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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 58.

THE SOY BEAN AS A FORAGE CROP.

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WITH AN APPENDIX ON

SOY BEANS AS FOOD FOR MAN.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1897.

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
DIVISION OF AGROSTOLOGY,
Washington, D. C., July 7, 1897.

SIR: I have the honor to transmit herewith an article on the soy bean, and to recommend its publication as a Farmers' Bulletin. In addition to the treatment of the soy bean as a forage crop by Mr. Thomas A. Williams, Assistant in the Division, there is presented a brief account of its value and use as food for man, compiled from agricultural experiment station reports and other sources, by Dr. C. F. Langworthy, of the Office of Experiment Stations.

The soy bean has been cultivated in China and Japan for many centuries, and although its introduction into this country is of comparatively recent date, its value for forage is already fully demonstrated, and it may yet prove to be highly valuable for food in many localities. For reasons that are set forth in the body of this bulletin, the name "soy" has been adopted in preference to "soja," by which it has hitherto been generally known.

This bulletin is designed to meet the many inquiries received respecting this plant, and fairly represents our present knowledge of the subject.

Respectfully,

F. LAMSON-SCRIBNER,
Agrostologist.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE SOY BEAN AS A FORAGE CROP.

GENERAL CHARACTERISTICS AND ORIGIN.

The Soy Bean (*Glycine hispida*), previously, but incorrectly, called soja bean, is a leguminous plant, native of southeastern Asia. De Candolle says that it originally occurred in the wild state in the region "from Cochin China to the south of Japan and to Java." It has been cultivated from very ancient times, and in some countries, notably Japan, it is a very important food plant, and its cultivation has reached such an advanced stage that innumerable varieties and forms have been developed. Professor Rein says it is the most important legume in extent of varieties, uses, and value grown in China or Japan. It is supposed to have been used for food in China even before the time of Confucius. Although it has been grown in China and Japan for such an extended period, its cultivation seems to have spread very slowly to the surrounding countries. Its introduction into India seems to have taken place in comparatively modern times. More recently it was brought to Europe, where it was grown in botanic gardens for more than a hundred years without attracting attention as a plant of much economic importance. Aiton says in his Hortus Kewensis that it was first brought to England in 1790. In 1875 Professor Haberlandt began an extensive series of experiments with this plant in Austro-Hungary, and in a work published in 1878 he gave the results of his studies and strongly urged the cultivation of the soy bean as a food plant for both man and beast. Although he succeeded in exciting a great deal of interest in its cultivation while making his experiments, and distributed a considerable amount of seed, very little seems to have come of it; for at his death, which occurred in 1878, the interest flagged, and the soy bean has failed to obtain the place as a staple crop which he prophesied for it. (Fig. 1.)

In our own country soy bean has been grown for a great many years, chiefly in the South, but it is only within the last fifteen years that it has received much attention as a forage crop. Recently it has been the subject of considerable experimentation at a number of the experiment stations, and its great value as a crop has been very clearly demonstrated.

The term "soy" applied to this bean is derived from a Japanese word "shoyu," denoting a certain preparation from the seeds which is a

favorite article of diet in that country. The term "soja" is often used in connection with this plant, but Professor Georgeson, who spent some time in Japan, and who, since his return to this country, has experimented extensively with this plant, says:

The term soja, often applied to this bean, is misleading, inasmuch as the species named by Siebold and Zuccarini *Glycine soja* is not cultivated there (Japan), or at least rarely cultivated, though wild in the south; and later this species was confounded with the cultivated species, *G. hispida* Moench., whence the origin of the term soja, as applied to the cultivated bean.

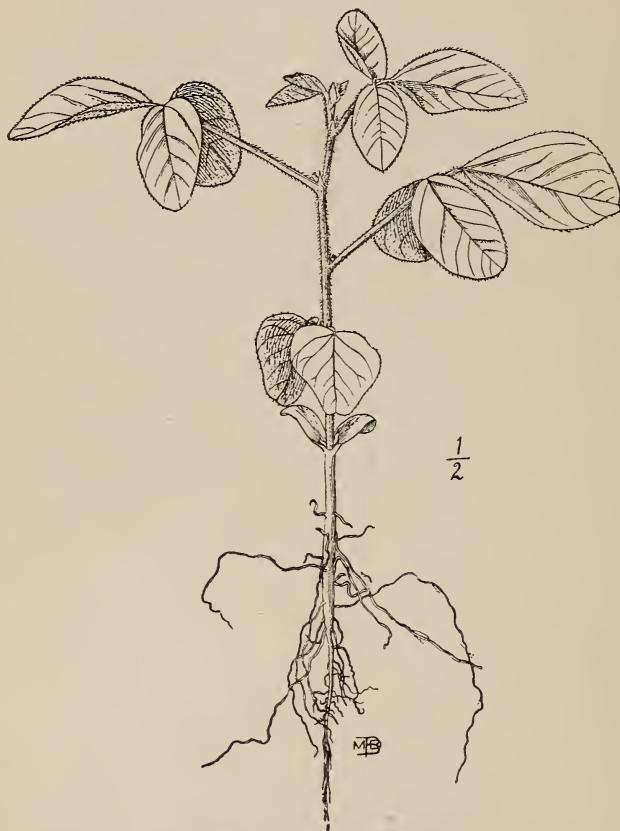


FIG. 1.—A young seedling soy bean.

Recent works on Japanese botany seem to substantiate this position, though it is still a matter of doubt as to what botanical name properly belongs to the cultivated species.

The soy bean is an erect, annual plant, with branching, hairy stems, trifoliate, more or less hairy leaves, rather inconspicuous pale lilac or violet colored flowers, and broad, two to five-seeded pods, covered, like the stem, with stiff, reddish hairs. The seeds vary in color from whitish and yellowish to green, brown, and black; and in shape from

spherical to elliptical and more or less compressed. (See fig. 2.) Under favorable conditions the plant may reach a height of 4 feet or more. In Professor Haberlandt's experiments in Austria-Hungary the plants bore about 200 pods and 450 seeds each, and though this is probably considerably above the average, it shows them to be remarkably prolific.

The fact that the flowers are self-pollinated makes the yield entirely



FIG. 2.—Soy bean: *a*, flowering branch (reduced $\frac{1}{3}$); *b*, one of the flowers (enlarged); *c*, pods of soy bean (reduced $\frac{1}{3}$).

independent of insects, and renders the soy bean free from an important obstacle in the way of the introduction of many legumes into new regions. A crop of seed is insured wherever conditions are such as to allow the plants to make the proper vegetative growth and reach maturity.

VARIETIES.

The different varieties of soy bean are distinguished largely according to the color, size, and shape of the seed, and the time required for the plants to reach maturity. They also differ more or less in the habit

of growth and in the character and degree of the hairiness of the various parts of the plant. The names applied to the varieties here in the United States usually refer to the time of reaching maturity and the color of the seed; as, for example, "Early White," "Medium Late Green," "Medium Black," etc. The early varieties generally fruit heavier in proportion to the size of the plant than the later ones, and hence are better to grow for seed, while the medium or late varieties are better for forage on account of the larger yield of fodder that may be obtained.



FIG. 3.—Extra early soy bean (planted May 5 and photographed May 12.)

The "Early White" soy bean is an excellent variety to grow when a crop of seed is desired, particularly in the North, where the growing season is likely to be short. (See fig. 3.) It is not a good variety to grow for hay or soiling however, on account of the small size of the plants and a tendency to drop the leaves early. "Medium Early Green" is one of the best varieties to plant for hay, as it yields heavily and retains its leaves well. For soiling or for ensilage "Medium Early Green," "Medium Early Black," or the "Late" green or black varieties may be used, according to the length of the season and the time at which the crop is

to be used. In the New England States the "Medium Early Green" variety is generally preferred, while in the Central States "Medium Early Black" seems to be the favorite. In the South the "medium" or "late" varieties are used, some preferring one and some another. For green manuring the large medium or late varieties are best; "Medium Late Black" being excellent for this purpose. (See fig. 4.)

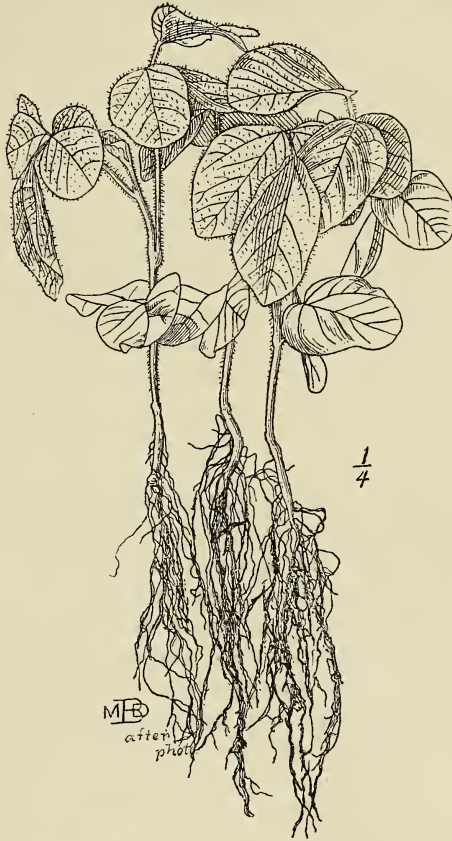


FIG. 4.—Medium black soy bean (planted May 5 and photographed May 12).

CONDITIONS OF GROWTH.

It is believed in Japan that in northern climates, soils of a rather strong character are best adapted to the soy bean. It is usually sown about the end of May, and when used for hay is cut early in August. In both Europe and America it has been found to thrive best on soils of medium texture that are well supplied with potash, phosphoric acid, and lime. It succeeds very well, however, on comparatively light soils, often giving an abundant crop on soils too poor to grow clover. Professor Haberlandt found that good results could be obtained in Europe

on a very great variety of soils, and similar results have been obtained in the United States. Professor Georgeson has obtained fairly good results in Kansas on very poor soils, and under very adverse conditions as to moisture. In South Carolina the soy bean gives excellent crops on sandy, limestone, or marly soils, and also on drained swamp or peaty lands that are well marled. Experiments in both Europe and America show that the soy bean possesses excellent drought-resisting qualities, enduring dry weather much better than the ordinary field or garden beans.

The soy bean requires about the same temperature as corn. Professor Haberlandt found that the earlier varieties of soy bean would mature in Europe rather farther north than the earlier varieties of corn. In the United States the relation of the soy bean to temperature has not yet been thoroughly tested, but it is very likely that the northern limit will be found very near to that of corn. Professor Brooks says that the earlier sorts will mature in Massachusetts with as much certainty as will the earlier varieties of corn. As a general thing, the soy bean is not so easily injured by frost as the common field or garden varieties of beans, and hence it can be planted earlier in the spring and can also be left in the field later in the autumn. At the Kansas Station, soy beans planted on the 25th of July on poor soil survived several light freezes and, when cut on the 17th of October, had matured a fair crop of seeds.

While the soy bean is possessed of excellent drought-resisting qualities, it at the same time seems to be able to survive a period of excess of moisture better than the cowpea or even corn. Mr. Robert C. Morris, of Illinois, reports, as an instance in his own experience in 1896, that, after standing in water for three weeks in July, the soy beans recovered, while corn and cowpeas under the same conditions were permanently injured. The upright, bushy habit of growth gives the soy bean a great advantage over the cowpea during wet weather and makes it easier to handle at harvest time.

METHODS OF CULTURE.

In a general way, the same methods of culture may be recommended for the soy bean as would be given to the ordinary field beans. The soil should be well prepared, so as to afford a good root bed, and should be left smooth and free from clods in order to facilitate the cultivation and harvesting of the crop. If the soil is lacking in potash and phosphoric acid, these should be supplied to secure the best results. From experiments carried on at the Massachusetts Hatch Experiment Station, it is probable that for this crop the potash can be best supplied in the form of the muriate. Under ordinary conditions it is not likely that there will be any necessity for using any nitrogen-containing fertilizer, as sufficient of this element is usually present in the soil, and, like other legumes, this plant assimilates the free nitrogen of the air. In

experiments with this crop where nitrogen has been supplied to the soil in various forms it has been found that there was but very little gain in the yield, and in but very few instances was this sufficient to pay for the extra fertilizer used.

Although soy beans may be planted quite early in the season, the best results will be obtained if the seeding is postponed until the ground has become thoroughly warm; and in case the earlier varieties are used, a fairly good crop of forage or even of seed may be obtained if the seeds are not planted until the earlier small grains, such as rye and barley, have been harvested. It may thus be possible to obtain two crops from the same field in a single season; one of small grain, and the other of soy bean, and yet to leave the land in better condition than if the second crop had not been grown. Another practice is to drill the beans in between the rows of corn after the last plowing; they are also sometimes planted between the hills of corn, as are field beans. The best method of seeding will depend somewhat upon the kind of crop which it is desired to harvest. If the soil is good, and a crop of hay or green fodder is desired, good results may be obtained by sowing broadcast or with a grain drill. If, however, a crop of beans is desired, it is best to plant in drills from 2 to 3 feet apart, according as the soil is light or heavy.

There is considerable difference in the amount of seed sown per acre in the various parts of the country; some farmers sow only about half a bushel per acre, while others prefer a bushel or even more. The proper amount will necessarily vary somewhat, according to the method of seeding and the character of the soil. As a rule, when grown for seed, from one-half to three fourths of a bushel per acre will be ample. When put in with a grain drill or sown broadcast, a greater amount of seed will be required; but in any case it will hardly be necessary to use more than 1 bushel per acre. Of course, less seed will be required when the grain drill is used than when the seed is sown broadcast, and as a rule better results will be obtained. When planted for beans enough seed should be used to give an average of five or six plants per foot in the row. If nothing better is at hand for planting the seed, an ordinary grain drill, with enough of the holes stopped up to give the desired distance for the rows, may be used. For example, if the holes are 8 inches apart, number 1 may be left open, numbers 2, 3, and 4 closed, number 5 open, etc., and the rows will be 32 inches apart, or, if a less distance is desired, number 4 may be left open and number 5 closed, and the rows will be 24 inches apart. In very light soil the latter distance would probably be best, but in heavier soils the former would be preferable.

When the seed has been drilled in rows close together or has been sown broadcast, very little cultivation will be necessary. It will sometimes be found advisable, however, to cultivate the drilled field soon after planting, as in case the land is very foul, the weeds are liable to get

such a start that they will interfere with the growth of the young soy plants. For this purpose use a light harrow. When grown for seed, thorough cultivation should be given, at least while the plants are young. As a rule, cultivation should be shallow and frequent if the best results are to be obtained. When the ground is inclined to pack or bake, it should be stirred after each rain, but care should be taken not to work the field when the plants are very wet from rain or dew. If the drills have not been made too far apart, it will be found that the plants will soon shade the soil sufficiently to keep the weeds in check and to keep the surface in good condition, so that much cultivation will be unnecessary. In fact, on good soil very fine crops have been obtained with but a single stirring of the soil after the seed had been planted. As a rule, this crop will require a smaller amount of cultivation than corn.

HARVESTING.

The time for harvesting the soy-bean crop will necessarily depend somewhat upon the use for which the crop is intended. From the analyses given in the following table it will be noticed that the plants, cut when the pods are well developed, contain larger amounts of crude protein and fat than those cut at early stages. But from the feeding experiments it seems likely that more of the plant will be eaten if cut in the earlier stages, and hence it is doubtful if very much is gained by the later cutting. Considering palatability and digestibility as well as chemical composition, it is probable that the best forage will be obtained by cutting just as the pods are forming.

Composition of the soy bean at different stages of growth.¹

Water-free substance.	Whole plant (just in bloom) August 21.	Stalk of preceding.	Whole plant (just in pod).	Whole plant (pods well developed but not hard).
Protein	12.84	3.38	14.41	14.43
Fats	2.57	0.80	3.78	3.85
Nitrogen-free extract.....	50.05	9.25	46.83	55.70
Crude fiber	27.31	81.34	28.20	20.38
Ash	7.23	5.23	6.78	5.64

¹S. C. Exp. Sta. An. Rep. for 1882, p. 122.

If the crop is to be used for soiling purposes, cutting can begin when the plants are in early bloom and can be kept up until the pods are beginning to ripen, though the length of the season will vary somewhat, according to the different varieties, some being better for this purpose than others. If the crop is to be cured for hay, it may be cut when the plants are in full bloom or the pods beginning to form, but this will also vary according to the variety grown, since some of the varieties begin to drop their leaves much earlier than others, and it is quite important that as many of the leaves should be saved as possible. It will be noticed from the preceding table that in the stalk of the plant

the percentage of protein and fats is very low, and that of the crude fiber is very high; hence the most important of the food elements are found in the leaves.

When the crop is to be preserved in the silo, it will be best to cut it at about the same stage as when used for hay. However, the plants can be cut at a later stage for the silo than for hay, since they are preserved in a much more palatable condition than when cured as hay, and the cutting necessary in preparing for the silo leaves the plant in condition to be more easily masticated by the animals.

Because of its coarse habit of growth, the soy bean is somewhat difficult to cure satisfactorily in moist climates. A good plan to follow in curing is to allow the plants to lie in the swath or windrow until well wilted (but not until they begin to become brittle), and then gather into small piles. Care should be taken to see that these piles are so constructed as to admit of thorough ventilation to the very center, in order that the plants may not mold and spoil. The hay should be handled as little as possible in curing and carrying to the barn or shed, in order that the leaves may not be broken off and lost.

Under ordinary conditions the earlier varieties will mature in 75 to 90 days from the time of planting. It is possible, however, and often even desirable, in harvesting the crop for seed to cut before the pods are entirely mature. If they become too ripe, they are liable to burst open in drying and carrying to the machine, and thus a portion of the seed may be lost. Some growers recommend cutting for seed when the pods are only about half mature. This is undoubtedly a good practice if the straw is to be used for feeding purposes, as in that case it will contain a larger amount of digestible nutrients, and will be much more palatable than if allowed to stand until the pods are thoroughly mature. In harvesting a crop for the seed, the plants may be pulled by hand or cut with a scythe or mower and gathered into small piles, which should be relatively high and of a small diameter, so that the plants may dry out readily. Thrashing can be done with a flail or with the thrashing machine. Very good results can be had with common grain thrashers by taking out a portion or all of the concaves and substituting blanks.

YIELD.

The amount of forage obtained from the soy bean will, of course, vary widely, according to the conditions under which the crop is grown. Under favorable conditions as much as 12 or 13 tons of fresh fodder may be produced per acre. In the New England States, under the ordinary farm conditions, yields of from 9 to 12 tons per acre are reported from the medium early varieties. The early varieties yield, as a rule, a less amount of forage. In the South, where the later and coarser varieties are grown, larger yields may be obtained. But in some parts of the South the yields have been so light that the crop has been regarded as an unprofitable one to grow, and in some parts of the colder Northern States the season is too short for any but the very

earliest varieties, and these often fail to mature seed. At the South Carolina Station, yields of 2 to 2½ tons of cured hay per acre are reported, and similar amounts have been obtained in many other portions of the United States. In Japan, the earlier varieties are said to afford on an average from 1½ to 2 tons of well cured forage per acre. At the North Carolina Station, in an experiment in which the soy bean and the cowpea were grown under similar conditions, a yield of nearly 2¼ tons of well cured hay was obtained from 1 acre of soy bean, while from 1 acre of cowpea a little less than a ton was secured.

Under ordinary conditions 25 to 40 bushels of seed per acre will be an average yield. If the conditions are very favorable, the yield may reach 100 bushels. On the other hand, drought and poor soil may reduce the yield to 15 bushels, or even less. In the experiments by Professor Georgeson, mentioned in the preceding pages, a yield of over 8 bushels per acre of well-cleaned seed was obtained from a field planted after a crop of rye had been harvested. In this case the beans were cultivated but once, and grew under very adverse conditions of both soil and climate. When it is remembered that this was the second crop from the land that season, and that the beans brought \$2 per bushel, it will be seen that the crop was a profitable one to grow.

CHEMICAL COMPOSITION.

The following tables on the chemical composition of the various parts of the soy bean used for feeding purposes have been arranged with great care, to show as far as possible the latest and best results obtained by experimenters in the United States during the course of their studies of this plant:

Chemical composition of the various kinds of forage made from the soy bean.

Soy-bean forage.	Number of analyses.	Fresh or air-dry substance.					Water-free substance.					
		Water.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.
Fodder (early bloom to early seed) ¹	13	76.5	3.6	1.0	10.1	6.5	2.3	15.3	4.1	43.0	27.6	10.0
Soy-bean hay (Japanese).....	1	16.0	16.9	2.2	23.1	35.9	5.9	20.1	2.6	27.5	42.7	7.0
Soy-bean hay (Mass.) ²	4	12.1	14.2	4.1	41.2	21.1	7.3	16.2	4.7	46.3	24.0	.....
Soy-bean straw (Mass.) ²	3	11.4	4.9	1.9	37.8	37.6	6.4	5.5	.....	42.7	42.4	.....
Soy-bean straw (hulls and vines after thrashing) ³	1	5.7	4.0	0.8	36.0	49.5	3.9	4.25	0.85	38.2	52.6	5.3
Soy-bean seed ⁴	8	10.8	34.0	16.9	28.8	4.8	4.7	38.1	18.9	32.2	5.4	5.3
Soy-bean meal ⁵	2	10.4	36.0	18.9	27.0	2.6	5.1	40.2	21.0	30.2	2.9	5.7
Soy-bean ensilage ⁶	1	74.2	4.1	2.2	7.0	9.7	2.8	15.7	8.7	27.0	37.6	11.0
Corn and soy-bean ensilage ⁷	4	76.0	2.5	0.8	11.1	7.2	2.4	10.4	3.3	46.3	30.0	.....
Millet and soy-bean ensilage ⁷	9	79	2.8	1.0	7.2	7.2	2.8	13.3	4.8	34.3	34.3	.....

¹ Ninth An. Rep. Storrs Exp. Sta., pp. 281, 285 (1896).

² Eighth An. Rep. Mass. Hatch. Sta., p. 87 (1896).

³ Second An. Rep. S. C. Exp. Sta., p. 179 (1890).

⁴ Bull. 15 U. S. Dept. Agric., Office Exp. Stations, p. 390 (1893).

⁵ Eighth An. Rep. Storrs Exp. Sta., pp. 183, 186 (1895).

⁶ Bull. Tenn. Exp. Sta., Vol. IX, No. 3, p. 106 (1896).

⁷ Ninth An. Rep. Mass. Hatch. Sta., p. 140 (1897).

If the preceding analyses are compared with those of other leguminous crops, it will be seen that the soy bean ranks high from a chemical point of view. The green fodder has much the same composition as red clover, being slightly lower in crude protein and higher in crude fiber. In the two most important substances, crude protein and fat, the soy bean is considerably richer than the cowpea. The hay also shows a relatively high fat and protein content. The only available analysis of soy-bean ensilage shows it to agree very closely in composition with red-clover ensilage, being higher in crude fiber and fat, and lower in extract matter. From the analysis of the beans it will be seen that these are about two-fifths protein and one-sixth fat, with but very little fiber present, making them almost as rich in crude protein as the best cotton-seed meal, with a higher percentage of fat. They contain three times as much crude protein and nearly three and a half times as much fat as oats; nearly three and one-half times as much protein and about three times as much fat as corn, and almost twice as much crude protein and over twelve times as much fat as peas; all of which shows them to form one of the most concentrated of our feeding stuffs.

The accompanying table gives an excellent comparison of the yield and composition of soy bean and fodder corn under similar conditions, and shows how admirably the one supplements the other when both are used in the feeding ration. At the Massachusetts Hatch Station, Longfellow corn gave an average yield of 16 tons of green fodder per acre, and medium early green soy bean gave a little over 10 tons. The soy bean, cut when the pods had formed but not hardened, afforded a little over 30 per cent of dry matter, and Longfellow corn, cut when the ears were glazed, gave a little less than 28 per cent. The total amounts of the various food constituents produced by each crop on an acre of ground may be seen by the following table:

Total amounts in pounds of food constituents produced on an acre of land by soy bean and fodder corn.

Crops.	Flesh formers.	Fat and heat producers.		
	Protein.	Crude fat.	Fiber.	Extract matter.
Green soy bean	1, 167. 2	233. 4	1, 418. 1	2, 430. 9
Longfellow fodder corn.....	871. 3	290. 1	1, 626. 0	5, 616. 8

DIGESTIBILITY.

The chemical analysis alone will not prove the feeding value of a forage crop. Other points must be considered, one of the most important of which is the percentage of digestibility of the various nutrient substances found in the plant at the time it is fed to the animal. As yet very few experiments on the digestibility of the soy bean have been

carried out in the United States, but of these the greater part has been made at the Connecticut Storrs Experiment Station; and sheep have been used in most of the tests.

Digestibility of soy-bean forage.

Soy-bean forage.	Kind of animals.	Number of trials.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Organic matter.	Ash.
Soy-bean fodder ¹	Sheep	8	75.1	54.0	73.2	47.0	64.5	18.9
Soy-bean meal and timothy hay ¹	do	8	77.7	73.6	66.2	61.3	69.1	47.1
Soy-bean meal alone (calculated from the above mixture). ¹	do	8	85.8	84.9	73.4	.....	78.0	21.3
Soy beans (seed) ²	Ruminants	2	87.0	94.0	62.0	.....	85.0	.....
Soy-bean pods ²	do	2	44.0	57.0	73.0	51.0	63.0	.....
Soy-bean straw ²	do	4	50.0	60.0	66.0	38.0	55.0	.....
Soy-bean hay	do	6	70.0	30.0	67.0	56.0	.....	.....
Soy-bean ensilage ³	{ Goats	2	76.0	72.0	52.0	55.0	.....	.....
	{ Steers ⁴	2	55.0	49.0	61.0	43.0	.....	.....
Corn and soy-bean ensilage ³	Sheep	3	65.0	82.0	75.0	65.0	.....	.....
Barnyard millet and soy-bean ensilage. ³	do	4	57.0	72.0	59.0	69.0	.....	.....

¹ Ninth An. Rep. Storrs Exp. Sta., pp. 248, 250 (1896).

² Sixth An. Rep. Storrs Exp. Sta., pp. 160, 161 (1893), taken from European tables by Drs. Dietrich and König.

³ Ninth An. Rep. Mass. Hatch Exp. Sta., p. 165 (1897).

⁴ Very low; probably quite mature when harvested.

Comparison of the preceding percentages with those of the clovers, cowpeas, alfalfa, and other legumes shows that the soy bean stands well as to its digestibility, especially as regards the more important nutrient substances.

The following rough computation will give an idea of the amount of digestible matter in the forage raised on an acre planted to this crop. Under ordinary farm conditions the yield of green fodder usually ranges from 6 to 12 tons per acre. Taking 8 tons as an average yield, the amount of dry matter will be about 2 tons, of which about 54 per cent is digestible. This will make the digestible matter raised on an acre of ground amount to nearly $1\frac{1}{10}$ tons. Of this amount about one-sixth is protein or muscle-making material and about three-fourths crude fiber and other fat-forming substances.

Soy-bean meal has a high percentage of digestibility. It contains almost two and a half times as much digestible protein and over five times as much digestible fat as the common roller-process wheat bran, and its digestibility is decidedly higher in everything but the fat than that of cotton-seed meal.

VALUE AND USES.

AS A SOILING CROP.

One of the most important uses of the soy bean is for green forage. The great variation in the season of maturity of the various varieties makes it possible to have a succession of forage lasting throughout a

great part of the summer and autumn. Wherever tried it has proved a most valuable forage for milk production. At the Massachusetts Station soy-bean fodder gave excellent results in every combination tried. A ration of grain, soy bean, and hay gave better results in five out of six cases than a ration of grain, vetch, oats, and hay, and also exceeded grain and rowen hay. In another experiment, in which vetch, oats, fodder corn, and soy bean were fed in connection with corn meal, gluten meal, and wheat bran or dried brewers' grains, the soy beans made a remarkably fine showing, especially when fed with the dried brewers' grains. This ration gave the largest average flow of milk in every case. The quality of the milk also improved. This clearly shows that the addition of soy-bean fodder to the ration of milch cows will have a beneficial effect upon both the quantity and the quality of the milk. It tends to produce a narrower nutritive ratio, and hence makes a more profitable ration for the production of milk and butter. Soy bean and sorghum make an excellent combination for green fodder; the former is rich in the muscle-making elements and the latter in the fat-forming ones. Both make large yields of forage per acre and both will thrive under a great variety of soil and climatic conditions. These crops are among the best that can be recommended for dairymen throughout a large portion of the United States.

AS A SILAGE CROP.

A number of the State experiment stations have conducted experiments in making and feeding soy-bean ensilage, and the results have been quite satisfactory. By using the larger, coarser-growing varieties a heavy yield of forage may be obtained. The silage keeps well, is eaten readily by stock, and the animals show good results in flesh or milk production. Again, the crop is an easy one to put into the silo as compared with some others that are often used for this purpose.

There are a number of reasons why the soy bean can usually be more profitably ensiled than cured for hay. The ensilage is more palatable than the hay and can be fed with much less waste. There is also usually less loss in cutting the crop and putting it into the silo, owing to the liability of the leaves to fall off during the process of curing and storing the hay. Furthermore, the plants can be ensiled at any time from early blooming to early maturity with fairly good results, while, if cutting for hay is delayed much after the pods are well formed, the quality may be considerably impaired by the stems becoming woody and unpalatable.

Excellent results are obtained by making a mixed ensilage of soy bean and corn, millet, or other crops rich in fat-forming nutrients but poor in muscle-makers. The one crop supplies what the other lacks, and thus a more evenly balanced ration is obtained. All things considered, corn is the best crop that can be used with the soy bean for making such a mixed silage. In filling the silo the corn and beans

may be put down in alternate layers, and whatever further mixing may be necessary can be done when the ensilage is fed out to the stock. Professor Phelps, of the Connecticut (Storrs) Experiment Station, recommends this mixed silage very highly as an economical feed for farm and dairy stock.

AS A HAY CROP.

There can be no question as to the high feeding value of hay made from soy bean, cut in the right season and properly cured and preserved. Even when the cutting is delayed until the seed is mature enough to harvest, the stem and leaves contain sufficient digestible substances to be of considerable value for forage. Unless the plants are cut in the proper season, however, much of the value of the forage will be lost on account of the woody character of the stems and the falling off of the leaves. It is, therefore, the best plan to ensile the crop if it becomes too mature before it can be cut. On account of its coarseness the hay is not eaten so readily as that of many other legumes, but this may be, in a measure, overcome by running the hay through a feed cutter before feeding it. All things considered, the soy bean can not be used for hay as advantageously as for soiling or for ensilage. Nevertheless, it may often be profitably grown for this purpose, as, for example, in short rotations and in localities where clover can not be relied upon.

AS A PASTURE PLANT.

In some parts of the country, particularly in the South, the soy-bean crop is often pastured. Although hogs are perhaps most frequently used, all kinds of stock can be pastured on it. The crop can often be fed in this manner to a great advantage. The labor and expense of harvesting is saved and the droppings from the animals are of great value to the land. Young stock, particularly sheep and hogs, can be very profitably pastured on this crop. Many farmers maintain that by this method of feeding the land is benefited as much as if the crop had been plowed under, and they obtain the pasturage in addition.

AS A SOIL RENEWER.

One of the great advantages in growing leguminous forage crops lies in the benefit which the soil derives from the nitrogen and other important elements of plant food that are left in it by the crops. Soils that have become impoverished by continuous cropping with small grains or other nitrogen-using crops may be restored to fertility by the use of leguminous crops, as, for example, the clovers, cowpeas, vetches, lupines, and the soy bean. The value of a crop as a soil restorer depends upon the amount of available plant food which it adds to the soil and also upon the effect which the roots have upon the mechanical condition of the soil. Leguminous plants, through the aid of the root tubercle organisms, are able to add to the available nitrogen of the soil, and hence are extensively used in restoring those deficient in that element.

The soy bean is highly valued in Japan as a nitrogen gatherer and is extensively grown in rotation with cereal crops. When the soy bean was first introduced into the United States it did not form root tubercles, owing to the absence of the tubercle organism from the soil, and it has been grown for several years in some localities without the appearance of any tubercles. In other cases the tubercles have developed in great abundance after a short time. At the Massachusetts (Hatch) Station the medium green soy bean produces great numbers of the tubercles. (See fig. 5.) At the same station it was found that a liberal application of nitrates interfered with the development of the tubercles.

In experiments made at the Storrs Experiment Station soy beans were planted in soil uninfested with the tubercle microbes, and then later in the season (about the middle of July) a portion of the field was inoculated with infected soil. Tubercles were produced on the plants in the inoculated land, but, owing to the lateness of the inoculation, they made but little development, and no difference could be noticed between the crops grown on the two parts of the field.

The manurial value of a crop of soy bean compares very favorably with that of other legumes commonly grown as green manures. In the following table is given a comparison of the fertilizing ingredients contained in the crop and roots produced on an acre by soy beans, cowpeas, and red clover.



FIG. 5.—Roots of soy bean showing tubercles (slightly reduced in size).

Yield of green forage per acre, and fertilizing ingredients in crop and roots of soy beans, cowpeas, and clover.¹

Crops.	Green forage.	Nitrogen.			Potash (K ₂ O).			Phosphoric acid (P ₂ O ₅).		
		In crop.	In roots, etc.	Total.	In crop.	In roots, etc.	Total.	In crop.	In roots, etc.	Total.
	<i>Tons.</i>	<i>Lbs.</i>	<i>Lbs.</i>		<i>Lbs.</i>	<i>Lbs.</i>		<i>Lbs.</i>	<i>Lbs.</i>	
Soy bean.....	9½	165	9	174	109	6	115	42	2	44
Cowpea.....	8	67	23	90	60	15	75	17	6	23
Red clover.....	13	138	44	182	152	32	184	32	13	45

¹Connecticut (Storrs) Sta. Bull., No. 6, pp. 13, 14.

At the Massachusetts (State) Station it was estimated that the cash value of the essential fertilizing ingredients (nitrogen, phosphoric acid, and potash) contained in a ton of green soy-bean fodder would be about \$2.44 and that of cowpeas about \$2.23.

When a crop of soy bean or cowpea is turned under for green manure, it should be well limed. This will obviate the bad effects sometimes experienced when a very heavy crop of legumes is plowed under.

Though soy beans possess a very high value as a green manure, they do not seem to leave the soil in as good condition when the crop is taken off as does clover and some other legumes, particularly perennials. After considerable experimentation in Massachusetts the conclusion was reached that soy bean failed to enrich the soil sufficiently in available nitrogen to produce as good yields of small grains following them as did the clovers.

VALUE OF THE BEAN FOR FEED.

There is no other crop so easily grown that is so rich and can be used to such good advantage in compounding feeding rations as the soy bean. Excepting the peanut, there is no other raw vegetable product known which contains such high percentages of protein and fat in such a highly digestible form.

For feeding to animals the beans should be ground and the meal used with some less concentrated feeding stuffs. Comparatively few experiments have as yet been made in the United States to test the feeding value of soy-bean meal. Professor Brooks, in Massachusetts, found that it compared very favorably with cotton-seed meal. Cows fed on soy-bean meal gave richer milk and produced a better quality of butter than when fed on cotton-seed meal, but on the latter the cream was richer. Professor Georgeson obtained excellent results in feeding hogs on a ration of which soy-bean meal was a prominent constituent. His experiments are reported in detail in Bulletin No. 61 of the Kansas Station, but the following brief summary, taken from an article in the *Industrialist* for January 11, 1897, gives the essential features of his tests:

It was found * * * that a lot of three pigs which was fed for 126 days on a ration consisting for the first eleven weeks of Kaffir corn meal alone and the last seven weeks of Kaffir corn meal and shorts gained a total of 191 pounds, while a similar lot fed two-thirds Kaffir corn meal and one-third soy-bean meal gained 547 pounds in the same time. Another lot of three pigs which was fed on corn meal for the first eleven weeks of the experiment and a mixture of two-thirds corn meal and one-third shorts for the last seven weeks of the experiment made a total gain of 306 pounds in 126 days, while a similar lot of three pigs fed on two-thirds corn meal and one-third soy-bean meal throughout the experiment gained 554 pounds in the same time. The largely increased gains in these pigs must be credited chiefly to the soy-bean meal.

SUMMARY.

The soy bean thrives best in soils of medium texture well supplied with lime, potash, and phosphoric acid. It endures drought well, is not easily injured by excess of moisture, and may be grown about as far north as corn.

The early varieties are best for seed crops, and the medium or late varieties for hay, forage, and silage. Seed may be planted at any time during the spring and early summer, but preferably as soon as the ground becomes well warmed up. Drill one-half to three-fourths of a bushel to the acre; broadcast three-fourths to 1 bushel.

Little cultivation is needed when growing for forage; when for seed keep weeds down until plants shade the soil. The soy bean may be used for soiling, pasturage, hay, and ensilage, or the beans may be harvested and fed as grain.

The forage is very rich in fat and muscle-making materials and should be fed with fodder-corn, sorghum, or some other feeding stuffs rich in fat-forming nutrients. The seed can be fed to the best advantage when ground into meal and is almost without equal as a concentrated food.

Cut for hay when the plants are in late bloom or early fruit; for ensilage the crop can be cut later, but it is better to cut before the pods begin to ripen; for green forage cutting may begin earlier and continue rather later than for either hay or ensilage; the crop may be cut for seed after the pods become about half ripe.

The soy bean is excellent for green manuring and for short rotations with cereal crops. It should be well limed when plowed under as a green manure.

APPENDIX.

SOY BEANS AS FOOD FOR MAN.

By C. F. LANGWORTHY, Ph. D.
Office of Experiment Stations.

The soy bean has been used as a food for man in Japan, China, and neighboring countries from the earliest times. In more recent years it has been cultivated for this purpose in Europe. As has been stated, there is a considerable number of cultural varieties. Analyses of the soy bean grown in various countries have been reported by a number of investigators. Some of these are given in the following table:

Analyses of the soy bean.

Variety.	No. of analyses.	In fresh, or air-dry material.						Calculated to water-free substance.	
		Water.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Protein.	Fat.
Black, grown in Germany and France.....	3	<i>Per ct.</i> 12.71	<i>Per ct.</i> 32.18	<i>Per ct.</i> 14.03	<i>Per ct.</i> 31.97	<i>Per ct.</i> 4.40	<i>Per ct.</i> 4.71	<i>Per ct.</i> 36.87	<i>Per ct.</i>
Yellow, grown in China, Germany, and Austria.....	25	9.89	33.41	17.68	29.31	4.67	5.10	37.08	19.57
Brown, grown in China, Germany, and Austria.....	13	9.25	32.90	18.03	30.17	4.76	4.89	36.25	19.87
Black, round, grown in China, Germany, and Austria.....	5	11.23	33.97	17.11	28.41	4.55	4.73	38.26	19.28
Variety unknown, grown in Switzerland.....	10.00	37.00	17.81	25.00	4.96	5.23	41.11	19.69	
Variety unknown, grown in China.....	9.00	35.50	16.40	22.59	11.65	4.86	39.01	18.02	
Variety unknown, grown in Hungary.....	10.16	27.75	16.60	28.97	11.65	4.87	41.11	19.69	
Variety unknown, grown in France.....	12.88	35.00	13.60	29.92	4.40	4.20	40.18	15.61	
Variety unknown, grown in Japan.....	11.30	37.80	20.90	24.00	2.20	3.80	42.60	25.55	
Variety unknown, grown in India.....	12.00	36.00	18.00	29.10		4.90	40.90	20.45	
Variety unknown, grown in Japan.....	11.92	37.51	18.02	24.87	3.99	3.69	42.59	20.46	
Do.....	12.87	37.62	18.11	24.52	3.53	3.35	43.18	20.78	
Do.....	10.30	39.75	11.98	28.59	5.43	3.95	44.31	13.36	
Do.....		42.05	20.46		4.53	4.19			
Yellow, grown in America.....	10.13	34.63	17.98	30.50	3.69	3.07	38.50	20.00	
White, grown in America.....	17.38	27.56	19.09	28.24	4.42	4.31	33.40	21.90	
Black, grown in America.....	19.27	26.25	16.38	26.57	6.13	5.40	32.50	20.30	
Variety unknown, grown in America.....	10.00	35.25	16.89	30.69	2.45	4.72	39.10	18.80	
Average of American analyses.....	10.80	33.98	16.85	28.89	4.79	4.69	38.10	19.00	

Comparatively little information is available concerning the chemical character of the different constituents of the soy bean. According to

the Japanese investigators, the bean contains on an average 7.5 per cent of nitrogen—6.9 per cent being albuminoid nitrogen, exclusive of peptones, 0.1 per cent amide nitrogen, and 0.3 per cent nitrogen of peptones. Osborne studied the nitrogenous constituents of white or kidney beans. He found that they contained on an average 23.5 per cent of protein, made up of phaselin and phaseolin. The percentage of protein in the soy bean is much higher than this, and it is not improbable that it differs materially in chemical character. According to Japanese authors, the soy bean contains no starch. No statements have been found concerning the character of the fat.

The fact is well recognized that beans of all kinds are valuable food because of the large amounts of protein and fat which they contain. In order that the nutrients may be available, the beans must be cooked or prepared in some way so that the cell walls may be broken down and their contents readily acted upon by the digestive juices. What is true of beans in general is especially true of the soy bean. Though it is eaten more extensively in China and Japan than in any other countries, so far as can be learned it is never eaten there as a vegetable, but more or less complex food products are prepared from it. At least five preparations are commonly made in Japan from the soy bean. These are natto, tofu, miso, yuba, and shoyu.

Natto is prepared by boiling the beans in water for five hours to render them very soft. The hot mass is then wrapped in small portions in straw and the bundles, securely tied at both ends, are placed in a cellar in which a fire has been kindled. The cellar is then closed for twenty-four hours and the cooked beans allowed to ferment in the warm, moist atmosphere. The fermented product is a thick, viscid mass and has a peculiar but not putrid odor.

Tofu, or bean cheese, is prepared as follows: The beans are soaked in water for about twelve hours, and crushed between millstones until of a uniform consistency. The ground material is then boiled with about three times its bulk of water for about an hour, and filtered through cloth. The filtrate is white and opaque, having somewhat the appearance of milk. It has, however, the taste and smell of malt. This milky liquid, to some extent, resembles cow's milk in composition, as is shown by the following table:

Comparison of the composition of soy-bean milk and cows' milk.

Constituents.	Soy-bean milk.	Cows' milk.
	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	92.53	86.08
Albuminoids.....	3.02	4.00
Fat.....	2.13	3.05
Fiber.....	0.03	.....
Ash.....	0.41	0.70
Nitrogen-free extract, including carbohydrates.....	1.88	.....
Milk sugar.....	.....	5.09

The protein in soy-bean milk is precipitated by adding the mother liquor obtained in the manufacture of salt from sea water, which contains considerable magnesium chloride. The precipitate is filtered off and formed into cakes with the hands. It is eaten in the fresh state or frozen. In the latter case it loses part of its water.

Miso is prepared from cooked beans which are rubbed to a thick paste and fermented with rice wine ferment. Miso is of two kinds, white and red, and to some extent resembles tofu.

A sort of film forms on the surface of soy-bean milk which in appearance suggests cream. This material is sometimes prepared in quantity by evaporating the milk, and when dried it is used as an article of food under the name of yuba.

Shoyu is a sauce prepared from a mixture of cooked and pulverized soy beans, roasted and pulverized wheat, wheat flour, salt, and water. The mass is fermented with rice wine ferment in casks for from one and a half to five years, being very frequently stirred. The resulting product is a moderately thick brown liquid. In odor and taste it is not unlike a good quality of meat extract, though perhaps a trifle more pungent. Under the name of soy sauce it has been known in India, and to some extent in Europe, for many years.

The composition of each of the above-described foods is given in the following table:

Composition of food products made from soy beans.

Soy-bean food products.	Water.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Fresh tofu.....	89.00	5.00	3.40	2.10	.....	0.50
Fresh tofu.....	89.29	4.87	.....	4.35	.....	0.48
Frozen tofu.....	18.70	48.50	28.50	2.60	.....	1.70
Natto.....	15.32	41.42	23.65	15.05	1.48	3.08
Yuba.....	21.85	42.60	24.62	7.65	.....	2.82
White miso.....	50.70	5.70	24.40	.....	12.60	6.60
Red miso.....	50.40	10.08	18.77	.....	8.25	12.50
Swiss miso.....	12.53	26.43	13.91	19.54	1.41	26.18
Shoyu.....	63.29	8.31	.....	5.10	.....	19.45
Shoyu.....	67.42	7.37	.....	4.06	.....	17.47

It will be noticed that most of these soy-bean products are fermented; that is, they are prepared with the aid of microorganisms. The cell walls and other carbohydrate material are broken down and the cell-contents rendered more accessible to the digestive juices, and at the same time peculiar and pleasant flavors are developed. The special microorganisms used in the preparation of these foods have been studied in recent years. The manufacture of these products is of very ancient origin, and affords an interesting practical illustration of the use of bacteria for economic purposes.

Though these soy-bean products are prepared chiefly in Japan and other eastern countries, their manufacture has been attempted to some extent in Switzerland and elsewhere.

The statement is frequently made that the Japanese live almost exclusively upon rice, eating little or no meat. It is not, however, generally known that the deficiency of protein in the rice is made up by the consumption of large quantities of shoyu, miso, or other soy-bean products. It is stated on good authority that these products actually take the place of meat and other nitrogenous animal foods in the Japanese dietary. They are eaten in some form or other by rich and poor at almost every meal.

A large number of dietary and digestion experiments have been made in Japan in which soy-bean preparations formed a considerable part of the food consumed, although no experiments have been made, so far as can be learned, in which such preparations were eaten alone. Generally speaking, the nitrogen was well assimilated. For instance, when 12 grams of nitrogen was consumed daily, the dietary consisting of bean cheese and rice, only 0.1 gram of nitrogen was excreted in the feces. When 13.9 grams of nitrogen was consumed daily in a dietary of bean cheese and barley, only 1.4 grams was excreted in the feces. According to one author, in a dietary containing a large amount of bean cheese, 90 per cent of the protein, 89.9 per cent of the fat, and 14.5 per cent of the crude fiber are digestible. The general opinion of Japanese investigators and others familiar with oriental dietetics is, that the protein in articles of food prepared from soy beans is in a very available form, and that these preparations are most valuable foods.

Bean sausages in considerable variety are prepared in Germany, and formed part of the ration of the German soldier in the Franco-Prussian war. So far as can be learned, these are always made from ordinary varieties of beans and not from soy beans.

Since soy beans contain no starch, they have been recommended as food for persons suffering from diabetes. A soy-bean bread is manufactured for this purpose in Paris.

Under the name of coffee beans, soy beans are eaten to some extent in Switzerland as a vegetable, and dried and roasted are also used as a coffee substitute. Their use for this latter purpose is not unknown in America. The attempt has recently been made by certain dealers to place the soy bean on the market as a new substitute for coffee and to sell it under other names at an exorbitant price.

Bulletin No. 98 of the North Carolina Experiment Station recommends soy beans as a palatable vegetable when prepared as follows: Soak the beans until the skins come off and stir in water until the skins rise to the surface and then remove them. Boil the beans with bacon until soft, season with pepper, salt, and butter, and serve hot. If the beans are green the preliminary soaking may be omitted. No other references to the use of soy beans for human food in the United States have been found.

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