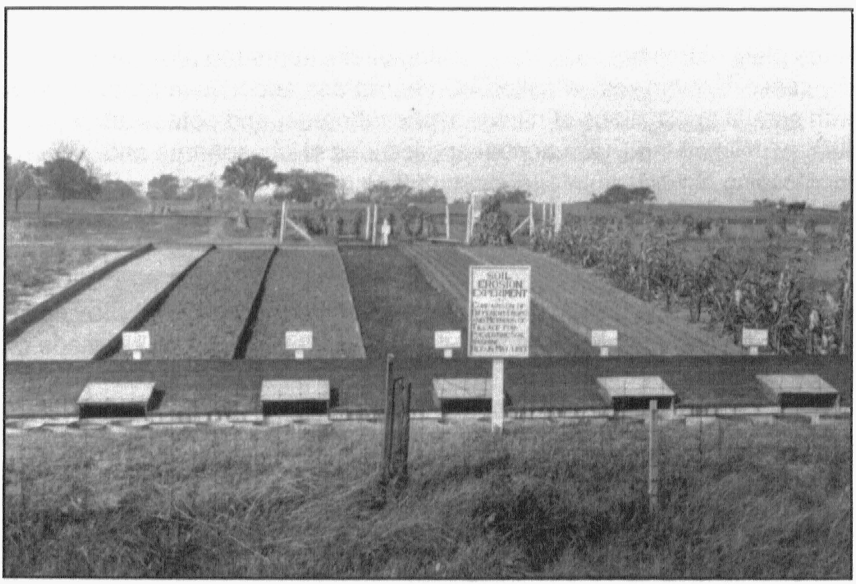
The original plan of the seven plots remained the same for 23 years. In 1940 Professor Miller questioned the advisability of continuing the study. The grass plot contained the original soil, but the soil surface of the adjacent corn plot had dropped several inches because of erosion. What use could be made of these plots that would provide information in the future?

Duley, on an adjacent area, had removed all of the topsoil to expose the clay subsoil. His small study suggested that all of the remaining surface soil could be removed and a study of soil renewal could be initiated, recognizing that long before erosion was brought under control much farming would occur on eroded land. This study, Duley surmised, could provide ideas for renewal of eroded land

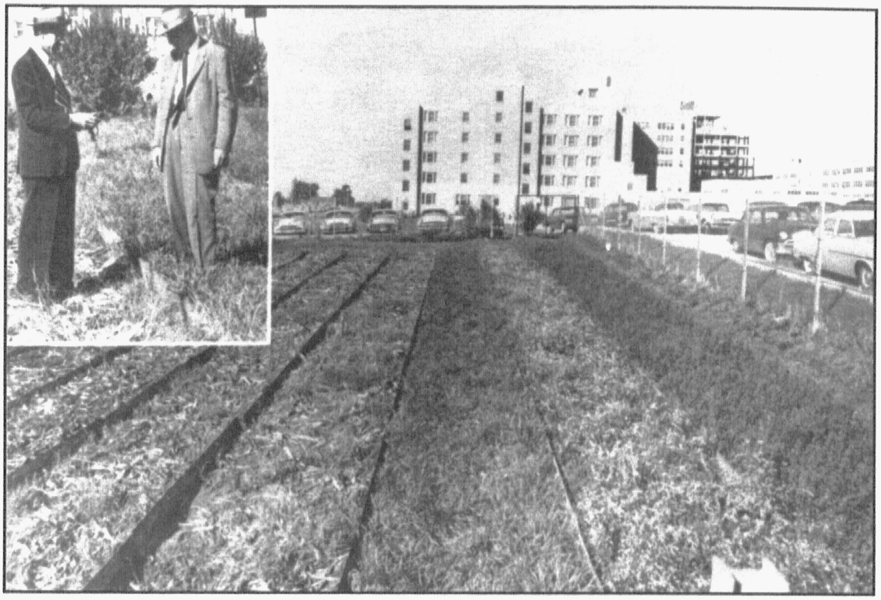
In fact, several important things were learned in the work that followed: Subsoil recovers at such a slow rate under unfertilized conditions that it may be several generations before the land provides a cover or grass suitable for pasture. Fertilized corn produces limited yields



The R.M. Vifquain plots in 1916, following measurements by R. W. McClure in 1915.



Seven plots installed by M.F. Miller and F.L. Duley in 1917 served as prototypes for control plots at 10 erosion research stations throughout the United States.



C.M. Woodruff and M.F. Miller, 1959, at the plots. Topsoil remaining after 25 years was removed from the plots so a study of soil erosion's effects on farming could be undertaken.

when planted thin because the cracking of clay tears the roots apart in dry seasons, even with irrigation. Orchardgrass and fescue produce well with annual applications of nitrogen, phosphorous, and potassium. Alfalfa on limed land, with annual applications of phosphorus and topdressing of potassium after each cutting, is very productive. The deep tap roots are not subject to the damage by soil cracking encountered with corn.

Miller said of this early work on soil erosion, "This is an example of a simple investigation, developed somewhat accidently, that provided much needed information at a time when important use could be made of it."

Today, as 70 years ago, funding of research for the inquisitive opens doors to the future that are not available to pure problem-solvers. The problems of today are not the problems of the future. Who knows what those problems might be? If an undergraduate student had not conducted a special problem in 1915, would Hugh Bennett have convinced Congress of the need for soil erosion research in 1928?

The importance of these erosion experiments was recognized in 1965 when the U.S. Department of Interior designated the University of Missouri facility as a Registered National Historical Landmark—the first recognition in the United States of an agricultural site as a national historic landmark.

George Smith, C.M. Woodruff, Max Lennon, and Luther Hughes, left to right, at the Miller Soil Erosion Plots on the University campus in April 1981.

Agricultural Experiment Station Research Bulletin 63, December 1923, by F.L. Duley and M.F. Miller provides an analytical diagnosis of the data as interpreted by Duley. The later Research Bulletin 177, November 1932, summarizes 10 years of data with a focus on the important role of crops and cropping systems as utilized by H.H. Bennett in obtaining appropriations for the first 10 federal soil erosion experiment stations.

Agricultural Experiment Station Research Bulletin 280, 1938, was that of J.H. Neal, a doctoral candidate, with L.D. Baver, entitled "The Effect of the Degree of Slope and Rainfall characteristics on Runoff and Soil Erosion."

An investigation of "The Effect of Slope on Soil Erosion" began in 1925 and continued through 1935 under the direction of F.L. Duley and M.F. Miller, was reported by H.H. Krusekopf in Research Bulletin 363, April 1943. The results deal with data from slopes of 6 and 8.5% and lengths of 60, 90, and 150 feet for a three-year rotation of corn, wheat, and clover, each plot paired with one in continuous corn.

The investigations at the Bethany Soil Erosion Experiment Station were reported in U.S. Department of Agriculture Technical Bulletin 833, 1945. That work was a cooperative project between the USDA's Bureau of Chemistry and Soils and Agricultural Engineering and the Missouri Agricultural Experiment Station.

The original plans for the research were formulated by M.F. Miller in cooperation with H.H. Bennett, and by J.C. Wooley in cooperation with C.E. Ramser. R.E. Uhland was chosen by Miller to serve as superintendent of the station and C.K. Shedd of the Department of Agricultural Engineering made the topographic survey and installed the terracing and watershed experiments.

C.M. Woodruff, center, on plot experiments in 1934 on the Erosion Experiment Station at Bethany on research to reclaim eroded land. The oats at the left are on non-eroded soil; in the center on eroded soil; and on fertilized eroded soil on the right.

Later personnel included C.M. Woodruff, A.T. Holman, Dwight D. Smith, Darnell Whitt, Austin Zingg, and J.L. Haynes.

The land for the Experiment Station was leased by the Bethany Chamber of Commerce and provided rent free. All efforts to purchase the land and make the station permanent were opposed by Miller who observed that most results of research obtained the first 10 years of a study were little improved by pursuing the work longer. He noted also that more benefit would accrue through pursuing the work on other soils and at other locations. It was apparent that Miller wanted studies pursued on the level silt loam prairie soils of northeast Missouri that were easy to till and in large level fields, well adapted to crop production, but giving very low yields. The consequence of this view was that when federal funds for the purchase of land became available in 1935 a suitable farm was located on the prairies of northeast Missouri near McCredie and this became the McCredie Soil Erosion Experiment Station. There is a history of research efforts, including a tile drainage experiment at Vandalia, in support of Miller's desire to develop the potential of the prairies.

In 1926 Miller supported Richard Bradfield in his attempts to open the claypan of the Moberly field with chemicals injected to a depth of 30 inches with a Kilifer subsoiler. Later, G.E. Smith opened these plots with a trencher and found crystals of sulphur where it was placed sealed in the clay as clean as it came from the chemical supplier. Miller knew that these soils had potentials if only the problems were solved. That solution came with the abundance of cheap nitrogen and phosphorus fertilizers made available from the ammunition plants after World War II. With such fertilizers the soils of the prairies achieved yield potentials along with the better soils of the state.

The plan of investigations at McCredie focused upon erosion from different crops as grown in various combinations. Results would provide a basis for designing crop rotations that could provide suitable income with a minimum soil loss. Results of these initial studies were published in USDA Technical Bulletin 1379 issued in February 1968. It was written by V.C. Jamison, D.D. Smith, and J.F. Thornton. Investigations at McCredie also included hydrology of watersheds, irrigation, fertilization, pastures, and channel designs for runoff discharge.

The work at the McCredie Station covered the period from 1937 when lime and fertilizers were used with legumes to provide nitrogen for grain crops up to and following World War II when abundant supplies of

Measuring runoff and erosion from crops and cropping sequences on the McCredie Field in 1963.

grain crops up to and following World War II when abundant supplies of nitrogen and phosphorus fertilizers became available. Fertilizers tripled and quadrupled grain crop yields and reduced erosion hazards of producing these crops. In 1957 ownership of the McCredie Station was transferred by the USDA to the Missouri Agricultural Experiment Station. The runoff plots continue to be useful in the evaluation of losses of pesticides as pollutants in runoff water.

LEGUME INOCULATION

Early in the history of soil investigations it was known that insufficient amounts of nitrogen were responsible for low crop yields. The first emphasis was upon the care and use of barnyard manure from livestock farming. This was followed by efforts to produce legumes that through bacterial nodules on their roots fixed nitrogen from the air in a form usable by plants. The nitrogen-fixing legume crops grew best in soils that were well supplied with lime and phosphates. However, with few established fields of legumes, many soils lacked the organisms necessary for fixing nitrogen. The first efforts to correct the deficit was to take the soil from a field that grew legumes satisfactorily and mix it with seed of the legumes when establishing a new stand of the crop.

There developed methods of culturing the bacteria with which to treat the seed so the growing plants would be inoculated. The expanding science of the soil demanded bacteriologists to improve and perfect legume inoculation with proper strains of bacteria for each of the commonly produced legume crops. For this work M.F. Miller, in 1914, obtained the appointment of W.A. Albrecht to the Department of Soils. With steam autoclaves for sterilizing media, he grew cultures of the various strains of rhizobia on agar gel fortified with minerals essential for the organisms. Not to be neglected in this life-giving soup, any essential unknown elements were provided by Albrecht by including suitable additions of wood ashes from his fireplace. The inoculum was distributed to farmers through county extension agents who promoted the production of legumes with clover and prosperity meetings. These meetings brought sweet clover into prominence as a green-manure crop plowed under ahead of corn.

The production and distribution of inoculum provided support of a graduate student (Harold Rhodes) and research projects of the department in the decade from the mid-twenties to the mid-thirties. Thereafter, the commercial production of inoculum developed to where it met demand.

THE CHEMISTRY OF COLLOIDAL CLAYS

The stimulus for this research was the clay concentrated in the subsoil of the Putnam soils of northeastern Missouri prairies. These soils were an enigma to M.F. Miller who, coming from the level productive glaciated soils of Ohio, recognized their potentials as farm lands in terms of a level terrain and a silt loam texture that was easy to work. Even so they were non-productive. Their poor condition was assumed to be associated with the tight claypan that retarded roots and the downward movement of water. Early attempts to improve such soils by means of tile drainage were not successful. Then a young PhD from Ohio, Richard Bradfield, in an interview convinced Miller that soil chemistry might be the solution to the problem. As explained by Miller "Bradfield was either a genius or a fool" and he employed him on the department staff.

Bradfield extracted colloidal clay from the Putnam subsoil using a steam-driven super centrifuge made by Sharples. At 34,000 rpm he obtained a colloidal fraction that in a three-cell electrodialysis chamber of his design separated the clay mineral from the surface-held cations leaving hydrogen ions in their place. This acid clay was then titrated with a base by which Bradfield characterized it as an exchange substance with an exchange capacity used today in characterizing the chemistry of soils and in their adjustments to produce crops through fertilization as guided by soil testing.

After Bradfield established a base there followed H. Jenny from Switzerland, a student of Wiegner in colloidal chemistry; L.D. Baver in soil physics, who took soil testing to the farmers on a railroad train car equipped as a soil-testing laboratory; C.E. Marshall, also a student of Wiegner, who elucidated the crystalline structure of the clay minerals in soils; William Upchurch in synthesis of clay from its elements; and, finally, by Ellis Graham who brought soil testing and tissue testing to its successful use in county soil testing laboratories throughout Missouri. (See Missouri Agricultural Extension Circular 345, March 1950, and Missouri Agricultural Experiment Station Bulletin 734, July 1959.)

In January 1938, as a sequel to Bradfield's work, Miller, upon the resignation of Baver, invited C.M. Woodruff to join the staff. Miller's suggestion was that Woodruff pursue the problem of low-crop yields from the Putnam soils. When Woodruff asked for suggestions, Miller started to speak and then stopped saying "no, I might influence you and you should pursue your own thinking on the subject."

Woodruff's first approach was to consider shattering the clay when it was dry in August and the soil was covered with a legume to withdraw the water and stimulate aggregation of the clay. This was done at the

McCredie Station with the assistance of Dwight Smith and Darnell Whitt by dual plowing to a depth of 16 to 20 inches in the summer of 1941. With a yield of 45 bushels an acre when average yields of corn through 1946 were no greater than 32 bushels, it was evident that this was not the source of the problem. Turning to Henry and Morrison's "Feeds and Feeding" it was evident that each bushel of corn produced required one pound of nitrogen in the above-ground portion of the plant, that 18,000 half-pound ears would be required to grow 125 bushels per acre and with these guide lines 128 bushels of corn per acre were produced in 1948 and yields in excess of 100 bushels per acre were repeated in five consecutive years.

Range J on the College's South Farms produced the first 128-bushel corn on an Experiment Station field in 1948 with 120 pounds of nitrogen at right. No nitrogen was used on the plot at the left. After 20 years in continuous corn the fertilized yield averaged 87 bushels an acre.

Graham and Woodruff took their message to a meeting of land appraisers. Graham talked about soil testing, tissue testing, and fertilization. Woodruff noted the capacity of any soil to grow 100-bushel corn if a four-foot deep post hole could be dug to provide the necessary water. D. Howard Doane, of the Doane farm management group, brought his staff to campus to hear further guides to the new production potentials. At the American Society of Agronomy meetings in Chicago, Bradfield indicated that Graham and Woodruff were misleading farmers on the potential of soils to produce such corn yields. However, the following year he applied the approach to a poor Upshur soil of New York State and produced his first 100-bushel corn after which he apologized for his criticism of the Missouri soil testing system as advanced by Graham.

An unfortunate aspect of this whole approach to production agriculture has been its universal adoption to the extent of surpluses that have lowered prices and removed the profits from farming. Farmers today are little better off than they were in the depth of the depression when average corn yields were never in excess of the 30-bushel category. The primary benefits of high-crop yields have been the support of an agribusiness industry providing farmers with fertilizers, seed, herbicides, insecticides, machinery, and huge tractors that leave no room for operators of small farms.

SOIL FERTILITY AND PLANT NUTRITION

This subject, contrary to the interest in crop yields, concerns an understanding of the role of elements in plant nutrition. Plant nutrition is also important to the animals feeding on the plants and this concern also extends to human nutrition in regard to bone strength, dental cavities, and some diseases.

Development of knowledge on this subject came through the insight and study of W.A. Albrecht who pursued the work in the face of obstructions and criticism from many sources. Even within the University he was not permitted to deal with animal nutrition since it was the prerogative of other departments. But, Albrecht circumvented this obstacle by using rabbits in which no one had an interest.

When he presented his views on the role of minor elements in plant and animal nutrition to the agronomy society, other department heads from adjoining states belittled his ideas. Yet, in a few years they were proposing investigations and seeking grants to support research on the subject.

Woodruff was introduced to the problem of animal nutrition through plants when he entered the College of Agriculture in 1928. Concrete Highway 40 had been opened the previous year and in 1931 when Woodruff went to the Bethany Soil Erosion Experiment Station, Highway 69 south to Pattonsburg had not yet been paved. Paving the highways provided mountains of crushed limestone at the quarries that had been screened from the gravel for concrete. The trucks of the time were four-cylinder flat-beds that preceded the dump trucks of a later day. Ground lime was hauled from the quarry eight miles with wagon and mules. Lime was scattered from the wagon with shovels for a small field of alfalfa. Trucks with mechanical spreaders were still 10 years away.

Albrecht recognized the lack of calcium in soils was associated with soil acidity. He connected this lack of calcium with milk fever of dairy cows prevalent throughout the state excepting the neutral alluvial soils of the Missouri River. He knew soils required lime to provide the calcium along with phosphorus which had already been accepted as a necessity for small grains and legumes. But Albrecht never visualized how sufficient lime could be applied to soils when crushing and hauling it was beyond the technology of the time. He suggested drilling fine lime with the seed but this approach proved inadequate.

To obtain information with which to support his assessment of the nutritional problem he asked county extension agents to wire collect whenever a cow came down with milk fever. The first call came from an agent at Steelville. Albrecht was unable to go but he asked Graham and Woodruff to see if they could get there before sundown and obtain color motion pictures of the cow. Neither were experienced in the use of the 16mm camera nor with color film. When Graham and Woodruff arrived the sun was down but they set the camera on a post and opened the lens obtaining the desired pictures. Then, a veterinarian injected calcium gluconate that brought the cow to her feet by the next morning. Samples of soil and of herbage from the pasture were deficient in both calcium and phosphorus. Albrecht's film "The Grass Is Greener on the Other Side of the Fence" did much to educate Missouri farmers to the need for lime and phosphorus in their soils. Crushed lime as a by-product of highway construction kept the lime trucks operating through the next three decades.

It is not possible to cover the detail of Albrecht's work in this history. A comprehensive treatment of the subject is in the Albrecht Papers published by Acres USA, P. O. Box 9547, Kansas City, Mo., 64133.

One of the key staff members in the investigation of soil fertility and animal nutrition was G.E. Smith of the Department of Soils. Not only did he promote the use of fertilizer throughout the state, but he supervised the animal feeding experiments that supported Albrecht's efforts. Few students coming from farms to the College of Agriculture today are familiar with the incidence of milk fever that existed a half century ago.

SOIL AND PLANT TISSUE TESTING

This subject is an old one. Back in the late 20s a few samples of soil sent in by farmers were tested. The first test performed was that for soil acidity. A strip of litmus paper was inserted in the center of a mudball. If the mud turned pink the soil was acid and needed lime. If it remained blue the soil was neutral or alkaline and needed no lime. The litmus was followed by the Comber test. This consisted of a solution of potassium thiocyanate in alcohol and acetone. Shaken with acid soil which made iron soluble the ferric thiocyanate was a deep red implying a need for lime. Neutral soils developed no red color. Then Richard Bray, Urbana, Ill., developed the "rich or poor" test for phosphorus. An acid solution of ammonium molybdate was shaken with soil in a test tube. After standing, the clear liquid above the soil was stirred with a tin rod to reduce the molybdate. A blue color indicated phosphorus. Most samples tested were colorless. George Browning, then a student, ran many of the soil tests. When a blue test was obtained he called all the staff from upstairs to come to the basement to see the blue color. These results are cited because people today deal with heavily fertilized soils that rarely test low in phosphorus and they have little concept of how poor soils were when 30 bushels of corn an acre was deemed a fair crop.

As a short appraisal of the development of soil testing in Missouri the following references are cited.

M. F. Miller, Extension Circular 339, *Testing Soils for Acidity*, 1936.

L.D. Baver and F.H. Bruner, Station Bulletin 404, *Rapid Soil Tests*, 1934.

E.R. Graham, Extension Circular 345, *Testing Missouri Soils*, 1950.

E. R. Graham, Station Bulletin 734, *Soil Testing*, 1959.

T.R. Fisher, Station Bulletin 1007, *Interpreting Soil Tests for P and K*, 1974.

Of these five the last two are of current importance. Bulletin 734 by Graham concerns the procedures of testing soils as established by O.T. Coleman, state extension soils specialist, in each of the county soil testing laboratories. This procedure is now the guiding system for the Experiment Station laboratory. Bulletin 1007 by Fisher is the first and only publication developing a theoretical approach to crop yield as a function of the supply of an element as measured by the soil test. As such, this bulletin is worthy of more recognition than it has received.

Today, the value and need for results of soil tests as guides for fertilizing soils is accepted almost universally by both farmers and technicians. Soil testing has become established as an essential practice for production agriculture.

LIME AND FERTILIZERS

The use of fertilizers in Missouri predates the Agricultural Experiment Station. At home during the holidays after his first course in soils, C.M. Woodruff suggested to his father that maybe the clover should receive some superphosphate. Woodruff grew up on a farm adjacent to the Missouri River where no one used fertilizer. Fertilizer was new. Woodruff's father's reply was that river soils didn't need fertilizer but that on the hill land of Gasconade County his father before the turn of the century used fertilizer on wheat or it didn't yield. What kind of fertilizer? The answer? Bone meal. Packing houses at Kansas and St. Louis disposed of slaughterhouse wastes as fertilizers. The first agricultural experiment stations to justify their existence analyzed fertilizers, collected fees for the work, and issued results to make certain farmers were getting what they thought they were getting in a bag of fertilizer.

The advent of lime came later. Farmers along the eastern seaboard dug marl from bogs as a source of lime. But use of lime to improve acid soils received little attention until Wheeler of Rhode Island published results on the subject in the last decade of the 19th century. His work attracted such attention that he was called to Washington by the U.S. Department of Agriculture to prepare bulletins on the subject and get researchers at the new experiment stations informed. M.F. Miller introduced lime treatments along with fertilizers on outlying experimental fields. He thought at first that Wheeler's experience was due to the acid glacial sands of Rhode Island and that midwestern prairies were much better soils. Litmus paper was Miller's first soil test and he found Missouri upland soils were acid and that legume crops responded to lime.

With agriculture dependent upon legumes for nitrogen prior to the availability of synthetic nitrogen after World War II the strength of the soil extension program was in advancing the use of lime on the land. Miller employed Paul Schowengerdt to join the extension staff in soils in order to develop a liming project. Schowengerdt coined the slogan "lime and legumes, clover and prosperity" that carried forward from the early 20s to well into the 70s. This program gave strength to the extension personnel in soils that through the years did much to help Missouri farmers keep abreast of advancements in the care of their soils. Among the staff of the soils extension project were O.T. Coleman, A.W. Klemme, John Falloon, William Shotwell, John Ferguson, Alva Preston, Marshall Christy, and although identified with the Department of Field Crops, there was Ross Fleetwood who obtained his masters degree investigating the response of crops to lime.

In later years research by W.A. Albrecht, G.E. Smith, and Earl Kroth did much to establish the role of lime in soils, and the quantities required on top-dressed pastures as contrasted with mixing in plowed soils.

It is difficult to pass up the opportunity to consider the role of lime on soils. It is a complicated, mixed-up role. Nothing simple as once thought. Albrecht emphasized the role of calcium as an essential element for plants and in the bones of animals that ate the plants. Growing legumes to fix nitrogen seemed to indicate that legume plants, usually containing more calcium than non legumes, required neutral soils. But field experiments with alfalfa and red clover indicated good growth in acid soils if the plants were provided sufficient nitrogen through fertilizer or manure. Apparently, the essentiality of neutral soils for legumes was a requirement of the rhizobia organisms that fixed the nitrogen rather than that of the host plant. Later attention focused upon the deleterious effects of aluminum in very acid soils, and of manganese in acid soils under anaerobic conditions. The advent of urea as a fertilizer that lost its nitrogen by volatilization when top dressed on top of recently applied lime injected another aspect of lime. The development of manganese deficiencies on shell soils was another such aspect, the snails seeming to prefer calcareous soils.

Now that fertilization has become an established practice in farming through the efforts of G.E. Smith, E.R. Graham, and A.W. Klemme, the current program of the department is carried forward by R.G. Hanson, D. Buchholz, J.R. Brown, and, in land use, by Neal Wollenhaupt.

IRRIGATION OF SUMMER GROWING CROPS

The history of irrigation as studied in the Department of Soils goes back to the department's beginning. Its need has always been recognized but how to use it with success has been slow to develop.

The first effective use of irrigation came on the alluvial soils of southeastern Missouri and along the Missouri and Mississippi rivers. The level terrain, the cash crops, readily available water in shallow wells, and development of pumps and power supplies account for the early adoption of irrigation in the lowlands.

Uplands were another problem. Here, attempts to irrigate received little attention until after the advent of fertilizers that would produce good yields of cash crops, primarily corn. Early research was influenced to much by the technology of the dry western states. It was a technology that could not be transferred to the sub-humid midwest.

Chuck Cromwell was brought in from Brawley, Calif. A.W. Klemme, after a stint with irrigation in Texas, undertook irrigation of both corn and soybeans in Missouri. Wayne Decker made investigations at the McCredie Field. The essence of this early work was that the water supply should provide 12 to 14 inches, that deep wells would not suffice, nor would surface impoundments. Also, when irrigating upland soils, maintaining soil moisture at field capacity did not permit developing the full-yield potential of the crop because of poor soil aeration and restricted root development.

The breakthrough in the investigations came in 1965 with natural rainfall on corn on Sanborn Field. Small, well-distributed rains through June, July, and August kept the surface soil moist throughout the summer but did not penetrate the claypan. When roots removed the water permitting air to follow downward until by crop maturity the available water of the deeper soil had been depleted. The result was a crop yield approaching 200 bushels an acre. This approach reduced the quantity of water needed from 12 to eight inches which could be supplied with surface impoundments. Irrigating corn on claypan soils is an accepted practice today and some farmers irrigate soybeans after corn is mature.

CLIMATOLOGY

M.F. Miller, upon his arrival in Missouri, stressed the importance of crop rotations as he had experienced them in the east where he grew up. After a few dry summers that eliminated new clover seedings, he concluded that the rotations of the east would not function in the Missouri climate and that a study of climate was an essential function of the Agricultural Experiment Station. Originally, the U.S. Weather Bureau was established to serve agriculture but the coming of the airplane changed the emphasis leaving agriculture somewhat neglected. Miller, after his retirement as dean of the College in 1945, succeeded in 1949 in obtaining the appointment of Wayne Decker as climatologist in the Department of Soils. Over the years additional personnel were added including Grant Darkow, Ernest Kung, and James McQuigg.

Upon reorganization of the Departments of Soils and Field Crops into the Department of Agronomy in 1967 the climatology group was established as the new Department of Atmospheric Science. Its contributions have proved of benefit to workers in soils, plants, animals, and engineering supporting Miller's recognition of agricultural needs for climatological information.

INSTRUCTION IN SOILS AND AGRICULTURE

After World War II a young GI came to C.M. Woodruff for advisement. He did not wish to obtain a degree. He intended to farm. His father who had attended the two-year winter short course for farmers in an earlier day advised him to attend the College of Agriculture to get acquainted with the professors, their thinking, and their work with field plots and animals that would allow him to keep abreast of developments through attendance at field days and extension meetings in later years. Woodruff placed him in courses that he considered to be helpful without meeting the prerequisites of enrolling him as a special student. The young GI attended two years, got married, and went home to a farming partnership with his father.

This incident is cited since it reflects the high regard with which former students of early years held their professors. It was not the subject matter. It was not the encyclopedia of facts buried in textbooks. Nor was it the attainment of good grades by regurgitating that which had been dealt with as classroom discussion and assignments. Rather, the emphasis of those mature individuals who had been students was placed in the character and thinking of the men who had taught them. These early professors were teachers in the true sense of the word. Their interests, their enthusiasm, their vision, and their understanding were attributes to be passed on to their students.

Looking back to the era of the mid-20s when the curricula of the College of Agriculture introduced a 35-hour requirement in science, the students found adequate opportunity to delve into the encyclopedia of facts as they were assembled in textbooks and elucidated by their teachers. This provided professors of agriculture ample time to dwell upon the interests of students in the subjects of agriculture, in the philosophy of farming, and in operating the family farm. Have we lost some of these early attributes of the College as it has grown into an extension of the educational system espoused for high schools?

In the beginning the Department of Soils was M.F. Miller, H.H. Krusekopf, and W.A. Albrecht. Before students entered the first course in soils, they were prepared by courses in chemistry, analytical chemistry, and organic chemistry; physics; botany; microbiology; and finally in agricultural geology. Somewhere along the line they also took zoology, agricultural chemistry, and animal nutrition. With such a background the subject of soils took on new meanings and opened new vistas and insights beyond anything a farm youth had ever anticipated.

To these early professors soil was a natural body to be studied from the viewpoint of how it developed into what it was. This is a reflection of the views of Curtis Marbut, a geologist, and with Krusekopf, who was strictly a pedologist. Soils were what they were to be classified on this basis and valued for what they were as they were responsible for good or poor agricultural purposes. Good farmsteads were found on good soils, poor ones on poor soils, hence soil classification and soil mapping came early in the pursuit of the subject. Not only did students study the soils of Missouri but Miller taught a course on soils of the United States. Soil management was another of his interests involving crop rotations, tillage, liming, and fertilization.

Understanding the functioning of the soil was Albrecht's focus. He taught courses on soil fertility and soil microbiology, stressing the chemistry of the mineral elements as they perform in soils and in plant nutrition and the role of microorganisms in the decomposition of plant residues to form the stable organic matter of soils. To Albrecht the whole future of the nation rested on soil productivity and its care necessary to maintain productivity.

Miller, realizing the meager knowledge of the functioning soil gained through his studies in Germany, added Richard Bradfield to the staff in the mid-20s. Bradfield dealt with the colloidal fraction of clay removed with a Sharples supercentrifuge and electrodialysed in a three-chamber cell of his design, by which he studied the exchange chemistry of the mineral ions held in the soil.

Following Bradfield there was Hans Jenny from Switzerland and C.E. Marshall from the University of Leeds in England. These investigators did much to establish a firm base of the functional chemistry of soils. Hans Winterkorn, from Heidelburg, Germany, worked in soil mechanics and established a course in the College of Engineering before proceeding on to Princeton.

As Bradfield moved on Miller obtained L.D. Baver who had studied under Bradfield and who was impressed by the importance of soil structure in the performance of soils as structure influenced the air and water relations of soils. Baver wrote one of the early textbooks in soil physics and generated a following of graduate students who took up this phase of soils in other institutions.

The generation of staff members that followed Miller, Krusekopf, Albrecht, Bradfield, Jenny, Baver, Marshall, and Winterkorn were G.E. Smith, E.R. Graham, C.M. Woodruff, Wayne Decker, and E.O. McLean who took a position at Arkansas shortly after World War II. It was the advent of synthetic nitrogen as ammonium nitrate and anhydrous ammonia that became available from the ammunition plants after the war that revitalized interest in soils and soil fertility. For several years the demand for agronomists by fertilizer companies, the extension service, and soil-testing laboratories kept the classes in soils subjects filled with students. New staff members included Victor Sheldon in soil microbiology who soon accepted a commercial position; Elsworth Springer in soil classification; James McQuigg, Grant Darkow, and Ernest Kung in climatology, who, with Wayne Decker, became the Department of Atmospheric Science in 1967 when soils amalgamated with crops as the Department of Agronomy. Also added to the soils staff prior to the advent of agronomy were George Wagner in soil microbiology and James Brown in soil fertility. Before Marshall retired William Upchurch continued the work with Marshall in soil development and clay mineralogy. C.L. Scrivner in soil classification followed. Earl Kroth and T.R. Fisher completed the new staff concerned with soil fertility and soil testing.

During the period after World War II, Dwight Smith, Darnell Whitt, and Walter Weischmeyer, as research associates on the Erosion Experiment

Station at McCredie, were instrumental in the initial emphasis on producing 100-bushel corn on the claypan soils and the development of a universal soil loss equation now used extensively by Soil Conservation Service nationwide. The McCredie plots were valuable teaching tools used extensively as evidence to students of the technology as viewed on class field trips and as special problems studied by students.

No student of soils ever graduated from the College of Agriculture without having experienced first-hand a tour of the major soil regions of the state. Missouri provided an unique setting for studying soils during the era when agricultural production was determined by the innate qualities of soils. The central location of the College was at the confluence of the glacial soils of the north, the limestone prairies of the great plains to the west, the Ozark uplift of granite and cherty dolomites of the Ozarks to the south, and through these ran the Missouri River bordered as it was by the loess of the hills. All of these could be seen from the top of the Memorial Tower at the center of the White Campus.

Albrecht, in 1938, purchased a Dodge bus by which students in soils could be taken on field trips through various soils regions that illustrated soil parent material, soils development and morphology, agricultural usage, and farming systems. This was the first bus owned by any department on the University campus. A ride in it through the river hills with Mr. Henley as driver will never be forgotten.

Students of soils of the early era were of two persuasions. The majority were students of general agriculture who hoped to become good farmers but, in reality, they became vocational teachers, county extension agents, farm managers, soil conservation technicians, and salesmen for agricultural products. The remainder of those studying soils found in the subject a field of interest that led them to pursue graduate studies to become university teachers, research workers with federal agencies, and with the Agricultural Experiment Station. Few students entering the College ever did so with a view to becoming a part of the University system. At the time there was the implied assumption that a degree from the College of Agriculture would enable a young farm youth to become a successful farmer. Having grown up on a farm, they liked what they saw and what they did and they wanted to be part of it in a better way than the economic condition from which they came.

After synthetic nitrogen and 100-bushel corn from 1950 to 1980 everything in agriculture was attractive to students. Interest in soil fertility, soil testing, and fertilizers topped off with irrigation to ensure success made agriculture a field of study with a future. There evolved a tremendous agricultural industry supplying farmers with seed, fertilizer, machinery, insecticides, and herbicides. The agribusiness industry became an outlet for graduating seniors seeking jobs.

In the end agriculture suffered. Production exceeded demand; prices of farm products declined until the returns from farming went to pay for the supplies required; escalated land value exceeded the income-producing capacity of the land; and the introduction of huge four-wheel drive tractors with associated tillage equipment, large combines and picker shellers for harvesting, and 18-wheeler trucks for transporting grain and cattle moved livestock production from the farm to the feedlot. All put together the small farmer was eliminated as an economic entity in agriculture, followed by bankruptcies of both farms and agribusiness industries. The impact of these changes in agriculture on the students entering the College of Agriculture changed the focus of their interests and the courses they took in soils. No longer may a student look forward to solving the problems of making poor soils productive. These problems have been solved. Much of the future lies in replacing the teachers and research workers of today as they must be replaced in the future. In the world today there is a demand for soil scientists to assist in solving agricultural problems of the tropics and of the developing nations. Thus, graduate students in soils today find ample opportunities for a lifetime of work in the field.

WHY SHOULD A STUDENT GRADUATING FROM HIGH SCHOOL CONSIDER OBTAINING A DEGREE FROM THE COLLEGE OF AGRICULTURE?

A youth finishing high school, usually 18, embarks upon a course molded a great deal by experiences and environment of the previous five to seven years. This is a rather short exposure to the swings and vicissitudes of life that will hopefully continue for another five to six decades. The choices made in the ensuing decade after high school establish the path into the future.

Choosing the College of Agriculture reflects an agricultural background, or a spark of interest generated by a teacher, a course in vocational agriculture, or a potential for employment in a field for which the individual has acquired a feeling of understanding and of competence. Farm youth seldom see themselves as architects, engineers, doctors, investigators, or in myriads of other fields.

Entering the College of Agriculture opens a vista of new opportunities in which the average farm youth thrives. Very often there is a change in objectives as the course of studies advances. This is an age when future mates are chosen and, with them, the responsibilities that are entailed. The particular profession that is chosen tends to attract one in terms of its stage of development at that particular time. Seldom does the student, or any individual for the matter, see the status quo of the present as what it might become in the future. With such an uncertainity, then, what is the contribution of a degree in agriculture to the welfare of the graduate as he or she marches away into the future?

This is written from the vantage point of 60 years after leaving high school in June 1928. My choice of entering the College of Agriculture was conditioned by the previous 10 years of growing up on a large Missouri River bottom farm in Ray County. The ferry boat crossing the river at Lexington landed on our place. This period began following World War I with halcyon days of my youth and of agriculture when the price for wheat went to $2.50 a bushel and corn to $1.50. Both of these were without costs of fertilizer, herbicides, insecticides, or high-priced seed. Ears of corn were selected from the crib and shelled as a source of seed. Automobiles were not ubiquitous as they are today. Farm tractors came into use, wheat was threshed by a machine that neighbors purchased when the price of threshing went to 18 cents per bushel. The new Minneapolis separator was run by a used 25-horse Geyser steam engine that previously had pulled 12, 12-inch moldboard plows. They paid for the rig threshing their own crops in three years.

The soil on our place was new, the stumps of trees still needed shooting with dynamite, which I learned to use working with my father. But 12 years of cropping to corn and wheat reduced yields to half of the original and that of wheat (Harvest Queen) was doubled where sweet clover cut as stubble hay was replanted to wheat that fall. These soils were rich in lime, phosphorous, and potassium but did not withstand the loss of nitrogen by intensive cropping. Declining yields, low prices for farm products, and high prices for consumer goods brought these glorious days of farming to a close in the mid-20s, inducing me to enter the College of Agriculture in September 1928 as a means of learning how to farm more profitably or to prepare for professional work in teaching or the agricultural extension service.

In 1929 the banks failed, farmers were bankrupt, and insurance and mortgage companies took possession of farms. Nearly all students in the College of Agriculture earned their room and board and in addition worked in the various departments of the College. Signs in front of houses along Hitt Street advertising room and board from $25 to $30 are remembered. The early years of the decade of the 30s brought no rewards in terms of high-paying jobs to the graduates of that period. Most graduates found home to be a welcome refuge in a world that provided little promise for the future.

The break came in 1933 with the federal program of work relief. Among those programs were the Civilian Conservation Corps—CCC—that took young men for work in conservation providing camps, food, clothing, and a small measure of funds for the family at home. The Works Progress Administration—WPA—initiated large construction projects that employed both men and materials. The Civil Works Administration—CWA—that employed men at marginal wages to provide food and living conditions for destitute families. Lastly, there was the Public Works Administration—PWA—that involved large-scale operations of a public nature.

These observations are cited because they required foreman, engineer, and supervisor positions that were filled with graduates of the College. Expansion of soil conservation by the Soil Conservation Service—SCS—absorbed many technically trained men, and the attempts of the U.S. Department of Agriculture to alleviate the problem of surpluses and low prices of farm products through the Agricultural Stabilization and Conservation Service—ASCS—provided many positions for older and experienced graduates of the College. Numerous farm management services evolved and employed personnel trained in agriculture. The Doane agency employed college-trained men.

The essence of this report on the decade of the 30s when agriculture was in the doldrums points up the importance of studies in agriculture and in the science of agriculture to the welfare of young farm people moving into the unknown of the future. It is sufficient at this stage to emphasize that the order of the past has been change; that change will characterize the future, and very likely at an accelerated pace. It is the preparation of the four years in college that enable most individuals to accept and adjust to change. It is easy to predict change. It is not easy to predict what that change will be: Consider what happened in the decade of the 40s and the lot of the graduate in agriculture.

It should be clear by this time that college graduates at the turn of the century were few indeed among a very large population of farm people and that, by the 40s, that ratio was narrowing. By the 80s the major narrowing of the ratio was not so much by increasing number of graduates as it was by decreasing numbers of farmers. The decade of the 40s brought World War II. Here, young graduates were found in the officer corps while at home those of an earlier era shouldered the responsibility of providing the production necessary to support the national effort. The termination of fighting released a flow of young men for training under the GI bill that absorbed every college-trained man available to teach, in both classroom and field, the young men returning to the farm. Coincident with this agricultural program was the remarkable advancement in agricultural technology made possible by the conversion of ammunition plants to fertilizer plants. The development of agricultural chemicals, hybrid corn, and large powerful machinery increased farm size and crop yields at the expense of farm people.

The accelerated developments in agriculture through the 50s, the 60s, and the 70s absorbed youth trained in the many facets of agriculture creating an agribusiness industry that was new to agriculture and to the people involved. But here again, as occurred in the 20s after World War I, surplus production, low prices for farm products, and ever-higher prices for farm inputs brought farm failures, bankruptcies in both farming and agribusiness, and disillusionment to many young families faced with making a change in direction in the midstream of life. The decade of the 80s presented the high school graduate with a need to prepare for a future of change, of new development, of old practices discarded, and most important of new opportunities that will arise. An education emphasizing the sciences, rather than practices, provides the foundation necessary in a changing world.

THOSE WITH SOILS RESPONSIBILITIES

The following are staff members in the soils area with approximate dates of appointment: M.F. Miller, 1904; C.B. Hutchison, 1906; H. H. Krusekopf, 1908; R.R. Hudleson, 1914; C.A. Le Clair, 1914; W.A. Albrecht, 1914; F.L. Duley, 1915; R. Bradfield, 1920; Hans Jenny, 1927; L.D. Baver, 1928; R.E. Uhland, 1930; C.M. Woodruff, 1933; Hans Winterkorn, 1934; D.D. Smith, 1935; D.M. Whitt, 1935; J.L. Haynes, 1935; C.E. Marshall, 1936; G.E. Smith, 1937; E.R. Graham, 1937; W.D. Schrader, 1941; Walter Weischmeyer, 1942; E.O. McLean, 1943; M.E. Springer, 1946; C.L. Scrivner, 1947; W.L. Decker, 1949; V.L. Sheldon, 1950; W. J. Upchurch, 1953; J. A. Roth, 1953; R.E. Burwell, 1954; G.H. Wagner, 1957; E.M. Kroth, 1959; J.R. Brown, 1963; E.C. Kung, 1966; G.L. Darkow, 1967; J.D. McQuigg, 1967; R.W. Blanchar, 1968; J.M. Bradford, 1970; T.R. Fisher, 1972; E.C.A. Runge, 1973; G.W. Colliver, 1974; R.B. Grossman, 1975; W.R. Teague, 1976; R.G. Hanson, 1976; L.B. Hughes, 1978; H.C. Folks, 1980; C.J. Gantzer, 1982; R.J. Miles, 1983; B.G. Volk, 1984; S.H. Anderson, 1985; and R.D. Hammer, 1986.

The following have held extension soils specialist appointments: Paul Schowengerdt, William Shotwell, O.T. Coleman, A.W. Klemme, John Falloon, John Ferguson, Alva Preston, Marshall Christy, C.J. Johannsen, D.D. Buchholz, N.C. Wollenhaupt.