AGRONOMY FACTS

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POLLINATION AND FERTILIZATION

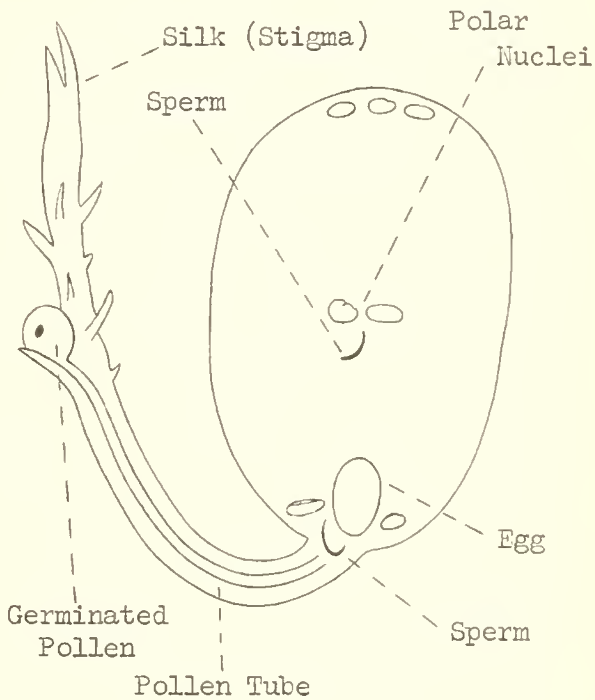
The pollen that we see flying in fields of corn in July and August plays an important part in the production of the corn crop. These tiny grains are essential for the formation of the kernel; without them the cob would be bare and useless. Pollination is essential not only in producing corn, but in producing all other crops. Without this process, almost all of the seed plants would disappear, leaving only those that reproduce by cuttings or other special mechanisms.

Pollen is produced by the male flowers of the corn tassel. The female flowers are borne on the ear. Plants of this sort, in which the flowers are carried separately, are said to have imperfect flowers. Most plants have perfect flowers; that is, the male and female parts are carried within a single flower, as in wheat, oats and soybeans. Plants that have perfect flowers are often self-fertilized, while those that have imperfect flowers are usually cross-fertilized. In many species with perfect flowers, stray pollen is usually excluded because pollination occurs before the flower actually opens. This makes it virtually certain that self-pollination will take place.

At the time of sexual maturity, mature pollen is released from anthers in large amounts. It has been estimated that a single corn tassel will produce as much as 25,000,000 pollen grains. This estimate is probably high, but even the most conservative estimate would be that each silk produces at least 9,000 pollen grains.

Mature pollen is transferred from the anther to a receptive surface, called a stigma, by wind, gravity, or insects. Upon alighting, the pollen grain germinates, and the pollen tube grows down the style (silk in corn) until it reaches the ovary.

Fertilization in Typical Grass Species (Schematic)



In corn this process usually takes 24 to 26 hours. Two sperm move down the pollen tube and enter the ovary. One of these sperm unites with the egg and the other unites with two polar nuclei. The egg and sperm union produces the embryo (the new plant), and the polar nuclei-sperm union produces the endosperm. This process is called fertilization. Cell division proceeds in these tissues until the mature seed is produced.

Endosperm in corn consists of the aluerone layer and the soft and horny starch of the kernel. In soybeans the endosperm is microscopic, and the food for the new embryo is stored in structures called cotyledons. Cotyledons are a part of the embryo itself, and in young soybean seedlings they look much like two thickened leaves.

Environment plays an important part in the success of pollination. For example, high humidity quickly bursts pollen of red clover. The higher seed set of this species in dry climates is doubtless due to the lower humidity. High temperatures usually reduce the time that pollen will live. Species vary in the length of time pollen remains viable. Barley pollen is particularly short-lived if removed from the flower. In contrast, wheat pollen can be collected and stored at room temperatures for as long as six hours and still effect fertilization. Corn pollen remains viable for a shorter period, possibly no longer than two or three hours under ordinary field conditions. Viability is lost much more quickly when temperatures are high than when they are low.

Under Illinois conditions, pollen viability rarely limits corn production. In 100° temperatures, pollen remains viable for only a short time. During early morning hours when temperatures are lower, enough pollen is usually shed to insure a satisfactory seed set. However, extremely high planting rates or drouth often causes late silking and many ears may not be adequately pollinated.

The pollination habits of a crop species largely determine the methods that plant breeders may use in improving that crop. In corn, the male and female flowers are widely separated, and hybrids may be produced easily and inexpensively. Thus their large-scale use is practical. Oats, wheat, and soybeans, however, cannot be easily hybridized because the flowers are perfect and tiny. Hybrids of these crop plants will therefore probably never be commercially available.

D. E. Alexander
10-17-55

AGRONOMY FACTS

THE FUNCTION OF CO_2 IN CROP PRODUCTION

Carbon constitutes 40-45 percent of the dry weight of most crop plants. No other element contributes as many atoms to the formation of a plant. Carbon molecules linked one to another form the basic skeleton of the carbohydrates, fats, proteins, and other substances that make up a plant. The oxidation or "burning" of the reduced carbon in fat and sugar provides the energy for plant growth. Obviously, an adequate supply of carbon is imperative for good crop production.

The basic supply of carbon for plants is in the form of a gas, carbon dioxide, or CO_2. Carbon in this form is at its lowest energy level--completely oxidized or burned--and is very stable. The normal CO_2 concentration of the atmosphere is about three parts in 10,000 parts of air, or 0.03 percent. Except in the vicinity of the soil or photosynthesizing plants, this figure is relatively constant. The constancy is maintained by a vast reservoir of CO_2 dissolved in the oceans, both as the gas and as carbonates (the reaction product of CO_2 and H_2O). Air passing over the oceans gains or loses CO_2 until the normal concentration is re-established, and large masses of air continually move from oceans to land and off to the oceans again.

The plant absorbs nearly all of the CO_2 it requires from the atmosphere, the gas diffusing in through small pores in the leaves. Some CO_2 is absorbed by the roots and is translocated to the leaves in the upward-moving sap, but the amount so supplied is believed to be of minor importance (about 5 percent at most).

Plant leaves are amazingly efficient in absorbing CO_2. They can remove as much as 50 percent of the CO_2 from a layer of air which is rapidly passed over photosynthesizing corn leaves. If it were not for this high absorption efficiency, plants would make very poor growth, since the concentration of CO_2 in the air is so very small.

The CO_2 that is absorbed by the leaf is transformed to sugars in the chloroplasts, which are small, more or less rounded bodies to be found in the cells of all green tissue. The chlorophyll of the chloroplasts absorbs light (principally the red and blue wave lengths, leaving the familiar green color) and uses the light energy to split off hydrogen from water. The hydrogen thus gained is used to "reduce" carbon dioxide to a higher energy state--the state in which it occurs in sugars and starch. This reduction to a higher energy state is an extremely complicated biochemical process, but it can be summarized as follows:

1. The CO_2 absorbed by the chloroplasts is added by an enzyme to a phosphorylated 5-carbon sugar. This forms an unstable 6-carbon compound, which immediately splits to give two phosphorylated 3-carbon acids.

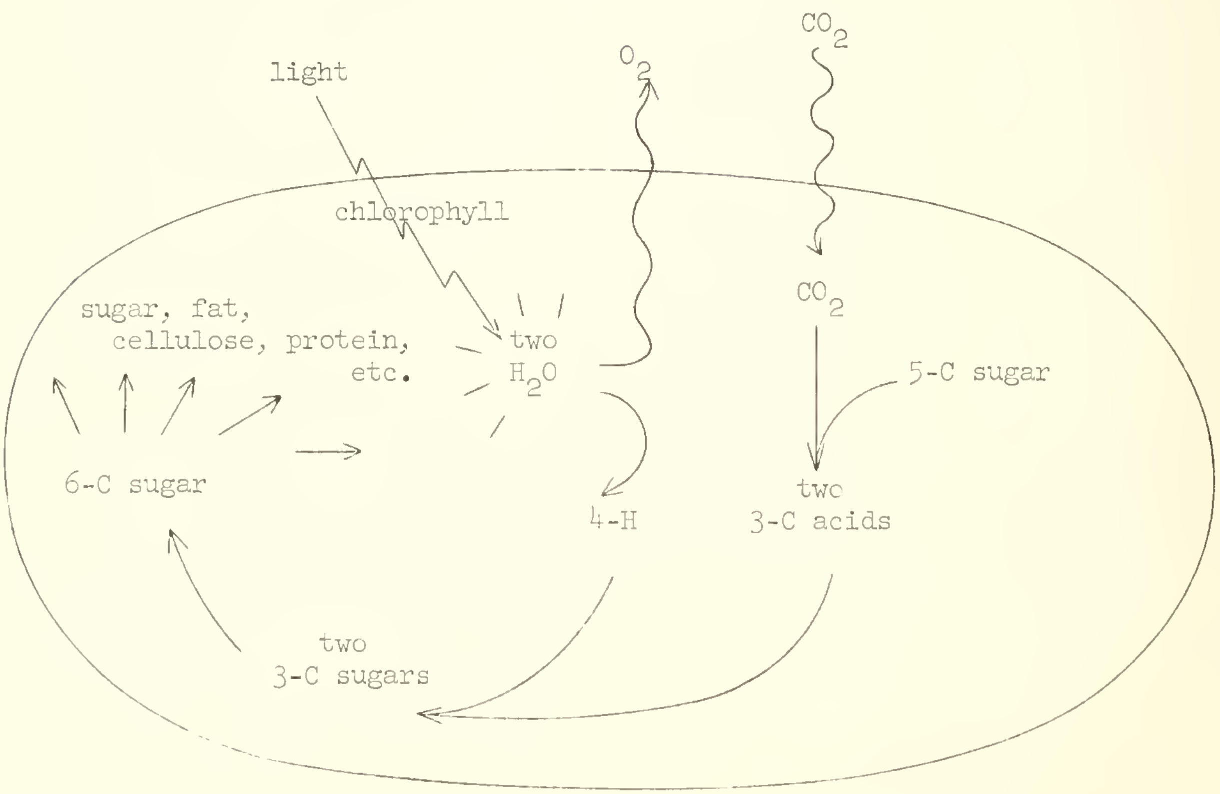
2. The hydrogen produced by the splitting of water is added to the 3-carbon acids, which then condense to give a stable 6-carbon sugar, a phosphorylated glucose. The phosphorylated glucose is a key compound that can be readily transformed to starch, cane sugar, fat, amino acids, etc. The figure on the back schematically depicts the photosynthetic process.

Greenhouse and laboratory experiments have shown that the concentration of CO_2 in the atmosphere is far from optimal for photosynthesis. By increasing the CO_2 concentration about 2.5 times, the photosynthetic rate of plants in bright sunlight can be doubled. There is some question, however, about the effect of still higher concentrations of CO_2. While short-time photosynthesis continues to increase, the higher concentrations of CO_2 have a toxic effect that reduces growth.

Many investigators have grown crop plants to maturity in CO_2-enriched air in greenhouses, and with few exceptions they report yield increases of 20 to 200 percent. Exceptions apparently occur when the CO_2 concentration is raised too high. There is no accurate evaluation of just what concentration of CO_2 would produce maximum photosynthesis without injuring the plant, but it appears that a 50-100 percent increase in concentration would be nearly optimal, depending on the species concerned.

Field studies on the effect of CO_2 enrichment have also been carried out, and for the most part these results also show yield increases. Field studies are much more difficult to make than greenhouse studies, because the gas is not contained and winds will carry it away. However, CO_2 is a heavy gas, and if released near the soil it will tend to "hang" in the vegetation in high concentration if there is not excessive turbulence due to winds. Even though marked yield increases of such crops as sugar beets have been obtained by CO_2 enrichment of the air, such "fertilization" is not commercially practical because of the excessive cost of supplying the gas.

Actually it appears that sizable yield increases could be obtained if one could only maintain the normal concentration of CO_2 around the crop during the daylight hours. As it is, the CO_2 concentration in a field of rapidly growing corn during the daylight hours will average about 25 percent less than normal. Measurements made at Ames, Iowa, show that even at 500 feet above the cornfield the concentration will be reduced 10 percent. Such depletions occur on windy as well as still days



and leave no doubt that the crop can absorb CO_2 more rapidly than it can be brought down from the upper atmosphere.

The upper atmosphere is not the only source of CO_2 for the plant, however. The respiration of microorganisms and plant roots produces large amounts of CO_2 in the soil, which diffuses up into the atmosphere about the leaves of the crop. A fertile, warm, moist soil, well supplied with organic matter, will give off as much as 300 pounds of CO_2 per acre during the daylight hours. Inasmuch as a very rapidly growing acre of corn will absorb about 400 pounds of CO_2 in the same period, it can be seen that the soil can do much to maintain favorable concentrations of CO_2 about the leaves. If it were not for this evolution of CO_2 from the soil, the concentration of the gas in the cornfield during the day would undoubtedly be reduced more than the 25 percent below normal previously quoted.

The point bears emphasizing, however, that, if the soil is to be effective in this respect, it must be fertile, moist, and warm, with a high organic matter content and a structure conducive to rapid gas exchange. In short, production of CO_2 by the soil will be maximal in those soils that have long been recognized as producing excellent crops. But just what share of the yield is to be attributed to increased CO_2 concentration about the leaves? Experimental evidence does not permit this question to be answered with exactitude, although an experiment conducted in Sweden with sugar beets 30 years ago suggests that it might be appreciable.

In this experiment, manure, instead of being worked into the soil, was allowed to ferment in troughs between the beet rows. This fermentation prevented the roots from obtaining the nutritive elements, but the air around the leaves was enriched by the escaping CO_2. A 19 percent increase in yield over controls was obtained by this treatment. Such results suggest that an appreciable part of record corn yields may be due to increased CO_2 coming from the heavily manured soils that seem to be an invariable part of such yields.

J. B. Hanson
1-16-56

AGRONOMY FACTS

RADIATION AND PLANT BREEDING

In 1927 and 1928 Dr. H. J. Muller, now of Indiana University, and the late Dr. L. J. Stadler, of the University of Missouri, reported that X-ray and ultra-violet radiation brought about heritable changes (mutations) in living organisms. (Doctor Muller was awarded the Nobel prize in Medicine in 1946 for this work.) Since the rate of mutation was thousands of times greater in irradiated material than in untreated material and, further, since some of the mutants appeared to have qualities that plant breeders were looking for, it was immediately suggested that plant breeders use this new technique.

At that time corn breeders were perfecting hybrid corn, and other breeders were convinced that the new tool was not well adapted to their programs. Most breeders and geneticists were impressed with the fact that the vast majority of the mutations were deleterious, i.e., the plant that possessed the new character yielded lower or was otherwise less desirable than already existing strains. Hence the use of irradiation in breeding was largely neglected.

If we examine critically the changes brought about in the hereditary material of an irradiated individual, we can make some interesting observations. Muller and Stadler found that these changes could be roughly placed into three classes:

1. Intra-genic changes, i.e., changes within the gene itself that are similar to those found in nature. These changes behaved in a Mendelian fashion. No differences in viability of pollen or egg were evident and normal segregation occurred in the F_2. Unfortunately, these changes are the least common ones that are induced by radiation.

2. Deletion, i.e., destruction of a small part of the chromosome itself. Critical studies by Stadler revealed that many of these changes were so small as to be undetactable when he looked at the chromosome under a microscope, but genetic studies showed that a number of genes had been destroyed.

3. Structural rearrangement of chromosomes. Many of the mutations involved the translocation of part of one chromosome to another chromosome, or the inversion, or change in gene order, of a single chromosome. These changes produced varying degrees of sterility, either on the female or male side, or on both.

Swedish plant breeders, however, started irradiation breeding in barley and other cereal crops and were able to show that mutants could be produced that matured earlier and had stiffer and shorter straw, greater resistance to certain diseases and, in a few cases, higher yield. However, these useful mutants were very rare. Swedish workers estimate that only one in a thousand of these mutations may be of value in a breeding program.

An increase in radiation breeding occurred after World War II in the U.S., largely because of the financial support of the Atomic Energy Commission. Radiation breeding in corn, wheat, oats, soybeans, rye, peanuts, cotton, and several other field crop species is currently under way in agricultural experiment stations throughout this country. It is still too early to anticipate the eventual outcome of all this work, but the conclusions on the following page appear to the justified as of now.

1. It is improbable that the mutants produced in a strain by irradiation will be used directly by farmers. It is more probable that the new quality will be incorporated into new varieties by conventional plant breeding methods and that these varieties will be released only if they possess advantages over existing varieties.

2. The use of radiation does not appear to be a profitable venture for plant breeders unless a desired quality does not exist or cannot be found in the species under improvement.

3. No drastically new and completely superior varieties can be expected through irradiation treatment alone. Since the discovery of the mutational effect of ionizing radiation in 1926, millions of individual seeds, plants, and pollen grains have been treated with X-rays, neutrons, and ultraviolet rays. Some heritable changes have been wrought. All of them are more or less similar to the changes that occur at rarer intervals without man's intervention, and most of them are deleterious to the individual that inherits them.

D. E. Alexander
3-26-56

AGRONOMY FACTS

THE YELLOW DWARF (RED LEAF) DISEASE OF OATS

The red leaf (yellow dwarf) disease of oats probably has been present in the U.S. for many years. Excellent descriptions of what appear to be the same disease were published as far back as 1898. Since 1945, however, the disease has become increasingly more prevalent. The reason for this increase is not known, but it does not appear to be associated with the continual change-over in oat varieties.

Red leaf is caused by a virus that can be transmitted by at least five species of aphids commonly infesting small grain and grasses. The virus cannot be transmitted mechanically, in the seed, or through the soil.

The virus has been shown to be identical with the one causing yellow dwarf disease of small grain in California. The name "yellow dwarf" was selected by California workers on the basis of outstanding symptoms produced by the virus on barley and wheat.

The disease usually appears first on the edges of a field and in "spots" or circular areas varying from a few feet to 30 or more feet in diameter. Sometimes these areas may overlap, and in years when aphids are very abundant a field may be uniformly affected. Farmers frequently have failed to associate earlier aphid infestations with the disease, since the first symptoms usually appear in about 14 days. Sometimes nearly all aphids have disappeared by the time the first symptoms can be seen.

The first symptom of the disease in oats is the appearance, usually near the leaf tip, of faint yellowish-green blotches that can best be seen by holding the leaf blade up to the light. When first formed, the blotches are somewhat variable in size and shape and are usually less than a few centimeters in size. The blotches enlarge rather rapidly, merge, and turn various shades of red, brown, and yellow-orange. Cool temperatures (70° F. and lower) favor the appearance of red pigments in the affected leaves, whereas temperatures of 75° F. and above suppress their appearance. At the same time, the yellowish-green blotches continue to appear on successively lower portions of the leaf in advance of the changes in color. The affected portions of the leaf often die rapidly.

In addition, a rather characteristic inward curling of affected leaves frequently occurs. Symptoms generally appear on the oldest leaves first and then successively involve the younger leaves. Occasionally the youngest leaves will show a longitudinal striping resulting from a yellow-green color in the interveinal areas and a darker green in the tissue over the veins. The root system is as severely stunted as the tops of the plants.

Blasting of the florets is the most serious aspect of the disease. It may vary from only a few blasted florets to complete failure of the plant to head. A shriveling and lower test weight of kernels also may occur. The severity of the disease depends on the variety of oat infected, the age of the plants at the time they become infected, and the strain of virus involved.

Winged aphids moving into small grain fields in the spring from various grasses are believed to be responsible for the initial spread. Each adult aphid is capable of producing daily from 10 to 20 young, which upon maturity (one to two weeks) also begin to produce. These later aphids are usually wingless and move about by crawling from plant to plant. When food conditions become unfavorable, winged forms develop which fly to other fields of small grain and grasses.

In order to transmit the virus to healthy plants, the aphid first must acquire it by feeding on diseased plants. However, once the aphid has acquired the virus, it apparently is able to transmit it for the rest of its life.

Virus-free aphids--less than a hundred per plant--cause very little damage to small grain. The greenbug is an exception, since it secretes a toxin. A single viruliferous apple-grain aphid is able to transmit the virus to a healthy oat plant in as short a time as four hours.

For an aphid-transmitted virus to cause serious loss in an annual crop raised from seed, the virus must spread rapidly. Rapid spreading can occur only if the crop is easily infected, the source of the virus is readily available, and the vector is very numerous and active. Fortunately, all of these conditions do not usually occur at the same time, and losses therefore vary greatly from year to year and from locality to locality.

No oat variety tested has been found to possess satisfactory resistance to red leaf disease. Therefore, an intensive effort is being made to locate sources of resistance in oats.

Early planting is the only practice that can be recommended at present. This recommendation is based on the fact that large plants are better able to "tolerate" the disease than smaller ones.

R. M. Takeshita
5-14-56

CORN HYBRIDS FOR SPECIALIZED FARM AND MARKET USES

Corn is an extremely versatile crop. Consequently, breeders are able to select types for particular uses. They may work with dent, sweet, pop, flint, floury, or waxy corn. These types, however, may be modified greatly by breeding and selection.

Livestock feed. From 75 to 90 percent of the corn crop in the United States is fed to livestock. In contrast, most of the corn crop in many other areas of the world is used for human food. Most livestock feeders in the United States prefer a dent grain that is yellow, soft, and high in quality and quantity of protein. Feeders in many other countries prefer a white flint corn.

Corn has certain limitations for feeding. It is low in quality and quantity of protein and is relatively low in vitamins. Some feeders also complain of poor palatability and reduced gains from certain hybrids. Many feeders grind the harder types.

Corn breeders need to develop special hybrids with high tonnage and better quality of silage and green feed. Multiple-eared, heavy-tillering strains may be useful for this purpose. Consideration must be given to yield and percentage of dry matter, proportion of ears to stalks and leaves, and percentage of crude fiber and protein. These studies should be supported by digestibility experiments and by feeding trials.

Milling industry. Wet millers desire strains that are high in starch, oil, and protein. Since corn contains about 70 percent starch (dry basis), a variation of one or two percent is important in large-scale operation. The industry claims that flinty types do not steep and process so well as softer types.

Most dry millers prefer a kernel that is semihard and vitreous and that does not have too much soft starch on either the tip or the dent end. They want neither the shoe-peg type nor small, round kernels. The dent must not be too deep or the hull too rough. Kernels of this type make chaffy or chalky products which are fit only to put into feed. The cob color is of little consequence.

An adequate supply of white corn is another requirement of dry millers. Consumers claim a distinct preference for the flavor and taste of meal made from white corn. The finished-product demand is for either pure white or pure yellow.

Protein content and quality. Protein is an expensive but necessary constituent of food and feed. The University of Illinois gave the first evidence that protein and oil content in corn could be greatly increased or lowered by breeding. After 50 generations of selection, the average protein content was 19.5 percent for Illinois High Protein and 4.9 percent for Illinois Low Protein. These open-pollinated strains yield only about 50 percent as much grain as adapted hybrids. Fortunately, the high protein trait can be transferred to standard inbred lines by breeding procedures.

Quality of protein is fully as important as quantity of protein. The corn kernel contains two main types of protein. That found in the endosperm is primarily zein. Zein is deficient in tryptophane and lysine, which are essential for animal nutrition. The other type of protein, found in both endosperm and germ, contains both tryptophane and lysine and is biologically balanced. The corn breeder would like to increase the percentage of these amino acids in the endosperm protein. The alternative is to add them to the diet from other sources.

Oil for industry and high-energy feed. Corn oil, a valuable by-product of the starch industry, is high in energy value for livestock feeding. Most of the oil is in the germ of the kernel. Germ protein contains tryptophane and lysine, is biologically balanced, and is probably more valuable for livestock feeding than endosperm protein. High-oil hybrids having a high proportion of germ to endosperm should therefore benefit both the starch industry and livestock feeders.

After 50 generations of selection at the University of Illinois, the average oil content of Illinois High Oil was 15.4 percent compared with 1.0 percent for Illinois Low Oil. Unfortunately, these open-pollinated high-oil strains are low yielding. High oil, however, was transferred to standard inbred lines at the Illinois station by crossing, followed by back-crossing, selection, and self-fertilization. Selection for high oil was accomplished by selecting ears bearing kernels with large germs.

Breeding programs have been inaugurated by several Corn Belt agricultural experiment stations and private hybrid seed corn companies to develop hybrids with high-oil or high-protein content. Some of these hybrids appear to be very promising. For example, Ill. 6063 produced 14.0 percent more protein, 32.8 percent more oil, and was 8.5 percent superior in grain yield to U. S. 13, a standard hybrid. However, these Illinois experimental combinations are not yet in commercial use.

Zein for special fabrics. Protein content of corn grain may be increased by breeding and by high applications of nitrogen fertilizers. Most of the increase of endosperm protein is zein, which is not high in nutritive value because it is poorly balanced among its constituent amino acids.

Zein is obtained from the gluten in the corn wet-milling process. The Northern Utilization Research Branch of the U. S. Department of Agriculture, Peoria, Illinois, studied dispersion of zein in strong alkali, "spinning" it into a fiber and stretching and curing to give the fiber added strength.

This fiber, which is available on the market under the trade name "Vicara," is used mostly in blends with wool for such garments as socks, swimming suits, and sweaters. Possible increased use of zein for special fabrics has created some interest in breeding corn for higher zein content.

Amylose for plastics, cellophane, and films. Amylose is a linear-type molecule which can be made into thin, transparent films resembling cellophane. Acceptable films require amylose of 80 percent purity. Ordinary corn starch contains about 27 percent amylose. Samples, however, have been found in which the starch was 62 percent amylose. Consequently, it appears that it may be possible eventually to obtain dent corn with a high enough amylose content for the practical production of plastics, cellophane, and films.

Vitamin A (B-carotene). An association has been found between the yellow pigment and vitamin A in corn. There is a direct quantitative relation between vitamin A and the number of genes for yellow pigment in the endosperm. In fact, the yellow endosperm genes act in an arithmetic, cumulative manner, each gene adding 2.5 units of vitamin A per gram of grain. Feeding tests have demonstrated that yellow corn is better than white corn for hogs on drylot feeding.

Niacin (nicotinic acid). Fortunately, wide differences in niacin concentrations have been found among various strains of corn. Hybrids tend to rank between their parents, and the seed parent generally exercises more influence than the pollen parent. Dent kernels are lowest in niacin content, waxy kernels intermediate, and sugary kernels highest. Adequate niacin in the diet eliminates certain malnutritional disturbances.

R. W. Jugenheimer
9-5-55

TOMORROW'S HYBRID CORN

It is becoming more and more difficult to develop hybrids that are definitely superior in all characteristics to the better ones now available in the Corn Belt. For this reason, the Corn Belt hybrids of 1965 may not be radically different from those of today. However, it should be possible to greatly improve the hybrids that are adapted to other areas of the United States and many other sections of the world.

Hybrids for special purposes and uses should soon be available. Producers and industry will be able to choose between better dent, flint, sweet, pop, waxy or possibly floury types.

Livestock feeders in the United States prefer a yellow grain that is soft and high in quality and quantity of protein. Multiple-eared, heavy -tillering strains will be useful for silage and green feed.

Industry will eventually be able to obtain more suitable types of corn. Dry millers prefer white kernels with smooth dent. Wet millers and livestock feeders will welcome high-oil hybrids. Waxy corn is available for food and glue. High-zein corn can be used for special fabrics, and a high-amylose corn would be valuable for plastics, cellophane, and films.

Yields of grain, silage, and fodder will gradually edge upward because hybrids will be better able to resist hazards. Effective disease inoculation and insect infestation techniques will result in hybrids that have greater resistance to diseases and insects. In general, flint corn germinates better and the seedings grow more vigorously than dent in the cooler climates.

Hybrids differ greatly in drouth resistance. The leaves of some strains remain green, while others are badly injured by heat. Some hybrids set seed satisfactorily under conditions of high temperature and low humidity, while others shed little pollen for only short periods.

Excellent standability has contributed greatly to the popularity of hybrids in the Corn Belt. This desirable trait needs more emphasis in many other places. Lodging lowers quality and yield and makes harvesting more difficult. Variations in standability between hybrids are caused by differences in stalk structure, root system, ear height, soil fertility, plant population, and resistance to insects and diseases.

For hand harvesting, farmers want single-eared strains with the ear borne at a convenient height. It may be possible to harvest future hybrids with a mechanical picker more easily and satisfactorily than the present types can be harvested. Hybrids with shorter plants may also be better adapted for field shelling and combine harvesting.

Other traits that may be added to future hybrids are better husk cover, better grain quality, higher shelling percentage, and resistance to chemical weed sprays.

By 1965 the use of male sterility and pollen restorers will probably eliminate much of the detasseling now required in producing hybrid seed. This development should lower production costs and result in a better product.

R. W. Jugenheimer
10-10-55

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

TEMPERATURE AND OTHER INTERRELATED FACTORS IN DROUGHT DAMAGE TO THE CORN PLANT

The question, "Is it high temperature or lack of moisture that is damaging the corn plant?" commonly asked in a hot, dry year is exceedingly hard to answer. The reason for this is that the two variables are so intimately interrelated that it is impossible to separate them under normal field conditions.

Some of the factors involved in "drought damage" of the corn plant under field conditions in addition to temperature are listed below and show the complexity of the problem.

1. Metabolic status of the plant
2. Soil moisture
3. Atmospheric moisture or relative humidity
4. Physiological moisture
5. Variety of the plant
6. State of development of the plant
7. Part of the plant

Since under field conditions all of these factors may be in operation at the same time, it is extremely hard to discuss the problem in general. This article will therefore emphasize temperature and try to relate the other factors to it.

The temperature factor. The following method is commonly used to determine the temperature that is required to kill plant tissue and cells: A leaf, branch. or section of tissue is cut off and immersed in water maintained at a constant temperature. The material is removed after an appropriate time interval, and staining techniques are used to determine whether the cells have been killed. By varying the temperature and the time of immersion, and determining the percentage of cells killed, it is possible to determine the "thermal death point." This term which is used to express the results is based on three components: time, temperature, and percentage of cells killed.

The main advantage of this method is that it separates temperature effects from many of the environmental factors. As an illustration, it was found that 100 percent of the cells of range grass roots were killed when immersed in water at 162° F. In contrast where the roots were placed in water which was slowly warmed over a 150-minute period, the lethal temperature was 126° F. This method, or modifications of it, has been used by many investigators to establish a critical temperature range that varies from 113° to 140° F. for many different plant species. The literature shows that the corn plant falls within this temperature range.

In visualizing how high temperatures kill a plant cell, it should be kept in mind that all the vital metabolic processes are carried out by proteinaceous compounds called enzymes. Heat, or dehydration by heat, can inactivate the enzymes by coagulation in much the same manner as egg protein is coagulated by frying or boiling.

Leaves in general, and corn leaves are no exception, tend to maintain themselves at the same temperature as the air surrounding them. Using over a thousand separate measurements, experimenters at the Kansas Experiment Station found the average temperature of turgid leaves to be 87.2° F. compared to an average of 87° F. for air temperature. Wilted corn leaves measured from 3° to 8° F. higher. This indicates that transpiration does not have a major role in regulating leaf temperature. The leaf then must maintain its temperature by a) reflecting a portion of the light and b) radiating heat. The latter is accomplished in much the same way as the "leaf-like" finned portion of an air-cooled motor dissipates heat.

Temperature and metabolism. Plants have two major metabolic systems that are "geared together," a) photosynthesis which synthesizes the carbohydrates which are used for "building blocks" and for energy and b) respiration which oxidizes (burns) carbohydrates to provide energy for maintenance and growth, and to supply "building blocks" of different types needed in plant growth. At a temperature of 68° F. the photosynthetic process exceeds the respiratory process by a considerable margin. This supplies an adequate amount of carbohydrates for the respiratory process and also provides the "building blocks" needed for growth. As temperature is increased, a compensation point is reached where input of carbohydrates just balances the consumption by respiration, while at higher temperatures (96° F.) the respiratory utilization exceeds that provided by the photosynthetic process. Prolonged exposure of the plant to high temperatures would therefore markedly curtail plant growth.

It has been observed that a wilted leaf absorbs but one-third the amount of CO_2 taken up by a turgid leaf. Naturally, this would reduce the photosynthetic production of carbohydrates by the same amount. This emphasizes the interrelation of moisture and temperature.

Although the information is meager, there seems to be some relationship between the levels of carbohydrates, proteins, and colloids in the plant cells and their resistance to dehydration. It has been pointed out that dehydration of the proteinaceous material of cells can result in their death. These levels of cellular constituents are controlled by the metabolism of the plant.

Temperature and moisture. Three major factors involved in maintaining an adequate physiological moisture level in the plant are: soil moisture, water-conducting system of the plant, and rate of transpiration of water loss from the plant. Soil moisture is the major reserve of water supply and must be adequate to meet the demands made by the plant for maintaining its physiological moisture level and transpirational losses. Since water is conducted from the soil by the xylem system of the plant, this "piping system" must develop rapidly enough and be large enough to supply the demands of all parts of the plant. It has long been known that certain varieties of corn are more susceptible to top leaf blasting than others. Recently it has been shown1/ that the susceptible varieties were much slower in developing xylem vessels in the leaves than the non-blasting varieties. Consequently, in high transpirational periods (hot, dry windy weather) the leaves of the plant with inadequately developed "piping systems" were severely desiccated and subsequently died. This desiccation could occur even with adequate soil moisture since the failure is in the water transport system.

The rate of transpiration from leaves depends largely on temperature, relative humidity, and air movement (wind currents). The relationship between temperature and relative humidity is shown by the following: air at 50°, 68°, and 100° F. must contain, respectively, 0.3, 0.6, and 3.5 ounces of water per cubic yard to achieve 100 percent relative humidity at each temperature. Air at 50° F. and a relative humidity of 80 percent if heated to 68° F. would drop to 40 percent relative humidity and at 100° F. would be only 0.6 percent saturated. The loss of water from leaves is controlled by the gradient between the relative humidity of the stomata of the leaves (assuming 100 percent R.H.) and that of the air. Rapid air movement tends to keep this gradient at a maximum.

Temperature and part of the plant. Some parts of the plant are more susceptible to heat and desiccation damage than other parts. For example, pollen and silk seem to be most sensitive. In field trials2/ representing some 7,000 pollinations, a good correlation was obtained between high temperatures and failure to set seed. At 75° F. the percentage of ovules setting seed was 65, while at 105-110° F. only eight percent seed set was obtained. Desiccation of pollen and silks rather than lethal temperature effects was considered the primary cause of the damage.

1/ Private communication from Dr. L. A. Tatum, Kansas State College, Manhattan, Kansas.

2/ Lonnquist, J. A. and Jugenheimer, R.W. Jour. Amer. Soc. Agron. 35:923. 1943.

R. H. Hageman
2-6-56

HOW TO ESTIMATE HAIL LOSSES TO CORN

Hail insurance on growing crops in this country increased gradually from 87 million dollars in 1934 to over 1 3/4 billion in 1953, or 20 fold. Payments to farmers for losses ranged from a low of 1.5 percent of the insured value to a high of 3.1 percent, with an average of 2.3 percent over the 20-year period.

The amount of damage inflicted by hail is hard to estimate. The stage of the crop when the storm strikes and the severity of the injury are the two main factors that need to be considered in appraising losses. Without data from experiments, an estimate of the loss resulting from a hailstorm might be no better than a wild guess. Fortunately, field trials have been conducted by agricultural experiment stations in Illinois (6 years), Iowa (7 years), Nebraska (9 years), South Dakota (2 years), and West Virginia (1 year), in addition to some extensive tests by insurance companies. The results of these experiments agree closely and make it possible to assess the damaging effect of a hailstorm on a crop of corn rather accurately.

Sometimes farmers are not fully satisfied with the appraisal of injury to their hail-damaged crops. They ask how the losses are estimated. This brief discussion is presented to explain the factors that need to be considered in arriving at an estimate.

Stage of crop development has an important bearing on the losses from hail injury. Corn plants in the tassel and ear-shoot-emerging stage are most subject to injury so far as grain production is concerned. No grain has been produced before the injury, and no new blades can be produced afterwards. If all the blades are removed by hail at this stage, the plant will therefore produce no grain. Removing all exposed blades when the plants are younger does little harm because defoliation at that time takes off only a little leaf surface and the plant produces new leaves as the stem pushes upwards inside the whorl. The later the blades are removed, the greater the percentage of leaf surface destroyed. Thus, grain yield goes down as blade removal is delayed, and this continues until the tasseling stage. After tasseling, however, grain yield goes up as blade removal is delayed. This relation between grain yield and stage of plant development at the time blades were removed was borne out in the experiments in all the states. So if a hailstorm occurs, carefully note the stage of development your crop is in when the hail strikes it.

Degree of injury is also important in estimating damage from hail. Any injury to the corn plant will usually decrease grain yield, because Nature does not provide the corn plant with enough leaf surface to permit part of it to be sacrificed without affecting the yield.

Experimental results show that grain yields are reduced in direct proportion to the amount of leaf area that is removed. There is a tendency, however, especially when only small percentages of leaves are removed, for the yield reduction to be somewhat less than the amount of leaf surface that is lost. This suggests that the efficiency of the uninjured leaf surface is stepped up after some of the leaves have been removed, possibly because the remaining leaves get more light.

As soon as possible after the storm subsides, get as careful an estimate as you can of the amount of blade surface removed from the plants by the hailstorm.

Blade shredding, midrib breaking, and stalk and ear bruising are other forms of injury caused by hail. Tests show that as long as any part of the blade remains attached to the plant it is capable of contributing to grain yield. In Iowa, when all the blades were severely shredded, yield of grain was 37 percent of normal even when the shredding was done at the beginning of tasseling. Severe shredding earlier and later caused progressively less damage.

Midrib breaking did not do much harm. With every midrib broken at the most critical time, namely, tasseling time, yield was 80 percent of normal.

Stalk bruising decreased yields about 10 percent beyond that caused by blade shredding. Ear bruising did little harm to yield, but when it occurred at the milk stage the market quality of the grain was reduced somewhat because of the damage to kernels.

Believe it or not, under some conditions hail injury may actually increase grain yields. This happened in Iowa during the dry year of 1930. Cutting out blades reduced transpiration, and the moisture thus conserved was more beneficial to the plant than the leaf removal was harmful.

Experimental data have taken much of the "guess" out of estimating losses to corn from hail injury. Yet it is still necessary to weigh the significance of the many factors that have a bearing on the outcome.

George H. Dungan
5-28-56

IDENTIFYING COMMON LEGUME SEEDLINGS

It is often necessary to identify certain legumes before they have flowered or after they have been closely grazed. Many times it is necessary to identify leguminous plants in the seedling stage. The following definitions and distinguishing features should be helpful in identifying some common legume seedlings.

Cotyledonary leaves - the seed leaves of the embryo which act as storage organs in seeds of plants.

Leaflet - one of the divisions of a compound leaf; e.g., the red clover leaf has three leaflets.

Petiole - the stalk of a leaf.

Pubescent - having fine, soft hairs.

Serrate - having sharp teeth.

Trifoliolate - having three leaflets.

Unifoliolate - having one leaflet.

Variegation - the barring (water marks) on leaves, seen in nearly all American strains of red clover.

Vein (nerve, rib) - nerve or rib in leaves, bracts, scales, sepals, etc.

In the following key to identifying legume seedlings, the cotyledonary leaves are considered to be the first and second leaves. Most of the common legumes exhibit epigean emergence; i.e., the cotyledons emerge aboveground. The pea and vetch, notable exceptions, exhibit hypogean emergence; i.e., the cotyledons remain underground during germination and emergence.

This key is greatly simplified. It should be remembered that many weed seedlings have characteristics similar to those of legume seedlings. Further, there are many variations within the different species presented in the key; e.g., most European strains of red clover are not pubescent. However, for practical field use, the key will help to identify some common legume species in the seedling stage.

Key to the Seedlings of Some Common Legume Species

1a. Third leaf unifoliolate (fourth leaf trifoliolate)

- 2a. Petiolar branches of unequal length
  - 3a. Leaflets one-third serrate - alfalfa
  - 3b. Leaflets completely serrate - sweet clover
- 2b. Petiolar branches of equal length
  - 3a. Vegetative parts pubescent
    - 4a. Variegation present - red clover
    - 4b. No variegation present - crimson clover
  - 3b. Vegetative parts not pubescent
    - 4a. No variegation present - alsike clover
    - 4b. Variegation present
      - 5a. Giant form - Ladino clover
      - 5b. Small form - common white clover

1b. Third leaf trifoliolate or both third and fourth leaves unifoliolate

- 2a. Third leaf trifoliolate, veins not prominent - birdsfoot trefoil
- 2b. Both third and fourth leaves unifoliolate, veins prominent - common, Korean, and sericean lespedeza

A. W. Burger
10-31-55

SELECTING ALFALFA VARIETIES

F-18

The main point to consider in selecting an alfalfa variety is the time you expect the alfalfa to stand before plowing it down. If you plan to use the stand several years for hay, plant seed of a winter-hardy, wilt-resistant variety like Ranger or Buffalo. If you plan to use it only one or two years for hay, you can use a winter-hardy, wilt-susceptible variety like Atlantic or Du Puits. In either case, use certified seed.

Bacterial wilt does not reduce alfalfa yield until about the third year. Because certain wilt-susceptible varieties, such as Atlantic and Du Puits, are as productive as Ranger and Buffalo during the first year or two, there is no advantage in using a wilt-resistant variety in short rotations.

Several varieties of alfalfa have been developed in the United States. There is a good seed supply of most varieties. Following are descriptions of several varieties and status of seed supplies.

Ranger, which is resistant to bacterial wilt, was developed at the Nebraska Experiment Station by intercrossing selected strains of Cossack, Ladak, and Turkistan. Ranger is a good forage producer and is as winter-hardy as the hardy common alfalfas. The flower color is variegated. Ranger is recommended for the northern two-thirds of Illinois. Seed supply is adequate.

Buffalo, also resistant to bacterial wilt, was developed by the Kansas Experiment Station out of Kansas Common. It is a good forage producer and is only slightly less winter-hardy than Ranger. Flower color is purple. Buffalo is recommended in the southern two-thirds of Illinois. Seed supply is adequate.

Atlantic, a high-yielding variety developed by the New Jersey Experiment Station, is not resistant to bacterial wilt. It was developed especially for the eastern states, where bacterial wilt is not serious. It is about as winter-hardy as Buffalo. Flower color is variegated. Atlantic is recommended throughout Illinois for short rotations. Seed supply is adequate.

Du Puits is a variety developed in France that has yielded exceptionally well in tests in Illinois and several other states. Du Puits is not wilt-resistant. It is about as winter-hardy as Buffalo. Du Puits is recommended for the southern two-thirds of Illinois in short rotations. Seed supply is limited.

Vernal is a variegated variety developed at the Wisconsin Experiment Station. It is very cold-resistant and highly resistant to bacterial wilt. It is not so susceptible to leaf and stem diseases as Ranger. This variety has not been tested in Illinois long enough to determine its value in relation to the recommended varieties. It is not recommended in Illinois at the present time. Seed supply is limited.

Narragansett, a high-yielding variety developed by the Rhode Island Experiment Station, is not resistant to bacterial wilt. It was developed for use in the eastern United States north of the area where Atlantic is adapted. Flower color is variegated. Atlantic is preferred to Narragansett in Illinois at the present time. Seed supply is limited, but it should be adequate to meet the demand.

Nomad has a high proportion of creeping plants that will root at stem nodes. It is from an old field in Oregon found to have this type of plant. Nomad is susceptible to bacterial wilt, and it has not been tested long enough to determine its adaptability. In most tests it has not appeared to be so vigorous as other varieties. Because of its creeping habit of growth, it may be useful in pastures.

It is not recommended in Illinois at the present time. A limited amount of seed is available commercially.

Rhizoma is a broad-crowned type of alfalfa developed at the British Columbia Experiment Station. It does not root at the nodes and thus is not a true creeping alfalfa. Rhizoma is a variegated, very winter-hardy variety that is not resistant to bacterial wilt. It becomes dormant very early in the fall and begins growth very late in the spring. For this reason it is not recommended in Illinois.

Certified seed is available for all the varieties recommended for use in Illinois, and it should be used in preference to uncertified seed.

Certified seed may be produced outside the region of adaptation, principally in California. For seed to be certified under such conditions, the seed fields must be established from seed produced in the region of adaptation.

Seed fields can remain down only six years; therefore certified seed of winter-hardy varieties that is produced in California is only one generation removed from plants that grew in the region of adaptation. Also, in fields growing certified seed, precautions must be taken to prevent the growth of volunteer seedlings. Winter-hardiness studies have shown that, when these precautions are taken, there is only slight loss of winter-hardiness. It is only when these varieties are grown for two or more generations outside the region of adaptation that there is serious loss of winter-hardiness.

J. A. Jackobs
12-26-55

HOW HYBRID SORGHUMS WERE DEVELOPED AND ARE BEING PRODUCED

Varieties of grain sorghums like Martin, Midland, Westland, Redbine 60, and Combine Kafir 60 and varieties of forage sorghums like Atlas, Leoti Red, and Kansas Orange are pure lines--just as are varieties of soybeans or oats. Hybrids of sorghums are first-generation single or three-way crosses between certain of these pure lines.

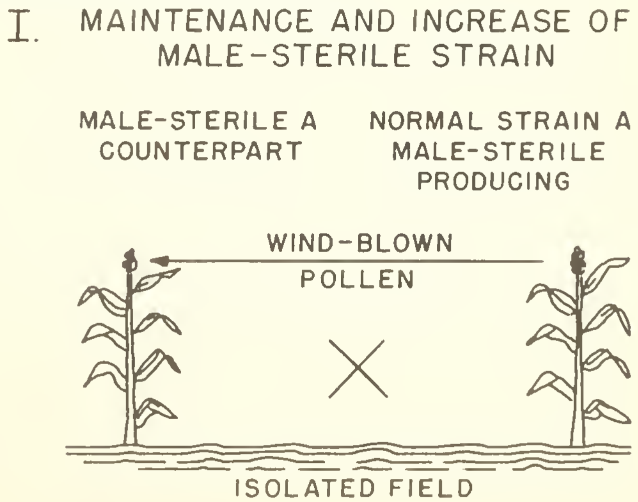
It has been known for a long time that, just as in corn, hybrid vigor will result from crossing certain varieties of sorghum. However, in the past, controlling pollination has been a major problem. Since the anthers, or the pollen-shedding organs, of the sorghums are located in the same floral envelope as the female parts, it is impossible to use the principle of detasseling to control pollination, as is done with corn.

Work to devise methods for producing hybrid sorghum seed in quantity has been under way at the Texas Agricultural Experiment Station, in cooperation with the United States Department of Agriculture, for more than 20 years. In 1929 J. C. Stephens of the Texas Station discovered an antherless character in Sudangrass, and in 1935 he discovered a better male-sterile in Texas Blackhull Kafir. In 1943 Glen H Kuykendall discovered a still better male-sterile in a field of the Day Milo variety on his father's farm in Cookeville, Tennessee, and in 1950 J. C. Stephens and R. F. Holland found cytoplasmic male-sterility in progeny of crosses between Milo and Kafir. The cytoplasmic type of male-sterility is utilized in single crosses and has advantages over the three-way cross which is used with the Day type of male-sterility.

Sorghum plants with male-sterility do not shed pollen, and the flowers are readily fertilized by pollen carried by the wind from normal plants. With this type of sterility, it is a simple process to produce and maintain both sterile and fertilized plants in crossing fields for producing hybrid seed at a reasonable cost. To make it clear how hybrid seed is and will be produced, it might be well to follow the method of production through all the steps from maintenance of parental stocks to production in farmers' fields. The necessary steps for maintaining stock and producing hybrid seed are shown in the following diagrams, originally prepared by J. C. Stephens.

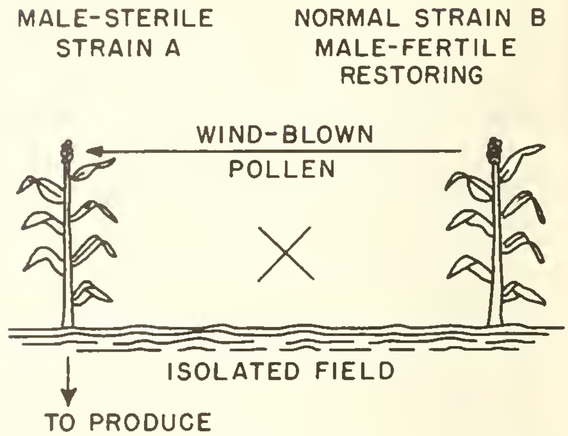
Diagrams Showing the Method of Maintaining Seed of a Cytoplasmic Male-Sterile Seed Parent and of Producing Hybrid Sorghum Seed

I. The maintenance and increase of a male-sterile line is illustrated. Male-sterile strain A and normal strain A are identical except that the male-sterile strain does not have anthers that shed pollen. The chromosome complement of both strains is the same, since the male-sterile strain is maintained by backcrossing to the normal A strain.



II. Hybrid sorghum seed will be produced in a second crossing block in which the seed parent rows will be male-sterile strain A and the pollen parent will be normal strain B. Lines chosen as male parents must restore normal fertility in the succeeding crop, give a good hybrid of combine height, and be good pollen producers. The hybrid seed from the male-sterile female rows is harvested and used for commercial production.

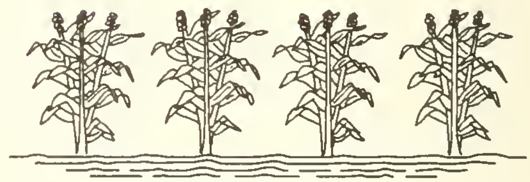
II. SEED-GROWER CROSSING BLOCK



III. The seed produced in the second crossing block will be planted by sorghum growers for commercial production. This is the single-cross A x B sorghum. All plants are completely male and female fertile. With these hybrids it is necessary to purchase new seed each year, just as is true of hybrid corn.

III. SINGLE CROSS (A X B) HYBRID SORGHUM

NORMAL CROP ON FARM



At present work in the main sorghum states is devoted to crossing many lines and testing to find the most suitable hybrid combinations. It will probably be several years before seed stocks can be increased, the various hybrids can be tested for adaptability, and seed of "proved" hybrids is made available for commercial production to any extent.

It should be emphasized that not all sorghum hybrids can be expected to be superior, but yield increases of 30 to 50 percent above those of present commercial varieties have been reported in states where these hybrids have been evaluated. Testing is needed and is being carried out in Illinois to determine the performance of hybrid sorghums at various locations in the state.

C. N. Hittle
4-23-56

SUDANGRASS IN ILLINOIS

Sudangrass is ideal for use as a summer supplemental pasture in Illinois. It may also be harvested for hay or silage. This forage grass, which is a sorghum and an annual, is very leafy, tillers profusely, and has great capacity for regrowth after cutting or grazing. It becomes somewhat dormant under conditions of severe drought, but resumes growth when rains come during mid- or late summer.

Sudangrass for Pasture

Sudangrass should not be pastured until the crop is 18 to 24 inches tall. At this stage the plants will contain roughly from 10 to 13 percent protein, and both common and sweet types will be readily eaten. The possibility of poisoning from hydrocyanic (prussic) acid is increased if Sudan is pastured at shorter heights. The grazing management should consist of rotational grazing with heavy stocking so that the growth may be grazed down rather quickly. The crop should then be allowed to grow until there is time for 18 to 24 inches of regrowth before it is grazed again. The place of Sudan in a balanced pasture program is for late summer grazing in conjunction with cool-season perennial pasture crops for spring and fall usage.

When Sudangrass is to be used for pasture, it may be planted with soybeans. This combination furnishes considerably more roughage than either crop alone and is ready for use in midsummer when other pasturage is short. Soybeans also provide added protein to the forage and, since they are not injured by chinch bugs, they aid in reducing the chinch bug damage on the Sudangrass.

Other Uses

Although Sudangrass is difficult to cure, it may be harvested for hay. The best quality hay is obtained if cut and properly cured when the very first heads begin to appear. Yields of up to three tons of good-quality hay may be expected from the finer-stemmed varieties. The coarseness of some of the new varieties makes them unsuitable for hay.

Sudan may also be ensiled and, when properly stored, makes good-quality silage. The yield for silage would be the best when the crop is heading to soft dough in stage. For use as hay or silage, it should be harvested before leaf drying occurs.

Prussic Acid Poisoning

Sudangrass contains a glucoside called dhurrin, which releases hydrocyanic acid when hydrolyzed in the ruminants. This may cause HCN (or prussic acid) poisoning. Quantities of prussic acid large enough to cause sickness are usually fatal, and a poisoned animal may die in a matter of minutes. However, a remedy that has sometimes proved effective is the intravenous injection of sodium thiosulfate. Symptoms of poisoning are depression, paralysis, stupor, and difficult breathing.

Shortly after animals are first turned in to a Sudan field, they should be observed closely for symptoms of prussic acid poisoning. Sudangrass whose growth has been slowed by drought or partially killed by frost may be dangerous to graze, since the cattle will graze the young, tender shoots that are much higher in dhurrin. Grain and silage sorghums are usually much higher in the glucoside than is Sudangrass, and if they are allowed to cross with Sudan the resulting hybrids will usually be higher in potential HCN producers than Sudan.

The danger of prussic acid poisoning can be largely eliminated by:

1. Using only certified seed or seed that is known to be pure Sudan.
2. Letting the crop grow at least 18 inches before grazing.
3. Not feeding excessively hungry cattle.
4. Not grazing frosted or drought-stunted crops.

Diseases

Probably the most severe disease of Sudangrass in Illinois is leaf blight, caused by the fungus Helminthosporium turcicum. Leaf blight lesions appear first as water-soaked areas. Drying out occurs as the lesions spread to elongated, irregular areas. Entire leaf blades may be and frequently are killed. Bacterial leaf diseases may also cause considerable damage. Best control of the leaf diseases may be obtained by the use of resistant varieties. Such varieties as Piper, Greenleaf, and Lahoma showed a relatively high degree of disease resistance in Illinois in 1954 and 1955.

Insects

The chinch bug is more harmful to Sudan than any other insect; and in years when chinch bug infestations are severe, stands of Sudan may be practically eliminated. None of the varieties are completely resistant to this pest, but the sweet types possess more resistance than do the common varieties.

Varieties

There are two main classes of Sudangrass: those which have sweet and juicy stalks and those which are non-sweet or relatively dry-stalked. The mid-rib of the leaf of sweet types is cloudy appearing, and the pith in the stalk is almost completely juicy. The palatability of the sweet types is high, even at later stages of growth, and they are generally eaten more readily when pastured than the non-sweet types. The dry-stalked varieties cure more readily when cut for hay and are usually higher in yield than the sweet types.

Sweet Sudangrass was developed in Texas from a cross of Sudangrass and Leoti sorghum. Its performance in Illinois has been good, and excellent quality certified seed has been available from Oklahoma, Texas and California. The damage caused by leaf diseases on Sweet varies considerably, depending upon the location and the year. Sweet is a juicy-stalked variety, quite early in maturity, and has reddish-brown colored seed.

Piper was developed by the Wisconsin Experiment Station and released in 1950. It is generally more vigorous in the northern states than other varieties, is mostly dry-stalked, has a lower level of hydrocyanic acid potential and increased resistance to leaf blight and anthracnose. The strain is not homozygous, being somewhat variable in seed and foliage color. In variety trials conducted in Illinois during the past two years, Piper has consistently outyielded all other varieties and has been damaged only slightly by leaf diseases.

Common, a dry-stalked type, was developed from many of the early introductions. In Illinois Common yields well, but because of its susceptibility to leaf diseases and extreme early maturity, it is not recommended when seed of other varieties can be obtained.

Greenleaf is a new juicy-stalked variety of Sudangrass released by the Kansas Experiment Station in 1953. It has a low HCN potential, and the seed is uniformly mahogany-colored. Preliminary results in Illinois show that it is exceptional in resistance to leaf diseases and degree of leafiness, but is somewhat lower yielding than many other varieties. Further testing of Greenleaf is necessary before its adaptability in Illinois can be determined.

Lahoma is a sweet Sudan and in tests in Oklahoma, where it was developed, it has shown uniformity, good leafiness, palatability, and greater resistance to leaf diseases and later maturity than other sweet Sudans. It is rather tolerant to chinch bug attack. At Urbana and Brownstown, Illinois, the yields of Lahoma have been relatively low, but at Carbondale it has performed very well. Lahoma also needs further evaluation in this state before its performance can be determined.

Carl N. Hittle
5-7-56

ORCHARDGRASS AND ITS MANAGEMENT

Orchardgrass is a long-lived perennial and a distinctly bunch-type grass with folded leaf blades and compressed sheaths. Because it does not produce stolons or underground rhizomes, it forms an open sod. This characteristic makes it a good companion crop for pasture and hay when seeded with such legumes as alfalfa, Ladino clover, red clover, and lespedeza.

Orchardgrass owes its common name to its shade tolerance and its consequent use in orchards and other shaded areas. In many other English-speaking countries, it is commonly known as cocksfoot, a name that aptly describes its distinctive stiff, finger-like panicles upon which spikelets are borne in dense clusters or glomules.

Regions of adaptation. Orchardgrass is grown most extensively and is most important in the southern half of the so-called timothy-bluegrass belt, extending from southern New York to southern Virginia and westward through Kentucky, Tennessee, southern Ohio, southern Indiana, southern Illinois, Missouri. and eastern Kansas. However, it can be grown to advantage in the northern part of Indiana and Illinois as well.

Orchardgrass is better adapted to and more productive in the southern range of the timothy growing belt than smooth bromegrass or timothy because it will tolerate more heat and drought. It will survive and grow better on thinner and less fertile soils than timothy and especially smooth bromegrass. However, orchardgrass is not well adapted to tight, poorly drained soils, especially if they tend to be cold. It responds well to high levels of soil treatment, particularly nitrogen supplied either from a chemical source or by a legume seeded in a grass-legume mixture.

Characteristics. Although less winter hardy than some of the other pasture-type grasses, orchardgrass starts to grow early in the spring and grows very rapidly. It matures for hay or seed about two weeks earlier than smooth bromegrass and about three weeks earlier than timothy. It recovers rapidly after mowing or grazing and produces large quantities of leafy pasturage or aftermath. It may produce less first-crop hay or silage than some of the other pasture-type grasses, but because it continues to grow during the summer, its total production of hay is equal to or higher than that of many other grasses. Because it will grow during the drier, warmer part of the summer and recovers rapidly following defoliation, its seasonal yield is also more uniformly distributed.

Uses of orchardgrass. Orchardgrass is used primarily for pasture, but it can be used for hay and silage as well. It is recommended for use in permanent pasture mixtures along with annual lespedeza, white and Ladino clover, and other grasses. It is frequently substituted for timothy in mixtures with red clover or alfalfa for hay; however, it may mature somewhat earlier than the legume, and the legume may have to be harvested sooner than normally to prevent the orchardgrass from becoming too mature.

Because of its vigor and productiveness, orchardgrass lends itself well to use in pasture renovation where short-term pastures are fitted into a forage program. Seedling stands are easily established, and excellent yields of forage can be obtained the first crop year.

Management. Although generally considered to be tolerant to grazing, orchardgrass does not persist under continuous close grazing. To best utilize the forage, it is therefore necessary to follow a program of rotational grazing.

To maintain a high-quality orchardgrass pasture, remove the early spring growth by grazing or clipping before it reaches the full head stage. Then rotationally graze the regrowth so that an area will be grazed for about one week and allowed to rest from three to four weeks. To control weeds and permit uniform regrowth, clip the grazed area to a height of about four inches with a field mower following removal of cattle. Undergrazing or delaying grazing not only reduces palatability and feeding value, but may also weaken the legume stand in a mixture as a result of excessive competition from the grass.

Orchardgrass makes excellent hay and produces high yields if cut in the earlier stages of maturity, preferably at the early head stage. After this stage it matures rapidly and becomes woody and unpalatable. This early maturity is often a disadvantage at the first cutting when orchardgrass is seeded in a mixture with alfalfa.

Orchardgrass makes excellent silage. If it matures before it can be grazed, it can therefore be ensiled. The silage can be used to supplement late summer pasture or as winter roughage. Often the entire first crop is removed for silage. Orchardgrass should be ensiled at about the early head stage to insure high yields of good-quality silage.

Seedling establishment. The best time to seed orchardgrass is usually in the early spring, although late summer or fall seedings are successful if made early enough to allow the seedlings to become established before winter. Orchardgrass seedlings are less winter hardy than many of the common pasture grasses, and fall seedings are more subject to winterkilling, particularly in the northern part of the state. Spring seedings should be made early enough to permit the seedlings to become established before weeds become a problem.

In general, good stands of orchardgrass can be obtained in mixtures seeded at four to eight pounds per acre. In pure grass stands, the rate should be increased to 10 or 12 pounds or more, depending on the germination percentage of the seed. Either broadcast or band seeding methods can be used, but band seeding requires less seed. For best results, soil fertility should be kept as high as possible. Orchardgrass is not seriously troubled with insect pests, but such diseases as anthracnose, leaf stripe, leaf rust, and scald do reduce the quality of the forage and may reduce the vigor of the stand.

Varieties of orchardgrass. Recently Potomac, a new variety, has been released for certified seed increase. It has some resistance to leaf rust and shows some superiority over the common strains in seedling vigor and leafiness.

Earl C. Spurrier
6-4-56

WINTER BARLEY IN ILLINOIS

Winter barley is not a new crop in Illinois, but there is a demand at present for a small grain crop to be planted on areas taken out of wheat production by acreage allotments. Winter barley might well substitute for wheat on these areas in the southern half of Illinois.

Winter barley has several advantages over spring-planted barley. When it survives the winter it yields more and its quality is better than the yield and quality of the spring types. Winter types normally mature earlier and thus escape the higher temperatures and some diseases that are serious hazards to the spring crop.

Winter barley makes excellent fall pasture and is a good companion crop for legumes and grasses. The grain makes excellent livestock feed and is considered nearly equal to corn in feeding value when fed to poultry and certain types of livestock.

U. S. Route 36, or a line from Hannibal, Missouri, through Decatur, Illinois, is usually considered about the northern limit for winter barley. But the right variety, planted early under favorable conditions, has a good chance to survive somewhat farther north. While it is somewhat hazardous to grow winter barley north of U. S. Route 36, if it winterkills you can still plant a spring crop with little extra seedbed preparation. Your only loss would be the cost of seed plus planting charges.

Cultural practices. Winter barley is not so winter hardy as winter wheat or winter rye, but it is hardier than winter oats. Early seeding is recommended to give the crop a chance to become established before cold weather prevents further growth.

Seed in time to insure a good root growth and at least four inches of top growth before the crop becomes winter dormant. The right date is about 10 days to two weeks ahead of normal wheat seeding, that is, from September 15 to October 15, depending on how far south you are. Seed with a grain drill at the rate of eight pecks an acre on a well-prepared seedbed.

Barley responds well to fertilizers, and fertile soils mean good root growth and more winter hardiness. A high nitrogen content in soils may cause barley to lodge. The straw of all barleys will break rather quickly once they are mature. For this reason it is important not to delay harvesting.

Varieties. Besides yield, winter hardiness and straw strength are the most important characteristics to consider in choosing a variety of barley. At present the following varieties are being recommended: Kearney, Reno, and Kentucky #1 for the area between U. S. Route 36 and U. S. Route 50 (which is from St. Louis east to Vincennes, Indiana) and these three plus Kenbar and Mo. B-400 for the area south of U. S. Route 50.

Kearney is one of the most winter hardy varieties, is medium early, and has a medium stiff straw. Reno has a slightly stiffer straw than Kearney but is not so winter hardy. Kentucky #1 is winter hardy, has a rather weak straw, and is later than either Kearney or Reno.

Kenbar is the earliest and the shortest of the varieties recommended. It is not quite so hardy as Reno but it has a much better straw. It is more resistant to smut, mildew, and scald than Reno, Kearney, or Kentucky #1.

Mo. B-400 is a high-yielding variety that is resistant to loose smut, mildew, and splot blotch. Because it grows rapidly and vigorously in the fall it makes excellent fall pasture. It is not so early as Kenbar nor does it have so good a straw.

The 1955 yields of the recommended varieties are shown in the following table:

Variety	Per acre yield				Average
	Urbana	Brownstown	Dahlgren	Carbondale	
	bu.	bu.	bu.	bu.	bu.
Kearney	55.7	39.9	24.3	25.2	36.3
Reno	68.6	52.0	26.0	32.9	44.9
Kentucky #1	54.0	39.8	19.6	30.7	36.0
Kenbar	24.8*	60.9	26.9	18.8*	32.8
Mo. B-400	62.4	....	....	31.1	46.7

*Poor fall stands due to low germination reduced yields at these locations.

R. O. Weibel
9-12-55

WINTER WHEAT

Winter wheat ranks third as a cash grain crop in Illinois. The agriculture of southern Illinois is strongly supported by this crop. The climate and soils of this area are well suited to the production of high-quality soft red winter wheat. On the other hand, hard red winter wheats produced in Illinois, especially in the southern half of the state, are usually too low in protein to produce a satisfactory bread flour. And because of the characteristic of the protein, the flour is not suitable for cakes or pastry.

Growing both soft and hard wheats in the same area has caused a considerable amount of concern. Because local elevator personnel cannot always distinguish between them, they are often mixed in handling or in shipment. Thus they are graded mixed wheat when they reach the inspection points. Mixed wheat is below the straight grades on the market. To protect himself, the local buyer, if in doubt, must class the wheat mixed.

This problem will continue as long as there is a price differential in favor of hard wheat and as long as we have no quick way to determine protein at the local buying points. We can help considerably by recommending that growers know the variety they are growing. All persons selling seed should stress the name of the variety and sell only those that are recommended.

Variety Descriptions. All of the varieties listed below have produced good yields in Illinois. All have acceptable grain quality for their class.

Recommended Varieties

Soft	Hard
Saline	Pawnee
Knox	Westar
Seneca	Ponca

Acceptable Varieties

Soft	Hard
Royal	Triumph
Vigo	
Butler	

New Varieties Being Increased

Soft

Dual
Vermillion

Of the recommended soft varieties, Saline is the tallest and also the latest. Knox has the shortest straw and is the earliest. Seneca is intermediate. Pawnee and Ponca, hard wheats, are very similar in maturity and straw strength. Both are a few inches shorter, a little earlier, and have slightly stiffer straw than Westar.

The grain of Ponca will not bleach out in the field so readily as Pawnee, and hence its milling quality is better. Westar is more resistant to mosaic than Pawnee or Ponca, but all three may become heavily infested when conditions are favorable.

Other characteristics of the recommended varieties are given in the tables on the back.

Table 1.--Characteristics of Varieties of Wheat Recommended for Illinois

Variety	CI. No.	Area of state where adapted*	Test weight	Lodging res.	Winter hardiness	Relative height	Head type	Grain texture
Saline	12674	All	Med.	Excel.	Excel.	Tall	Bearded	Soft
Knox	12798	C & S	Med.	Excel.	I-med.	Short	Smooth	Soft
Seneca	12529	S	Low	Excel.	Fair	Med.	Smooth	Soft
Royal	12558	C & S	High	Med.	Excel.	Tall	Bearded	Soft
Vigo	12220	C & S	Med.	Med.	I-med.	Tall	Smooth	Soft
Butler	12527	S	Med.	Excel.	I-med.	Tall	Bearded	Soft
Dual	13083	C & S	Low	Excel.	Excel.	Med.	Smooth	Soft
Vermillion	12748	All	Med.	Excel.	Excel.	Med.	Smooth	Soft
Pawnee	11669	N & C	Med.	Med.	Excel.	Short	Bearded	Hard
Ponca	12128	N & C	Med.	Med.	I-med.	Short	Bearded	Hard
Westar	12110	N & C	Med.	Med.	Excel.	Med.	Bearded	Hard
Triumph	12132	N & C	Med.	Med.	I-med.	Short	Bearded	Hard

* N = North; C = Central; S = South.

Table 2.--Reaction of Wheat Varieties to Diseases Common in Illinois

Variety	Mosaic	Leaf rust	Stem rust	Loose smut	Covered smut	Mildew	Septoria	Scab	Hessian fly
Saline	R	I	I	S	S	S	S	S	S
Knox	R	R	S	S	S	S	S	S	S
Seneca	R	S	S	I	S	S	S	S	S
Royal	R	S	I	S	S	S	S	S	S
Vigo	R	I	S	I	S	S	S	S	S
Butler	R	S	S	I	I	S	S	S	S
Dual	R	R	S	S	S	I	S	S	R
Vermillion	R	R	S	S	S	S	S	S	S
Pawnee	S	I	R	R	R	S	S	S	S
Ponca	S	I	R	R	R	S	S	S	R
Westar	I	I	S	I	S	S	S	S	S
Triumph	S	S	S	I	S	S	S	S	S

R = Resistant; S = Susceptible; I = Intermediate.

R. O. Weibel
9-19-55

AGRONOMY FACTS

"BLAST" IN OATS

"Blast" is a term that is applied to a type of sterility in oats. It is evidenced by white, empty glumes in the lower branches at the base of the panicle about the time the oats are in full head. The condition is also called blight, blindness, and white ear.

Blast is not a disease; it results from inability of some of the spikelets to develop completely. Anything that interferes with the physiological processes during development of the plant, particularly the panicle, may cause blast. Late seeding, lack of moisture, nutrient deficiencies, insect attacks, and disease, either singly or in combination, will increase the condition. Tillers are affected more than main stems.

The base of the panicle is where blast is most prevalent. The sequence of development in the oat panicle makes it easy to understand why. An oat panicle is composed of many branches, each of which ends in a many-flowered spikelet in which usually only two flowers produce seed. The main axis of the panicle terminates in a spikelet. Beneath the tip spikelet, and placed alternately on the main stem of the panicle, are five to six groups of spikelet-bearing branches. The number of spikelet-bearing branches increases from the tip of the panicle downward.

The first structure that develops from the main axis of the panicle is a branch primordium (a branch of the first order), which is the beginning of the group of branches at each node of the panicle. From the first-order branches, branches of the second order are formed; from the second order, the third order; and so on. At the nodes, especially the basal group, branches of the fifth and sixth orders may be found.

The oat panicle starts to develop from the tip spikelet and proceeds to the base. At any node, development begins with the first-order branch, followed in sequence by the second, third, etc. Consequently the panicle is oldest at the tip and youngest at the base, and at any node the first-order branches are oldest and the fifth- or sixth-order branches are youngest.

It takes some time for a panicle to develop. At Urbana a panicle of Clinton requires 15 to 18 days, or from about May 10 to 25 or 28, to develop fully. Heading occurs about 15 days later.

Adverse changes during panicle development, especially the first half, will affect the youngest parts more than the oldest. The youngest parts are more susceptible because they are farthest from producing seed. We can thus expect to find more blast in the basal groups of branches because that is where the largest number of high-order branches are found.

Varieties differ in amount of blast even though their environment and maturity are similar. This fact would indicate that plant breeders can produce varieties that have a low percentage of blast and hence higher yields.

O. T. Bonnett
9-26-55

WINTER RYE IN ILLINOIS

The acreage of winter rye has climbed steadily since 1951, according to the Illinois Crop Reporting Service. The crop harvested in 1955 was the largest since 1919. Perhaps we should take a closer look at this age-old crop that is making a comeback in Illinois. Why the increased interest in rye?

1. Wheat and corn acreage allotments have resulted in extra land.

2. More rye is being used for pasture and forage.

3. Rye is being interseeded as a winter cover and as a green manure crop in corn and soybean fields both before and after harvest.

Characteristics. Winter rye is the hardiest of the cereals--"the roughest, toughest of them all." It will grow on poorer soil, in drier soil, and in colder weather than our other grain crops. It will produce in soil that is sandy or low in fertility where other cereals will do little or nothing. On good soils rye is capable of making high yields, although not so high as wheat.

Two-year comparisons of average acre yields from several rye varieties with average yields from wheat varieties grown in the same field showed the following results: Urbana, central Illinois - wheat 48 bu. and rye 39 bu. DeKalb, northern Illinois - wheat 36 bu. and rye 30 bu.

Although a little spring rye is grown in the western United States, the Illinois rye crop is all of the winter type and therefore is fall seeded. Rye differs from the other common small grains in being almost completely cross fertilized. That is, the flowers on one plant are fertilized not by their own pollen, but by pollen from other rye plants.

Culture. Rye will respond to good cultural practices and to fertilizers, but the return for fertilization is generally greater on wheat and other grains. A seeding rate of 5 to 6 pecks per acre is thought best for Illinois. The crop can be sown from August to November. Although a good seed bed is desirable, rye has the ability to germinate and grow under poor seeding conditions.

Uses. Rye may be used as a cash grain, as a grain feed, as pasture, or as a green manure crop.

As a cash grain the crop generally goes into the following trade channels: distilling, dry milling, feed, export, and seed. The distilling industry uses rye for whiskey and alcohol. The dry millers make rye flour, which is generally blended with wheat flour to make the kind of rye bread Americans prefer. The feed industry also blends rye with other grains.

Although rye may be used as a feed crop on the farm, it is less valuable than corn, wheat, or barley. Alone, it is somewhat unpalatable and is considered heavy and sticky. For best results, it should be mixed with other grains.

Rye makes excellent fall and spring pasture. It is superior to other small grains in Illinois because it will grow later in the fall and start growth earlier and more rapidly in the spring.

The protein content of young rye plants may run 30 percent or higher in the spring on fertile soils.

Use of rye as a green manure is relatively new in the Corn Belt. At present the agricultural experiment stations are doing a great deal of research on the various aspects of this potentially important cultural practice. In addition to supplying organic matter, rye serves as a winter cover or guard against erosion and it may also be pastured. If corn is to follow rye, the land should be plowed in late April or early May, and nitrogen should be added.

The success of rye as a green manure will depend to a great extent on soil moisture. In late, wet springs, the crop will mature before it can be plowed, and in dry springs it will remove large amounts of water from the soil profile before corn is planted.

Results from Winter Rye Variety Trials at Urbana and DeKalb, Illinois, 1954 and 1955

Variety	Yield						Test weight	Height	Plant erect-ness	Head-ing date
	Urbana			DeKalb						
	1954	1955	Av.	1954	1955	Av.				
	bu.	bu.	bu.	bu.	bu.	bu.	lbs.	in.	perct.	
Adams	41.7	43.8	42.8	22.0	34.5	28.3	51.7	57	45	May 9
Balbo	37.9	44.9	41.4	29.4	30.6	30.0	51.5	55	57	" 3
Caribou	....	37.9	....	....	....	....	51.2	50	..	" 13
Emerald	37.3	38.4	37.9	33.2	36.4	34.8	51.0	56	47	" 9
Imperial	29.1	41.9	35.5	34.3	36.6	35.5	51.0	57	55	" 10
Pierre	34.6	40.8	37.7	30.7	32.8	31.8	51.8	54	51	" 8
Tetra Petkus	37.0	36.9	37.0	....	13.4	....	50.1	53	75	" 16

Balbo is believed to be the first choice for pasture because it will grow earlier in the spring. In extreme northern Illinois, however, it may suffer from winter-killing and Pierre or Emerald might be better. Tetra Petkus has larger kernels and wider leaves, but it has not out-yielded Balbo in either grain or forage.

J. W. Pendleton
10-3-55

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

S-5

ROOT AND STEM ROT OF SOYBEANS

Root rots occur on soybeans in Illinois from time to time, depending largely on weather conditions. They are likely to be noticeable in wet seasons, especially in low spots in fields where drainage is poor. One of these root rots is caused by Rhizoctonia, a fungus that is present in most soils where crop plants are grown. The fungus usually attacks young plants when the soil is abnormally wet, causing a reddish-brown decay of the outer layer of the main root and basal stem. Much of the secondary root system is destroyed, and the plants wilt and die. Dead plants occur typically in areas four to 10 feet in diameter, usually distributed irregularly over a field. In most seasons Rhizoctonia root rot is of little economic importance.

During the 1955 season, a root and stem rot new to Illinois was discovered in five or six fields in northern and central Illinois. This disease affects plants of all ages. Seedlings that have just emerged may shrivel and die, leaving gaps ranging from a few inches to several feet in the rows. Older plants wilt and dry up, or they may be severely stunted and perhaps wilt only slightly at midday. When such plants are dug or pulled, they show a badly decayed root system. The disease is, however, not confined to the roots; often the brown decay is noted on the stem several inches above the soil line.

Although this root and stem rot is especially damaging in poorly drained areas of the field, it sometimes occurs on higher ground. The disease is not widespread or serious in Illinois at present, but it should be watched closely because of its potential threat to soybean production.

This same root rot has been present in northwestern Ohio since 1951. It has become prevalent and destructive in the clay soils of the old lakebed region. The disease is caused by a fungus, identified by Ohio Experiment Station pathologists as a Phytophthora. Sometimes it is impossible to differentiate the Phytophthora root rot from the one caused by Rhizoctonia. However, the Rhizoctonia root rot lesion usually has a reddish brown color, while that of the Phytophthora root rot is brown. Also, the Phytophthora root rot seems to persist throughout most of the growing season, while the Rhizoctonia root rot usually disappears before mid-July.

Work at the Ohio Station indicates that the varieties Illini, Monroe, and Blackhawk are resistant to Phytophthora, while Hawkeye, Lincoln, and Harosoy are susceptible. Seed treatment has no value in preventing seedling blight. It is recommended that rotation with other crops be practiced on land where the root rot has appeared.

Investigations on Phytophthora root and stem rot are under way at the Illinois Experiment Station, and more information on this disease will be made available as controls are developed or resistant varieties are released.

D. W. Chamberlain
Plant Pathologist
U. S. Dept. of Agriculture
5-21-56

AGRONOMY FACTS

ESTIMATED HAIL LOSSES TO SOYBEANS

Because soybeans grow throughout the cropping season, they are subject to injury by hailstorms. Fully two-thirds of the hailstorms that occur in the Corn Belt come between May and September, when soybeans are in the field.

Insurance to protect the farmer against loss of his crop by hail is becoming more common each year. Insurance companies have conducted and are conducting experiments designed to get information on how to evaluate losses to soybeans from hail injury. Experiment stations, too, have studied the problem, and the insurance companies have supported some of this work. Illinois has been conducting such tests for six years, Iowa for six years, and North Carolina for one year.

Effect of stage of development on recovery from injury. The soybean plant possesses great ability to recover from injury, particularly at certain stages of development. Knowing the stage at which the damage occurred is therefore just as important in estimating losses as knowing the extent of the injury.

Unless the plants are broken off at the ground or are otherwise destroyed by beating of the hail, they will yield some grain. That is to say, there is no stage when injury will completely eliminate all yield.

The stage of lowest recoverability is just at the end of blossoming. At this time the pods on the lower branches are nearly full length and beans are developing in them. The pods on these branches are far enough along to yield some grain, but pods in the top part of the plant are just starting to form. No new blossoms or leaves form afterward, and removal of the leaves robs the plants of the photosynthetic area when it is needed most.

Results at the Iowa Station showed that when all leaves were removed at the blossoming stage the yield of beans was 18 percent of normal, and when the stems were broken in addition to 100 percent leaf removal the yield was 16 percent of normal (see Stage 7 in diagram). Leaf removal earlier and later than this critical period caused progressively less reduction in yield.

Recoverability is highest when plants are about three weeks old and after three or four trifoliate leaves have unrolled. Although leaf removal at this stage causes some reduction in yield, the drop-off in production is less than before or after this stage. In the diagram this stage is shown as 2.

Extent of injury. In general, yield is reduced in direct proportion to the percentage of leaf surface removed. Bruising of the stem also affects yield. Tests at Iowa showed that breaking of stems lowered yield below that caused by leaf removal. This decrease amounted to only 15 percent at the first-bloom (2) stage, but increased to over 50 percent at the critical (7) stage.

A severe storm that kills plants outright will reduce the stand and consequently the yield, but the reduction will vary with stage of growth. If it occurs during the early (1 to 3) stages, as many as 50 percent of the plants can be destroyed without any great reduction in yield. But at Stage 6 or later, a reduction in stand will mean a marked decrease in yield. By the end of the blooming period, the plants have lost their capacity to spread out and take up the extra space.

Other effects. Loss of leaves before the critical (7) stage delays maturity of the plants, but such injury after this stage seems to hasten maturity. Actually, however, maturity only appears to be speeded up. The crop comes only from the most advanced pods because the leaf area is not sufficient to provide reserves for the later formed pods.

Large leaf losses reduce seed size and also decrease the oil content of the seed if the loss occurs while the grain is filling.

Estimating losses. It is hard to determine the percentage of leaves removed by a hailstorm. It is possible to tell the stage of plant development by carefully observing the plants immediately after a storm. But figuring out how many leaves remain in relation to the number before the storm is like probing in the dark.

Because of this difficulty, Dr. James C. Neill, who did his Ph. D. thesis on the effects of artificial hail on soybeans at the University of Illinois, suggested the possibility of determining the degree of injury by counting the terminal buds that had been knocked off. In two-year tests (1950-51) Neill blew cracked ice through a three-inch rubber tube onto soybean plants at various stages of development. In this way he inflicted injuries similar to those caused by natural hail, removing different percentages of leaves and at the same time damaging stems and removing terminal buds.

Neill counted the leaves before treatment and then counted those left on the plants after treatment. He also counted the plants from which the topmost or terminal bud had been removed. In both years in which he made these tests he found a very high correlation between the percentage of leaves lost and the percentage of terminal buds lost.

Because in these tests the correlation between loss of leaves and loss of terminal buds was so close and because the percentage of terminal buds that are lost can be easily and accurately determined after a hailstorm, Neill suggests that the severity of injury be estimated by counting the number of plants in a hundred from which the terminal buds have been removed.

G. H. Dungan
6-18-56

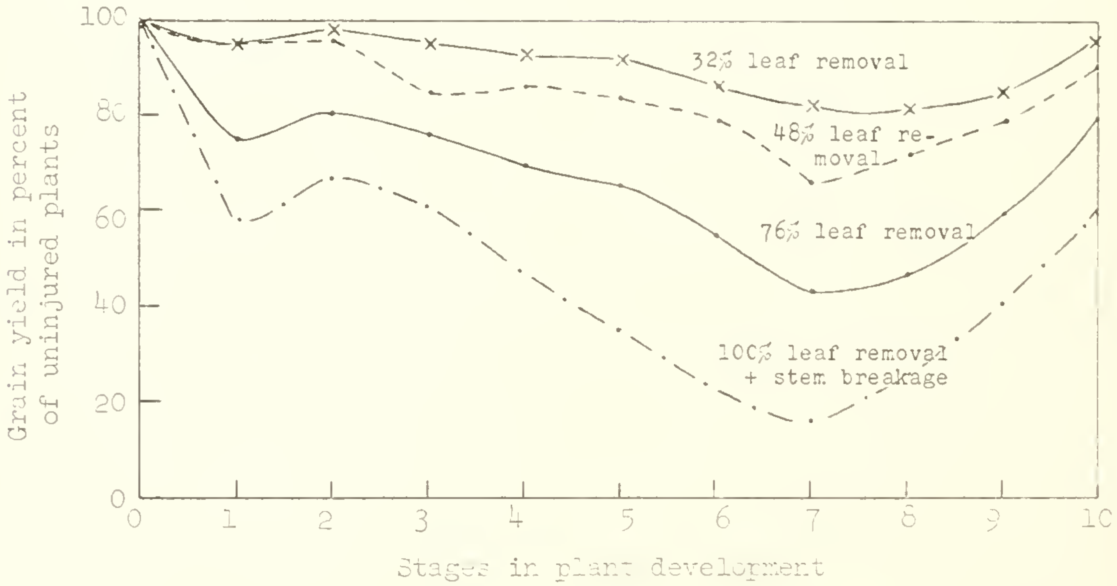


Diagram of grain yield reduction as a result of four severities of hail damage at 10 stages of soybean plant development.

CHEMISTRY OF ORGANIC NITROGEN IN SOILS

Nitrogen is different from the other nutrient elements in the soil because it occurs almost entirely in organic combination. Only a very small fraction of the nitrogen--usually from 1 to 3 percent--is in the inorganic forms at any one time.

During the year nitrogen is released slowly from the organic matter to the mineral forms, which are the available forms of nitrogen in soils (see SF-4). The amount that is released depends on the kind and amount of nitrogen in the organic matter, on climatic conditions, and on the physical condition of the soil.

Several methods are used to estimate the quantity of nitrogen converted to the available forms during the growing season, but all of these methods have certain limitations (see SF-17). If we knew more about the nature of organic nitrogen in soils, we could overcome some of the uncertainties involved in estimating nitrogen availability and in making fertilizer recommendations.

Unfortunately, we know very little about the nature of soil organic nitrogen or about how soils differ in their contents of organic nitrogen compounds. Do fertile soils contain nitrogen compounds that are not found in infertile soils? Are some nitrogen compounds in humus easily mineralized while others resist attack by soil microbes? Are well-fertilized and manured soils different from infertile soils in their contents of certain kinds of organic nitrogen compounds?

To answer these questions the Department of Agronomy has a research project under way that is concerned with the chemistry of humus nitrogen. As indicated above, the purpose of this study is to find out what forms of organic nitrogen the soils contain and to determine how cropping and management practices affect these forms.

Recently a study was made of the protein nature of soil humus. The building units of the proteins--the amino acids--were isolated from several soils and their amounts were determined. Briefly, the results showed that soils differed in the quantity and quality of their proteins. In some soils as much as half of the nitrogen was in the form of proteins; in others less than a third of the nitrogen was proteinaceous. Also, the amino acid composition of the protein material in one soil was quite different from that in another. This difference suggests that the ability of humus to supply nitrogen to the plant may depend considerably upon the nature of its proteins.

The famous Morrow Plots at the University of Illinois were used to determine the effects of some long-time rotations on the distribution of amino acids in soils. The results of this study were very interesting. It was found that the proteins in the soils from the untreated plots (such as the untreated continuous-corn plot) were low in the kinds of amino acids that would be expected to be ready sources of nitrogen--for example, mono-amino acids like glycine, alanine, valine, and leucine, and the amino acid amides, asparagine and glutamine. The proteins in the soil from the corn-oats-clover rotation plot that had been manured, limed, and supplied with phosphate were high in these amino acids.

These results show that when soils are heavily cropped they lose heavily in certain kinds of amino acids. Hence, not only does an intensive system of farming deplete the soil of proteins, but the protein material that remains is of low quality.

Needless to say, more research needs to be done before the full practical significance of these findings can be determined. But the results obtained thus far have served to emphasize the desirability of using management practices that will furnish a continuous supply of actively decomposing organic matter to the soil. The soil organisms use plant residues and manures as sources of food. During growth and reproduction they synthesize body proteins. It is these proteins that later become good sources of mineralizable nitrogen.

Research work on the chemistry of organic nitrogen in soils is continuing. In the future we can look forward to unraveling some of the mysteries surrounding the availability of humus nitrogen in soils.

F. J. Stevenson
10/31/55

1955 WHEAT YIELDS - ILLINOIS SOIL EXPERIMENT FIELDS

Field	Location	Cropping system	1 O	2 M	3 ML	4 MLP	5 O	6 R	7 RL	8 RLP	9 RLPK
		Dark-colored soils									
			bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Aledo	Mercer	C-C-O-W	..	..	..	..	44	42	39	40	46
Carlinville	Macoupin	C-B-W-H	26	44	39	38	31	32	37	40	45
Carthage	Hancock	C-B-W-H	28	36	43	43	29	24	28	32	39
Clayton	Adams	C-B-O-W	..	..	..	..	18	29	30	33	37
Dixon	Lee	C-O-H-W	42	48	51	50	41	46	44	52	49
Hartsburg	Logan	C-C-O-H	..	..	..	..	41	47	41	43	39
Joliet	Will	C-B-C-O-W-H	20	26	29	34	17	15	20	34	36
Kewanee	Henry	C-O-W-H	..	..	..	..	31	36	44	51	49
Lebanon	St. Clair	C-B-W-H	11	25	33	36	13	12	28	35	37
McNabb	Putnam	C-C-O-W	..	..	..	..	17	37	38	43	..
Minonk	Woodford	C-C-O-W	..	..	..	..	37	39	37	39	42
Mt. Morris	Ogle	C-O-W-H	..	..	..	..	18	21	31	37	37
Average			25	36	39	40	28	32	35	40	41
		Light-colored soils									
Brownstown	Fayette	C-B-W-H	..	..	..	..	..	1	33	45	51
Enfield	White	C-O-W-H	4	11	26	30	4	4	15	20	33
Ewing	Franklin	C-B-W-H	0	4	23	31	2	4	17	20	27
Oblong	Crawford	C-B-W-H	13	27	36	41	6	9	26	40	40
Raleigh	Saline	C-O-H-W	6	13	27	26	15	12	17	25	32
Toledo	Cumberland	C-B-W-H	9	22	52	56	10	11	24	36	39
Average			6	15	33	37	7	7	22	31	37

Cropping System Symbols: C = Corn, B = Soybeans, W = Wheat, O = Oats, H = Hay (legumes and mixed grasses).

Soil Treatment Symbols: O = Untreated land, M = Manure returned equal to crops removed, R = Crop residues, L = Limestone, P = Rock phosphate, K = Muriate potash.

(Continued on back)

Average wheat yields in Illinois for 1955 were the highest on record, 31.5 bushels. Nevertheless yields varied widely from location to location and with different soil productivity and management practices. Yields from the Illinois experiment fields (see table) illustrate those variations, as they represent a cross section of the productive capacity of Illinois soils.

On untreated dark-colored soils yields ranged from 13 to 44 bushels an acre. On fully treated land the range was 32 to 52 bushels. The response to treatment varied from none to 26 bushels. Similar variations occurred on the light-colored soils of the state.

This kind of information should alert agricultural workers and farmers to the danger of making prodictions regarding the response that can be expected from a given fertilizer or management practice in any one year. The data also show the advantages of keeping a soil adequately supplied with plant food and ready for any favorable growing conditions that come along, such as those of 1955.

The yields given in the table were obtained after bulk application of such fertilizing materials as manure, crop residues, limestone, rock phosphate, and muriate of potash (on individual plots) and under the cropping system described. In these experiments no attempt is made to fertilize the individual crop. Materials have been applied in quantities adequate to determine the needs of the various soils and to supply all crops in the system under a wide range of seasonal conditions.

On many of the fields additional tests have been made with complete mixed fertilizer, various phosphate carriers, nitrogen, and potash. In some cases yields have been increased by annual direct applications, and in other cases they have not.

A detailed explanation of the treatments, cropping systems, and soil types is given in Illinois Bulletin 516, "Effect of Soil Treatment on Soil Productivity." This publication is supplemented by a mimeograph pamphlet that brings data on each field up to date for each year. These publications are available from the Agronomy Department, University of Illinois, Urbana.

A. L. Lang
11-14-55

EARTHWORMS

In 1777 Gilbert White published a paper in which he said: "Worms seem to be the great promoters of vegetation, which would proceed but lamely without them, by boring, perforating, and loosening the soil, and rendering it pervious to rains and the fibers of plants, by drawing straws and stalks of leaves and twigs into it; and, most of all, by throwing up such infinite numbers of lumps of earth called worm-casts, which, being their excrement, is a fine manure for grain and grass. . .the earth without worms would become cold, hard bound, and void of fermentation, and consequently sterile."

Since 1777 much information concerning the relation between the earthworm population and soil conditions has been collected. In spite of this knowledge concerning the activities of earthworms and the conditions under which they flourish, it still is not clear whether they affect the productivity of soils materially.

Certain facts are, however, recognized and a few of them are worth enumerating:

1. Earthworms occur in fairly large numbers in many farm soils. Observations in the United States and in other countries indicate that under favorable conditions the number may exceed a million an acre, with a total live weight of more than 1/4 ton.

2. The worms are most abundant in soils that are high in organic matter. Consequently they may be found most extensively in forest, pasture, and heavily manured soils.

3. Cultivated soils are less favorable for earthworm survival than are areas that are covered with sod crops. This difference is explained in part by their sensitivity to sudden changes in the soil temperature when the late-fall freezes occur. They apparently need the insulating protection that vegetation cover gives the soil.

4. Earthworms appear to need a continuous supply of calcium, which they excrete from their digestive tract. Their numbers therefore decrease as the pH of the soil goes down. Different species also differ in their tolerance to soil acidity.

5. In virgin soils and in pastures the worms drag into their burrows leaves and other dead surface litter. Microorganisms then attack the litter and convert it into the so-called humus fraction of the soil.

6. It is believed that earthworm activity improves soil aeration. The channels the earthworms make help to improve air and water movement. These channels may also serve as passageways for plant roots. Since the worms that burrow deeply in the soil may carry lime and plant nutrient elements into their channels in the subsoil, the occurrence of roots in subsoils, which ordinarily would be unfavorable for them, may be due to earthworm activity.

Correspondence wwith farmers indicates concern in some areas about the effect of use of anhydrous ammonia on the earthworm population. Although no experimental data are available on this subject, the lack of proof of the value of earthworms in soil productivity suggests that arguments for and against the use of anhydrous ammonia should be based on factors other than its effect on the earthworm population.

O. H. Sears

11-21-55

BAND APPLICATION OF FERTILIZERS IN ILLINOIS - PART I

Banded fertilizer may be defined as any fertilizer that is banded or drilled with seed. Banding or drilling fertilizer has been a standard practice in the East and South for many years. Interestingly enough, fertilizer so applied is generally called starter fertilizer in the Midwest. An eastern or southern farmer merely says that he is fertilizing his crop.

Banded fertilizers may serve a number of useful functions. It is perhaps unfortunate, therefore, that the term starter fertilizer was coined. Under certain conditions, banded fertilizers promote rapid, early plant growth and vigor. The seedlings, therefore, are better able to overcome such early hazards as grape colaspis, a root-feeding insect, and adverse weather. Also, by promoting early, uniform, vigorous growth in row crops, banding makes it possible to do a more thorough job of weed control. These functions help to get the better stands that are essential for top yields.

On moderately phosphorus- and potassium-deficient soils, banded fertilizers may promote deeper and more extensive rooting. In wheat, this reduces winter heaving and assures better winter survival. Banding may also lead to more complete fertility exploitation by all crops. Critics of banded or starter fertilizers often cite this argument to discredit band or row applications, saying that banded fertilizers make it possible to more thoroughly mine or deplete soils. This may be true where small amounts of low-analysis fertilizer are applied, but it is not true where adequate amounts of high-analysis fertilizer are applied for each crop. In fact, it is possible not only to maintain the mineral fertility of productive soils, but also to maintain very satisfactory yields on infertile soils by applying adequate amounts of high analysis fertilizer provided other good management practices are followed.

On the other hand, there are alternative management and fertilization practices through which high yields can be secured without the use of banded fertilizers. The farmer's choice of the alternatives is not solely an agronomic problem--it is a joint agronomic-economic problem.

In Illinois the fields are frequently large and the rows long. Application of banded fertilizers, particularly in adequate amounts, requires frequent filling of hoppers, adds to the labor and reduces the acreages planted per day as much as 25 percent. Many farmers are sold on the value of banded fertilizers, others question their need, and occasionally some even say that yields have been reduced. Virtually all complain of the added labor and weight-lifting.

In most cases starter effects induced by banding fertilizer are primarily a reflection of seedling response to highly available soluble phosphorus. So let us examine the chemical aspects of applying soluble phosphates to soils. This will help to clarify the reasoning that gave rise to the practice of banding or drilling phosphatic fertilizers or mixed fertilizers containing available phosphorus.

When soluble phosphorus is applied to strongly acidic soils or soils that contain excess lime, phosphorus fixation takes place. Soil chemists at first believed that phosphorus fixed by strongly acidic soils was permanently converted into unavailable forms. The original thinking behind placement of phosphorus-containing fertilizers, therefore, was to minimize soil-fertilizer contact. Concentrating the fertilizer close to the seed made it possible for the plants to take up most of the phosphorus they needed before fixation occurred. The economic loss of phosphorus through fixation was believed to be reduced.

A better understanding of the chemistry of soil phosphorus has developed in recent years. Soil chemists have found that the phosphorus fixed by acidic soils is not permanently lost. The fixed phosphorus is now merely considered "difficultly available" to plants. It has been learned that the use of sufficient lime makes it possible for plants to use the phosphorus that acidity had made physiologically unavailable. Strongly acidic soils already containing large amounts of difficultly available phosphorus will not respond to phosphorus for several years when first limed to neutrality. This does not mean that lime can be substituted permanently for phosphorus on such soils. It means that lime makes it possible to reclaim much of the phosphorus previously unavailable to the plant.

The fixation of phosphorus to difficultly available forms in calcareous (shelly) soils is a more serious matter. It is sometimes claimed that rock phosphate is produced. Chemically this is an untenable hypothesis. On calcareous soils the fixation to difficultly available forms is caused by excess lime. There is no practical way to remove the lime. Fortunately the reversion to difficultly available forms is slow, usually taking a full growing season. Annual applications of phosphate-containing fertilizers are preferable on calcareous soils.

To avoid excessive fixation, the fertilizer may be banded or drilled with the seed. Broadcasting is also satisfactory if excessive mixing (disking) is avoided and if the phosphate-containing fertilizer is applied just ahead of seeding. Top-dressing of permanent meadows in the spring is preferable. Banding or drilling is best, however, and leads to the most efficient use of soluble phosphates, particularly where small applications are made.

A second problem in the use of mixed fertilizers containing phosphorus is posed by the immobile nature of soil phosphorus. For all practical purposes plant roots must forage for phosphorus. The degree to which seedlings are stimulated into faster growth depends, therefore, on the extent of the soil phosphorus deficiency. An estimate of the early growth stimulation of various crops is illustrated in Figure 1. It is evident that on very phosphorus-deficient soils the starter effects can be quite large. Early plant stimulation may or may not be reflected in final yields. On moderately acid soils testing medium to high in available phosphorus, the growth stimulation effects, except for wheat and clovers, are apt to be small or even absent.

Potassium is likewise an immobile nutrient for which plant roots must forage. The stimulating effects of potash in mixed fertilizers will vary with the level of soil potassium availability, much as is the case for phosphorus. On most soils, however, early growth stimulation is essentially a phosphorus effect because the phosphorus requirements of seedlings are usually very high.

The production of radioactive phosphorus by the Atomic Energy Commission at Oak Ridge, Tennessee, has made it possible, through the use of tagged radioactive phosphorus, to trace the proportion of

Table 1.--Percent of Phosphorus in Corn Secured From Banded Fertilizer During the Growing Season

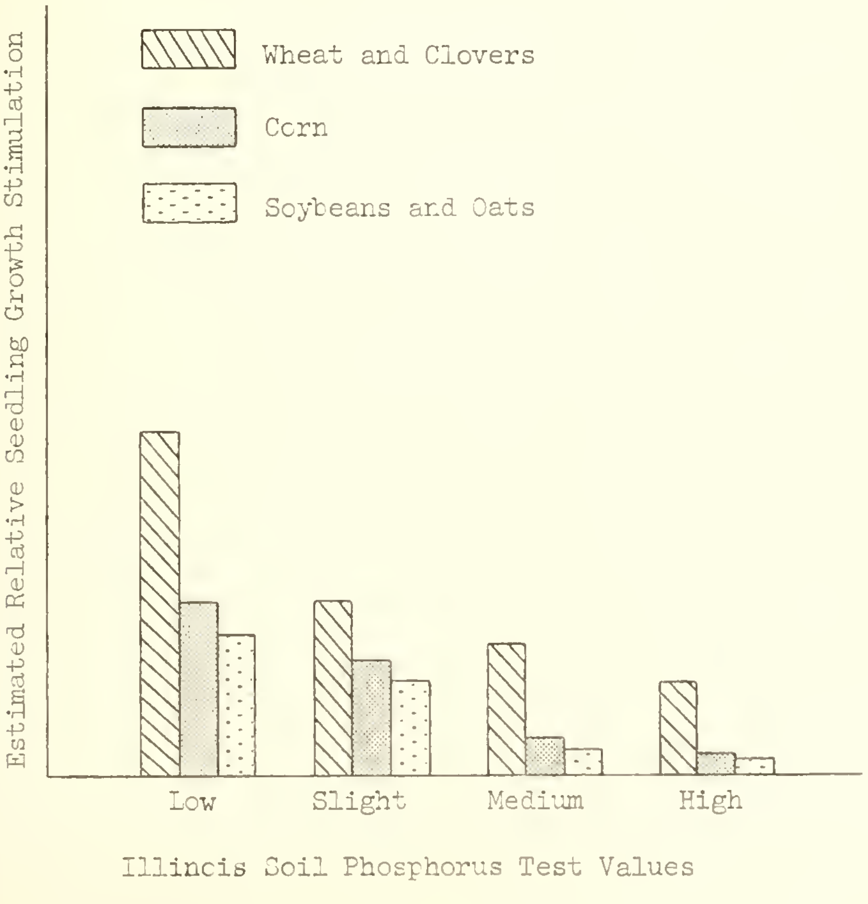
Available phosphorus in soil	Percent of phosphorus in plant from fertilizer			
	30 days	60 days	90 days	110 days
Low	58	36	28	23
High	26	21	17	15

the phosphorus absorbed by plants from fertilizers throughout the growing season. Results of such an experiment conducted with corn in North Carolina are given in Table 1.

These data indicate that during the first 30 days of growth corn absorbed slightly more than twice as much phosphorus from band applications on soils that were low or deficient in available phosphorus as from the same applications on soils that were high in available phosphorus. In other words, the phosphorus in banded fertilizers can be expected to be more effective in promoting rapid, early growth with increasing soil phosphorus deficiencies.

The data also show that, regardless of the level of available soil phosphorus, less and less phosphorus is derived from the fertilizer as growth progresses and the root system develops. After 110 days, on soils that were high and low in available phosphorus, only 23 and 15 percent, respectively, of the phosphorus needs of the crop came from the applied fertilizer. The remainder of the phosphorus that was absorbed--some 77 and 85 percent--came from the soil. This explains why, on moderately fertile soils, early growth stimulation of corn by banded fertilizers often is not reflected in the final yield. This being the case, benefits other than yield increases must be assigned to banded fertilizers for some soils.

Fig. 1.--Estimated Relative Early Growth Stimulation Induced by Soluble Phosphorus Applied in Bands to Soils of Different Soil Phosphorus Test Values



E. H. Tyner
12-5-55

AGRONOMY FACTS

BAND APPLICATION OF FERTILIZERS IN ILLINOIS - PART 2

The preceding Fact Sheet was devoted primarily to some of the fundamental aspects of band fertilization. This sheet will deal with the more practical aspects of the problem--amounts, fertilizer ratios in relation to soil test values, etc.

Except on calcareous (shelly) soils, banding fertilizers with each row crop is not urgent on soils testing at least M- in available phosphorus or above 170 pounds in available potassium. On such soils the primary benefits from banded fertilizers, if any, are likely to be secured only with wheat and legumes (see Fig. 1, Fact Sheet SF-40).

Under these conditions applying maintenance amounts of phosphorus and potassium once in the rotation will maintain enough mineral fertility for high crop yields, assuming adequate nitrogen fertility. Moreover, these amounts can be applied with bulk distribution equipment during slack periods. One exception might be where grape colaspis must be controlled, but it can also be controlled with pesticide sprays. Farmers who have serious grass weed problems or who are shooting for extraordinary yields may still prefer to apply some banded fertilizer in order to insure better stands.

Banded fertilizers applied to each crop, however, have a definite place where depleted farms are operated by tenants with uncertain tenure, or where capital is not sufficient for build-up applications or where it is needed more in other phases of the farm business than for rapid build-up of basic soil fertility.

In general, on very deficient soils one cannot apply enough fertilizer to get maximum yields by hill-dropping or banding in the row. Even so, it is possible to get good yield increases with mixed fertilizers alone, provided the analysis supplies reasonable amounts of the most needed nutrients and provided nitrogen fertility is adequate. Table 1 lists first-year phosphorus and potassium requirements for moderately high yields at various soil test values.

Table 1.--Phosphorus and Potassium Required the First Year at Various Soil Test Values

Test value	Phosphorus (P_2O_5)	Potassium (K_2O)
	lb./A	lb./A
L-	60	...
L	54	...
L+	48	...
S-	42	...
S	36	...
S+	30	...
40	..	120
80	..	70
120	..	40
170-200	..	30

The above requirements are stated in terms of phosphorus (P_2O_5) and potassium (K_2O) needed per acre. How can we use such information in determining the proper fertilizer analysis to buy? Let us assume that the soil test indicates phosphorus availability as L- and potassium availability as 120 pounds. On the basis of this information, we would need to apply 60 pounds of P_2O_5 and 40 pounds of K_2O per acre. The P_2O_5:K_2O ratio needed in a mixed fertilizer would therefore be 1.5 to 1.0. It would be difficult to find a mixed commercial fertilizer with this ratio. Therefore, we will choose a fertilizer with a 2 to 1 phosphorus-potassium ratio, such as 0-20-10. If we were to apply 300 pounds of this analysis per acre, it would supply the 60 pounds of P_2O_5, but only 30 pounds rather than 40 pounds of K_2O. Even so, we could still obtain satisfactory yields.

Can this amount of fertilizer be hill-dropped or banded for row crops? Large amounts of fertilizer close to the seed can delay or even prevent germination. The reason is that the "salt action" inhibits moisture uptake by the seed or the roots just emerging from the seed. In general practice, it is only the nitrogen and potassium in mixed fertilizers that are "hot" and that interfere with germination.

A good rule-of-thumb is not to hill-drop or band more than 30 pounds of "hot" solubles (nitrogen (N) plus potassium (K_2O)) per acre. It is apparent that the safe amount will vary with the analysis, e.g., 3-12-12 (200 pounds), 10-10-10 (150 pounds), 3-9-27 (100 pounds). The 30-pound rule is for dry to average seasons. In wet seasons higher rates may not be injurious. According to this rule, the 300-pound application of 0-20-10 could be made provided the fertilizer attachment would deliver this amount. If not, 100 pounds could be banded and the rest broadcast and either plowed under or disked in.

This explanation shows why it is difficult to prescribe certain fertilizer ratios for use on crops grown on soils that may vary considerably in basic fertility. Moreover, a certain analysis may be satisfactory to apply for a few years, but carry-over effects may cause the ratio and the amount to change. Periodic soil testing will help to determine the most practical and profitable ratios and rates.

How necessary is nitrogen in mixed banded fertilizers? This is a question on which agronomists do not agree. Experimental evidence indicates that nitrogen increases the uptake of phosphorus. It may therefore be argued that nitrogen in banded fertilizers serves a very useful purpose. This may be true on soils that are highly deficient in available phosphorus, but it is not so important on soils that are moderately supplied with available phosphorus. More will be said on this point later.

In general, where experience indicates a substantial response to nitrogen, large amounts of nitrogen must be applied. It is usually best to apply a nitrogen material, e.g., 20-0-0, 33-0-0, 82-0-0. This does not mean that 12-12-12, etc., are not satisfactory sources of nitrogen. Such analyses, if used in amounts adequate to supply the required nitrogen, often supply more phosphorus and potassium than can be used efficiently. But the excess phosphorus and potassium are not lost through leaching and can be used later.

Applying nitrogen in large amounts in mixed fertilizers can, therefore, lead to inefficient use of phosphorus or potassium if the soil already tests moderately high in these elements. Where high nitrogen mixed fertilizers are used, the carry-over effects of excess phosphorus and potassium should be carefully analyzed before subsequent fertilizer applications are made.

In general, conditions preceding planting and level of available soil phosphorus should determine the advisability of applying amounts of nitrogen in mixed fertilizers, such as 3-12-12. Normally the decay of soil organic matter will take care of the small nitrogen requirements of seedlings. If the weather is abnormally cool with frequent rains before corn is planted, it might be advisable to use a mixed fertilizer containing some nitrogen, particularly on phosphorus deficient soils. On the other hand, if temperatures are normal and moisture is average, it is questionable whether nitrogen will be needed in starter fertilizers even to increase phosphorus uptake. Nitrogen in mixed fertilizers may, however, be beneficial in most seasons on weedy fields where a considerable amount of trash, particularly straw, has been plowed under.

Is nitrogen necessary for establishing stands of winter wheat. If wheat follows soybeans and is seeded just after the fly-free date, the value of applying nitrogen in mixed fertilizer to stimulate fall growth is questionable. On the other hand, if seeding is delayed because of wet weather, some nitrogen--perhaps not more than 3 to 5 pounds per acre--might be desirable. Applying nitrogen in the fall on clay-pan soils to avoid the need for spring applications is a different matter. See Fact Sheet SF-28.

E. H. Tyner
12-12-55

AGRONOMY FACTS

PROGRESS REPORT ON A GREEN-MANURING PROJECT

In 1953 an experiment was started to determine the value of northern and southern alfalfa varieties, red clover, ladino clover, sweet clover and lespedeza as green-manure crops. A comparison of the green-manure crops with chemical nitrogen was also included.

The Series 1102 plots on the Agronomy South Farm, where the various green-manure crops were seeded in oats in 1953, had the following crop history:

1948 Corn followed by an application of 14 tons of manure an acre.

1949 Corn

1950 Soybeans harvested for seed

1951 Oats in which clover was seeded but failed

1952 Wheat (straw left on land)

1953 Before oats were seeded, three tons of 200-mesh limestone, 500 pounds of 0-20-0, and 110 pounds of 0-0-50 were applied

The Series N-600 plots had been in a rotation of corn, corn, oats, and clover for 50 years. The clover failed in 1953 and oats were seeded again in 1954 as a companion crop for the green-manure crops.

In each series the green-manure crops were plowed under about a year after seeding. To some plots where a green manure had not been seeded $(NH_4)_2SO_4$ was applied in 1954 and plowed under at once. NH_4NO_3 was used in the same way on certain plots in 1955. Corn was planted by hand at the rate of four kernels per hill. A nearly perfect stand was secured in each year.

The yields of No. 2 corn on these plots for the years 1954 and 1955 are given below.

CORN YIELDS FOLLOWING GREEN-MANURE CROPS AND WITH NITROGEN FERTILIZERS

Green-manure crops	Acre yields 1954	Acre yields 1955
	bu.	bu.
Alfalfa		
African	119	102
Chilean	120	111
Indian	123	103
New Mexico	120	108
Northern Common	121	109
Ranger	119	110
Clover		
Ladino	119	103
Medium red	124	103
Lespedeza (Korean)	122	103
Sweet clover		
White blossom	117	109
Yellow blossom	116	109
AVERAGE	120	103
None	119	103
None plus nitrogen 60 pounds/acre	111	97
None plus nitrogen 120 pounds/acre	--	99

In each year a randomized block design with four replications was used. Consequently it was possible to make a statistical analysis of the data.

Although some differences in corn yields were associated with the previous green-manure crops and with nitrogen fertilizer these differences were not statistically significant. On the basis of this information, it can be concluded only that neither nitrogen fertilizer nor leguminous green-manure crops had a measurable effect on yields of corn in these plots in 1954 and 1955. This information should not be interpreted to mean that in other years or on other soils in the same years the use of leguminous green-manure crops or nitrogen fertilizers would not or did not affect corn yields favorably.

The question then arises why increased corn yields did not occur. While it is not possible to say with authority why these results were obtained, some possible explanations can be presented: Obviously these soils were furnishing a larger amount of available nitrogen than is usually the case. Again the question why arises naturally.

In the years 1953, 1954 and 1955, there were no periods of excessive rainfall. In fact, a moisture deficiency occurred for several extended periods in each of these years. As a result, it seems reasonable to postulate that the soils, even without green manure, furnished sufficient available nitrogen for maximum yields under the seasonal conditions that prevailed. This large amount of available nitrogen was the result of:

1. Moisture and temperature favorable for nitrate formation.

2. Not enough soil moisture to cause leaching losses of nitrate nitrogen or denitrification.

In other areas on the Agronomy Farm there was evidence that the availability of soil forms of nitrogen was high in 1954 and 1955. Consequently the response to added nitrogen was less than many people expected.

These data should not be construed to mean that leguminous green-manure crops and chemical nitrogen are not important in the nitrogen economy of the land. Rather, they indicate that seasonal conditions must be considered in evaluating the worth of any soil-improving practice in a particular year.

J. A. Jackobs & O. H. Sears
1-9-56

COMPOSTS

Composts have been used in agriculture for centuries. Roman farmers prepared composts from the straw and chaff of grain crops and from the leaves of forest trees. Although the farmers of ancient times did not understand all of the principles involved, they were familiar with the kinds of ingredients needed for successful composting.

One kind of composting, known as sheet composting, has been used in Illinois for more than half a century. It consists of plowing under such materials as straw, manure, and green manure crops grown for soil improvement purposes.

Composts have been used extensively in the United States for mulching shrubbery where it is not desirable to incorporate the organic residues in the soil. They have also been used to some extent in vegetable crops and flower gardens to conserve moisture and to prevent the soil structure from being destroyed by beating rains.

One advantage of decomposing organic matter is lost when composts are prepared in a compost heap. One reason for incorporating organic matter in the soil is to improve soil structure or tilth. As the organic materials decompose, the microbes produce substances that increase the aggregation or crumb structure of the soil. Although soil tilth is not improved solely by microbial activity, it is recognized generally that microbes have an important function in keeping soils in good physical condition.

Many materials can be used in the compost heap, including leaves from trees and shrubs, weeds, lawn clippings, and garden residues. Even table scraps can be used, but grease and meat scraps will develop offensive odors and attract rats and flies.

During composting a considerable part of the materials decay and part of them go into the air as gases. The remainder is similar to well-rotted stable manure. A good manure from composts must go through this decomposition process.

Bacteria and molds are largely responsible for decomposition. Although they derive energy from the refuse which they decompose, they also need other substances for growth. One of the most essential is nitrogen. Because most of the substances which go into a compost heap are low in this element, it is necessary to furnish additional nitrogen if a rapid rate of decay is to be obtained.

In the process of decomposition, acids are produced. Some nitrogen fertilizers also form acids. Consequently, it is advantageous to add limestone.

A satisfactory compost may be prepared by using the following:

Organic residues (dry weight)	100 pounds
Ammonium sulfate	.5 pounds
Limestone.	.5 pounds

Five hundred pounds of green plant residues will contain about 100 pounds of dry material. A bushel of leaves weighs about 5 to 8 pounds, depending upon condition and packing.

To build a compost heap, place about 1/5 to 1/6 of the leaves, grass clippings, or garden residues in a layer 10 to 12 inches thick. Moisten this layer and spread 1/5 to 1/6 of the mineral mixture over it. Alternate the layers of residues and minerals until the stack is complete. Make the top of the stack concave to catch and hold rain. If the material is kept moist, rotting will proceed rapidly. One ton of dry material will produce about 2 1/2 tons of moist artificial manure.

If the heap is made in early or even late summer, the compost will be available for early spring use. However, if the materials are not composted until late fall, when the temperatures are low, decay will be slow, and a sufficient degree of decomposition may not be obtained by early spring.

Although it is not necessary to add phosphates to decompose the residues, 2 pounds of superphosphate added to the mineral mixture will increase the value of the manure, particularly if it is to be used on soils that are low in available phosphorus.

Even though artificial manure in the stack does not have a noticeable odor during decomposition, when spread it has an odor resembling that of natural manures.

Prepared mineral mixtures are available in some localities. More recently a number of commercial products which are said to contain the microbes needed for decomposition have been sold. Investigations in California and Florida indicate that there is little need to apply microbial concoctions. The same results may be secured by adding small amounts of fertile soil to the compost.

O. H. Sears
4-2-56

THE NATURE OF EXCHANGEABLE CALCIUM AND MAGNESIUM AND THEIR RELATION TO SOIL ACIDITY AND LIME REQUIREMENT

In moist soils calcium and magnesium are present mainly in exchangeable form. This form is attached by valence bonds to the surfaces of the soil clay and organic matter particles. Exchangeable potassium also occurs on these surfaces, although usually only in small amounts in relation to calcium and magnesium.

The exchangeable form is usually the principal available form of each of these soil nutrients--the form the plant depends on for growth.

However, calcium and magnesium play another role in soil fertility. They control the acidity or pH of the soil. If the clay and organic matter particles are covered mostly with calcium and magnesium, the soil will be nearly neutral or "sweet." But whenever a cation like the calcium or magnesium ion is lost by leaching or removed by plant roots, hydrogen, the "acid" ion takes its place and the soil becomes more acid. Liming is merely the process of replacing the exchangeable calcium and magnesium lost by leaching in order to bring the soil back to a pH favorable for plant growth.

In the claypan soils of southern Illinois, the native soil is usually highly acid. The calcium and sometimes the magnesium are so low that liming is needed for two purposes: First, liming adds calcium and magnesium and thus overcomes deficiencies to the extent that these nutrients are supplied in available form. Second, proper liming corrects the acidity sufficiently to make the soil reaction (pH) favorable for plant growth.

In one sense the two functions of liming are completely independent of each other. In fact, except in southern Illinois, most of the soils in the state already contain so much exchangeable calcium and magnesium that they provide plenty of nutrient for plant growth, yet they are often so low in these elements in relation to the acid ion that the soil can be harmfully acid to some crops. Except in these claypan soils, therefore, the chief purpose of liming is usually to change the soil reaction.

One effect of changing the pH upward is that it makes it possible for plants to feed more efficiently on the available phosphorus in the soil. Another is that many legumes nodulate only at the higher pH levels. (A low pH means a more acid reaction.) Organic matter appears to decompose more readily at the higher pH levels.

Except in soils that are very low in clay and organic matter, a favorable pH level is practically a sure sign that calcium will not be deficient. In such soils a high pH could theoretically be due mostly to potassium and magnesium. But such situations have never been found in Illinois.

The pH of a soil is not determined by how much or how little exchangeable calcium and magnesium it contains, but rather by the proportion of these basic ions to the acid hydrogen ions. The total amount of exchangeable cations Ca^{++}, Mg^{++}, and H^{+} held on the clay surfaces is called the base exchange capacity and is measured in terms of milligram-equivalents per 100 grams of soil (m.e. per 100 grams).

One m.e. per 100 grams is about the amount of calcium and magnesium contained in 1,000 pounds of high-grade limestone. If a soil contains on its clay and organic matter surfaces 8 m.e. of bases and 2 m.e. of acid ion, or a total of 10 m.e., it will be in the sweet range because it is 80 percent saturated with exchangeable bases and only 20 percent saturated with the acid ion. If it contains 16 m.e. of bases and 4 m.e. of acid, it will have a total of 20 m.e., but the percent of saturation and also the pH will be the same as before. So the degree of acidity or pH depends not on the actual amount of acid that is present, but rather on the proportion of acid to base.

Lime requirement is another matter. Suppose the first soil has 5 m.e. of bases and 5 m.e. of acid, for a total of 10 m.e. It is then 50 percent saturated with bases and is in the unfavorable range of acidity. A more favorable range is 80 to 90 percent saturation with bases. This means that from 3 to 4 m.e. of hydrogen must be neutralized. This is equal to 3,000 to 4,000 pounds of pure limestone. Hence the tentative lime requirement is 3,000 to 4,000 pounds.

Now suppose a 20 m.e. soil is also only 50 percent saturated and it is desirable to increase the saturation to around 80 to 90 percent. Fifty percent of 20 m.e. is 10 m.e. of the bases present. Eighty to 90 percent saturation is 16 to 18 m.e. of bases needed. If 10 m.e. are present and 16 to 18 are needed, then 6 to 8 m.e. or 6,000 to 8,000 pounds of limestone is the tentative lime requirement.

Silt loam and clay soils have higher base requirements for the same pH value than do the lighter soils. Sands generally have the lowest.

Theoretically, in order to estimate a practical lime requirement, one should first know the magnitude of the base-exchange capacity and the sum of the milliequivalents of the bases present. This would require a quantitative estimate of the exchangeable calcium, magnesium, and hydrogen (acid ion).

But that is not all one would have to know. Knowing that, theoretically, it would take 6,000 pounds of pure limestone to sufficiently neutralize the soil is only one item. Next one must consider the neutralizing value of the limestone. If it is only 90 percent C.C.E. (calcium carbonate equivalent), the original 6,000-pound calculation must be increased to compensate for the 10 percent impurities. This increases the requirement to 6,666 pounds.

However, this is still not the answer.

The fineness of the limestone must be rated according to its rate of neutralization, i.e., how much acid it can neutralize within a relatively short time. For years, until a government agency took over limestone inspection, such ratings were made on all Illinois limestones and an effectiveness score was given to the stone. If the effectiveness score is low, more limestone is needed. Now suppose the limestone has a score of 85 percent effectiveness over the first three years. This was about the average score for Illinois quarries at the time effectiveness inspection was discontinued. Applying this correction to the above 6,666 pounds gives 7,840 pounds as the corrected requirement.

But again this is not the whole story. Many, if not most, soils have acid subsoils. But the acidity of the subsurface varies; in the claypan soils it is higher than in the dark-colored silt loams. With deeper plowing this acid soil gets mixed with the top soil, increasing the acidity. Also the transfer of bases downward increases when subsoils are more acid. These things would all affect the need for limestone over a period of years.

And, last, there is the matter of quickness of leaching. A sandy soil with a sufficiently low exchange capacity can become acid through the loss of only one milliequivalent of calcium. And more water moving through such a soil hastens leaching. But heavy soils change in pH much more slowly because their capacity is higher and less water goes out the tile. The limestone recommendation must include recognition of this point.

So estimating a practical lime requirement is not merely a matter of knowing the amounts of exchangeable bases and acid present, although this is the soundest starting point for estimating the theoretical requirement. Other considerations are the effectiveness of the limestone (fineness), purity of the limestone, acidity of the subsurface, and rate of leaching of the exchangeable bases. When all of these things are considered, the final recommendation may appear to have little relation to the theoretical requirement.

For example, some sands in Illinois have a base-exchange capacity of 3 milliequivalents per 100 grams. This means that they can hold calcium and magnesium equivalent to not much over 2,500 pounds of a fine 100 percent C.C.E. stone. Yet when they are acid, 3 to 4 tons of ordinary limestone are commonly added after considering screen score, C.C.E., and especially the high rate of leaching on sandy soils. On the other hand, a soil like Muscatine silt loam with a base-exchange capacity of 20 m.e. per 100 grams will, at the same pH, have a much higher theoretical requirement, but the practical requirement may be little higher than the practical requirement for the sand when all the other factors are considered.

It is therefore not "fool proof" to base the lime requirement on measurement of the exchangeable bases and the exchangeable hydrogen (acid) alone.

The lime requirement recommendations based on pH or thiocyanate readings have resulted from practical experience over a period of 30 or more years. While a thorough study of Illinois soil types and of their base-exchange capacities and pH—degree of saturation relationships was made a couple of decades ago, it has not yet appeared practical to apply this knowledge to refining the lime requirement recommendations made in our county laboratories.

The Missouri "Lime Meter" method represents one approach to this problem, but when corrected for these other factors it correlates too closely with our recommendations based on pH or thiocyanate to make it practical to use.

The pH and thiocyanate methods, while they do not involve a determination of the bases and acid, do give a measure of degree of saturation with bases and can be interpreted in terms of lime requirement when the base-exchange capacities of the soil types are known.

In general, the high-capacity soils occur in the northern two-thirds of Illinois, and their capacities and pH vs. degree of saturation relationships have been thoroughly studied and found sufficiently similar to make it practical to use pH or thiocyanate as a measure of the lime requirement.

On the other hand, the soils of southern Illinois, while lower in base-exchange capacity, have much more acid subsoils, which would tend to increase the rate at which a limed soil becomes acid and thus require more than the theoretical amount of lime.

Measuring the theoretical amount is therefore not the whole answer. The higher cost of the required tests leads to a tendency to run only one or two samples, whereas in the Illinois plan 11 samples in a 40-acre field are analyzed. Given a choice, the 11 samples run by the pH or thiocyanate test are generally preferable and may be more accurate than a single composite of a whole field run by a theoretically better method. In fact, some results reported to us of interpretations based on theoretically better determinations indicate that the interpretations must have been made by persons with so little knowledge of soil chemistry that the recommendations were unsound and worthless.

Years ago this station put out a very simple titration-indicator method that involved using several samples of the same soil and shaking each one with a salt containing a different amount of a base. This procedure measured the theoretical lime requirement directly, regardless of variations in base-exchange capacity, and is easier to run than methods involving the total of each ion involved.

Roger H. Bray
6-11-56

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

SOIL MANAGEMENT & CONSERVATION

AGRONOMY FACTS

SM-12

OBJECTIVES OF CROP ROTATIONS - INTRODUCTION AND EROSION CONTROL

This is the first in a series of five Agronomy Fact sheets devoted to the "Objectives of Crop Rotations." This one is concerned with control of soil erosion. The second one will discuss the effects of crop rotations on soil physical properties, such as absorption of rainfall, internal drainage, and compaction. Number 3 will explain how crop rotations may help to control insect pests and crop diseases. Number 4 will take up the problem of plant nutrients with particular emphasis on nitrogen. The fifth and last of this series will discuss the economic factors to be considered in deciding what crop rotation to follow.

Crop Rotations and Erosion Control

The effectiveness of a crop rotation in controlling soil erosion depends upon the type of growth, the amount of growth and the time of growth of the crops included in the rotation and the proportion of the time that the crops with different characteristics are on the land.

Type of Growth

Grasses and legumes are erosion resisting crops. If a good stand of such crops occupies the land, erosion losses are negligible even on relatively steep slopes. At the other extreme is bare soil which is subject to serious erosion even on gentle slopes. Inter-tilled crops, like corn and soybeans, furnish some protection against erosion and are therefore better for the soil than no crop. Small grains are intermediate between grasses and legumes and inter-tilled crops in holding down erosion.

Amount of Growth

In the case of any crop the amount of top growth determines to a considerable extent its effectiveness in controlling erosion. The more completely the soil is covered by a crop the less it is exposed to the beating action of raindrops which break up the soil crumbs or granules. The character and extent of the root system of a crop are also important. For example, in August a crop of soybeans may cover the ground as completely as a crop of alfalfa and still the soil may be subject to much greater erosion losses. This is due to the fact that the bean ground is in a looser condition than the alfalfa ground. The bean roots are also less extensive and are usually localized in rows.

Abundant root growth of crops improves the physical condition of soils so that water is more readily absorbed and the soil is less damaged by the beating action of raindrops. A soil full of roots also resists the cutting action of water concentrated into small streams.

Time of Growth

The amount of erosion that may be attributed to a particular crop depends largely on the time of its growth. In Illinois much of the corn is planted in May, when the amount and intensity of rainfall is relatively high. Since the soil is loose from tillage and the soil gets no protection from the crop, erosion losses are usually high. In June the corn is in the active growing stage, the soil is cultivated and the amount and the intensity of rainfall are relatively high. In this month also erosion losses are high. From 40 to 60 percent of the annual soil losses from corn land on the Agronomy South Farm occurred in June.

Expected Soil Losses

From available data it is possible to estimate the soil loss by erosion that will occur on different slopes, from different kinds of soils under a particular rotation. If the soil loss is greater than the estimated permissible loss, then more sod crops must be included in the rotation. Usually in Illinois farmers are interested in growing corn and soybeans. To figure out a crop rotation that will satisfactorily control erosion just enough sod crops are included to keep the soil loss down to a permissable amount. Permissable loss is the amount in tons per acre which it is estimated can be lost annually from a particular soil and still maintain the land in continued productivity. (The table appearing at the end of this report shows how this works.)

Supporting Practices

By using supporting practices a rotation may be followed that would permit too high soil loss without the supporting practices. It works like this! A farmer selects the crops he wants to grow and the amount of a particular crop, like corn, he wants to include in the rotation. This is checked for the condition of his land, the percent of slope, the length of slope, the kind of soil and its condition, particularly with reference to past erosion damage. If the erosion losses are higher than permissable under the conditions, the use of supporting practices, such as contouring, strip cropping, and terracing may reduce the soil loss enough so the desired rotation can be followed.

Expected Soil Losses from Selected Rotations on Four Soil Types on a 200-foot Contoured Slope in Illinois[a/]

Rotation[b/]	Flanagan 2% Slope	Swygert 5%	Clinton 8%	Grantsburg 5%
	Tons/A	Tons/A	Tons/A	Tons/A
CCCG*	1.9	6.2	14.6	7.8
CCCGM	1.2	4.2	9.8	5.3
CCGM	1.0	3.4	7.8	4.2
CGM	.6	2.0	4.5	2.4
CGMM	.4	1.2	2.8	1.5
CGMMMM	.2	0.8	1.8	1.0
Permissable Loss	4.5	1.5	3.0	2.5

(Losses below heavy line are small enough to permit use of rotation indicated.)

a/ Calculations are based on expected losses on soils with 8 or more inches of surface soil remaining. Average management is assumed in preparing the table. With poor management the losses should be multiplied by 1.3. For high-level management of crops and soil multiply by 0.7.

b/ C - corn; G - small grain; M - meadow. *G - small grain with catch crop to plow down.

C. A. Van Doren & R. S. Stauffer
1-30-56

SM-13

EFFECT OF CROP ROTATIONS ON SOIL PHYSICAL CONDITION

The physical condition of soils is determined largely by their texture, state of compaction, and degree of aggregation. Cultural practices have little effect on soil texture, but such management variables as organic matter management, surface cover, and tillage will change soil compaction and aggregation and thus help to determine physical condition.

Organic matter management. The degree of aggregation is closely related to the amount of readily decomposable organic matter in the soil. For this reason, cropping systems that add large amounts of readily decomposable organic matter to soils are the systems that promote good aggregation and thus improve physical condition. The effectiveness of residues in increasing organic matter in the soil, and thus improving soil aggregation, depends on the amount of residues, their ability to decompose, and the thoroughness with which they are mixed with the soil.

If other conditions are constant, crop rotations that add the greatest amount of readily decomposable crop residues to the soil will be most effective in creating good physical condition.

Surface cover. The amount of protection provided by the crops grown in the rotation also affects soil physical condition. Cropping systems that provide a protective vegetative cover, either living or dead, for the soil during the greatest part of the year help to lessen the impact of raindrops. Heavy rains destroy aggregation in the surface soil and often cause serious crusting. Air and water cannot then move freely into the soil, and seedlings may not be able to emerge.

Tillage. Tilling tends to cause soil physical condition to deteriorate, particularly when the soil is wet. Crop rotations differ greatly in the amount of tillage they require. Intertilled crops have a greater structure-depleting effect than others.

Sod crops provide readily decomposable organic matter and vegetative cover and require fewer tillage operations than intertilled crops. It is thus easy to understand how the sod crops help to improve soil structure. Possibly some of the new techniques now being used to produce intertilled crops may eventually reduce their structure-depleting effect enough to make it necessary to reevaluate their usefulness in crop rotations for improving soil physical structure.

M. B. Russell
2-13-56

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

SOIL MANAGEMENT & CONSERVATION

AGRONOMY FACTS

SM-14

CROP ROTATIONS AND INSECTS

Cultural practices are essential in combating attacks of many species of insects. Crop rotations are a cultural practice that reduces the number of insects farmers have to combat and thus cuts down the amount of insecticide they have to use. Insecticides are only a supplementary means of controlling insects. If populations were not reduced by rotations and other cultural practices, as well as by the weather, the insecticide bill on each farm would be astounding.

Northern corn rootworm is a good example of how insects can be controlled by correct crop rotation. This pest, which has a life cycle of one year, presents a serious problem where corn is grown in the same field for more than two years in succession. The rootworm overwinters in the egg stage, and the small larvae hatch in the spring and stay in the soil waiting to feed on the corn roots. The damage they do may cause the corn to lodge seriously.

Correct rotations will adequately control this pest. Growing other crops in the rotation for two years after corn reduces the number of larvae and emerging adults, providing adequate control without use of an insecticide. A two-year break is necessary, however, because rootworms will survive for one year on some crops besides corn. Wheat jointworms can also be partly controlled by rotating crops.

White grubs are another pest that can be controlled by rotations, but not so easily as the northern corn rootworm. Because grubs have a three-year life cycle, rotation plans must be made two years before the damage is expected. In the first year of the cycle, June beetles, the adults of white grubs, lay their eggs in the spring. The grubs hatch, feed, and overwinter. The next summer, during the second year of the cycle, they feed heavily, severely damaging the crop roots. During the third year, they feed during May, pupate, and remain in the soil as adults the following winter, emerging in the spring to lay eggs.

To avoid damage from grubs during the year of heavy feeding, it is necessary to have had some crop on the land that was not suitable to the adults for laying eggs during the previous season (the first year of the cycle). Such crops are clover, alfalfa, and corn. At one time soybeans were included in the list of resistant crops, but there is now one species of grub that will lay eggs in this crop.

A carefully planned rotation will also reduce some species of wireworms and cutworms. If length of life cycle and other facts about the insect are known, then a crop rotation can be planned that should reduce its attacks on the crop.

H. B. Petty
2-20-56

(Over)

CROP ROTATIONS AND DISEASE

It is obvious that continuous cropping perpetuates and increases the pathogenic organisms in the soil. Good examples of this process in Illinois are the increase in the amount of take-all and of bunt through soil infestation in fields where wheat has followed wheat for two successive years. Under such situations rotating crops would constitute a good method of control. Crop rotation may, however, be recommended as a means of controlling disease without considering whether the pathogen or pathogens would be effectively reduced.

The first question to consider in recommending crop rotation as a means of controlling a specific disease is to determine whether the pathogen that is responsible for the disease is a true soil inhabitant or whether it is a soil invader of short duration. Some organisms are capable of living in the soil for 10 to 20 years without coming into contact with their natural host. Some examples are species of Fusaria and damping-off and root-rotting fungi like Pythium. Crop rotation could obviously be of little value in controlling diseases caused by this group because it would take too long to eliminate them.

On the other hand, those fungi that can live for no more than two to four years in the soil without their natural host may be at least partly eliminated by rotating crops. Most of these fungi, however, are parasites of vegetable crops. Some of the more common ones are the organisms causing bean anthracnose, blackleg of cabbage, and bacterial blight of common beans.

Some work done in Illinois to determine the persistence of the soil-borne wheat mosaic virus showed that growing nonsusceptible crops for at least four years reduced the amount of virus but did not eliminate it. Therefore crop rotation cannot be recommended as an adequate control for this disease, in which the virus is known to persist in the soil for a long time.

In most cases rotation is of little value as the sole means of controlling soil-borne diseases in agronomic crops. On the other hand, crop rotation together with other types of control could be very effective. Often the two combined will keep the disease-producing organisms from building up or hold them to a minimum so that they will cause little loss in yield. If they accomplished no other purpose, this result alone would make crop rotation worth while.

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2-20-56

(Over)

AN ANALYSIS OF THE NITROGEN STATUS OF THE AGRONOMY SOUTH FARM ROTATIONS

Numerous experiments have shown that satisfactory, although not necessarily maximum, grain yields can be maintained by using rotations where the legume-grain crop ratio is 1 to 3 or 1 to 4. The marked improvement in soil physical condition (tilth) caused by the legume meadow and the noticeable deterioration in physical condition after several years of tillage have tended, however, to obscure the primary function of legumes in rotations, namely, to restore and maintain nitrogen. It is only when nitrogen is applied to grain crops several years removed from the legume that it becomes evident that the decline in crop yields which necessitates a return to legumes is primarily a reflection of lower nitrogen fertility rather than of tilth deterioration.

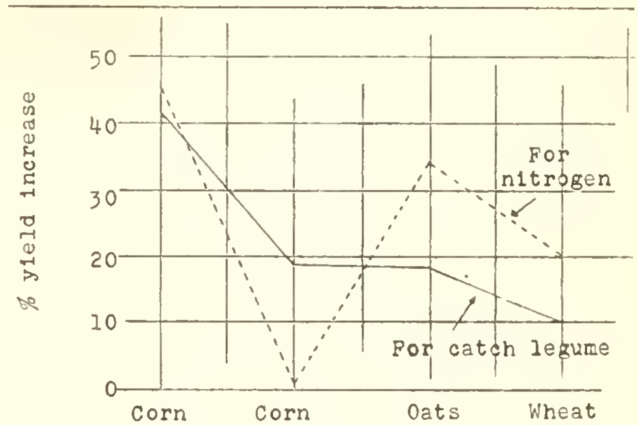

Fig. 1. Percent of increase in grain yields for planting a catch legume and using nitrogen only where yields of plots receiving no nitrogen or legume seedings are the standard for comparison. For nitrogen graph line only: first corn, 100 lb. N; second corn, no N; oats, 20 lb. N; wheat, 20 lb. N. (Data from Illinois Agronomy South Farm)

The transitory nature of nitrogen fertility in rotations where legumes are the primary source of nitrogen is illustrated in Figure 1. The corn, corn, oat, wheat rotation was planned to determine the effects of catch-legumes sown in small grains on subsequent grain yields. There were check plots where legumes were not seeded and plots where legumes were seeded. Thus it is possible to evaluate the yield effects of seeding the catch legumes.

Figure 1 shows that the catch legume increased yields of all grains. The yield effect of the legume, however, expressed as percent of increase in yield, was always greatest the first year. A rather sharp break in the residual yield effect of the legume is evident in the second year. The yield effect of the legume continues to decline thereafter, but at a lesser rate.

The data in Figure 1 for the yield effects of commercial nitrogen indicate that commercial nitrogen is equally as satisfactory as legume nitrogen in so far as first-year corn yields are concerned.

The residual effects of commercial nitrogen applied to first-year corn on second-year corn yields were insignificant. In this respect legume nitrogen was superior to commercial nitrogen. It is quite apparent, however, that the legume system did not supply enough available nitrogen for maximum small grain yields, because oat and wheat yields were higher when nitrogen was applied.

The preceding discussion presented evidence of the transitory nature of nitrogen fertility. Figure 2 gives a generalized concept of the nitrogen fertility pattern one might expect in rotations where the ratio of non-legume to legume crops is 3 to 1. The pattern is carried through nine years, or two full rotation periods, to show the saw-toothed cyclic nature of nitrogen fertility induced into rotations by periodic legume growth.

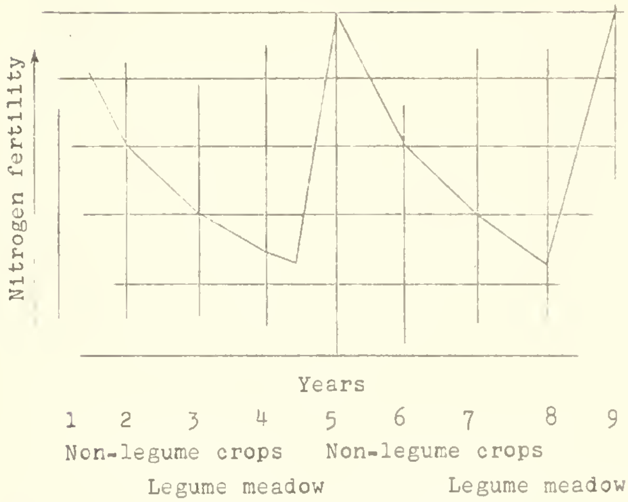

Fig. 2. A generalized nitrogen fertility pattern for rotations where the grain to legume ratio is 3 to 1.

Two areas in the nitrogen fertility pattern are of interest: the peak and the floor. In terms of minimum rotational nitrogen availability, the floor can be expected to vary with the organic matter content of soils, the activity of decay of this organic matter, and the residual legume nitrogen. If the legume is not sown or if it fails, there can be no peak. The floor of minimal nitrogen availability would then appear to broaden and gradually sink, since nitrogen availability at this point depends primarily on the decay rate of an ever-decreasing soil organic matter supply.

If the stand is pure, the height to which nitrogen availability or fertility rises following a legume would appear to be determined primarily by the amount of nitrogen the legume contributes. Lower peaks, and frequently double peaks, with the higher of the two peaks in the second year, are possible where mixed legume-grass sods or legumes mixed with a considerable amount of straw are turned under.

Figure 3 shows examples of multiple nitrogen availability peaks of this nature. Thus the generalized nitrogen fertility pattern illustrated in Figure 2 can vary with different rotations. Moreover, the peak nitrogen fertility associated with a specific rotation may not represent the optimum nitrogen fertility needed for maximum grain yields.

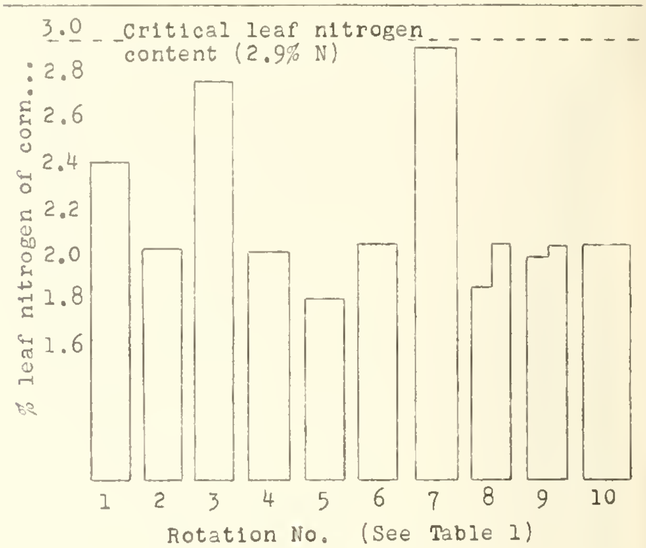

Fig. 3. Nitrogen adequacy peak measure by leaf analysis for various rotations, Illinois Agronomy South Farm.

Leaf analysis studies with corn have indicated that a leaf nitrogen content of 2.9 percent gives maximum corn yields. This is the critical leaf nitrogen percentage for corn. By means of leaf analysis it has been possible, in terms of leaf nitrogen contents, to define the nitrogen fertility peaks associated with various rotations at the Agronomy South Farm. Ten rotations and associated corn leaf nitrogen contents are listed in Table 1. The results are presented graphically in Figure 3.

Table 1. Rotations and associated corn leaf nitrogen contents at the University of Illinois Agronomy South Farm*

Rotation number	Rotation	Percent leaf nitrogen
1	Corn, soybeans	2.42
2	Corn, oats	2.17
3	Corn, oats**	2.67
4	Corn, oats, wheat**	2.67
5	Corn, corn, wheat**	1.80 & 1.70
6	Corn, oats, wheat, timothy	2.14
7	Corn, oats, wheat, alfalfa	2.85
8	Corn, corn, oats**, wheat**	1.82 & 2.07
9	Corn, corn, soybeans, wheat**	1.94 & 2.07
10	Corn, soybeans, oats, wheat**	2.05

*All plots included in rotation experiment have been limed and phosphated. Soil test indicates adequate potash.
**Catch legumes seeded.

Rotation 7, which is a corn, oat, wheat, alfalfa sequence, was the only rotation in which soil nitrogen fertility, as indicated by leaf analysis, approached that considered optimum for first-year corn. Rotations 2, 4, 5, 6, 8, 9, and 10, judged by the same standard, gave soil nitrogen fertility peaks that were substantially suboptimum for maximum corn yields.

The leaf nitrogen content observed for rotation 1, a corn-soybean sequence, is of considerable interest. Most workers do not consider that harvested soybean residues contribute much nitrogen to the soil. Yet, except in rotations 3 and 7, the leaf nitrogen content of corn following soybeans exceeds that for other rotations.

The microbial demands for nitrogen set up by corn residues probably have no effect on yields of nodulated soybeans. Thus soil nitrogen perhaps contributes toward the decay of most of the corn residues during the season in which soybeans occupy the land. Corn following soybeans would then appear to grow in a soil environment that is virtually free of microbial competition for nitrogen. Thus the greater part of the available nitrogen is released from soil organic matter. This nitrogen plus that released from partly decayed corn and decaying soybean residues probably makes the soil nitrogen fertility status higher than one might expect. It should be obvious, however, that this practice can not assure above-average corn yields indefinitely because under this highly nitrogen-deficient rotation the soil organic matter will eventually be drastically reduced, leading to progressively lower corn yields.

The effect of the kind of residues that precede corn on net soil nitrogen availability can be evaluated by comparing rotations 1 and 2. Where soybeans precede corn, microbial nitrogen demands are probably at a minimum for the reasons previously given. Where corn follows oats (rotation 2), microbial competition for available nitrogen apparently persists during most of the growing season. This is reflected in lower leaf nitrogen contents and lower corn yields for the corn-oat sequence. Planting a catch legume in the oats (rotation 3) appears to greatly increase the net nitrogen availability, and this increase is reflected in a higher leaf nitrogen content.

Multiple nitrogen fertility peaks, with maximum nitrogen fertility in the second year, are not uncommon for some rotations. This is true for rotations 8 and 9. It would appear that the nitrogen contributed by the catch legume that preceded corn was not sufficient to overcome all of the microbial nitrogen demands occasioned by the decay of the wheat straw. Thus first-year corn is produced in a less favorable soil nitrogen availability environment.

The initial decay processes that reduce first-year nitrogen availability, however, appear to be more or less complete prior to August of the second year. The subsequent release of available nitrogen previously withheld during decay then gives a higher second-year nitrogen fertility pattern, as the data for corn leaf composition show.

The nitrogen fertility pattern illustrated in Figure 2 might be considered to represent a normal nitrogen fertility pattern. The data in Figure 3, however, indicate that rotations can alter the normal pattern, i.e., multiple nitrogen peaks. Moreover, it is apparent that the nitrogen fertility peaks achieved by some rotations do not constitute nitrogen adequacy in so far as maximum yields are concerned. Supplementary nitrogen fertilization throughout such rotations is needed to obtain maximum grain yields.

Edward H. Tyner
2-27-56

ECONOMIC OBJECTIVES OF CROP ROTATIONS

Four previous Agronomy Fact sheets have discussed the various agronomic objectives of crop rotations: controlling erosion, maintaining desirable soil physical properties, controlling insects and diseases, and supplying plant nutrients to crops. Attaining any one of these four objectives to the fullest extent is likely to mean sacrificing the complete fulfillment of one or more of the others. They must therefore be balanced when a rotation is selected and put into effect in the farm business.

An economic analysis of this problem should consider the "best" use of labor and capital, as well as the "best" use of the land. In short, the economic objective of crop rotations should be to select the rotation that will give the maximum profit for the total farm business over a period of years.

Economic Principle Involved. One crop can be substituted for another to varying degrees in rotations. For example, going from a C-C-O (clover catch crop) rotation to a C-C-O-M rotation means that meadow is being substituted for part of the corn and oats. In terms of total production of each crop (per acre yield times number of acres), the result of substituting one crop for another in a rotation is not always the same. For example, the number of bushels of corn sacrificed for each ton of legume hay gained is likely to be less in shifting from, say, a C-C-O-M to a C-C-O-M-M rotation than in shifting from a C-O-M-M to a C-O-M-M-M. This difference is due to the different effects of crop sequences on yields as the proportion of land in each crop changes.

The economic principle involved in selecting a rotation is that, in order to maximize profits, one crop (for example, meadow) is substituted for another (for example, corn) until the returns sacrificed by decreasing corn production are exactly balanced by the gain in returns from increasing meadow.

Rotation experiments frequently show a "complementary" effect on corn when legumes are added to the rotation in small amounts. That is, total corn production (per acre yield times number of acres) increases, up to a point, as legumes occupy a larger percent of the rotation. If legumes and corn are complementary, adding legumes to the rotation will be profitable even if the roughage that is produced is not sold or used by livestock. In many commercial fertilizer programs, however, this complementary relationship disappears, and corn and legumes compete throughout a wider range of rotations. This means that the farmer has a larger number of choices, and thus his decisions regarding cropping systems become more difficult.

Basic Data Needed for Choosing Rotation. The economic principle can be applied by using expected yields from each alternative rotation. The expected yields summarize, in a sense, the combined effect of the relationships described in the four previous Agronomy Fact sheets on rotation objectives. Since the problem of selecting a rotation cannot be divorced from that of applying fertilizer to individual crops within the rotation, alternative fertilizer programs and their expected effects on yield must be considered in combination with each rotation.

Except where a cash-grain system is to be followed, the livestock system must also be considered. Roughage-consuming livestock may be desirable to use labor during slack seasons. Livestock may in turn require a higher percent of legumes in the rotation than would be dictated by a simple cost-returns analysis of the cropping system by itself.

For example, a cost-returns analysis of the cropping system made independently of the livestock system might show a catch-crop rotation to be more profitable than a stand-over rotation. If, however, the farm is small and the farmer wishes to increase his volume of business by using roughage-consuming livestock, the stand-over rotation will be more appropriate.

The place of manure and its effect on yields also needs to be taken into account. And the effect of substituting supporting practices for meadow to satisfy soil conservation objectives must be estimated.

Comparing Relative Profits of Rotations. Using the basic data outlined above, the farmer can make a "budget" of estimated costs and returns for each alternative rotation, including other parts of the farm business that are related to the rotation. This comparison of costs and returns can be simplified by considering only those costs that differ among the alternative plans. For example, such fixed costs as taxes, interest on land, overhead on machinery, etc., can be omitted because they stay the same regardless of rotation. Operator and family labor can also sometimes be omitted. Since all costs are not included, the resulting figures should not be confused with "profits." This budget is simply a tool to help compare the effects of different rotations; it is not a measure of profitability of the farm business.

Legume Nitrogen vs. Commercial Nitrogen. An added advantage in selecting a rotation as part of the total farm business is that there is less need for "internal" accounting. We need not, for example, attempt to calculate a cost for producing nitrogen from legumes. So long as the yield estimates for each rotation adequately reflect the effect of the crop sequence, and varying levels of nitrogen are considered in combination with the rotations, the value of the legume will show up in subsequent yield increases and, in a livestock system, in increased livestock production. Interest should focus on the comparative returns from the alternative total farm plans and not on the value of "goods-in-process."

Computing Net Returns for a Period of Years. Adoption of a rotation implies that the farm operator expects to receive income and to incur expenses over a period of years. Alternative cropping systems may give him a choice in the way his income and expenses are spread over this period. For example, some cropping systems may require heavy initial expenses for fertilizer, while others may require smaller initial expense but cover a longer time. The time at which the crop sequence will affect yields also differs among rotations. The farmer must consider these differences in developing a budget that is designed to help him pick a rotation.

Budgets of returns and expenses over a period of years can be compared more accurately by using a discounting procedure. This will give the net returns over a period of time from each plan in terms of its present value. For instance, using an annual discount rate of 5 percent, we find that an income of $100 three years from now is worth only $86 today. The same procedure must be applied to costs. Discounting is especially important in comparing alternative plans that have widely different timing of expenses of income.

Comparative Risks. Some farmers prefer a lower, more stable income to one that is higher but varies more from year to year. Since weather and price fluctuations do not affect all crops in the same way, rotations differ in variability of returns as well as in average level of returns. In the final selection of a rotation, these differences in risks need to be balanced against the comparative returns from the alternative rotations.

Earl R. Swanson
3-5-56

CONTINUOUS CORN

SM-17

How often should corn be grown on (productive) corn-belt soil? This much-discussed question has been studied experimentally for 80 years on the Morrow plots on the campus of the University of Illinois. Many other tests have been made on experiment fields and on farmers' fields throughout the state.

At the Momence soil experiment field in Kankakee county, corn was grown continuously for 14 years, beginning in 1902. Average yields were 6.5 bushels an acre on untreated land; 44.3 bushels with limestone, phosphate, and potash (LPK); and 50.6 bushels with limestone, phosphate, potash, and nitrogen (LPKN).

Fertilizers were applied at the following acre rates each year: phosphorus as bone meal, 200 pounds; potassium as muriate of potash, 150 pounds; and nitrogen as dried blood (12%NO), 800 pounds. The soil was peaty loam.

On the Davenport plots at Urbana, a continuous corn experiment was operated for 13 years, beginning in 1901. Fertilizers were used in the same amounts as described above in the tests at Momence. Average yields were as follows: LPK, 50.1; and LPKN, 61.4. During these same years (1901, 1913), a rotation of corn, oats, clover, and wheat catch crop was also used on the Davenport plots. Average yields were 57.9 bushels with no soil treatment and 78.7 bushels with LPK. No nitrogen fertilizer was used on the rotation plots. The soil on this area was Flanagan silt loam.

A continuous corn culture study was started on the Dixon soil experiment field in 1932. To maintain a high test level, soil treatments have included lime, superphosphate, and potash. Since 1942, 600 pounds of ammonium sulphate an acre have been plowed under each year, and 130 pounds of 3-12-12 have been used as a starter. Rye has been seeded in the fall as a cover crop since 1951.

Twelve-year average corn yields (1944-55) for these plots and for corn under rotation at Dixon and at the Morrow plots are reported in Table 1. Growing costs are indicated in terms of bushels of corn (calculated at $1.25 a bushel). These costs were subtracted from yield to give "take-home" corn per acre.

During recent years hybrid corn, cheaper nitrogen fertilizers, and corn price supports have caused renewed interest in continuous corn. At the Lebanon experiment field on Jarvis-LeClaire silt loam and at the Newton experiment field on Cisne silt loam, tests with continuous corn were established in 1951 on land that had been in rotation with soil treatment for many years. Treatments with continuous corn include the use of non-legume cover crops and nitrogen at the rate of 140 pounds each year. Yields were low as a result of severe drought in 1954 and moderate drought in 1955. Table 2 gives average corn yields for the four years 1952-1955 with continuous corn and with corn in a corn, beans, wheat, hay rotation.

At the Urbana Mumford (M-9) plots an area of land has been in continuous corn culture since 1935. Average yield on the untreated areas of these plots from 1940 to 1952 was 64 bushels an acre. Table 3 lists treatments and yields for the past three years (1953-1955). This soil is a Drummer clay loam that has been adequately limed and phosphated.

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L. B. Miller
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P. E. Johnson
D. L. Mulvaney

3-26-56

Table 1. Continuous Corn Versus Rotation Corn at Dixon and at Morrow Plots 12-yr. Averages, 1944-1955

Rotation	Soil treatment	Acre yield	Costs in bushels of corn per acre: Soil treatment	Costs in bushels of corn per acre: Total costs 1/	"Take-home" corn	Ratio 2/ of yield to "Take-home"
Dixon Soil Experiment Field - Tama Silt Loam						
		bu.	bu.	bu.	bu.	
Continuous corn	LPKN 3-12-12	75.9	18.0	58.2	17.7	4.29
Continuous corn	L	49.2	1.0	38.6	10.6	4.64
C-O-Cl-W	LPK	95.1	5.0	47.0	48.1	1.98
C-O-Cl-W	O	58.5	-	38.5	20.0	2.92
C-O-W(legume)	LPK	80.2	6.0	46.6	33.6	2.39
C-O-W	LPK	46.0	4.0	41.3	4.7	9.79
Morrow Plots - Flanagan Silt Loam						
Continuous corn	O	22.0	-	39.0	-17.0	x
Continuous corn	MLP	64.0	5.0	44.0	20.0	3.20
C-O-Cl	O	68.0	-	39.4	28.6	2.38
C-O-Cl	MLP	108.0	5.0	48.2	59.8	1.81

1/ Includes fertilizer costs, harvesting, and marketing @ 12¢/bu. plus all other costs, based on Detailed Cost Report for Central Illinois. (A. E. Mimeo 2969)

2/ This ratio indicates how many bushels of corn must be harvested for each bushel of net or profit. It also shows how many bushels must go to market or be added to surplus for the producer to make the same net profit.

Table 2. Continuous Corn vs. Rotation Corn at Newton and Lebanon, 1952-1955

Cropping	Soil treatment	Average corn yields: Newton	Average corn yields: Lebanon
		bu.	bu.
Corn continuous	LPK	35.7	61.0
Corn continuous and cover crop	LPK	30.1	54.3
Corn continuous	LPKN	35.1	63.0
Corn continuous and cover crop	LPKN	37.9	64.3
Corn, beans, wheat, hay	LPK	45.9	83.4

Table 3. Continuous Corn With and Without Rye, Mumford Plots, M-9, Urbana

Year	K Rye	K	K Rye N1/	10-10-10 1/ N 1/	10-10-10 1/ Rye N 1/
	bu.	bu.	bu.	bu.	bu.
1953	57	66	69	79	74
1954	58	65	69	72	68
1955	59	71	87	88	90
Average	58	67	75	79	77

1/ Treatment 500 lb./A 10-10-10, N - 100 lb. N alone or 50 lb. with 10-10-10.

THE PRODUCTIVITY OF SOME IMPORTANT SOUTHERN ILLINOIS SOILS

In the last few years a considerable amount of interest has centered on increasing the yield possibilities of some of the southern Illinois soils. This interest has arisen as a result of the relatively higher prices received for central and northern Illinois soils and some rather favorable responses to soil management on experimental fields in the southern area.

Productivity is the ability of a soil to produce crops or other plants under various management practices and weather conditions. Productivity may be measured in per acre yields of certain crops or in terms of an index of combined yields of grain crops, forage, or timber (see AG-1443).

The soils included in this report occur generally south of a line from Calhoun county, Illinois, on the west to Clark county on the east. On the soil association map (see AG-1443) they occur in Areas M, N, O, and P. These soils have generally developed in less than five feet of loess lying on a weathered glacial till of Illinoian age (SP-1). In most cases they are leached of free carbonates, and their degree of base saturation is low (SM-7).

Soils in Areas M, N, and P were generally developed under a native prairie grass vegetation and are somewhat better supplied with organic matter and with the desirable base nutrients (Ca, Mg, K) than are the soils of Area O. The soils

Table 1.--Average Per Acre Yields of Hybrid Corn, Soybeans, and Wheat Obtained by Farmers on Southern Illinois Soils Under Medium and Moderately High Management Levels*

Soil assn. area	Soil type or associated types	Hybrid corn, management**		Soybeans, management**		Wheat, management**	
		Med.	Mod. high	Med.	Mod. high	Med.	Mod. high
		bu.	bu.	bu.	bu.	bu.	bu.
M	Herrick silt loam and Virden silty clay loam	61	68	#	[illegible]	#	#
M	Herrick silt loam	54	59	25	28	30	32
N	Cowden silt loam and Oconee silt loam	48	62	#	#	25	27
N	Cowden silt loam	47	56	#	#	24	26
P	Cisne silt loam	45	53	22	30	21	24
O	Bluford silt loam and Ava silt loam	46	57	[illegible]	#	19	20

*About 95 percent of data represent the 1940-50 decade.

**The standard error of estimate of these figures, when considered as 10-year average yields, is calculated to be about ± 5 percent.

#Insufficient data reported.

of Area O were generally developed under forest vegetation and are usually quite acid (pH 5.0) in their untreated state.

The yields presented in Table 1 are based on data reported by farmers who have been cooperating with the Agronomy Department in a state-wide project aimed at evaluating the productivity of some major Illinois soils. The calculated yields, based on farm-reported data, are given for two levels of management. For convenience, these management levels are referred to as medium and moderately high and are expressed in terms of pounds of nitrogen, phosphate, and potash used and the interval of time between legumes and the crop under study.

For hybrid corn and soybeans, yields were calculated by assuming 6.5 inches of total rainfall and an average maximum temperature of 90^{o} for the months of July and August. These figures are averages for the period 1925-50 reported by the weather stations in the area.

A medium level of management for estimating hybrid corn yields consisted of 50 pounds of N per acre in the current and the previous year, contributed from both legume and nonlegume sources; 20 pounds each of equivalent P_2O_5 and K_2O per acre, applied or estimated as residual from previous applications (30 pounds for Bluford-Ava soils); and a legume or legume-grass mixture two years before the corn crop.

Comparable figures for a moderately high level of management were 100 pounds of N per acre, 40 pounds of P_2O_5 (60 pounds for Bluford-Ava soils), 60 pounds of K_2O (40 pounds for Herrick soils), and the equivalent of an alfalfa—red clover mixture immediately preceding the corn crop.

For soybeans and wheat the comparable figures for medium and moderately high management are approximately one-half of those given for corn.

Table 2 lists yields from similar crops grown on University of Illinois soil experiment fields having the same soils as those included in Table 1 or closely associated soils. Huey silt loam listed in Table 2 includes many of the so-called slick spots in southern Illinois (AG-1443 and SM-8).

The check-plot yields show the productivity of these soils in an untreated condition, and particularly the influence of so-called slick spot soils. The combination of slick spots and low organic matter content in the soil surface may be partly responsible for the low soybean yields at the Sparta field. Good germination and early growth are frequently poor because of "crusting" after rain.

The yields on the plots having full treatment show how these soils respond to adequate fertilization and appropriate rotations. These yields are higher than those reported for a moderately high management level in Table 1. Farmers whose long-time yields are similar to those given in Table 1 may wisely examine their crop production practices not only with regard to soil management, but also weed and disease control, choice of hybrids or varieties, planting rates, and harvesting procedures. The adoption of appropriate improved management practices should bring their soil up to such a level that they could, within a reasonable time, expect to obtain yields similar to those shown in Table 2.

Table 2.--Average Per Acre Yields of Hybrid Corn, Soybeans, and Wheat Obtained on University Soil Experiment Fields, 1940-1954*

Soil assn. area	Soil type or associated types	Hy. corn, treatment		Soybeans, treatment		Wheat, treatment		Experiment fields***
		None	Full**	None	Full**	None	Full**	
		bu.	bu.	bu.	bu.	bu.	bu.	
M	Dominantly Herrick silt loam	49	90	23	32	17	32	Clayton Carlinville Lebanon
P	Cisne silt loam	23	73	11	21	5	27	Oblong
P	Cisne silt loam and Hoyleton silt loam	18	62	8	21	2	25	Ewing
P	Cisne silt loam and Huey silt loam	9	58	9	21	1	22	Newton
O	Wynoose silt loam and Huey silt loam	6	52	2	12	3	26	Sparta

*See Ill. Bul. 516, Effect of Soil Treatment on Soil Productivity, for history of fields and yields prior to 1942.

**Full treatment represents an average of yields obtained on plots treated with manure, limestone, and phosphate (MLP) and with residues, limestone, phosphate, and potash (RLPK).

***See SF-21 for rotations used. A rotation of corn-soybeans-wheat-hay is used on most of the fields.

R. H. Rust
11-28-55

CORN ROOT DISTRIBUTION IN FERTILIZED AND UNFERTILIZED FLANAGAN SILT LOAM

Comparison of corn root development in fertilized and unfertilized Flanagan silt loam at Urbana, Illinois, during the moderately dry season of 1954 showed greater root penetration and root growth and also higher corn yield on the fertilized than on the unfertilized plot.

Over a long period, the fertilized plot had received residue (stover, straw, legumes), lime, and rock phosphate, whereas the unfertilized plot had received only crop residues.

Soil tests indicated that, except for nitrogen, the greatest difference in fertility was in the surface soil, where the available phosphorus was high on the fertilized plot and low on the unfertilized plot. There was very little difference in available phosphorus below the surface soil, and practically no difference in acidity or in available potassium throughout the soil profiles from the two plots.

Although Flanagan is a dark-colored, permeable, naturally fertile soil, crop yields invariably decrease with continued farming unless a good soil management program is followed.

Corn yield was 79 bushels an acre on the fertilized plot and 66 bushels on the unfertilized plot. Total root weight on the unfertilized (R) plot was 1,398 pounds an acre, and the roots penetrated to about 48 inches (see illustration on back). To this depth this soil is capable of storing about 10.5 acre-inches of available water.

On the fertilized (RLP) plot, total root weight was 1,846 pounds an acre, and the roots penetrated to about 60 inches. With this larger rooting volume, the soil had a greater available soil moisture storage capacity (12.8 acre-inches) and a greater supply of nutrients for the crop to draw upon.

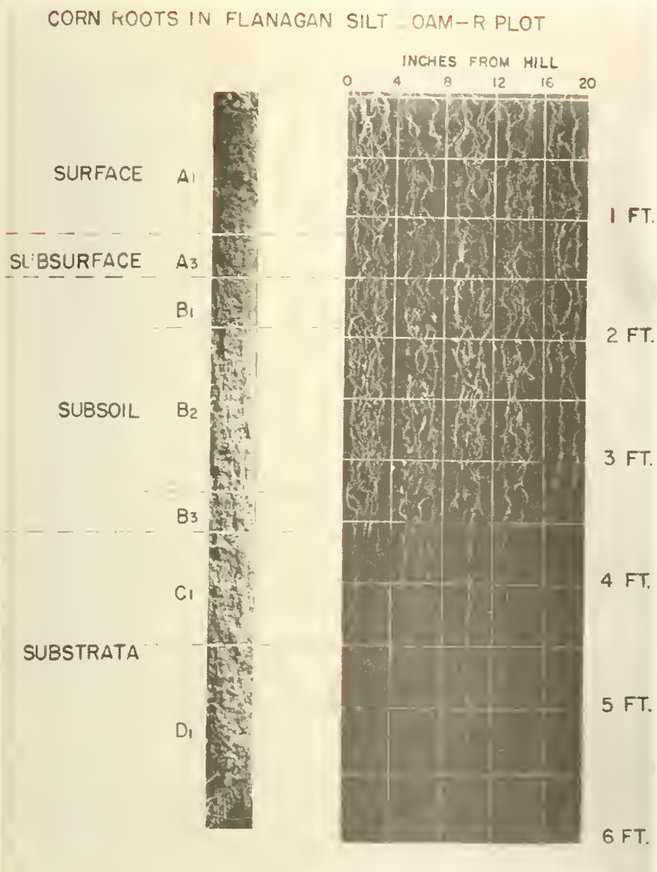
Calculated acre weights of corn roots by soil horizons are given in the table on page 2. Soil horizons are marked on the left of the photographs on page 3.

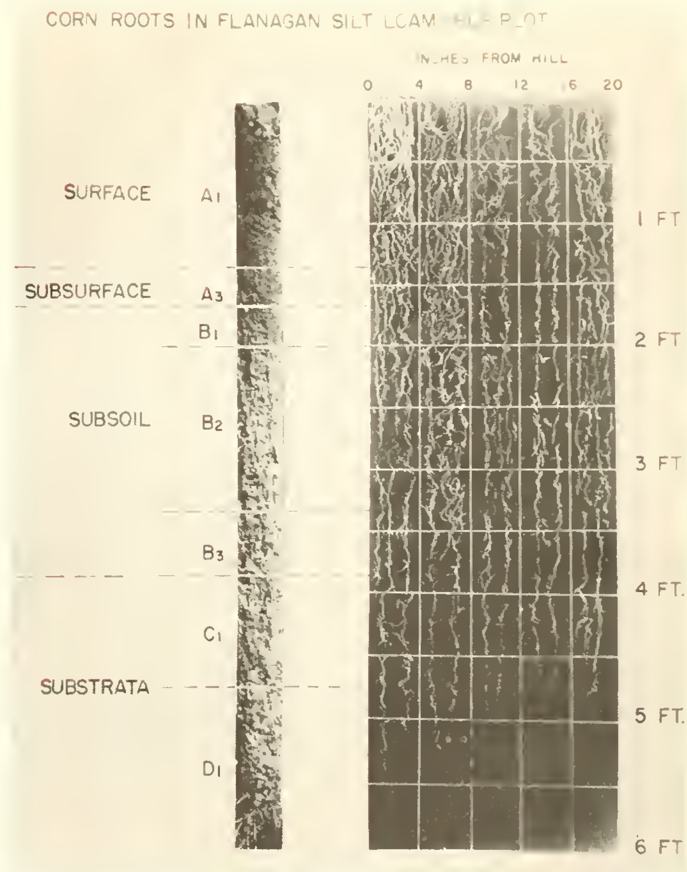
Roots were sampled with a soil-core sampling machine that took four-inch diameter cores to a depth of 72 inches. Core samples were taken in five concentric rings each four inches wide around corn hills. In this way root samples were obtained up to 20 inches from the corn hill, or halfway to the next hill, since the corn was checked 40 by 40 inches. Each of the five vertical sections of roots in the photographs is from one four-inch diameter core 72 inches long at distances from the corn hill specified at the top of the root panels.

For comparison of corn root development in fertilized and unfertilized Cisne silt loam during the moderately dry season of 1952, see Agronomy Facts SM-5.

J. B. Fehrenbacher
12-19-55

Soil horizon	Depth	Calculated root weights per acre	Calculated root weights per acre-inch	Percent of total roots
	in.	lb.	lb.	perct.
		R Plot		
A_1	0-14	444	32	31.8
A_3	14-18	145	36	10.4
B_1	18-23	168	34	12.0
B_2	23-39	458	29	32.7
B_3	39-43	85	21	6.1
C_1	43-54	77	7	5.5
D_1	54-72	21	1	1.5
Total		1,398	--	100.0
		RLP Plot		
A_1	0-16	769	48	41.7
A_3	16-20	143	36	7.7
B_1	20-24	142	36	7.7
B_2	24-40	435	27	23.6
B_3	40-46	165	27	8.9
C_1	46-57	138	13	7.5
D_1	57-72	54	4	2.9
Total		1,846	--	100.0





Corn roots in Flanagan silt loam from a fertilized (RLP) plot on the left and an unfertilized (R) plot on the right. In both photographs each of the five vertical sections of the root panels is from one soil core 4 inches in diameter and 72 inches long. Distance of each vertical section from the corn hill is indicated at the top of the root panel.

THE PRODUCTIVITY OF DARK, TILL-DERIVED SOILS IN NORTHEASTERN ILLINOIS

Soils in the northeastern one-fifth of Illinois are derived primarily from calcareous glacial till of Wisconsin age. Although most of these soils are dark colored and appear similar to the casual observer, they differ widely in productivity (Table 1).

These differences in productivity of the various soils are related to the texture of the subsoil and underlying glacial till (SP-7). The underlying parent material of Clarence-Rowe soils contains so much clay that moisture movement (data in Soil Sci. Soc. Am. Proc., Vol. 14: p. 51-55, 1950, and Agricultural Engineering, Vol. 30: p. 384-386, 1949) and root penetration (unpublished data of J. B. Fehrenbacher) are restricted and crop yields are rather low, even under a moderately high level of management. In contrast, such soils as Saybrook, Lisbon, and Drummer, which are derived from permeable loam till, produce considerably higher crop yields under comparable management. Such management problems as drainage and erosion are also much more difficult on Clarence-Rowe soils than on Saybrook, Lisbon, and Drummer. The physical properties, productivity, and management problems of Swygert-Bryce and Elliott-Ashkum soils are intermediate between those of the preceding two soil associations.

Table 1.--Average per acre yields* of corn, soybeans, and oats obtained by farmers on certain northeastern Illinois soils under medium and moderately high levels of management

Soil association area**	Texture of underlying glacial till	Soil series**	Corn		Soybeans		Oats	
			Medium mgt.	Mod. high mgt.	Medium mgt.	Mod. high mgt.	Medium mgt.	Mod. high mgt.
			bu.	bu.	bu.	bu.	bu.	bu.
C	Loam	Saybrook, Lisbon, and Drummer	70	79	28	33	56	65
E	Silty clay loam	Elliott and Ashkum	62	66	27	30	50	53
G	Silty clay	Swygert and Bryce	56	64	25	26	44	51
G	Clay	Clarence and Rowe	53	61	21	27	36	49

*About 95 percent of the yield data represent the decade from 1940 to 1950. The standard error of estimate of these figures, when considered as 10-year average yields, is calculated to be approximately ± 5 percent.

**Described in Illinois Agricultural Experiment Station publication AG-1443, entitled "Illinois Soil Type Descriptions."

The crop yields in Table 1, which are based upon detailed records kept by farmers, are given for two levels of management. These two management levels, designated "medium" and "moderately high," are defined in terms of pounds of nitrogen, phosphate, and potash used and the interval of time between legumes and the crop under study.

For corn and soybeans, yields were calculated by assuming 6.1 inches of total rainfall and an average maximum temperature of 86° F. for the months of July and August. These figures are averages for the period 1925-50 reported by the weather stations in the area.

A medium level of management for estimating corn yields consisted of 50 pounds of N per acre in the current and previous year, contributed from both legume and nonlegume sources; 20 pounds each of equivalent P_2O_5 and K_2O per acre, applied or estimated as residual from previous applications; and a legume or legume-grass mixture two years before the corn crop.

Comparable figures for a moderately high level of management were 100 pounds of N per acre, 40 pounds each of equivalent P_2O_5 and K_2O per acre, and the equivalent of a legume mixture, such as alfalfa-red clover, immediately preceding the corn crop.

For soybeans and oats the corresponding requirements for medium and moderately high management were approximately 70 percent (ranging from 40 to 100 percent) of those given for corn.

Crop yields on the Joliet experiment field, which is located on Elliott silt loam and Ashkum silty clay loam, are given in Table 2. These data indicate that both limestone and phosphate are needed on these soils if near-maximum crop yields are desired. Comparison of yields obtained with RLPK treatment on the Joliet experiment field (Table 2) with the yields in Table 1 for Elliott and Ashkum soils indicates that farm yields under the moderately high level of management are approximately 80 to 90 percent of the yields with RLPK treatment. These results indicate that with improved management practices farmers may obtain higher crop yields on Elliott-Ashkum and probably other till-derived soils in northeastern Illinois.

Table 2.--Average per acre yields of corn, soybeans, and oats obtained with various soil treatments* on Elliott silt loam and Ashkum silty clay loam at the Joliet Experiment Field, 1944-1955

	Yields with various treatments*			
Crop**	0	RL	RLP	RLPK
	bu.	bu.	bu.	bu.
First-year corn (after alfalfa—red clover)	40	53	77	84
Second-year corn (after soybeans)	32	47	60	72
Soybeans	23	25	29	32
Oats	51	52	62	58

*Symbols for the various soil treatments are: 0 = no treatment; R = crop residues; L = limestone; P = rock phosphate; K = muriate of potash. Refer to Illinois Agricultural Experiment Station Bulletin 516 for information on soil treatment and cropping prior to 1942.

**The cropping system followed is corn, soybeans, corn, oats (legume catch crop), wheat, alfalfa—red clover.

R. T. Odell
1-2-1956

BOTTOMLAND SOILS OF ILLINOIS

Because interest in the management of bottomland soils has been increasing, the following brief discussion and the key on the opposite page are given to help identify such soils and group them according to their management needs and adaptation.

All of the soils in the very poorly drained column in the key need drainage. Bonnie, Jacob, Fordyce, Karnak, Darwin, Turtle Creek, Muskrat, and Wabash are so slowly permeable to water that drainage by tile is usually not practical. In such soils open ditches are recommended and are usually used. Jacob is so difficult to drain that it is best used for timber or pasture. Some of the others, like Karnak, Darwin, Muskrat, and Wabash, sometimes occur in sloughs where very poor outlets make drainage impractical. Such areas are best used for production of water-loving species of trees or for wildlife.

Most large areas of any of the very poorly to poorly drained soils except Romeo need some dredging to get proper outlets for either tile or open-ditch drainage systems. Some of the soils having sandy substrata, like Newart, Riley, Gorham, and Ambraw, may present difficult problems of ditch-bank maintenance if ditches must be cut through them into the sandy, underlying materials.

The soils in the moderately well to well drained column do not need drainage. Some of the soils in the imperfectly drained column, like Belknap, Dupo, Wakeland, Coffeen, Tice, and Gorham, need drainage for best crop growth. Of this group, Belknap is least responsive to tile drainage, and in it open ditches are usually recommended. The others usually have low enough water tables and are permeable enough to keep drainage from becoming much of a problem.

Surface soil texture and also organic matter content, of which color is a fairly good indicator, determine workability to a large extent. So far as possible in the key, surface texture is arranged within pH groups, with the coarser textures at the top and the finer textures at the bottom. On the fine-textured soils (silty clay loam or finer), plowing in the fall and working only when moisture conditions are favorable will help to prevent compaction and cloddiness.

Assuming adequate drainage, the light-colored soils have the highest nitrogen needs, and the dark-colored soils the lowest nitrogen needs for satisfactory crop growth. The strongly to moderately acid ($pH<5.8$) light-colored soils have the highest limestone, phosphate, and potash needs. Superphosphate and mixed fertilizers should be used for specific crops on those soils that are alkaline ($pH>7.5$). Limestone should not be used on the soils that have high pH values.

Most of the soils having pH values within the range of 5.8 to 7.5 are medium to high in available phosphorus and available potassium. However, the soils in this group having pH values near 5.8 will need some limestone, phosphorus, and potassium to produce high yields of most crops, particularly legumes.

Two of these bottomland soils, Burnside and Romeo, are not well suited for general crops because they have only shallow soil profiles over bedrock. Pasture, or in some cases timber, is the best use for these two soils. Perks, because of its very sandy texture, is usually drouthy and not well suited for summer crops like corn and soybeans.

Lack of space makes it possible to show only the major characteristics that are useful in identifying and classifying the bottomland soils in the key.

KEY TO BOTTOMLAND SOILS OF ILLINOIS

Color[a] of surface soil	(pH)[b] of profile	Inches of surface	Texture: Surface soil	Texture: Below surface	Soil series[c] grouped according to natural drainage[d] of profile: Very poor to poor	Imperfect	Moderately well to well
Light	<5.8	12-36	silt loam	sandstone		Burnside	Burnside
		>8[e]	silt loam	silt loam		Belknap	Sharon
		<8	silt loam	silt loam	Bonnie		
			silty clay loam	silty clay loam	Piopolis		
			silty clay to clay	silty clay to clay	Jacob		
	5.8 to 7.5	12-36	fine sandy loam	sand			Landes
		15-40	silt loam	silty clay loam to silty clay	Dupo	Dupo	Arenzville
		>8	silt loam	silt loam		Wakeland	Haymond
		<8	silt loam	silt loam	Birds		
				silty clay to clay	Fordyce		
			silty clay loam	silty clay loam	Petrolia		
			silty clay to clay	silty clay to clay	Karnak[f]		
	>7.5	>8	sand	sand			Perks
			silt loam	silty loam to silty clay loam		Jules	Jules
Moderately dark	5.8 to 7.5	30-40	silt loam	sand		Newart	
			clay loam to silty clay loam	sand		Newart	
		8-30	silty clay loam	sand		Riley	
		>8	silt loam	silt loam	Coffeen[g]	Coffeen[g]	Kemper[g]
			silty clay loam	silty clay loam	Beaucoup	Tice	Allison
			gravelly clay loam	gravelly clay loam	Beaucoup		
			clay loam to silty clay loam	clay loam to silty clay loam	Ambraw[h]	Gorham[h]	
			silty clay to clay	silty clay to clay	Darwin Turtle Creek		
Dark	5.8 to 7.5	12-30	silt loam	silty clay loam		Radford	
		>8	loam	sandy clay	Muskrat		
				sandy loam to clay loam	Otter		Huntsville
			silt loam	silt loam			Huntsville
			gravelly clay loam	gravel			Huntsville
			silty clay loam	silty clay loam	Sawmill		
			clay loam	silty clay loam	Sawmill		
			silty clay to clay	silty clay to clay	Wabash		
	>7.5	>8	loam to silt loam	loam to silt loam	Millington	DuPage	DuPage
		2-10	silt loam	limestone	Romeo	Romeo	

a/ Light colors have values of 4 or more on Munsel soil color charts (dark gray to brown or lighter). Moderately dark color values are usually 3 (very dark gray to dark brown). Dark color values are usually 2 (black to very dark brown).

b/ pH refers to reaction: pH < 5.8 is strongly to moderately acid; pH 5.8 to 7.5 is slightly acid to neutral; pH > 7.5 is alkaline (usually calcareous).

c/ Soil series name plus surface soil texture equals soil type name.

d/ For an explanation of natural soil drainage classes, see Agronomy Facts SP-3.

e/ The symbol > 8 means more than 8. The symbol < 8 means less that 8.

f/ The pH of Karnak may be as low as 5.0.

g/ Tentative series (not yet correlated).

h/ Ambraw and Gorham are sandy below 40 inches.

J. B. Fehrenbacher
1-23-56

ORGANIC SOILS IN ILLINOIS

Organic soils are soils that contain more than about 25 to 30 percent of organic matter. They occur in moist to wet locations where organic material--primarily plant remains--accumulated faster than humus decomposed or decayed.

Organic soils are of two kinds: Peat soils are those in which the plant remains are sufficiently well preserved to permit the plant forms to be identified. Muck soils are those in which the plant remains are so thoroughly decayed that the plant parts cannot be recognized.

In most areas peat probably formed before muck. Some muck may possibly have formed without first going through the long period of thick peat accumulation. The development of muck in this way, however, would have required short but regular wet periods for organic matter to accumulate, alternating with drier periods for it to decompose. This alternating wet and dry cycle would have had to continue throughout the entire period of muck development.

About one-fourth to one-third of the total area of organic soils in Illinois is peat, and the remainder is muck. Little or no true woody peat exists, although shrubs and trees contributed part of the plant remains in some areas, such as the area at Manito in Mason county. Also, there is very little true Sphagnum moss peat in this state. This is the strongly acid type of peat so well known in Canada and northern United States. Only two small areas, located in Lake county, are known in Illinois.

Peat materials in Illinois are chiefly of two kinds: fibrous (reed-sedge variety) and sedimentary or colloidal. Differences between these two peats are due to the botanical composition of the plant remains and to the nature of accumulation. These in turn are responsible for differences in texture, color, shrinkage, etc., and determine the uses to which the peat materials may be put.

Fibrous peat is the most commonly known peat in Illinois. It is formed in shallow water from marsh plants like sedges, reeds, certain grasses, and rushes. These are upright-growing plants that live where the water table remains permanently at or near the surface. A few of the more common mosses, particularly some species of Polytrichum and Hypnum, also helped to form the fibrous peat, but not to the same extent as the marsh plants.

Fibrous peat in Illinois is a matted or felted, stringy mass that resembles firmly compressed, half-rotted straw. It is usually brown in color and about neutral in reaction unless it contains large amounts of snail shells or shell fragments. The shells and shell fragments sometimes give a grayish cast to the whole mass and also provide an excessive amount of calcium carbonate. Freshly exposed fibrous peat usually gives off hydrogen sulfide gas, which has a very distinctive odor.

Fibrous peat is low in ash, usually containing less than [illegible] percent. It is high in [illegible], ranging for the most part [illegible] percent, and [illegible], averaging between [illegible] percent. It has about as much [illegible] the surface layer of [illegible] silt loam prairie soils such as [illegible] or Elliott. It contains [illegible] potassium [illegible] than the surface [illegible]. It is considerably high in cellulose, hemicellulose, and lignin.

Sedimentary peat is formed in small lakes where the water is at least a foot or two deep. It is composed primarily of the remains of aquatic plants, such as water lilies, pondweeds, and stonewarts, and free-floating plants, such as algae, duckweeds, and diatoms. The remains of such plants tend to disintegrate rather thoroughly--except diatoms, which are already very small--and upon settling to the lake bottom form a finely divided, incoherent, structureless ooze.

The sedimentary type of peat is mostly gray in color and calcareous--i.e., high in lime--and will effervesce with dilute hydrochloric acid. Compared with fibrous peat, it is high in ash, averaging between 40 and 50 percent. It contains less organic matter than fibrous peat (about 30 percent) and considerably less nitrogen (between 1 and 2 percent). It is also relatively low in cellulose, hemicellulose, and lignin.

Sedimentary peat is soft and smooth when wet, shrinks greatly upon drying, and dries to a fine, powdery dust. This dust is easily stirred up by tillage and by wind, and the diatoms, which have silicified cell walls, cause itching when the soil contacts the skin.

In Illinois most sedimentary peats are covered by a layer of fibrous peat. After drainage and cultivation, however, this layer of fibrous peat decays rapidly and soon becomes muck. Most mucks are black and usually contain some added mineral matter. Although muck soils are harder to form than the mineral soils, they are more stable than the peats and usually need less specialized fertilizer treatment and management.

More than 90 percent of the organic soils in Illinois are in the northeastern one-fifth of the state or in the region lying north, northeast, and east of McLean county. The few remaining important areas are in Whiteside, Henry, Bureau, and Mason counties, although other small spots occur in various other parts of the state.

Individual areas of organic soils vary in size from small spots of less than one acre up to more than 1,000 acres. The combined area of such soils in Illinois totals about 250 square miles. Although this area is small compared with the total area of the state (about 1/2 percent), the organic soils are extremely important on the individual farms where they occur. They often differ radically from the mineral soils with which they are associated in drainage and fertilizer requirements, workability, and adaptation to crops.

Three series of organic soils--Houghton, Lena, and Edwards--have been established in Illinois to date. Houghton peat (No. 97) is fibrous peat that is about neutral in reaction, and Houghton muck (No. 103) is muck that is approximately neutral in reaction and that decomposed primarily from fibrous peat. Lena peat (No. 324) is primarily calcareous fibrous peat or fibrous peat that is highly charged with snail shell fragments, and Lena muck (No. 210) is calcareous muck formed from both calcareous or shelly fibrous peat and calcareous sedimentary peat. Edwards muck (No. 312) is neutral to calcareous muck between 12 and 36 inches thick on marl. It is decomposed from either fibrous or sedimentary peat. No areas of sedimentary peat that are covered by fibrous peat have been mapped. A few areas of peat and muck consisting of shallow to mineral material of sand, silt, and clay textures are known, but to date they have not been described and designated as separate soil series.

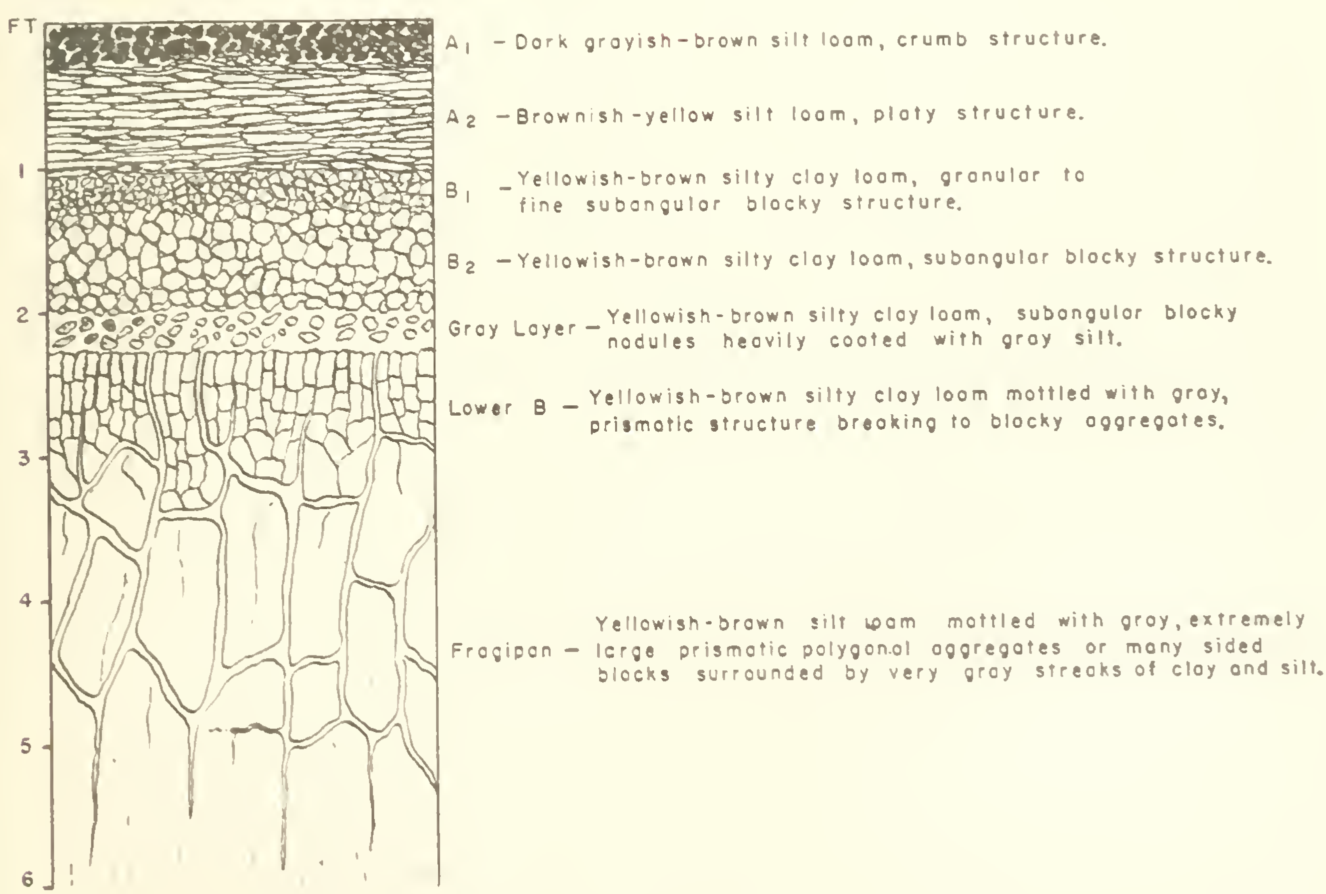
H. L. Wascher
3-12-56

FRAGIPANS IN ILLINOIS SOILS

The term fragipan was formed by combining part of the Latin word fragilis (fragi), meaning brittle, with the word pan which, in reference to soils, means a horizon or layer that is strongly compacted and dense, indurated, or very high in clay.

Fragipans differ from claypans in usually being relatively low in clay, but having a high silt and/or sand content. Fragipans that are high in silt have often been called "siltpans." These very slowly permeable, dense horizons that are extremely hard when dry usually occur in soils in the lower part of the subsoil.

In Illinois fragipans are most common in some of the upland soils in the southern part of the state. In this area upland soils that developed from moderately thick and thin loess usually nave "pan" horizons. On the flats, claypans are found; and on the moderately rolling, but not steep, better drained areas, soils with fragipans are common. The Grantsburg, Hosmer, and Ava soils of southern Illinois all have fragipan horizons of varying degrees of development in the lower part of their subsoils. In the thick loess areas bordering the Mississippi and Wabash river valleys, weathering or soil development has not progressed far enough for fragipans to have formed. However, there is little doubt but that soil development in these thick loess areas is in the direction of fragipan formation.



The usual morphology of southern Illinois soils with fragipan horizons is shown in the diagram on the opposite page. The major type of structure in each horizon is shown in the diagram and is also indicated along with color and texture in the description at the right.

The upper part of the profile above the gray layer has uniform colors of a well drained soil; but because of the mottled colors in and below the gray layer, the entire profile is considered to be only moderately well drained. Fragipan horizons are mixed yellowish brown and gray. When dry they are very hard and brittle, but upon thorough wetting they slake down to a noncohesive or only slightly plastic mass. They seem, therefore, to be reversibly cemented by some agent. Whether the cementing agent is chemical or whether it is small amounts of cohesive clay between closely packed silt particles is still a question.

Fragipan horizons are not entirely lacking in structure, although the structural aggregates are usually very large, as shown in the diagram on the opposite page. The large aggregates are separated by gray or almost white streaks that are composed largely of clay. The sides of the large aggregates next to the gray streaks are often covered with a black substance. The vertical dimensions of these large aggregates, bounded by the gray streaks, are usually greater than the horizontal widths so that in excavations with big machinery, such as is used in road construction or strip mining, the aggregates break out as large prisms.

Fragipans are very slowly permeable to water and restrict root penetrations largely to the gray streaks. In soils such as Grantsburg and Hosmer, water moves readily through the upper part of the profile above the gray layer. Because of the very slow permeability of the fragipan, the water often moves laterally in the gray layer above the pan. During late winter and early spring the upper part of the profile often is saturated with water, whereas the fragipan may be only moist. The moisture storage capacity of the fragipans of southern Illinois, in the range available to plants, is reasonably good, but the inability of roots to penetrate the pan means that plants are usually deprived of most of this water.

In Illinois soils fragipans occur at various depths, depending on soil type, slope, and amount of erosion. In most uneroded areas the top of the pan is below $2\frac{1}{2}$ or 3 feet. The lower boundary is often indefinite, but the pan is commonly 2 to 3 feet thick.

At present there is no proved and practical means of correcting the adverse conditions in fragipans. Deep tillage or mechanical breaking up of the pan requires tremendous power, and the beneficial effects of such treatment, if any, are unknown. Chemical treatment has not been tried to any great extent to date. Fragipans usually have low pH values, ranging from 4.5 to about 5.5. Base saturation and available phosphorus are low, but available potassium is generally moderate to high. The poor chemical properties appear to be easier to correct than the adverse physical properties.

Controlling erosion on soils with fragipan horizons is doubly important. Erosion not only removes valuable topsoil, but also reduces the depth to the fragipan and thus reduces the rooting depth of plants.

J. B. Fehrenbacher
4-9-56

BASIS FOR SEPARATING AND CLASSIFYING SOILS

Soils are characterized and classified primarily for two reasons: (a) to understand how they differ and why they differ and (b) to develop, as a result of laboratory, greenhouse and field research, systems of management suitable for different kinds of soils.

The identification and separation of soil types are based upon the important characteristics of the profile (see SP-2), especially the following:

1. Color of the various soil horizons

2. Number, thickness, and arrangement of the horizons

3. Texture of the horizons

4. Structure of the horizons

5. Chemical characteristics of the horizons, such as total cation exchange capacity, kind and amount of exchangeable ions, percentage of base saturation, pH, etc.

6. Mineralogical composition of the horizons, with special emphasis on the clay mineral fraction.

Color is one of the most easily observed soil characteristics. In Illinois, as elsewhere, color tends to indicate two entirely different properties: (a) organic carbon accumulation and (b) degree of oxidation and diffusion of iron and manganese compounds.

Organic carbon is black and its accumulation is responsible for the very dark gray to dark brown to black soil colors, particularly of the upper or surface horizons. The accumulation of organic carbon (organic matter) tends to be greater under grass vegetation than under forest, other things being equal (see SP-1 and 2), and greater under anaerobic (wet) conditions than under aerobic (dry). Thus the greatest accumulation of organic carbon and resulting blackness of the surface or "A" horizon occurs under grass vegetation in wet places. Oxides of manganese are also dark brown to black, particularly in the hydrated state, but in Illinois they are never present in sufficient quantity to produce more than a few dark concretions or dark splotches on some of the soil aggregates.

Oxides of iron, primarily in the ferric state, vary from yellowish brown to reddish brown. Under aerobic (well drained) conditions these compounds are diffused throughout the soil mass (see SP-3). They coat so many of the individual soil particles that the color is uniform where it is not obscured by organic matter. Under anaerobic (poorly drained) conditions the iron compounds are in the reduced state and are more generally concentrated into concretions. It is believed that, as some soils age, molecules of water are lost from the iron compounds and the color gradually changes from yellowish brown to reddish brown.

The number, thickness, and arrangement of soil horizons, discussed at some length in SP-2, are also rather easily observed characteristics that are used in identifying soil units. Unweathered parent material is thought of as having one soil horizon, i.e., a "C" horizon. As weathering progresses, horizons develop one by one. In some areas in Illinois as many as six horizons have developed, each having features that tend to distinguish it from adjacent horizons. The soils known to be most productive for agricultural purposes under the climatic conditions prevailing in Illinois are those having a few medium-textured (loam, silt loam, silty clay loam) horizons and a thick, dark surface.

Texture is another rather easily observed soil characteristic. It often varies markedly from one horizon to another. In the field it is determined by rubbing some soil between the thumb and fingers (see Ill. Cir. 758), but experience is needed in texturing standard samples before close correlations can be made. Laboratory analyses are sometimes needed for final comparison.

Texture is a function of relative particle size and therefore is an indicator of permeability. Coarse materials, such as gravels and sands, have large pores through which water moves freely. As the particles become smaller and smaller, a point is eventually reached in very fine clay where the pores are so small that moisture and air movement are often seriously restricted.

The kind and arrangement of structural aggregates in the various soil horizons are also useful in characterizing soils. The size, shape, and arrangement of structural aggregates give some indication of the moisture-absorptive capacity of a horizon, as well as some indication of its permeability. Loosely packed granular to rounded aggregates absorb water more readily and permit easier air and water movement than tightly packed angular to square or platy aggregates. But any form of aggregation tends to produce cleavage planes or channels that permit freer water movement and root penetration than would otherwise be possible.

Soil acidity, including the presence or absence of highly calcareous material, is used as a criterion in separating certain soil types. Tests with dilute hydrochloric acid are used to detect areas of high-lime (calcareous) soils. pH tests indicate the relative acidity or alkalinity of a soil, its probable response to liming materials, and its approximate base saturation. A soil or any one of its horizons having a pH of 5.0 or less is considered strongly acid. It is also likely to be relatively low in exchangeable bases, such as calcium, magnesium, and potassium. Soils having a pH of about 6.0 are considered slightly acid, and many of them will be about 70 to 80 percent saturated with bases. Neutral soils with a pH of 7.0 are in general 90 to 100 percent saturated with bases, whereas soils of pH 8.0 usually contain free basic salts, primarily calcium carbonate and, less frequently, salts of magnesium and sodium.

The kind and amount of clay minerals are important in classification as well as in the use and management of many soils (see SP-8). Clays impart sticky or plastic properties to soils, and any increase in clay above a certain point increases tillage and drainage difficulties. On the other hand, any decrease in clay content below a certain point, especially of montmorillonitic clay, reduces the ability of a soil to hold nutrients in a readily available form and release them to plants.

The accurate characterization of soil units consolidates past experience with those units and indicates the probable future behavior of the soils under similar conditions. Classifying soils through accurately defined characteristics is not only an attempt to better understand and interpret nature, but a means of preserving in an orderly manner the facts known about the soils that produce our food.

H. L. Wascher and R. T. Odell
4-16-56

AGRONOMY FACTS

W-6

CONTROLLING WILD GARLIC AND WILD ONION

It has been estimated that wild garlic and wild onion cost Illinois farmers well over a half-million dollars yearly. This loss is mainly through dockage in wheat and does not include loss of milk and meat products due to undesirable flavor caused by these weeds.

Wild garlic (Allium vineale) is much more common than wild onion. Wild onion (Allium canadense) is found in the same areas as wild garlic but usually presents a small problem compared with its neighbor.

How to Tell the Plants Apart

	Wild garlic	Wild onion
Leaves		
Form	Cylindrical	Flat
Base	Sometimes aboveground on stems	At ground level, rising out of the bulb
Bulbs (underground)		
Number	Clusters at base of each plant	One at base of each plant
Covering	Fibrous	Netlike
Kind	Hard-shelled (brown) and soft-shelled	All soft-shelled
Flavor and odor	Strong	Moderate

Both of these weeds begin to grow in the fall from the old plants as well as from the bulblets. Fall growth starts any time from September to November, depending on fall rains. Both weeds seemingly "grow under the snow" during the winter. Wild garlic begins to form underground bulblets in March. In May the aerial bulblets begin to form on both wild garlic and wild onion.

Both plants have matured by small grain harvest, and the aerial bulblets are harvested with the small grain. By mid-July they become dormant, and plowing or disking during the summer has little effect on them. The old plants and the new bulblets are ready to start their life cycle again with the fall rains of September and October.

Both wild garlic and wild onion can be controlled and eliminated by growing crops that can be plowed in either late fall or early spring. If such crops can be combined with one that can be cultivated during the growing season, such as corn or soybeans, both weeds can be eliminated in three to four years.

Plowing in late fall or early spring is particularly effective because it smothers the plants that have germinated and fall plowing usually prevents the underground garlic bulblets from forming. The cultivated crop then destroys any seedlings that may appear with rains during the growing season. Three or four years of this program will practically exhaust all seeds or bulblets that are in the soil.

2,4-D is also effective in destroying wild garlic. Experiments conducted from 1948 to 1950 by the Agronomy Department showed that 1 1/2 to 2 pounds of 2,4-D ester in late fall destroyed both the old plants and the newly germinated seedlings. The same rates in early April were only slightly less effective than the late fall spraying.

Unfortunately, winter wheat will not tolerate these rates of 2,4-D. Only pastures or stubblefields can be sprayed with these amounts.

The following table on wheat yields indicates that winter wheat will not tolerate a rate of 2,4-D that will effectively control aerial bulblets without seriously reducing yields.

Rate of 2,4-D ester/A	Yield of wheat	Percent control of aerial bulblets
Fall Application, November 22, 1948		
Check	32.0	0
1/8	28.0	20
1/4	31.1	40
1/2	25.3	65
1	23.5	100
1 1/2	20.9	100
Spring Application, April,5, 1949		
Check	21.4	0
1/4	18.8	25
1/2	19.1	50
1	16.4	70
2	16.6	80
Spring Application, April 29, 1949		
Check	16.8	0
1/3	16.3	0
2/3	14.4	10
1 1/3	12.0	30
2 2/3	13.0	40

Applications made about the first week in April at 1/2 pound of 2,4-D ester per acre have had very **little** effect on wheat yields but have reduced aerial bulblet formation an average of 50 percent. In addition, the remaining plants have been so deformed that the combine has picked up very few of them. Applications in late April have not been effective in controlling garlic in winter wheat.

The best way to control both wild garlic and wild onion is to change the cropping sequence so that cultivated crops are grown continuously for three to four years. If this program cannot be carried out, then applications of 1/2 pound of 2,4-D ester applied to winter wheat about the first week in April will materially reduce aerial bulblet formation and will gradually thin out stands of wild garlic. One and a half to 2 pounds of 2,4-D acid in the ester form is highly effective in eliminating garlic either in pastures without legumes or in stublefields. The application can be made either in late fall or in early spring.

F. W. Slife
10-24-55

AGRONOMY FACTS

W-7

REACTION OF VARIOUS WEEDS AND BRUSH TO 2,4-D AND 2,4,5-T

Many weeds and woody plants are not killed when sprayed with 2,4-D and 2,4,5-T, while others are easily controlled. Following is a listing of various weeds and woody plants and their reactions to 2,4-D and 2,4,5-T herbicides.

Weeds and Their Reaction to 2,4-D

Annuals - Susceptible

- Beggar-ticks
- Bitter wintercress
- Black medic
- Carpet weed
- Cocklebur
- False flax
- Flower-of-the-hour
- Hemp
- Hemp-nettle
- Henbit
- Jewelweed
- Kochia
- Lambsquarters
- Marsh elder
- Morning glory, annual
- Mustards
- Peppergrasses
- Pigweeds
- Plantain, annual
- Prostrate verbain
- Radish, wild
- Ragweeds
- Rape, annual
- Rough cinquefoil
- Sow thistle, annual
- Stinkweed
- Sunflower
- Vetch
- Yellow star thistle

Annuals - Less Susceptible
(Plants may recover under some conditions)

- Bedstraw
- Buckwheat, wild
- Chickweed
- Dodder
- Dog-fennel
- Fleabane
- Goosefoot
- Jimsonweed
- Knotweed
- Lettuce, wild
- Mallow, roundleaved
- Purslane
- Russian thistle
- Shepherd's purse
- Smartweeds
- Speedwells
- Velvet weed

Annuals - Not Susceptible

- Annual grasses
- Black nightshade
- Buffalo bur
- Catchfly
- Corn cockle
- Cow cockle
- Wild cucumber
- Wood sorrel

Perennials and Biennials - Susceptible
(Frequently killed by one application)

- Artichoke
- Broadleaf plantain
- Buckhorn
- Bull thistle
- Burdock
- Catnip

Perennials & Biennials - Susceptible (Cont.)

- Chicory
- Cinquefoils
- Coneflowers
- Creeping charley
- Dandelion
- Dragonhead
- Evening primrose
- False ragweed
- Figwort
- Four-o-clock
- Gummweed
- Heal-all
- Hedge bindweed
- Hedge nettle
- Hoary alyssum
- Horsetail
- Licorice, wild
- Moonseed
- Nettle, stinging
- Poppy, mallow
- Roadside thistle
- Rosin weed
- Skelton weed
- Slender rush
- Verbains
- Water hemlock
- Wild parsnip

Perennials & Biennials - Less Susceptible
(Tops are killed but regrowth may occur)

- Bouncing Bett
- Buttercups
- Canda thistle
- Carrot, wild
- Docks
- Dogbane
- Field bindweed
- Goatsbeard
- Goldenrod
- Lettuce, blue
- Pokeweed
- Poverty weed
- Sorrel, red
- Teasel
- Yarrow

Perennials & Biennials - Not Susceptible

- Asters
- Bittersweet
- Bracken
- Catchfly
- Cattail
- Chickweed, mouse-ear
- Climbing milkweed
- Ferns
- Foxglove
- Goatweed
- Ground cherry
- Hoary verbain
- Milkweeds
- Mullen, common
- Nettles, horse
- Ox-eye daisy
- Russian knapweed
- Smartweed, swamp
- Sorrel, yellow
- Spurges
- Strawberry, wild
- Tansy ragwort
- Tick-trefoils
- Toadflax
- Violets
- White cockle

Woody Plants

A mixture of 2,4-D and 2,4,5-T or straight 2,4,5-T is more effective than 2,4-D alone on most of these plants.

Woody Plants - Susceptible

(Current growth killed but retreatment may be required.)

Alder
Apple, crab
Aspen
Barberry
Birch, black
Blackberry
Boxelder
Buckbrush
Cherry, wild
Cottonwood
Currant
Dogwood
Elderberry
Elm
Gooseberry
Grape, wild

Woody Plants - Susceptible (Cont.)

Hackberry
Hazelnut
Honeysuckle
Locust, black
Mulberry
Osage orange
Persimmon
Plum, wild
Poison ivy
Sassafras
Sumac
Tamarisk
Trumpet vine
Virginia creeper
Walnut, black
Willows

Woody Plants - Not Susceptible

Ash
Basswood
Bittersweet
Lead plant
Locust, honey
Oak
Raspberries
Red cedar
Rose, wild

Earl C. Spurrier
4-30-56