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CORN AND SOYBEANS

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THIS BULLETIN AT A GLANCE

For the most valuable mixture of corn and soybeans, both crops must be planted together in the row at the same time.

Soybeans planted with corn, at corn-planting time, may be expected invariably to reduce the yield of corn, the reduction varying with the proportions of corn and beans planted in the mixture.

There is always a substantial yield of soybeans in the corn and this yield is increased by planting the beans thick and the corn thin. The yield of beans is sometimes even greater than the loss in corn, but more frequently it equals about one-half to three-fourths the corn loss.

Probably the most productive combination of corn and soybeans for average upland soil, would be drilled in 44-inch rows at the rate of 6 pounds of corn and 3 pounds of beans per acre. This drilled rate would be equivalent to 2 stalks of beans per check-rowed (44-inch) hill.

In proportion to the area occupied, corn and soybeans mixed by alternate rows or by alternate pairs of rows, make much higher yields than where planted as separate crops. The possible usefulness of this method is thus suggested for thin dry soils on which the success of a crop of corn is very uncertain.

In a 5-year feeding test the corn-soybean combination was more valuable than corn alone, acre for acre, for fattening hogs.

When hogs pasture down the corn-soybean combination, they leave a substantial portion of the beans which can later be turned to good account in pasturing other kinds of livestock.

Soybeans planted in corn at ordinary rates on upland soil, may produce pasturage for sheep or cattle at the rate of a half-ton or less of cured hay per acre. This would greatly increase the value of the stalk pasture.

Satisfactory varieties of soybeans to plant with corn for hogging down on very fertile to average land are Morse, Mid-West, Haberlandt, and Mikado. For cattle or sheep pasturage, for silage, or for hogging down on thin land, Virginia or Wilson is ideal.

When corn is damaged by chinch bugs the yield of the associated growth of soybeans will probably be increased, and will provide a highly important compensation for the loss in corn.

When corn is ruined by drought, the yield of the associated growth of soybeans is so reduced by the same cause that it will provide no important compensation for the loss in corn. Indeed the growth of the beans has contributed to this very loss.

The corn-soybean combination leaves the land more fertile than corn alone. It will, when completely pastured, probably return to the soil at least as much nitrogen as it used; but in view of the constant loss of nitrogen by soil erosion, pasturing the corn-soybean combination should not be depended upon as the sole means of maintaining the fertility of upland soils.

CORN AND SOYBEANS

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Abstract.—In this bulletin the results of seven years of investigation of the corn-soybean combination are reported. Yields of the mixed crop and of corn alone are recorded and discussed. The comparative feeding value of corn and soybeans and of corn alone, for fattening hogs, is shown in the summary of a five-year test. Yields of forage for sheep or cattle, produced by soybeans in corn are recorded. The relation of the mixed crop to drought, chinch bugs and soil fertility is discussed. The best methods for producing the corn-soybean combination are suggested.

The corn-soybean combination, grown chiefly for hogging down, is based on the common belief that the mixed crop is more valuable per acre than corn alone. The practice of combining these crops began in Missouri as soon as our farmers knew the soybean plant itself, is now very common and apparently increasing; although the total acreage thus handled is not definitely known, due to the difficulty in securing reliable statistics on mixed crops.

Double cropping with corn and soybeans is a most plausible practice and the very ease with which it can be promoted has caused the Missouri Experiment Station to reserve a formal recommendation concerning it until experimental evidence to determine its actual value could be secured. After seven years of investigation the evidence now seems sufficient and will be presented herewith.

THE CORN-SOYBEAN PROBLEMS

Aside from certain technical problems in the growths of associated plants, all questions concerning corn and soybeans are summarized by the following three:

1. Is the combination of corn and soybeans a more valuable feed per acre, year after year, than corn alone?
2. What are the best methods for producing this combination?
3. What is its effect on the soil, as compared with the effect of corn alone?

The evidence we shall offer bears directly upon the first and second questions. The third can be answered only in general terms. Other important problems in supplementing the corn-soybean mixture with commercial concentrates and minerals will be discussed by other investigators in Missouri Experiment Station Bulletin 224. In this report we are comparing simply the corn-soybean combination with corn alone. The more productive of these feeds may be the basis for whatever supplements are desired.

THE EXPERIMENTS

In the beginning, 1917, we assumed (1) that when a growth of soybeans is produced in a stand of corn suited to the resources of the land, the yield of corn is necessarily reduced; and therefore (2) that the proportions of corn and soybeans and the method by which they are combined will determine the yield of beans and the relative loss in corn. Accordingly all methods which seemed to offer practical returns under local conditions of growth were tried to find the few most productive as subjects of intensive study.

The crops were grown in duplicate series of adjacent plots which, unless otherwise described, were 130 feet long and contained four rows spaced 44 inches apart. Except for accidental losses during the season perfect stands were maintained in all plots; and all were kept perfectly free from weeds, except the special cases hereafter mentioned. The two border rows of each plot were always discarded in harvesting, leaving two inside rows to be weighed for yield. All harvesting was done carefully by hand. Forage yields were calculated as air-dry material and grain yields on the basis of a 12½ per cent moisture content. The average yields of duplicate plots are recorded in the tables. Reid Yellow Dent corn and Wilson soybeans were used in all experiments, except as otherwise stated. The soybeans were always thoroughly inoculated; they had always an abundance of large nodules. The yields recorded in Tables 1 to 7 and 9 to 11 were produced on slightly rolling upland silt loam (Putnam). Those in Table 8 were grown on creek bottom land. The productivity of growth conditions is indicated by the yields themselves. All other details of method are recorded in the tables.

RESULTS

In Tables 1, 2, and 3, are the results of planting soybeans in corn at various stages in the growth of the latter.

TABLE 1.—BUSHELS OF GRAIN AND TONS OF CURED FORAGE (CORN FODDER AND SOYBEAN HAY) PER ACRE, WHEN SOYBEANS WERE PLANTED IN A SINGLE ROW, AT 20 POUNDS PER ACRE, BETWEEN ROWS OF CORN *Drilled* 44 INCHES APART—1917

Methods of planting	Grain		Forage	
	Corn	Soybeans	Corn	Soybeans
Corn alone, at a rate equal to 3 stalks per 44-inch check-row hill	65.4	---	2.6	---
+Soybeans drilled in at 1st cultivation of corn	58.0	4.6	2.3	1.9
+Soybeans drilled in at 3d cultivation of corn	68.2	0.0	2.8	0.0
+ Soybeans drilled in at 4th cultivation of corn	62.8	0.0	2.6	0.1

Table 1 shows the failure of soybeans to grow when planted between corn rows at late stages. At the time of its third or fourth cultiva-

TABLE 2.—BUSHELS OF GRAIN PER ACRE FROM CORN AND SOYBEANS, WHEN SOYBEANS WERE BROADCAST AT 60 POUNDS PER ACRE IN CORN DRILLED IN ROWS 44 INCHES APART

Methods of planting	1917		1918		1919		Total 3-yr. av. yields		Total 3-yr. acre loss of corn	Lbs. of soybeans produced for each 100 lbs. of corn lost
	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans		
Corn alone, at a rate equal to 3-stalks per 44-inch check-row hill	65.3	----	9.6	---	37.5	---	112.4	----	----	----
+ Soybeans broadcast when corn was planted	16.5	11.8	0.0	2.4	1.6	4.4	18.1	18.6	94.3	21.1
+ Soybeans broadcast at the 3d cultivation of corn	62.4	0.0	8.8	0.0	41.3	0.0	112.5	0.0	0.0	0.0
+ Soybeans broadcast at the 4th cultivation of corn	64.5	0.0	7.3	0.0	39.4	0.0	111.2	0.0	1.2	0.0

TABLE 3.—TONS OF CURED FORAGE (CORN FODDER AND SOYBEAN HAY) PER ACRE, WHEN SOYBEANS WERE BROADCAST AT 60 POUNDS PER ACRE IN CORN *Drilled* IN ROWS 44 INCHES APART

Methods of planting	1917		1918		1919	
	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans
Corn alone, at a rate equal to 3 stalks per 44-inch check-row hill	2.6	---	2.3	---	2.7	---
+ Soybeans broadcast at 1st cultivation of corn	1.6	2.0	0.5	0.2	1.3	0.4
+ Soybeans broadcast at 3d cultivation of corn	2.9	0.2	2.2	0.1	3.2	0.0
+ Soybeans broadcast at 4th cultivation of corn	2.8	0.2	2.5	0.1	3.2	0.0

tion, corn had reduced surface moisture so low that soybeans planted then could not germinate well or could make but little growth which failed to produce seed. When drilled in corn at the first cultivation, the beans made a good yield, but caused a material reduction in the yield of corn. This method was discarded after one year, because (1) when planted late the beans made no growth, (2) when planted at the first cultivation of the corn they left the corn liable to damage from weeds, since no further cultivation could be made, and (3) in either instance an extra planting was required.

If Tables 2 and 3 are read together, for yields of grain and forage in the same years, the results of broadcasting will be found generally similar to those of drilling. Therefore the same objections may be raised against both methods. The only points of interest in broadcasting are that (1) even when done late it sometimes produced a small growth of beans (Table 3) which though making no seed (Table 2) seemed to injure the corn, and (2) when done early it produced enough growth to practically ruin the corn. In 1918, a season of extreme drought, beans broadcast at the first cultivation of corn apparently caused the corn to fail completely, although the beans made a small yield (Tables 2 and 3). In that extremely dry season, soybeans could outgrow corn when the two were competing in a combination of broadcast beans and rowed corn. This brings us to the general point of the relative influence of the season upon the corn-soybean combination, and for later reference we present in Table 4 a record of the June, July and August rainfall during the years of these experiments.

TABLE 4.—INCHES OF RAINFALL ON THE EXPERIMENT FIELD DURING JUNE, JULY AND AUGUST, 1917-1923.

Month	1917	1918	1919	1920	1921	1922	1923
June	2.60	3.25	4.10	1.20	3.05	1.17	5.92
July	0.88	0.73	2.30	2.69	2.11	4.03	3.04
August	5.17	6.96	5.30	3.31	5.44	2.90	4.20
Total	8.65	10.94	11.70	7.20	10.60	8.10	13.16

The quantity and distribution of the July rainfall have a very great influence upon the yield of corn at Columbia; and therefore any extreme variation of these factors during this critical period is reflected in the growth of the crop. So, when in 1918 after a very wet June there was only about three-quarters of an inch of rain distributed in mere sprinkles from July 1 to August 10, corn was badly damaged by drought and made a very small yield. Also in 1917 the total July rain was remarkably light, but most of it came in a ½-inch fall in the middle of the month, and this, supplemented by abundant rains early in August, saved

the crop and helped to make one of the largest yields in the whole course of the experiments. There were no other extreme variations in rainfall, but the complete record is given for comparison with 1917 and 1918.

CORN AND SOYBEANS PLANTED AT THE SAME TIME

In 1918, being impressed by the 1917 failure of soybeans planted in corn at late stages, we began a series of experiments in planting corn and soybeans at the same time, by various methods and in different proportions. The results are recorded in Tables 5 to 11.

In Table 5 corn alone is shown to have yielded much more grain per acre than corn and soybeans combined in alternate rows or alternate pairs of rows; but two acres of separate crops, one of corn and one of soybeans, together yielded much less than two acres of mixed crops. For example, in 1920, corn alone yielded 60 bushels per acre and soybeans alone 20.2 bushels—a total of 80.2 bushels on two acres; but on one acre of the crop mixed by alternate rows, corn yielded 41.3 bushels and soybeans 14.0—a total of 55.3 bushels for one acre or 110.6 bushels for two acres. The difference in favor of the mixed crop on a two-acre basis was therefore 30.4 bushels. Such a general difference resulted in each year, the average in favor of the alternate-rowed crop being 15.9 bushels per two acres. Results from the crops mixed by alternate pairs of rows are also similar, although this mixture produced less corn and more beans than alternate single rows.

These surprising comparisons can be explained only superficially. Corn in rows 88 inches apart in the alternate row series, where two rows of corn were separated by a row of beans, was spread over an acre at half the rate of planting corn row after row 44 inches apart, and being thus afforded better conditions for growth, made a larger yield in proportion to the space it occupied than did corn in 44-inch rows. The same explanation applies to the higher proportional yields of soybeans in rows separated by rows of corn. In proportion to the area occupied in alternate rows or alternate pairs of rows, both corn and beans made higher yields than when grown separately, because competition from their own kind was reduced. Thus it is assumed that competition between row after row of corn or row after row of soybeans was greater than competition between alternate rows of corn and soybeans.

Although these results are from only three years' crops, we believe they are substantial, because they were secured under very diverse conditions of growth, which are indicated by the yields themselves. The locations of the several plots were changed from year to year and the seasons varied extremely. The season of 1918 was extremely unfavorable, due to severe drought in July; in 1919 the season was dry from July 16 to

TABLE 5.—YIELDS OF GRAIN PER ACRE FROM CORN AND SOYBEANS *Drilled* SEPARATELY IN ALTERNATE ROWS AND ALTERNATE PAIRS OF ROWS, ALL ROWS BEING SPACED 44 INCHES APART

Rates and Methods of Planting	1918	1919	1920	Average
Corn alone, at a rate equal to 3-stalks per 44-inch check-row hill	22.4 bu. corn	31.1 bu. corn	60 bu. corn	37.8 bu. corn
Soybeans alone, at 20 pounds per acre	11.8 bu beans	10.4 bu. beans	20.2 bu. beans	14.1 bu. beans
Alternate rows of corn and beans, at above rates	14.5 bu. corn	20.3 bu. corn	41.3 bu. corn	25.4 bu. corn
	5.4 bu. beans	6.2 bu. beans	14.0 bu. beans	8.5 bu. beans
Alternate pairs of rows of corn and beans, at above rates	13.1 bu. corn	16.9 bu. corn	36.7 bu. corn	22.2 bu. corn
	6.5 bu. beans	6.7 bu. beans	15.5 bu. beans	9.6 bu. beans

TABLE 6.—BUSHELS OF GRAIN PER ACRE FROM CORN AND SOYBEANS *Drilled* TOGETHER IN ROWS 44 INCHES APART AND FROM SOYBEANS DRILLED ALONE IN ROWS THE SAME WIDTH

Rates of drilling stated as plants per 44-inch check-row hill	1920		1921		1922		Total 3-yr. Acre yields		Total 3-yr. acre loss of corn	Lbs. of soybeans produced for each 100 lbs. of corn lost
	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans		
3 stalks of corn	65.7	----	26.5	----	36.6	----	128.8	----	----	-----
+ 2 stalks of soybeans	61.2	4.8	22.7	2.3	34.0	4.8	117.9	11.9	10.9	117.0
+ 3 stalks of soybeans	55.6	5.7	22.5	3.5	29.9	5.6	108.0	14.8	20.8	76.2
2 stalks of corn	66.6	----	33.4	----	35.3	-----	135.3	----	----	-----
+ 2 stalks of soybeans	61.4	8.2	29.9	2.9	31.9	7.2	123.2	18.3	12.1	162.0
+ 3 stalks of soybeans	53.4	9.8	25.8	4.1	27.0	8.9	106.2	22.8	29.1	83.9
20 pounds of soybeans per acre, drilled alone	----	24.7	----	20.1	----	19.8	----	64.6	----	-----

TABLE 7.—BUSHELS OF GRAIN PER ACRE FROM CORN AND SOYBEANS PLANTED TOGETHER IN HILLS CHECK-ROWED 44 INCHES APART AND FROM SOYBEANS PLANTED ALONE IN ROWS THE SAME WIDTH

Rates of planting in check-row hills	1918		1919		1920		1921		1922		Total 5-yr. acre yields		Total 5-yr. acre loss of corn	Lbs. of soybeans produced for each 100 lbs. of corn lost
	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans		
3 stalks of corn	10.8	----	47.0	----	66.3	----	33.8	----	50.7	----	208.6	----	----	----
+ 2 stalks of soybeans	7.0	1.2	27.7	2.7	63.1	4.9	30.6	1.9	48.1	3.6	176.1	14.3	32.5	47.1
+ 3 stalks of soybeans	6.1	1.5	26.7	3.5	58.4	5.9	27.9	2.7	41.0	4.4	160.1	18.0	48.5	39.8
2 stalks of corn	14.4	----	47.3	----	69.0	----	36.3	----	43.9	----	210.9	----	----	----
+ 2 stalks of soybeans	10.9	1.8	35.8	3.6	53.4	6.2	33.6	2.6	42.5	5.1	176.2	19.3	34.7	59.6
+ 3 stalks of soybeans	9.0	2.1	34.9	5.0	54.2	7.0	35.0	3.0	39.0	5.8	172.1	22.9	38.8	63.2
20 pounds of soybeans per acre, planted alone	----	13.5	----	19.7	----	25.2	----	20.9	----	22.8	----	102.1	----	----

August 7, but the drought was far less severe than in 1918; and 1920 was an extremely favorable season, being marked by a comparatively dry June and moderate, well distributed rainfall in July and August.

We hope practical readers will not find the foregoing yields confusing. The comparison is simply between (1) mixed crops of corn and soybeans and (2) corn and soybeans grown separately. The mixed crop was more productive in total bushels of grain than equal areas of separate crops. If, however, the largest yield of either corn or soybeans only is wanted, then corn or soybeans must be grown alone at normal rates of planting. Fifty acres of corn alone will certainly produce a larger yield than fifty acres of corn mixed with soybeans by this method. But if both corn and soybeans are wanted on the fifty acres, the method of alternate rowing is apparently more productive than separate cropping. Alternate rowing is frequently used on thin land in the South and will produce a limited yield of corn, in addition to a growth of legumes, where a thicker planting of corn would fail. The mixed crop is difficult to harvest, but the corn can be husked and the stalks and soybeans pastured; and the apparent difficulty in planting can be solved by using two rows of corn and two rows of beans, rather than single rows of each. Wherever thin, dry soils make unlikely the success of a full crop of corn, alternate rowing of corn and soybeans might be a good practice.

From Tables 6 and 7, which represent combinations of corn and soybeans by check-rowing and drilling, the following results may be summarized:

(1) The yield of corn was invariably decreased by the addition of soybeans—the more soybeans produced, the less corn.

(2) The total loss of corn in this way, during five years, amounted to about an average crop for one year.

(3) There was always an important yield of soybeans in the corn and this yield was increased by planting the beans thick and the corn thin. It was sometimes even greater than the loss in corn, but more frequently about one-half to three-fourths the loss, in pounds of grain per acre.

(4) There was generally a larger yield of soybeans in drilled corn than in check-rowed corn, from similar rates of planting. This was due, probably, to a better distribution of plants, since the drilled combination was located on plots which generally produced less corn than the check-rowed plots.

It is often asserted that, when corn and soybeans are grown together on bottom land, the corn is not affected by the beans because fertility is abundant for both. We planted soybeans with corn on rich,

moist creek-bottom, for evidence on this point, in 1919. The plots were three rows (44-inch check) wide and 1015 feet long, the yields of the middle rows only being measured. The results are in Table 8.

TABLE 8.—BUSHELS OF GRAIN PER ACRE FROM CORN AND SOYBEANS PLANTED TOGETHER ON FERTILE BOTTOM LAND, IN HILLS *Check-Rowed* 44 INCHES APART

Rates of planting in check-row hills	1919		Acre loss of corn	Lbs. of soybeans produced for each 100 lbs. of corn lost
	Corn	Soybeans		
2 stalks of corn	81.5	---	----	----
+ 2 stalks of soybeans	70.9	2.4	10.6	24.3
3 stalks of corn	85.8	---	----	----
+ 2 stalks of soybeans	71.0	2.9	14.8	21.0

Here an important loss in corn is shown under extremely favorable conditions of soil, although in proportion to the yield of corn planted alone it is less than occurred on many of the upland plots. At the same time the yield of soybean seed was smaller than the average yield on upland. Apparently these results were due to the extremely rank vine growth of beans, which affected the corn but made only a small yield of seed. It is characteristic of soybeans to grow this way on rich bottom land, and their seed production was naturally limited by the shade of such a rank growth of corn. Because of inconvenience we did not repeat the bottom-land test; and indeed the results of 1919 are so similar to those of all other years on upland soil that repetition would now seem to have been unnecessary. That rich bottom land makes no exception to our general finding that an acre of corn and soybeans combined will produce less corn than an acre of corn alone, seems a very reasonable conclusion.

It occurred to us in 1922 that an extremely thin planting of soybeans —as thin as could be dropped by the planter—might make a moderate yield of beans without materially affecting the corn. Accordingly we planted in that year a series of plots whose yields are shown in Table 9.

TABLE 9.—BUSHELS OF GRAIN PER ACRE FROM CORN AND SOYBEANS PLANTED TOGETHER IN HILLS *Check-Rowed* 44 INCHES APART

Rates of planting in check-row hills	1922		Acre loss of corn	Lbs. of soybeans produced for each 100 pounds of corn lost
	Corn	Soybeans		
2 stalks of corn	37.3	---	---	-----
+ 1 stalk of soybeans	32.3	3.9	5.0	83.6
+ 2 stalks of soybeans	32.3	5.3	5.0	113.6
+ 3 stalks of soybeans	31.5	6.1	5.8	112.7
3 stalks of corn	50.7	---	---	-----
+ 1 stalk of soybeans	52.0	0.9	1.3 gain	-----
+ 2 stalks of soybeans	48.1	2.6	3.6	77.4
+ 3 stalks of soybeans	41.0	4.4	8.7	54.2

The thin planting of soybeans—one stalk of soybeans per hill of corn—when combined with a thin planting of corn made a yield of nearly 4 bushels of seed per acre and reduced the yield of corn 5 bushels. When combined with three stalks of corn, the single stalk of soybeans made less than one bushel of seed per acre and showed no effect on corn yield, although a slight effect may have been lost through experimental error or off-set by soil variation. Clearly then these results, though brief, are in line with those from our longer experiments in showing that the yield of corn is reduced according to the proportion of soybeans in the mixture.

DISCUSSION

The results of our experiments in the production of the corn-soybean combination have clearly shown that the mixed crop may be expected to produce less corn per acre than will corn grown alone. The competitive growth of the soybeans necessarily reduces the growth of corn, the degree of reduction, as measured in bushels of grain, varying with the rates of planting the corn and the beans, when other conditions are equal. Corn planted at the optimum rate may be expected to suffer the greatest competition from soybeans; corn planted at less than the optimum rate will be less affected. But it is not possible to determine the best stand of corn for a given time and place, although a stand satisfactory for general conditions over long periods is easily arrived at. In Missouri corn is generally planted at rates equal to two stalks or three stalks per check-rowed hill, the hills being 42 inches or 44 inches apart. There are some adjustments of these rates to soil conditions, but the common tendency is to plant too thick. In common practice then, soybeans will be mixed with corn when the latter is planted at one of the rates just mentioned.

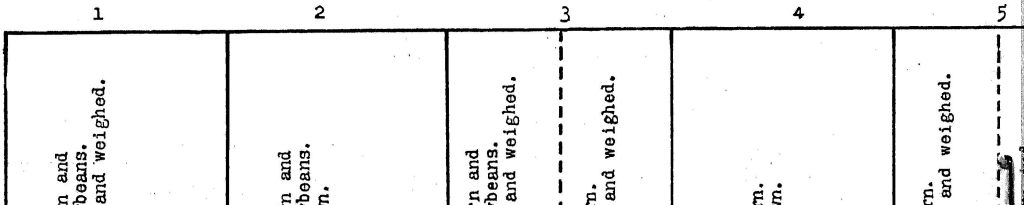
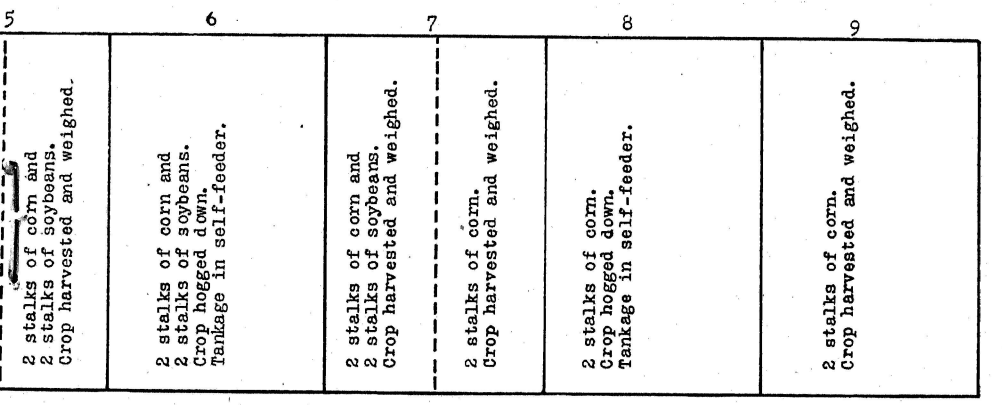


Fig. 2.—The arrangement of plots in the combined test of crop yields and pork production. The rates of planting and th were divided between corn alone and corn-and-soybeans, to determine the yields of similar crops in Plots 2, 4, 6 and 8, which w

In our experiments soybeans were invariably more productive in corn planted relatively thin, and were more productive in drilled corn than in check-rowed corn; and their yield increased also with their own rate of planting. These facts, together with the above consideration of the practical rates of planting corn, suggest that for their highest production soybeans should be planted at three stalks per hill in corn drilled at a rate equal to a two-stalk check-row rate. In weight of seed per acre these rates would amount to about six pounds of corn and four pounds of soybeans. On the other hand it is equally clear that if the highest yield of corn from the mixed crop is wanted the soybeans must be planted at a minimum rate—one or two stalks per hill of corn. The rate of planting corn itself will be determined by local custom and will usually be too thick. In our experiments on upland soil a two-stalk rate was generally more productive than a three-stalk rate; but on bottomland the three-stalk rate was more productive. Similar results are generally found on average uplands and rich bottoms in this State.

The relative yields from given rates of planting corn and soybeans cannot be stated for a given place and season. The inter-relation of controlling factors—soil and season, varieties, mechanical treatments, infestations of weeds, insects and diseases—is too complex to permit a seasonal forecast of the yield of soybeans or the reduction in yield of corn. For example, in Table 7 the acre loss in corn yields from the addition of two stalks of soybeans to two stalks of corn ranged during five years from 1.4 bushels in 1920 to 15.6 bushels in 1922. The highest loss of corn was 20.3 bushels in 1919, from a mixture of three stalks of beans and three stalks of corn. In the same table the acre production of soybeans in the corn ranged from 1.2 bushels to 7.0 bushels, although in drilled corn (Table 6) it rose to nearly 10 bushels in the extremely favorable season of



d the disposal of the crop are stated within the outline of each plot. The plots were one acre in size, but Plots 3, 5 and 7, n were hogged down. All plots were rotated annually.

1920, when three stalks of soybeans were planted with two stalks of corn. Clearly then accumulated yields from long periods furnish the soundest information on this point. Total results for long periods determine the value of a practice. Therefore observe again in Table 7 that the total five-year loss of corn was not in any mixture very far from an average annual crop of corn grown alone on that land in the same period and that the total production of soybeans equals roughly about half the loss in corn. Observe finally that in the drilled mixture, Table 6, production of soybeans has equaled about three-fourths to one and one-half times the loss in corn. These figures would seem to provide a fairly sound basis for practical estimates of total relative yields over long periods. Nevertheless, we believe they indicate the maximum rather than the minimum or even the average loss of corn that might occur under farm conditions. Our plot stands were perfect; hence in the mixed crop a full stand of corn competing with a full stand of soybeans would, by comparison with a full stand of corn grown alone, necessarily show a maximum loss. Now perfect stands of either corn or soybeans would not be found under practical conditions. The stands would be more or less irregular— at some places in the field there would be thin stands of both corn and beans— and since competition between the corn and beans would diminish with the reduction in the numbers of each kind of plants, the loss in corn would necessarily be less. However, the difference between the loss under farm conditions and the loss under experimental conditions cannot be calculated. It is simply pointed out as an obvious fact.

But of course the main question here is the relative feed values of the mixed crop and corn alone. Will the mixed crop make more pork or other animal products per acre of feed than will corn alone? Or, in other words, will the beans compensate profitably for the reduction in corn yield which they cause? This question can be answered only by a direct comparison of animal products from the two crops. An experiment to secure evidence for this comparison was conducted cooperatively by the departments of Field Crops and Animal Husbandry, during the period 1919 to 1923.

THE FEEDING EXPERIMENT

Nine 1-acre plots were planted in Ninety-day yellow corn and Morse soybeans, on average upland soil, fairly uniform in productivity. Their arrangement and rates of planting are shown in Fig. 2. They were rotated annually—where a crop was pastured down one year it would be harvested for yield the next, and vice versa. Fairly uniform, though not perfect, stands were maintained in all plots. Cultivation was clean. Altogether we tried to produce the crops about as a good farmer would have produced them, though probably our stands and our cultivation

were nearer the standards for experiment plots than his would have been. Plots 1, 3, 5, 7, and 9 were harvested and weighed to determine by comparison the crop yields in plots 2, 4, 6, and 8, which were hogged down.

When the corn was nearly hard uniform lots of spring shoats were turned into Plots 2, 4, 6, and 8, and remained there until the corn was consumed. In Plots 6 and 8 tankage was supplied in a self-feeder. All measurements of pork production were secured by the Department of Animal Husbandry and we are indebted to that department for the direct comparison of the feeding values per acre of corn alone and corn and soybeans. Table 10 shows for Plots 2 and 4 the crop yields as determined by comparisons with Plots 1, 3, and 5, the number of hogs carried, their average initial weights, average daily gain per head, total feeding periods, average final weight per head, and the total gains made on the corn-soybean mixture and on corn alone. Results from the addition of tankage to the corn-soybean mixture and to corn alone will be reported by the Department of Animal Husbandry in Bulletin 224.

The five-year average of the results in Table 10 show the corn-soybean combination to have produced more pork per acre than corn alone, by a substantial margin. In three years the combination was more productive, in one year corn alone was more productive, and in one year the two crops made pork about equally. The results of one year, 1922, are especially significant, since corn and soybeans then made more than twice as much pork as corn alone. For this remarkable result we can offer no other explanation than the fact that the corn was badly damaged by chinch bugs, while the soybeans made a large yield in the thin stand of corn, with the net result of a much larger yield of grain from the corn-soybean combination than from corn alone. This result is in line with the repeated claims of farmers that soybeans in corn will provide a very important compensation in case of chinch bug damage.

It is important now to add that a substantial quantity of beans was left after the hogs had finished the corn in the mixed crop and were removed from the plots. An average of about a bushel per acre was harvested from the standing crop, after the hogs; and probably an equal quantity, at least, was left shattered on the ground. Such a remnant could of course be utilized later by sheep or hogs on winter pasture and is therefore valuable.

Briefly then, the corn-soybean combination is, by direct comparison shown to have been more valuable than corn, acre for acre, for fattening hogs, and its value is increased when the remnant of beans is taken into account.

Doubtless the yields of corn shown in Table 10 are somewhat higher than the quantities actually consumed by the hogs in Plots 2 and 4,

TABLE 10.—SUMMARY OF CROP YIELDS AND PORK PRODUCTION BY THE CORN-SOYBEAN COMBINATION AND BY CORN ALONE

	1919		1920		1921		1922		1923		Five-Yr. Av.	
	Corn-Soys.	Corn	Corn-Soys.	Corn	Corn-Soys.	Corn	Corn-Soys.	Corn	Corn-Soys.	Corn	Corn-Soys.	Corn
Pounds of shelled corn per acre	1831	2005	2016	2800	2022	2430	1137	1294	1473	2162	1696	2138
Pounds of soybean seed per acre	144	----	264	----	306	----	348	----	186	----	257	----
Pounds of corn decrease per acre, due to soybeans	174	----	784	----	408	----	157	----	689	----	442	----
Total pounds of grain per acre	1975	2005	2280	2800	2328	2430	1485	1294	1659	2162	1953	2138
No. hogs per lot	21	20	15	14	10	10	10	10	10	10	13.2	12.8
Days of feeding period	19	19	17	21	32	32	18	20	26	25	22.4	23.4
Average initial weight of hogs, pounds	115.35	115.85	111.1	105.5	102.6	101.6	117.6	118.0	126.2	125.8	114.6	113.4
Average daily gain per head, pounds	1.083	0.816	1.055	1.310	0.809	.816	1.089	.410	1.389	1.372	1.085	0.944
Average final weight per head, pounds	135.88	131.35	128.9	133.1	128.5	127.7	137.2	126.3	162.3	159.9	138.6	135.7
Total gain per lot, pounds	431	310	269	385	259	261	196	82	361	343	303	276.0
Pounds of soybeans harvested per acre after hogs were removed	--	--	--	--	30	--	67	--	86	--	61*	--

*Average of 3 years only. Soybeans were not harvested after hogs in 1919, 1920.

since they were estimated on the basis of *hard* corn yielded by Plot 1, 3 and 5, while the hogs were turned into Plots 2 and 4 when the corn was *nearly* hard. And, due to this fact, the difference between estimated yield and actual consumption, while probably not large, would cause an error in the calculation of a grain-pork ratio from these figures.

THE CORN-SOYBEAN COMBINATION FOR SHEEP AND CATTLE PASTURAGE

Soybeans in corn make excellent pasturage for sheep, and when the corn is harvested they greatly increase the value of the stalk pasture for cattle. In Table 11 are recorded yields of field-cured hay for five years from soybeans grown with corn, both crops being planted at ordinary rates on upland soil. These yields include the yields of soybean seed recorded in Table 7, and suggest the probable yields of soybean pasturage for cattle and sheep, which may be produced by the ordinary corn-soybean combination. Drilling the corn and soybeans is more favorable than check-rowing for the production of soybean pasturage, as we have already shown. If more soybeans are wanted than can be provided by ordinary combinations, the method of alternate rowing discussed on pages 7 to 11 is suggested.

TABLE 11.—TONS OF HAY PER ACRE FROM SOYBEANS PLANTED WITH CORN IN HILLS *Check-Rowed* 44 INCHES APART AND FROM SOYBEANS PLANTED ALONE IN ROWS THE SAME WIDTH

Rates of planting in check-row hills	1918	1919	1920	1921	1922	Av.
3 stalks of corn						
+ 2 stalks of soybeans	0.2	0.3	0.6	0.2	0.3	0.3
+ 3 stalks of soybeans	0.3	0.4	0.6	0.3	0.4	0.4
2 stalks of corn						
+ 2 stalks of soybeans	0.3	0.4	0.6	0.3	0.2	0.4
+ 3 stalks of soybeans	0.3	0.5	0.8	0.3	0.2	0.4
20 pounds of soybeans per acre, planted alone	2.5	3.1	4.1	1.8	2.3	2.8

VARIETIES OF SOYBEANS FOR PLANTING WITH CORN

The choice of a variety of soybeans to plant with corn depends mainly upon the purpose for which the mixed crop is to be used. For hogging down, a variety which makes a heavy yield of seed and matures with the corn is desirable. The best varieties of this type for Missouri are Morse, Midwest, Haberlandt and Mikado for average to very fertile land; and Virginia or Wilson for thin land. For pasturing with sheep or cattle a variety which makes a large production of forage with a medium yield of seed is probably more desirable than the short woody seed yielders used for hogging down; and for this purpose Virginia and Wilson are ideal. For silage a tall variety is necessary, since a short one would leave too much of its growth in the stubble if the mixture were cut with a

binder. Virginia and Wilson, being tall and erect in growth, are doubtless the best varieties for the silage mixture, among those commonly grown in Missouri.

THE RELATION OF THE CORN-SOYBEAN COMBINATION TO DAMAGE FROM CHINCH BUGS AND DROUGHT

The fact that when corn is badly damaged by chinch bugs, soybeans will make a larger growth in the broken stand of corn and thus will partly offset the loss from corn, is sufficiently discussed on page 15. It is a highly important advantage of the mixed crop, which should not be overlooked. Some persons believe that soybeans in corn actually repel chinch bugs and thus guard the corn against their attacks. There seems, however, no good reason for this notion. The mere fact that the soybean

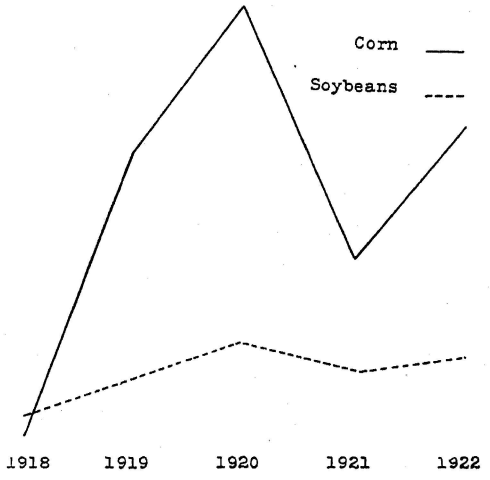


Fig. 3.—The percentage variation from year to year, of the yields of corn and soybeans grown separately, is illustrated by these lines.

plant itself is not eaten by chinch bugs is no evidence that it prevents chinch bugs from eating corn, nor that it has even a repellent quality. In a similar case, the presence of clover or alfalfa does not prevent chinch bugs from damaging the nurse crop of wheat, oats or barley. Chinch bugs eat no legume, but no legume is known definitely to repel them.

We can offer no specific evidence on this question, but in our daily observation of the corn-soybean mixture for seven seasons we have not noted that chinch bugs damage of corn associated with soybeans was less than that of corn alone. Had there been such a difference it could hardly have escaped our notice.

Sometimes there is also the assertion that when corn is damaged by drought there will be a compensation from the associated growth of soybeans, which is assumed to be drought resistant. This is a half-truth only. Soybeans are, in a practical sense, far more drought resistant than corn, when the two crops are grown separately; and while even in the mixed planting they will probably withstand drought better than corn, they are then at the great disadvantage of competing with corn for a limited supply of moisture and will make only a small growth when the drought is intense. But their growth, small as it may be, takes out of the

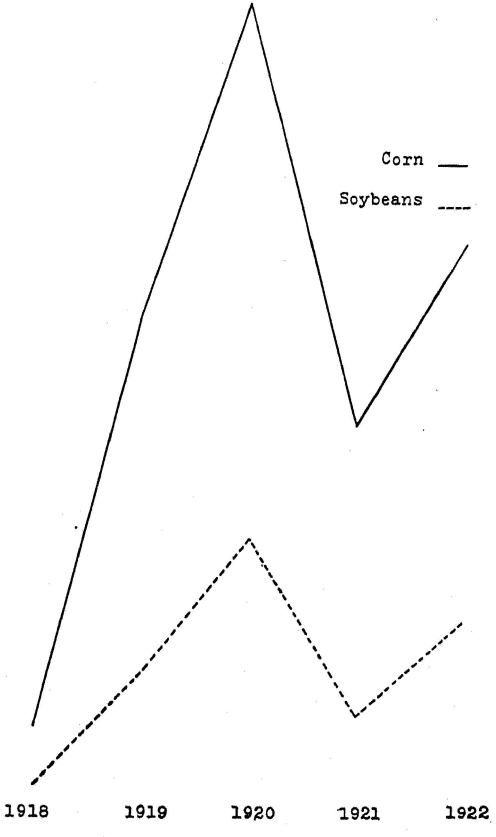


Fig. 4.—The percentage variation, from year to year, of the yields of corn and soybeans in a mixed crop, is illustrated by these lines.

soil a certain amount of moisture the corn so greatly needs, and thus intensifies the condition of drought the corn must endure.

In Table 7 it may be seen that where corn and soybeans were grown

separately the fluctuation in soybean yields was far less than in corn yields; but that where the two crops were combined in a mixed planting the fluctuation in yields of soybeans paralleled closely the fluctuation in yields of corn. These facts are illustrated in Figures 3 and 4. They apparently show that while the yield of soybeans as a separate crop was less influenced by the character of the season than was the yield of corn, where the two crops were combined in a mixed planting their yields were similarly affected by a seasonal variation. To take extreme examples; in 1918 a season of ruinous drought, the yields of both corn and beans in the mixed plots were extremely small, while in the highly favorable season of 1920, the yields of both were very large, for the land. The relative growths of other years, though differing less, provide similar comparisons. Always the yields of corn and soybeans in the mixed planting rose or fell together; for when moisture was not sufficient for corn, certainly it was not sufficient also for an additional growth of soybeans. There was competition between growths, and each growth suffered from the effect of the other in some proportion to the limitation of moisture for which they competed.

It may therefore be concluded: (1) that when the yield of corn is reduced by drought, an associated growth of soybeans does not escape the influence of this condition but is reduced in about the same proportion as corn; and (2) that the soybeans can then provide no compensation for the loss in corn, except in proportion to their own reduced yield.

THE RELATION OF THE CORN-SOYBEAN COMBINATION TO SOIL FERTILITY

Does the corn-soybean combination leave the land more fertile than corn alone? Obviously many separate and distinctly different cases are covered by this question and each case would require separate consideration. Moreover, in the lack of specific evidence, the answer in any case can be based only on broad facts and therefore can be stated only in general terms. And so we hope our practical readers will understand that our answers are not exact calculations of what must occur in specific cases; but are merely broad estimates of what is likely to occur.

A five-year average yield of corn on average upland soil was, in round figures, 42 bushels per acre (Table 7). In a corn-soybean combination on the same land during the same period, corn yielded approximately 35 bushels per acre and soybeans 3.5 bushels. The 42-bushel corn crop used in its production 63 pounds of nitrogen; the 35-bushel crop 52 pounds. When the corn was mature two-thirds of this nitrogen was in the grain and one-third in the remainder of the crop. The 3.5 bushel yield of soybeans was the equivalent of approximately 0.4 of a ton of air-cured soybean hay, as indicated in Table 11. One ton of moisture-free

soybean hay has been estimated to contain from 40 to 70 pounds of nitrogen—let us say 55 pounds. Our 0.4 of a ton of air-cured hay containing 8.5 per cent of moisture might therefore contain, on a dry basis, 20 pounds of nitrogen. Under average conditions two-thirds of the nitrogen in a well inoculated crop of soybeans has been taken from the air and one-third from the soil. In harvesting soybeans by any method commonly employed in the Middle West, probably not more than 80 per cent of the entire crop is removed, the remainder being left in the root and stubble. Therefore, on the basis of the foregoing figures, our 0.4 of a ton of soybean hay would contain 13.3 pounds of nitrogen taken from the air and 6.6 pounds from the soil.* If the crop—corn alone or corn and soybeans—is pastured, approximately three-fourths of the nitrogen it contained is returned to the land in the manure of the animals; but if the crop is otherwise harvested and no part of it is returned to the land in any form, the nitrogen it contained is, of course, definitely taken away. Simply for comparison the following summary will apply these broad facts and figures to cases in which a 42-bushel crop of corn alone and a mixed crop of corn and soybeans, yielding 35 bushels of corn and 0.4 of a ton of hay, are harvested by different methods.

TABLE 12.—LOSSES OF NITROGEN WITH DIFFERENT CROPS AND VARIOUS METHODS OF HARVESTING

Method of harvesting	Pounds of nitrogen lost per acre	
	Corn alone (42 bushels)	Mixed crop (Corn 35 bushels; soybeans 0.4 ton of hay)
Whole crop pastured	11	3 (gained)
Whole crop cut for silage	63	55
Corn husked; soybeans and corn stalks plowed under	42	18
Corn husked; soybeans and corn stalks pastured	47	27
Corn cut and removed; soybeans plowed under with corn stubble	63	35

With the understanding that the figures presented in this summary are intended merely to suggest the comparative effect of corn alone and the corn-soybean combination, it is apparent that the combination leaves the land more fertile than does corn alone. But that the mixed crop, even when completely pastured, makes little or no improvement of the original condition of the soil is obvious, contrary to the opposite opinion too common among farmers. The gain from soybeans is offset by the loss from corn, when the two crops are mixed in ordinary proportions. Only when the mixture was made with a small proportion of corn and a large proportion of soybeans, and pastured completely, could it be expected to return to the soil a materially larger quantity of nitrogen than was used in its growth. Whether a mixture of such proportions

*We are indebted to the Department of Soils, Missouri College of Agriculture, for the use of these data and for advice in the consideration of this question.

is desirable must depend upon the primary object of the crop—(1) to improve the land, or (2) to produce a large yield of corn. Both of these desirable objectives cannot be gained at the same time, by the same crop.

Finally, the effect of erosion should not be overlooked by those who would depend upon pasturing the corn-soybean mixture as the sole means of maintaining the fertility of upland soils. It is estimated that upland soil of average fertility and even a moderate slope loses annually by erosion a quantity of nitrogen approximately equal to that taken out by the average crop of corn it produces. Here then is a definite loss of nitrogen which far exceeds any small gain from pasturing a mixed crop of corn and soybeans. But, granting the loss from erosion, the fact still is clear that the mixed crop leaves the land more fertile than corn alone.

SUMMARY

1. For the most valuable mixture of corn and soybeans, both crops must be planted together in the row at the same time. If the beans are planted late in the corn, by any practical method, they are not likely to succeed.

2. Soybeans planted with corn, at corn-planting time, may be expected invariably to reduce the yield of corn, the reduction varying with the ratio of beans to corn, as planted in the mixture. When three stalks of soybeans were mixed with three stalks of corn in check-rowed hills on upland soil, the total five-year loss of corn was fully equal to an average annual crop on the same land—about 40 bushels. On the other hand when the mixture was drilled at a rate equaling two stalks of corn and two stalks of beans per check-rowed hill, the total acre loss of corn during a three-year period was only 12 bushels.

3. There was always a substantial yield of soybeans in the corn and this yield was increased by planting the beans thick and the corn thin. The yield of beans was sometimes even greater than the loss in corn, but more frequently it equaled about one-half to three-fourths the corn loss.

4. It seems doubtful that even on fertile bottom land, soybeans will fail to reduce the yield of corn, when the crops are mixed in ordinary proportions. The rank growth of beans there will probably have about the same general effect on corn that was found on upland soils.

5. Probably the most productive combination of corn and soybeans for average upland soil, would be drilled in 44-inch rows at the rate of 6 pounds of corn and 3 pounds of beans per acre. This drilled rate would be equivalent to 2 stalks of corn and 2 stalks of beans per check-rowed (44-inch) hill.

6. In proportion to the area occupied, corn and soybeans mixed by alternate rows or by alternate pairs of rows, made much higher yields than when they were planted as separate crops. The possible usefulness of this method is thus suggested for thin dry soils on which the success of a full crop of corn in very uncertain.

7. In a 5-year feeding test the corn-soybean combination was more valuable than corn alone, acre for acre, for fattening hogs.

8. When hogs pasture down the corn-soybean combination, they leave a substantial portion of the beans which can later be turned to good account in pasturing other kinds of livestock.

9. Soybeans planted in corn at ordinary rates on upland soil, may produce pasturage for sheep or cattle at the rate of a half-ton or less of cured hay per acre. This would greatly increase the value of the stalk pasture.

10. Satisfactory varieties of soybeans to plant with corn for hogging down on very fertile to average land are Morse, Midwest, Haberlandt, and Mikado. For cattle or sheep pasturage, for silage, or for hogging down on thin land, Virginia or Wilson is ideal.

11. When corn is damaged by chinch bugs the yield of the associated growth of soybeans will probably be increased, and will provide a highly important compensation for the loss in corn. However, it seems hardly possible that the soybeans will actually lessen chinch bug attacks.

12. When corn is ruined by drought, the yield of the associated growth of soybeans is so reduced by the same cause that it will provide no important compensation for the loss in corn. Indeed the growth of the beans has contributed to this very loss.

13. The corn-soybean combination leaves the land more fertile than corn alone. It will, when completely pastured, probably return to the soil at least as much nitrogen as it used; but in view of the constant loss of nitrogen by soil erosion, pasturing the corn-soybean combination should not be depended upon as the sole means of maintaining the fertility of upland soils.

14. We believe the advantages of the corn-soybean combination outweigh its disadvantages, and we therefore recommend it as a farm practice. We hope, however, that our practical readers will not put aside this bulletin with a hurried reading of the summary. If they will read the body of our report they will come to a better understanding of both the value and the limitations of the mixed crop.