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Soybean Production in Missouri

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The soybean is a hardy, drought resistant crop, capable of producing good yields of hay on a wide variety of soils. Profitable yields of seed are obtained only on the better soils. For many years soybeans were regarded as the best legume for hay on land where red clover and alfalfa were not dependable crops. Korean lespedeza, however, is now replacing soybeans as a hay crop on some of the soils that are not adapted to alfalfa and clover. The soybean is still grown for hay on a broad scale, but the current trend seems to be toward an increased acreage for grain and a reduced acreage grown for hay. Soybeans are also grown for purposes other than hay or seed. Approximately 200,000 acres are planted with corn, mainly in the south-east Missouri lowlands for soil improvement and pasture.

The various uses of soybeans on the farm and in industry are here briefly discussed. But the principal purpose of this Bulletin is to give practical information on soybean varieties, methods of growing and harvesting soybeans, management of the crop in a rotation, and on the soil fertility relations of the soybean crop.

USES OF SOYBEANS

Hay.—Soybeans make an excellent legume hay if properly handled. The feed value of the part consumed is approximately equal to that of alfalfa. However, a small per cent of soybean hay consists of coarse stems which are refused by the animals and must be considered as waste.

Seed.—One bushel of seed when processed will yield about 9 pounds of oil and 49 pounds of meal. The remainder of the original weight is accounted for in milling and moisture losses.

Soybean oil is used in a variety of products. At present about 52 per cent goes into vegetable shortening, 21 per cent into margarine, 10

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per cent into salad oil and other edible materials, 7 per cent into paints and varnishes, and the remainder into a variety of products such as linoleum, oilcloth, ink, soap, foundry core binder, etc.

Approximately 96 per cent of the soybean meal is used for livestock feed. It is generally accepted as fully the equal of cottonseed and linseed meal. Under some conditions it is superior to the other meals. Increasing amounts of soybeans and soybean meal are being converted into soybean flour, which is used in a variety of food products such as bread, cookies, soybean milk, etc.

Whole or Ground Soybeans.—It is sometimes practical but not recommended to feed soybeans without first having them processed. There are, however, some serious limitations in the use of soybeans for feed before the oil is removed. The use of more than 10 per cent of soybeans in the grain rations of hogs results in the production of soft pork, and is therefore poor economy.

Green Manure.—Soybeans produce a nitrogen-rich forage that is excellent green manure. However, it is generally unprofitable to utilize a full season crop for this purpose.

Pasture.—It is seldom practical to utilize soybeans for pasture where they are grown in a pure stand. Pasturing, however, is a very efficient method of utilizing a crop grown in a mixed planting of soybeans and corn. Here again is a possibility of the soft pork problem where “fattening” hogs are given access to a field of soybeans.

Miscellaneous.—Soybeans are also used with varying degrees of success as a soiling and silage crop. And there is a rapidly growing interest in the green shelled and dry vegetable varieties for table use.

SOYBEAN VARIETIES

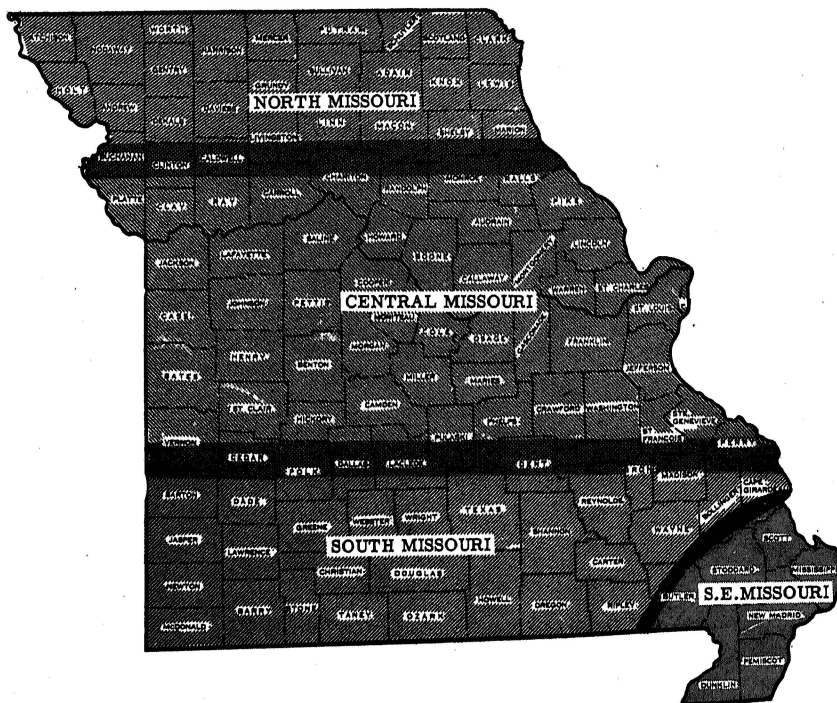
Very few crops include a greater number of varieties than the soybean. The varieties differ widely in time of maturity; plant height; growth habit; resistance to shattering, lodging, and diseases; quality of the forage; color, size, shape and chemical composition of the seed; and there are many other smaller differences not usually noticed. Finally, there is a difference among varieties in adaptation to local conditions.

Good adaptation to local conditions is broad in meaning. It means among other things that a variety in question has (1) an inherent capacity to produce high yields, (2) that it is adapted to the prevailing soil fertility level, (3) to the length of the growing season, (4) to mechanical harvesting, and (5) to the purpose for which it is grown. Some varieties are best for the production of hay; others for the production of grain for processing into soybean oil and soybean

meal; others for planting with corn; and still others for the production of beans for table use. Certain varieties can be used for two or more purposes with excellent results, while others will efficiently serve only one purpose. The description of edible varieties is reserved for a future publication.

Adapted Hay and Grain Varieties

More than a hundred varieties of soybeans are grown for hay or grain in the United States. Not more than twenty of these can be grown with reasonable success in Missouri. Only eleven of them are especially adapted to Missouri, and even some of these are adapted only in certain parts of the State. As an aid in pointing out the regional adaptation of varieties, the State has been divided into four sections as shown in the accompanying map.



For convenience in explaining where different varieties of soybeans are best adapted in Missouri the State is divided into four regions, as shown on this map.

It may be noted that approximately the northern fourth of the State is designated as North Missouri, the central half as Central Missouri, and that the southern fourth is sub-divided into Southern

Missouri and Southeast lowlands. From the standpoint of varietal adaptation, there is naturally an overlapping of these sections. Thus a variety indicated for certain sections might be grown with good success nearby in adjacent sections.

Varieties best adapted to the various sections are grouped according to their utility value and listed in the following table:

TABLE 1.—SOYBEAN VARIETIES ADAPTED FOR GRAIN AND HAY PRODUCTION IN DIFFERENT SECTIONS OF MISSOURI.

Section of State	For grain		For hay
	Planted at normal time	Planted late or to be followed by small grain	Planted at normal time or late
North Missouri	Illini Dunfield Chief Scioto Manchu	Dunfield Illini	Virginia Wilson, or grain types on very rich land*
Central Missouri	Chief Scioto Boone Manchu	Illini Dunfield Manchu	Virginia Wilson, or grain types on very rich land*
South Missouri	Boone Scioto Manchu	Manchu	Virginia Wilson, Laredo**, or grain types on very rich land*
Southeast lowlands	Ral soy Ark soy Boone	Boone	Virginia Wilson, Laredo or grain types on very rich land*

*Should be sown at heavy rate to insure good quality of forage.

**Laredo is very late maturing and is not usually recommended where fall sown small grain is to follow.

These varieties have all been grown in the various sections and can be classed as good yielders. Within a moderate range, each of them shows certain desirable and undesirable features which might be a sound basis for the grower choosing one over the other. For this reason the hay and grain types are described here, each under their respective headings.

Hay varieties.—The varieties in this group are distinguished by brown or black seeds and their good yields of fine quality forage. The seeds are low in oil, and otherwise undesirable for the manufacture of oil and meal.

The best hay varieties for Missouri as a whole are Virginia and Wilson. Virginia is superior to Wilson on all soils medium to low in fertility. On good land Wilson and Virginia give approximately the same yields, but Wilson produces a finer quality of hay and is slightly more resistant to lodging than Virginia on the better soils. Both of these varieties if planted in May or early June will require about 85 to 95 days to reach the hay stage and 120 to 130 days to mature

seed. Planting in late June or early July will produce mature crops in much shorter periods. Laredo is well adapted for the production of hay in the extreme southern part of the State, and there, will produce high yields of fine-stemmed leafy hay; but on the better soils it produces a long trailing growth of vines that makes it difficult to handle. It is also late maturing and is not recommended where fall sown small grain is to follow the bean crop.



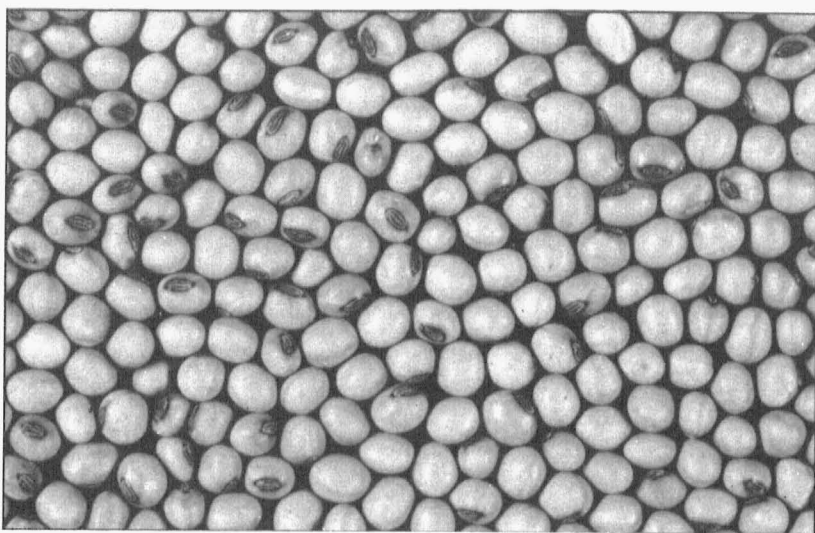
This crop of Virginia soybeans was grown on the University south farms at Columbia, on land of moderate fertility. No further seedbed preparation was required for the wheat crop that followed the soybeans.

The seed types are satisfactory for the production of hay on good land. On very fertile land where Virginia and Wilson produce a rank, viney growth that lodges readily and is difficult to handle, the grain types might well be given a strong preference over the hay types for the production of forage. Most of the seed types normally produce rather coarse stems and should be sown at a heavy rate to insure a good quality of hay.

Seed varieties.—This group of varieties is characterized by capacity to produce good yields of yellow seed, rich in oil and protein, which are strongly preferred to the brown and black seed types by the soybean milling industry.

It has already been noted in Table 1 that Illini, Dunfield, Manchu, Boone, Chief, Scioto, Ral soy, and Arksoy are the varieties best adapted in Missouri for seed production. Their special features of adaptation

and possible means of identifying them are described here. The plant characters and number of days required to mature are based on results obtained in varietal experiments in Missouri. The oil and protein percentages are based on analyses of composite samples from a number of locations in Missouri, Indiana, Illinois, and in some cases, samples grown in Ohio and Iowa were included in the composites. The analyses were made by the U. S. Regional Soybean Industrial Products Laboratory at Urbana, Illinois.



Yellow seed of good quality and rich in oil and protein are preferred by the soybean milling industry.

Illini is a pure line selection from the A. K. variety at the Illinois Experiment Station. Normally the plants are of medium height, comparatively slender, and show a tendency to lodge, particularly on very fertile soil. The variety is poorly adapted for soils low in fertility. In some seasons *Illini* shows a pronounced tendency to produce many "duds"—plants making a low yield of grain and remaining green several weeks after normal plants have ripened and shed their leaves.

Pubescence* gray; flowers white; pods mostly three-seeded, hold the seed well for combining; seeds medium sized, straw yellow with brown hilum;** oil 18.01 per cent;*** protein, 38.39 per cent; maturity about 110 days.

*Fine hairs on the pods and stems.

**The "eye" of the seed.

***Percentage of oil and protein are averages and are calculated on a 10 percent moisture basis.

Dunfield was introduced under P. I. No. 36846¹ from Manchuria in 1913. It is similar in plant type to Illini. The plants are of medium height with short side branches and on most soils show little tendency to lodge. The variety is resistant to shattering and is otherwise well suited to combining. *Dunfield* like Illini is adapted only to the better soils.

Pubescence gray; flowers white; pods mostly three-seeded; seeds, medium size, pale yellow with brown hilum; oil 18.85 per cent; protein, 37.32; maturity about 110 days.

Manchu was introduced from Manchuria in 1911 under P. I. No. 30593. It is one of the older and better known varieties in Missouri. There are several different strains of *Manchu* which differ in time of maturity but are similar in plant and seed characters. Only the later strains that mature in about 110 to 115 days are recommended for Missouri. Plants are medium to short, coarse stemmed, and produce side branches in thin stands that tend to settle to the ground as the plants approach maturity.

Pubescence tawny; flowers purple; pods mostly three-seeded; seeds medium large, straw yellow with black hilum; oil, 17.48 per cent; protein, 39.70 per cent; maturity about 112 days.

Scioto is a selection from *Manchu* by the Ohio Agricultural Experiment Station in 1935 and resembles the parent variety in growth habits. The plants are medium to short and heavy stemmed, and in thin stands or wide rows produce side branches that break down easily, causing a loss of seed. The variety is a heavy yielder and from the processor's standpoint is one of the best because of high oil and protein contents.

Pubescence tawny; flowers purple; unusually high percentage of pods are three-seeded; seeds medium to large, straw yellow with black hilum; oil 18.28 per cent; protein, 38.26 per cent; maturity about 115 days.

Chief is a new variety developed by the Illinois Agricultural Experiment Station from a cross between Type 95, a selection of *Manchu*, and Illini. The plants are tall for a grain type but are not as coarse as *Scioto* and *Manchu* and they stand remarkably well for combining considering their height. These desirable plant characters in addition to a capacity to produce good yields and resistance to shattering, indicate *Chief* to be a valuable variety in sections where it is adapted.

Pubescence gray; flowers purple; pods mostly three-seeded; seeds medium sized; straw yellow with slate to brown hilum; oil 18.92 per cent; protein 37.12 per cent; maturity about 115 days.

¹Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Dept. of Agr. Number.

Boone is a pure line selection from P. I. 54563-3 by the Missouri Experiment Station in 1930. The variety, only recently named, was released for commercial production in 1935, and is grown on a moderate scale in a number of localities in Missouri. *Boone* is grown under different names in various localities, more often as "Missouri Selection." It is generally liked by farmers, particularly for upland soils of moderate fertility in central and southwest Missouri. The most common objection to the variety is that its late maturity brings its harvest too late in the fall to be followed by timely seeding of wheat.

Boone has been grown experimentally at eight different locations in the State, either on State maintained experiment fields or in cooperation with farmers. The results obtained on the experiment fields are recorded here.

TABLE 2.—YIELDS OF BOONE AND CERTAIN OTHER HIGH YIELDING SEED TYPES. LOCATION AND BUSHELS OF GRAIN PER ACRE.

Variety	Columbia 4-yr. ave.	Elsberry 3-yr. ave.	Sikeston 5-yr. ave.	Paris 1-yr.
Boone	21.0	24.8	23.8	16.7
Scioto	21.6	22.1	--	18.3
Illini	16.5	21.1	18.7	14.6
Dunfield	17.5	18.3	14.4	13.5
Manchu	19.5	20.1	18.1	--

Other important features of *Boone*, either from the standpoint of identification or utility, are: plants medium tall, side branches short; stalks medium coarse, and stand well for harvest except on very rich land.

Pubescence gray; flowers white; pods mostly two-seeded, resistant to shattering; seeds medium to small, straw yellow with light brown to pale hilum; oil, 17.92 per cent; protein, 38.00 per cent; maturity 125 to 130 days, or essentially the same as the Virginia variety.

Arksoy is a late maturing variety introduced from Chosen under P. I. No. 37335. The plants are medium in height, coarse stemmed, and produce long heavy side branches in thin stands or in wide rows. *Arksoy* is a mixture of types showing considerable variation in height, time of maturity, flower color and side-branching. It is well adapted, however, for the production of grain in the southeast Missouri lowlands.

Pubescence gray; flowers purple and white; pods two to three-seeded; seeds medium to large, straw yellow; hilum color usually brown; maturity about 140 to 145 days. Comparative oil and protein percentages are not available.

Ral soy is a pure line selection made in 1936 from *Arksoy* by G. H. Banks of the Ralston Purina Company. It is more erect in growth habit than *Arksoy* and the pods are set near the main stem in clusters,

radically different from the seeding habit of the parent variety. Ral soy has been grown experimentally in Missouri only a few years, but its short time performance indicates that it is an excellent variety for grain production in the lowlands. It requires 140 to 145 days to ripen and is therefore recommended only for the extreme southern part of Missouri.

Pubescence gray; flowers white; pods two to three seeded; seeds, medium to large, straw yellow with brown hilum; stalks coarse, very erect, and resistant to lodging; pods medium to large, light color, and hold the seed over a long period. Comparative oil and protein percentages are not available.

Miscellaneous grain types.—There are several other varieties not given in the list of recommended varieties that can be grown with reasonable good success under certain conditions. Patoka, a low growing, coarse stemmed type is adapted to fertile bottom land in central and northern Missouri. Mukden and Richland, two very early types, are suitable for late planting in the extreme northern part of the State. Macoupin, a variety similar to Boone in time of maturity and plant type can be grown in the same sections of the State as Boone. According to results obtained in varietal experiments, however, Boone can be expected to outyield Macoupin 1 to 3 bushels to the acre. Gibson, a new variety developed by the Indiana Experiment Station, has shown excellent performance in yield trials in Missouri but further testing will be required to determine its full range of adaptation.

PRODUCTION METHODS

Preparation of the Seedbed

A good seedbed for soybeans can be prepared by essentially the same methods employed in preparing land for corn. However, soybeans respond well to some extra tillage that is not usually given in preparing corn ground. Weeds are more difficult to control in a field of soybeans than in corn, especially where the crop is close drilled, so that any extra working of the bean land before the crop is planted that will reduce weeds is highly advantageous, particularly on land badly infested with weed seeds. Also a smooth, firm seedbed is required for soybeans, to permit planting the seed to a uniform and moderately shallow depth.

The ideal seedbed for soybeans is smooth and mellow at the surface, firm and moist underneath, and free of weeds. Ordinarily land can best be brought into this condition by the following tillage operations; (1) Plowing early to allow time for weathering and settling of the soil, or a thorough working with a disk or field cultivator will serve

well the same purpose as early plowing, if the soil is mellow and the surface reasonably free of trash; (2) disking the land at intervals of two or three weeks, or as often as a crop of weeds appear; and (3) finally disking and harrowing immediately before planting to pulverize and smooth the surface, and to rid the land of any weed growth that may have developed subsequent to the earlier diskings.

Time of Planting

Soybeans may be sown over a longer period than most crops. Successful plantings are made in Missouri every year during the period from March to late July. The very late plantings (June 15 to July 30) are limited largely to that portion of the acreage sown as a catch crop after small grain, and on low bottom land fields where other crops have been destroyed by overflows. The very early seedings (March 15 to May 1) are limited almost entirely to that part of the crop planted with corn and in small grain in the southeast Missouri lowlands. Practically the entire acreage sown alone as a full season crop for hay or seed is sown during the period from May 1 to June 15. For the State as a whole this is approximately the correct range in planting dates. For any section, however, the range narrows to a three or four weeks period, any time during which the crop can be planted without an appreciable effect on the yield.

The long standing recommendation to sow soybeans a week or ten days after the normal corn planting time is a safe rule. This will usually bring soybean planting within the period from May 15 to June 5 in the northern third of the State, May 10 to June 1 in the central third, and May 1 to May 25 in the southern third. Soybeans will stand about as much cool weather as corn, but it is nearly always advisable to postpone planting to allow additional time for ridding the land of weeds with a disk before the beans are sown. There is also a greater danger of poor stands in early seedings than in later ones made after the soil is warm.

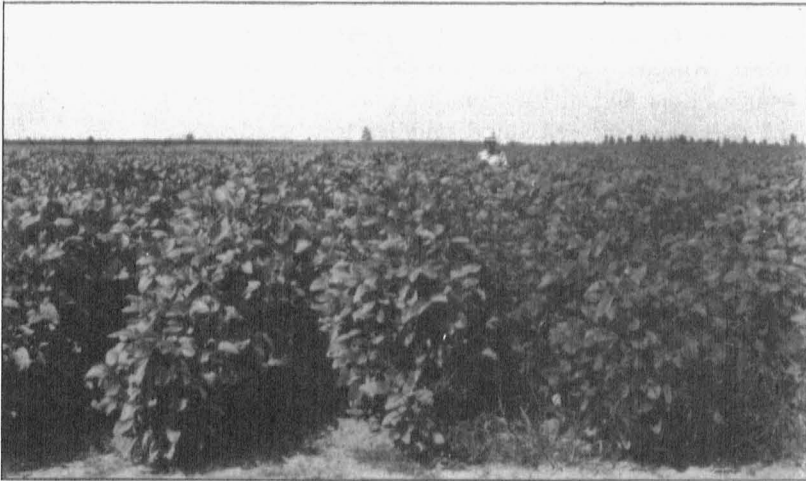
For Missouri as a whole the yield of both hay and seed declines sharply with each day planting is delayed after about June 5 to June 10. Grain yields are reduced in greater proportions by delayed planting than hay yields. However, Illini, Dunfield, and other quick maturing varieties, planted as late as June 25 in the northern half of the State and July 5 in the southern half, will usually mature a seed crop, but the yields will be reduced 40 to 50 per cent by planting this late. Soybeans planted as late as July 30 will produce hay and green manure crops, if there is moisture enough in the ground to sprout the seed. Here again the yield will not be large, but these

late plantings are an efficient means of utilizing land that might otherwise be idle during summer and early fall.

Methods of Planting

Soybeans may either be drilled solid or planted in rows far enough apart to permit row cultivation. Rows 36 to 40 inches apart are the most convenient if corn machinery is to be used in planting and cultivating the bean crop. Slightly higher acre yields of seed are to be expected on good land from 20 to 24 inch rows than from wide rows, but special machinery is usually required for successful production in the narrow rows.

Whether soybeans should be planted in rows or drilled solid will depend largely on the purpose for which the crop is grown, fertility of the soil, "foulness" of the land with weed seed, and erodibility of the land. If the land is subject to excessive erosion, drilling solid, and preferably on the contour, should be practiced regardless of all other factors. The recommendations made here that call for row planting are therefore applicable only on land where erosion is not a serious problem.



For seed production, planting in rows wide enough to permit row cultivation is usually the preferred method on level land where the soil is badly infested with weed seed.

For seed production, soybeans may either be planted in rows or drilled solid on land capable of producing 30 or more bushels of corn in a favorable season. On less productive land planting in cultivated rows is best. Row planting to permit thorough cultivation is also advisable on rich land if it is badly infested with morning glory, pigweed, cotton weed, or other rank growing weeds. However, soy-

beans can be satisfactorily produced by drilling even on very foul land, if the seedbed is prepared in such manner that two or three crops of weeds are killed before the beans are sown.

The cost of production is increased by planting in rows, by the two or three extra cultivations required. Furthermore, cultivation may be required at a time when all available labor and equipment is needed for cultivating corn. On the other hand, the disadvantages of growing beans in rows are offset somewhat by a saving in seed since 2 to 4 pecks less seed to the acre are required for planting in cultivated rows, than for drilling solid. Then too, there is an element of safety in rowing a crop—safety from a total crop failure in extremely dry seasons such as 1934 and 1936, and safety from heavy infestations of weeds, especially for an inexperienced grower or even for a highly skilled grower operating under conditions where it is impossible to bring the weeds under control before the beans are planted.

For hay production, soybeans should be drilled solid, except on land too poor to support the growth of plants in a thick stand. On the better soils the crowding of plants in the thick stands results in a fine quality forage that cures more quickly and is more palatable and more digestible than the coarse, heavy stemmed growth that develops in rows. Another objection to rowed hay crops is that a considerable amount of dust and dirt accumulates on the plants as they are being raked over the bare cultivated middles into windrows.

Rates of Seeding

Within a broad range the rate of seeding has no appreciable effect on yield. There must, however, be a sufficient quantity of seed sown to produce enough plants to utilize fully the resources of the soil and suppress weed growth, but the plants should not be in such numbers as to cause undue crowding and competition for moisture and plant food between the soybean plants themselves.

The rate of planting required to insure maximum returns is governed by a number of factors, including (a) method of planting, (b) purpose for which the crop is grown, (c) fertility of the land, (d) size of seed, and (e) condition of the seedbed. The minimum rate for drilling solid the medium small sized seed under favorable soil and seasonal conditions is 60 to 75 pounds to the acre; or 40 to 45 pounds for 22 to 24 inch rows; or 25 to 30 pounds for 36 to 40 inch rows. These rates should be increased 30 to 50 per cent if the soil is fertile and foul with weed seeds, or if the seedbed is rough and cloddy. Where the crop is to be cultivated with a harrow or rotary hoe, there should be an increase in rate of seeding to offset the loss of plants

which results from this kind of cultivation. The rate for large-seeded varieties is higher than for small-seeded kinds. Good yields of fine quality forage are obtained from heavier rates of seeding than are required for maximum seed yields. Fertile soil will support a thicker stand of plants grown either for hay or seed than will poor soil. There is very little danger of getting the plants too thick for hay except on very poor soils, but excessive crowding and shading in thick stands will lower the yield and quality of a seed crop.

Depth of Seeding

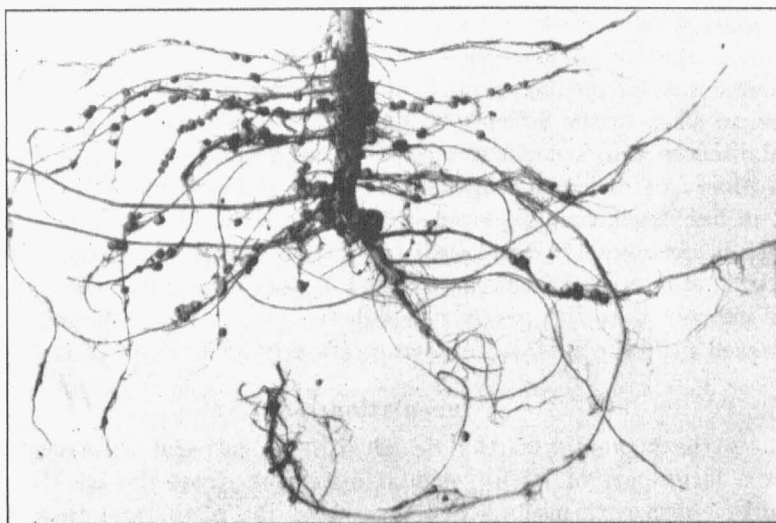
Poor stands frequently result from improper depths of seeding. The principal cause of the difficulty is planting too deep. The seeds should be planted only to a depth that is required to bring them in contact with plenty of moisture to promote rapid germination. Normally 1 to 2 inches is sufficient to meet this requirement. If planting much deeper is necessary to reach moisture, it is advisable to wait for a rain. This alternative can be avoided by preparing the seedbed in such manner that the greatest possible amount of soil moisture is conserved near the surface for germination in shallow plantings.

Inoculation

The soybean plant with the aid of nitrogen gathering bacteria can draw a large part of its nitrogen requirements from the air. These organisms attach themselves to the roots of the plants and form the nodules which are definite proof of their presence. The kind of bacteria found on soybeans will not thrive on other legumes, nor will the kind found on other legumes thrive on soybeans. It is essential therefore in growing soybeans that the bacteria be supplied by artificial means, where the land has not grown a crop of well nodulated soybean plants in recent years. The length of time the bacteria will survive in large numbers in the soil without a bean crop being grown on the land is variable with the condition of the soil. It might be five years in one case and ten in another. There is safety in inoculating when in doubt.

There are two practical methods of inoculating a crop. One method is through the use of a pure culture of the bacteria. This can be obtained from the Soils Department of the Missouri College of Agriculture and from commercial firms, with complete directions for use. The other method is known as the soil transfer method. The soil used in this method should be taken from fields where heavy soybean nodulation occurred the year before, and it is best to take the soil from around the roots of the last year's plants. There are several

modifications of the soil transfer method. One that has been used with good success in Missouri is to moisten the seed with water, then mixing the seed and finely sifted soil in the proportion of 1 to 2 quarts of soil to a bushel of seed. Another method is to make a heavy suspension of soil and water and sprinkle just enough of the mixture on the seed to give them a soiled appearance.



Bacteria living in nodules on the roots of soybeans draw nitrogen from the air, which is used by the plants. If these organisms are not present the plants take all their nitrogen from the soil the same as corn, wheat, and other non-legume crops.

Cultivation

Soybeans planted at the right time on land that has been properly prepared do not require much cultivation. A few timely and thorough cultivations, however, are very beneficial to most crops. Whether the crop is planted in rows or drilled solid, cultivation with a rotary hoe or a spike-tooth harrow is the most efficient method when the plants are small.

It is sometimes advisable, and even necessary in some cases, to cultivate before the beans are up. Heavy rains soon after planting may cause a hard crust to form on the surface of the soil that must be broken to permit the plants to come through to a full stand. A rotary hoe is the best implement for pulverizing a soil crust, although a spike-tooth harrow can be used successfully on some fields. Either of

these implements can also be used for cultivating until the plants are four to six inches tall. After this stage is passed, no further cultivation is practical for crops that are drilled.

The cultivation of rowed crops should be continued after the plants are too large for broadcast cultivation. Two cultivations with a cultivator equipped with sweeps for shallow level cultivation are usually sufficient to control weeds until the plants are 10 to 15 inches high. By that time the crop is shading the ground and making such heavy demand for moisture and plant food that weed growth is largely suppressed and further cultivation is not needed.

Harvesting Soybeans for Hay

Stage for harvesting.—There are several important factors that should be considered in deciding on the stage at which a crop of soybeans should be cut for hay. Briefly they are: (1) The leaves are at their maximum weight when the pods are well formed and first begin to fill. (2) The weight of the crop and total protein content increase until the pods are well filled with seed, and the leaves are yellowing from maturity, but before they have begun to shed. Thereafter the weight of the crop declines as the mature leaves are dropped. (3) Hay cut before the pods are full cures more quickly, and brings hay harvest at a time of the year when there is less danger of damage by rains than when cut at a later stage. Still another factor, not related to the yield and quality of the crop, has an important bearing on the stage for cutting. Winter grain sown on bean land following an early harvest produces higher yields, and affords better protection from erosion than if it follows a late soybean harvest.

From these facts it is evident that soybeans should not be cut for hay until after the pods are formed and begin to fill, for earlier cutting results in a low yield of leaves, the most valuable part of the plant for hay, and a reduction in total yield. Cutting at a very early stage may of course be advisable where alfalfa is to follow soybeans.

The most advanced stage of growth that might be considered for hay is when the pods are plump with seed and the leaves are maturing. There are three to five weeks between the extreme limits of the hay stage. As already indicated, the weight of the crop increases gradually during this period, except where there is premature shedding of leaves. Thus there are the advantages of maximum yields of hay and protein in harvesting during the late stage. On the other hand, there are the advantages of economy and safety in curing the crop, and better performance of winter grain that follows the soybeans by harvesting during the early hay stage. When the advantages of

harvesting in the early stage and those of harvesting in the late stage are brought together and analyzed, a compromise seems logical. By cutting when the pods are one-third to one-half filled, the reduction in yield is only a fraction of the maximum production possible, and yet the advantages of early harvest enumerated above are realized in a large measure.

Methods of cutting and curing.—Soybeans are more difficult to cut and cure than alfalfa, timothy, and other fine-stemmed plants, but with a little skill and care they can nearly always be saved in a palatable and nutritious form. There is no one best method to follow in making soybean hay, but there are certain fundamental practices that should be observed. A crop should not be cut when wet with dew or rain. Nor should it be cut when the surface of the ground is wet, for the plants on the upper side of the swath may become dry and bleached before those underneath are ready to rake.



This good yield of fine quality soybean hay was grown after barley. As soon as the hay was removed the land was again sown to barley and the barley was pastured several weeks during October and November.

A mowing machine is generally the most satisfactory implement to use in cutting soybean hay. A grain binder also can be used successfully if the crop is not too heavy, if it stands up well, and is free of vines or tendrils that cause difficulty in elevating and binding. Less labor is required for the whole job of cutting, curing and handling if the binder is used. On the other hand, there is considerable danger of loss from molding and rotting in the center of the bundles, although this can be partly overcome by making small, loosely bound bundles and placing them in small shocks for rapid drying.

If the crop is mowed it should be left in the swath until thoroughly wilted regardless of the time required. It should then be windrowed promptly before the leaves are bleached and made brittle by excessive drying. Curing can be completed in the windrow, but it is much better in several respects to work the crop into tall narrow shocks to complete the curing process rather than to leave it in the windrow.

The hay must be thoroughly cured before it can be safely housed or stacked. Practical experience is the safest guide in determining when it is ready, but when the stems and leaves throughout the shocks are dry and brittle, there is no further danger of molding or rotting. More thorough curing is required before hay can be safely baled from the shock or windrow than is required for storing loose in a barn or in stacks and ricks. Indeed it is seldom safe to bale from shocks or windrows, except in seasons of unusually favorable curing weather. It is best as a rule to stack or rick the hay and allow it to pass through the "sweating process," after which there is no danger of spoiling in the bale.

Harvesting Soybeans for Seed

Methods of harvesting.—The combine is by far the most efficient implement to use in saving a seed crop. Less labor and expense are involved, fewer beans are lost, and a higher grade is obtained one year with another than under any other method of harvesting.



Although combining is the most efficient method of harvesting soybean seed, a crop can also be cut with a grain binder and shocked in the field to cure for threshing with a grain separator.

A seed crop can also be cut with a grain binder and later threshed with an ordinary grain separator. This method has one advantage

in that it clears the land early for seeding of small grain, provided the shocks are placed in rows so as not to interfere too much with any seedbed preparation that might be needed or with drilling the grain.

Threshing equipment should be adjusted to avoid cracking and splitting the grain as far as possible. The market grade and the seed quality are lowered with increasing amounts of "splits," due to the fact that splits may produce a low quality oil, and they have no value whatever for planting.

Storage of soybeans.—Soybean seed containing more than 14 or 15 per cent moisture are likely to heat and mold if stored in bulk. If there is any question as to the keeping qualities of the seed at the time of threshing, they should be hauled to the elevator or spread on a wooden floor to a depth not to exceed two feet. The seed should be examined daily for a week or two and if any indications of spoiling are noted, they should be turned and stirred with a shovel. Unless soybeans are very high in moisture, they can be stored safely in loose woven bags placed in such manner as to permit free circulation of air between the bags.

Growing Soybeans in Mixtures

Soybeans are grown with varying degrees of success in combination with other crops. The possible advantages from these mixed plantings are higher total yield, better balanced feed, easier curing where the mixture is utilized for hay, and greater benefits to the soil.

Soybeans and Sudan grass.—These crops when grown in combination produce a good mixed hay. The best results are obtained by planting the beans in rows and keeping the land clean by level, shallow cultivation until the plants are 4 to 6 inches high, then drilling the Sudan seed between the rows with a one-row drill. If a drill is not available, broadcasting the seed and working them into the soil by shallow cultivation is a substitute for drilling. This method of growing hay, though satisfactory in several respects, has some obvious disadvantages. Under average farm conditions it is more practical to grow the required amounts of soybean and Sudan hay in pure stands rather than in mixed plantings.

Soybeans and small grain.—Soybeans can be grown with reasonably good success in the southeast Missouri lowlands by drilling the seed in small grain fields. The method has been tried in other parts of the State but with little or no success. Drilling beans in small grain was a common practice in the lowlands some eight or ten years ago on land that would not grow clover, but lespedeza has largely

replaced the soybean, and some cases the clover, as a crop for sowing on grain fields.

Laredo is the best variety to grow in combination with small grain, though any adapted variety can be used. Wheat, rye, and barley are better companion crops for the soybeans than spring oats. The merits of winter oats as a companion crop have not been determined. The soybeans should be drilled when the grain is first beginning to joint. This may be any time from March 15 to April 15, depending on the season, the kind of grain, and the variety.

Soybeans and corn.—This combination, now grown on a scale estimated as 200,000 acres annually, exceeds the acreage of all other mixed soybean plantings by a wide margin. Nearly all of it is produced in the southeast lowlands.



Soybeans and corn grown together in the southeast lowlands is shown here. The lower part of the mixed crop is obscured by the thick stand of alfalfa in the foreground.

Tests conducted on upland soil by the Missouri Experiment Station and other stations in the corn belt, have shown that the yield of corn is reduced by soybeans 5 to 25 per cent depending mainly on the rainfall, rates of planting, and fertility of the land. The compensation for this loss of corn by an increase in total yield, feeding value, and benefits to the soil has also been variable. Generally the yield of soybean seed has not equalled the loss of corn, bushel for bushel, but the mixed crop has produced more protein than corn alone. It is a question then of how to utilize the increase in protein in order to derive

returns from the mixture in excess of that from corn alone. If the beans are turned back to the soil in the same manner as a green manure crop, the increase in yields of succeeding crops will seldom offset the loss in corn yields. If the mixture is pastured, the benefits to the animals resulting from a better balanced feed, and increase in organic matter and nitrogen from the manure and plant residue should add up to a gain that outweighs the corn losses. But regardless of the theoretical merits of the corn-soybean combination, it has not proved its worth with practical farmers throughout most of the State, and has nearly disappeared from cultivation except in the southeast lowlands. There it is grown on a large scale, reached after a yearly increase in acreage throughout the past two decades.



Soybeans grown in corn are sometimes harvested for grain after the corn is husked out. A comparatively heavy seeding of soybeans is recommended where the mixed crop is to be utilized in this manner.

The simple explanation of the popularity of the mixture in the lowlands is that it nearly always gives returns in excess of that of corn alone—returns that are obvious and easily realized. They are in the form of greater feeding value of the mixed crop as compared to corn alone, benefits to succeeding crops, and a higher cash value of grain on the several thousand acres where the soybean seed as well as the corn is harvested. The most efficient method of utilizing the mixed crop on a majority of the farms is to harvest the corn early, pasture the stalks and the bean crop during the fall and winter, and plow the manure and plant residue into the soil during early spring for the crop that is to follow. Cotton and also other crops respond

well to these additions of nitrogenous material, especially on soils medium to low in fertility.

Several factors contribute to the relatively good performance of the mixed crops in the lowlands. The great depth of the soils and a slightly higher rainfall in that section tend to minimize the destructive effect of competition between the beans and corn. It is true that in dry seasons the yields of both crops are reduced sharply as a result of competition, but the reduction is not so great either in unfavorable or favorable years as those that occur on upland soils.

Another factor that contributes to the success of the mixture is the kind of soybeans grown. Late maturing types including Mammoth Brown, Arksoy, Ralsoy, and others that require 145 to 160 days to ripen where sown in corn at the usual corn planting time are best used. During the first 110 to 125 days after planting, depending on the corn variety, both crops draw on the soil supply of moisture and plant food. By the end of that period the moisture and plant food requirements of the ripening corn plants are declining rapidly. So for some 20 to 45 days, depending on the variety of corn and beans, the bean crop grows with little or no competition from the corn. It is this growth that makes up a substantial part of the increase in yield of the mixture over that of corn alone.

A second important advantage of growing the late maturing soybeans is that the corn can be harvested before the bean crop has weathered and shattered to such a degree that it is no longer of much value for pasturage. It would seem that there are some good possibilities in the use of late maturing soybeans for better returns from the corn-soybean mixture on upland soils.

The most effective method of planting a mixture of soybeans and corn is to use a special bean attachment on the corn planter. Mixing the corn and beans in the same hopper will result in uneven stands, but the method can be used with fair success if the seed is frequently stirred. Drilling is preferable to checking the mixture, except where cross cultivation is required to control weeds. The rate of planting in pounds of seed to the acre will vary widely, depending on the fertility of the land, size and quality of the seed, and the uses that are to be made of the mixed crop. Three to five soybean plants for each corn plant are about the right proportions under average conditions. The thick stand of soybeans will result in a greater reduction in corn yields than a thin stand; on the other hand the returns from the soybeans are increased by thick planting.

SOIL RELATIONS

From the standpoint of their effect on the land and on the yield of other crops, the soybean shows certain well defined characteristics, some of which are desirable, while others are undesirable. These characteristics are not necessarily peculiar to the soybeans, but nevertheless, are of such a nature that they must be taken into account in fitting the crop into the general farming scheme in a manner that will give the maximum net returns in the long run.

Soybeans Loosen the Soil

The fact that soybeans leave the soil loose has long been recognized by farmers and investigators alike. Whether this good state of tilth is due altogether to soil changes caused by the plants, or due partially at least to the protection afforded the soil by the thick leafy growth of a standing crop, is not clear. In preparing the seedbed, the land is usually worked into good tilth with a disk and harrow immediately before planting. This is an essential step in the successful production of soybeans under all conditions. The growing crop soon develops a canopy of leaves over the land that breaks the force of falling rain, thereby preventing in a large measure the puddling and packing that normally occurs on unprotected soil. Thus the good tilth created mechanically in preparing for soybeans is scarcely diminished throughout the growth period of the crop, and will naturally endure for some time after the crop is ripe for harvest. The degree to which the cover afforded by soybeans maintains the tilth is easily noted on a field of wide-rowed beans. Toward the end of the growing season the unprotected soil in the middles is usually hard and compact, while that beneath the leafy cover is loose and mellow. It is quite true, of course, that some of the difference could be due to a greater intensity of root action in the soil near the plants, as compared to that midway between the rows.

But regardless of the nature of the several possible causes of the unusual soil conditions found in a bean field, they are all conveniently described by the statement that "soybeans loosen the soil."

Soybean Land Easily Worked

The loosening of the soil by soybeans is a very desirable feature of the crop in some respects. It is desirable in that the soybeans leave the land in such good tilth that little or no seedbed preparation is required for fall sown grain following the bean crop. The tilth improving property of the soybean can be used very efficiently in conditioning Wabash clay (gumbo) and closely related bottomland types for re-

ceiving the seed of the grain crops. This improved state of the soils, although of a temporary nature, carries over in the heavy bottomland types until oat sowing time the next spring, so that little or no seedbed preparation is needed for this crop. It may even last in a large degree until corn planting time if spring rains are moderate. In that case, the land can be brought into suitable condition for corn, and other late spring planted crops as well, by a few thorough diskings.

Soybeans are Conducive to Erosion

The loosening of the soil by soybeans, though highly beneficial on bottomland and comparatively level upland may contribute to serious soil losses through erosion on rolling or hilly land. The loosening of the soil is, however, not the only factor contributing to losses by erosion. The harvest leaves very little plant residue on the land except where the crop is combined. Furthermore, the soybean, naturally a deep-rooted plant, is only sparsely rooted in the surface soil, and these few surface roots decompose rapidly. Thus the soybean not only leaves the soil loose, but leaves it without much protective cover and fresh, durable fiber to hold it in place.



Where soybeans and other late spring planted crops such as sorghum, cowpeas, corn or cotton follow corn on erodible land, serious soil losses often occur before or soon after these late spring sown crops are planted. Erosion damage such as that shown here can be reduced by planting these crops on properly prepared sod land. (Courtesy of Soil Conservation Service)

Clearly, therefore, the growing of soybeans on rolling land may lead to heavy losses through erosion. A considerable portion of the erosion damage that results from including soybeans in the rotation

can, however, be traced to faulty methods in crop production and management, rather than to the soybean crop itself. The most serious errors in handling soybeans on rolling land are (a) following corn or other row crops with soybeans (b) planting the beans in rows of corn-planter width in the direction of the slope, and (c) leaving the stubble land bare from bean harvest until oat or corn planting time the next year.

Where beans follow a row crop, corn for example, the soil is highly susceptible to erosion prior to planting, and for three or four weeks thereafter until the plants are large enough to afford protection. It might be said in this connection that land is neither more nor less susceptible to erosion before and soon after planting soybeans than it is before and soon after planting corn, sorghum, cowpeas, cotton, other late spring planted crops that require essentially the same type of seedbed preparation as soybeans. Soybeans planted in rows furnish no great amount of protection at any time, neither does corn or cotton which, by necessity, are planted in rows, and cowpeas and sorghum are not very effective against erosion unless they are drilled solid.

If, after harvest, the bean land is left bare until oat or corn planting time the next year, erosion is almost sure to take a heavy toll. Where the crop is combined and the straw well scattered, there will usually be adequate protection on moderate slopes. However, on land highly susceptible to erosion because of a sharp slope or poor physical structure, other means must be employed to hold the soil in place.

How Erosion Losses May be Reduced

In view of the causes of erosion associated with the growing of soybeans and the time and conditions under which it occurs, certain methods suggest themselves as means for overcoming the difficulty to a large degree. If instead of growing the soybeans in a corn-soybean-corn or oat sequence, or in a similar combination, as they usually are grown, they are grown in the sequence of sod-soybeans-fall sown grain, the erosion losses will not be very great. The efficiency of the sequence as a means of erosion control will, of course, be increased through the use of good methods in producing the crops.

Within a large group of sod crops, the particular kind used in the sod-soybean-small grain sequence is not important from the standpoint of erosion control. It might be timothy, red top, bluegrass, orchard grass, or any combination of these crops; in brief any good sod-forming crop that is adapted to local conditions. Lespedeza, though not strictly of the sod forming type, will serve with great efficiency

as a crop to precede soybeans where the land is not left practically bare by close grazing or clean mechanical harvest.

Grass sod should be plowed in early spring and worked down gradually by occasional diskings. Lespedeza sod can best be prepared by working across the slope with a field cultivator. A plow will usually cover the residue from last year's crop to such depth that it will be of little benefit in keeping down erosion. A disk can also be used in preparing the seedbed though it is not as effective as the field cultivator in stirring the soil to the proper depth and in keeping the plant residue on or near the surface where it will do the most good.



Soybeans grown in rows on rolling land may lead to heavy soil losses through erosion. On land similar to that shown above the beans should be drilled solid, and preferably on the contour.

Two to four, usually three, workings with the cultivator or disk will be needed. They should be given at intervals of two to four weeks beginning in the early part of April. A thick stand of volunteer lespedeza plants will be showing by that time. Whether it is practical to destroy a stand of lespedeza to make way for soybeans is another question.

Land worked with a field cultivator may require a light disking and harrowing immediately before planting, in order to smooth the surface.

Erosion losses that normally occur while the beans are on the land can be largely prevented by drilling solid. Drilling should be on the contour rather than up and down the slope. The effectiveness of a thick stand of soybeans in holding the good state of tilth created by mechanical means in preparing the land has been discussed earlier. By preventing soil packing and puddling the capacity for rapid water absorption is also sustained. Surplus water that does accumulate on a field of soybeans where the plants are lined across the slope in drill rows flows at such reduced rate that, as a rule, no great amount of damage is done. Heavy downpours of 2 or 3 inches will result in heavy losses, and there are but a few crops that are entirely effective against erosion under such extreme conditions.

The most critical stage in the management of the sod-soybean-small grain sequence comes when the beans are cut. The soil is in a highly erosive state and is without much surface protection except where the



It is a serious error to leave rolling land bare over winter, following the harvest of a soybean crop. Instead the land should be sown to small grain early to provide protection from erosion.

crop is combined and the straw well scattered. This is adequate protection only on moderate slopes. Combining should be across the slope to prevent gullies where the wheels cut into the soil. Normally, however, heavy losses through erosion are to be expected from the

time the crop is cut until the newly seeded grain is large enough to protect the soil. This period can be shortened by prompt seeding of the grain. The grain should be drilled across the slope and should be fertilized in nearly all cases. The kind and amount of fertilizer applied will be governed by the needs of the crop. On most soils 150 to 200 pounds of superphosphate or like amounts of a suitable mixed fertilizer are sufficient.

The kind of grain that should be sown following the soybeans is governed by a number of factors. If the land is cleared of the bean crop before fly-free date, rye should be given preference over wheat in the northern half of the State. In the southern half either rye or barley is preferable to wheat. Either wheat or rye may be used where soybean harvest comes after fly-free date. Barley might also be sown in south Missouri after fly-free date, but that is a little too late for the best results with the crop.

Terracing combined with the crop management and production practices outlined above affords additional protection from erosion.

The foregoing suggestions regarding the management of soybeans and associated crops on rolling land are not necessarily a recommendation to grow soybeans on that kind of land, but rather it is the recommendation of a method whereby the serious losses that frequently result from growing soybeans on rolling land can be reduced.

Soybeans May or May Not Increase Soil Nitrogen

Soybeans properly inoculated obtain the larger part of their nitrogen from the air. The amount of nitrogen finally added to the soil by the soybean crop will depend on how the crop is used. Substantial gains in soil nitrogen result under some methods of handling, while under others there is a loss.

The largest gain possible comes through turning the soybeans under as green manure, but it is seldom practical to use a full season crop in this manner. If the crop is cut for hay and fed to livestock, and the manure is properly handled and returned to the land, there will be a substantial gain in nitrogen. A small gain results where the crop is harvested with a combine, leaving all the straw, leaves and stubble on the land.

Where a seed crop is harvested with a binder, leaving only the stubble and leaves on the land, there will be a small loss of nitrogen. The greatest nitrogen losses are incurred where the crop is cut for hay, and the hay is sold, or fed, and no manure is returned to the land. The loss in pounds of nitrogen per acre is then about the same as the nitrogen gain where the crop is fed and the manure returned.

Soybeans Draw Heavily on Plant Nutrient Supply

Although soybeans add nitrogen to the soil under some methods of handling, there is a reduction in the mineral elements of the soil under all methods of handling, except where the crop is used for green manure. The extent to which soybeans and various other crops remove nutrient elements most commonly deficient in soils is shown in Table 3. In case of a crop where only grain or seed yields are shown, the figures do not take into account the quantities of the several elements drawn from the soil and deposited in the stem and leaves.

TABLE 3.—AMOUNTS OF PLANT FOOD REMOVED FROM THE SOIL BY CERTAIN SPECIFIED ACRE YIELDS OF SOYBEAN AND VARIOUS OTHER CROP PRODUCTS. POUNDS PER ACRE*

Crops	Acre yield	Nitrogen	Phosphorus	Potassium	Calcium
Corn (grain)	35 bu.	32.1	5.5	8.2	.2
Oats (grain)	35 bu.	21.5	3.6	4.4	1.0
Wheat (grain)	15 bu.	21.3	3.8	3.9	.24
Soybeans (seed)	15 bu.	17.5**	5.2	17.1	1.8
Soybeans (hay)	1½ tons	23.7**	7.4	24.4	28.8
Red clover (hay)	1½ tons	18.9**	5.3	47.1	36.3
Lespedeza (hay)	1½ tons	20.5**	5.6	25.0	29.7

*Calculated on the basis of data taken from several sources.

**These amounts are calculated on the basis that the legumes take $\frac{1}{3}$ of their nitrogen from the soil and $\frac{2}{3}$ from the air. These proportions will vary widely under different soil condition.

It is beyond the scope of this bulletin to estimate the net removal of plant food from the soil through the growing of these crops, and disposing of them in various ways. The purpose here is to show by way of comparison the amount of plant food removed, or stated in other terms, the amount of plant food required to produce a crop of soybeans.

The table shows some very significant facts. A 15-bushel seed crop of soybeans requires roughly the same amount of phosphorus as a 35-bushel corn crop, twice as much potassium and nine times as much calcium. In a comparison of a 15-bushel soybean crop, a 15-bushel wheat crop, and a 35-bushel oat crop, soybeans require approximately $\frac{1}{3}$ more phosphorus and 4 times as much potassium as oats and wheat. The actual differences in pounds of calcium required are small, though the percentage differences are large. Comparing a 35-bushel corn crop and a 1½-ton soybean hay crop, soybeans require approximately $\frac{1}{3}$ more phosphorus, 3 times as much potassium, and 144 times as much calcium as the corn crop. The amounts of plant food required for a 15-bushel crop of soybean seed and a 1½-ton crop of soybean hay serve as a basis for an interesting comparison. It should be emphasized again that the elements deposited in the bean plants that

produced the seed are not taken into account. In this comparison it is noted that the hay crop requires about $\frac{1}{3}$ more phosphorus, $\frac{1}{3}$ more potassium, and 16 times as much calcium as the 15-bushel soybean seed crop. There are remarkably small differences in the amounts of nitrogen drawn from the soil by the various crops. Only in the case of corn does the difference appear to be of practical significance.

In a broad comparison of the mineral elements required by the three cereal grains as a group and the three legume hay crops as a group, the hay crops require roughly $\frac{1}{3}$ more phosphorus, 6 times as much potassium, and 39 times as much calcium as the grain crops. However, soybeans draw only slightly more or slightly less of the several elements than red clover and lespedeza, except that red clover is a rather heavy user of potassium. Thus the removal of the plant food elements by soybeans appears to be moderate or very large depending on the crop with which it is compared.

The net losses of mineral plant food from the soil resulting from growing soybeans will be large, moderate, or comparatively small, depending on the amount of the crop that is returned to the land in the form of manure or plant residue. Or there may be no loss if the entire crop is plowed back to the soil. Losses, whatever their magnitude, occur each time soybeans are grown for harvest.

Response of Soybeans to Fertilizer

Although the soybean draws heavily on the plant food supply in the soil, as compared to some crops at least, it has shown a rather indifferent response to direct applications of fertilizer. On the other hand soybeans respond abundantly to a general increase in the productivity level. Methods for raising the productivity level of the soil through the use of fertilizer, lime, barnyard manure, green manure crops, crop residues, and various other means have been widely taught in the State by the Missouri College of Agriculture and do not need to be reviewed here.