HAWAII AGRICULTURAL EXPERIMENT STATION
J. M. WESTGATE, Agronomist in Charge,
Honolulu, Hawaii.

BULLETIN No. 46.

Under the Supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

THE PIGEON PEA (CAJANUS INDICUS): ITS CULTURE AND UTILIZATION IN HAWAII.

BY

F. G. KRAUSS, Superintendent of Extension Division.

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[Under the supervision of A. C. TRUE, Director, States Relations Service, United States Department of Agriculture.]

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THE PIGEON PEA: ITS CULTURE AND UTILIZATION IN HAWAII.[1]

CONTENTS.

INTRODUCTION.

The pigeon pea, also commonly called the Porto Rican pea, was introduced into Hawaii from Porto Rico. It has been grown in a limited way in Hawaii for at least 20 years and is now commonly cultivated as a back-yard shrub. It does not appear, however, to have been thought of as a field crop until comparatively recently. Between the years 1906 and 1908, the Hawaii Experiment Station grew several varieties or types of pigeon peas as an experiment; and in a comparative test with leguminous field crops that had been given extensive trials the pigeon pea was found to attract especial attention on account of its vigorous growth and heavy seeding qualities. In the experiment just referred to, three test rows, each 100 feet long, were spaced 10 feet apart. The middle row was planted to the variety known at the station as No. 218, which yielded 102 pounds of prime seed within eight months from the time of planting. This was at the rate of 1.02 pounds per running foot of row; and if calculated to acre yields, the product would amount to nearly 2¼ tons of shelled seed per acre. The plant, being a perennial, yielded two subsequent crops which were harvested within the succeeding 12 months, the combined yield of seed approximating that of the initial crop. The seed of this variety (No. 218) was well distributed and undoubtedly is now to be found growing in widely scattered sections of the islands.

[1] See also Hawaii Sta. Bul. 23 (1911), pp. 21–23.

As early as 1910, reports from Fred S. Lyman, of Pupakea, Oahu, and others stated that the stems of the pigeon pea and the accompanying seed in pod, when harvested and fed fresh from the plant, were proving an excellent feed for work horses, mules, dairy cows, and poultry; and that all kinds of stock browse freely upon the growing plants. Of the pigeon pea as a green manuring and cover crop, C. G. White, of Haiku, Maui, wrote in 1910:

It is the hardiest legume of all I have tried at Haiku. It maintains itself for years, and no insects have seriously bothered it so far. It does not start well when planted in winter, but November plantings loiter along and grow vigorously at the coming of warm weather. Its chief drawback is its size. With special care and arrangements, plowing one-half acre a day, I have turned it under fairly well when four years old, using a disk plow and four large mules. * * * In three months' time the plants had rotted so that it gave no trouble in replowing and fitting the land in good shape. * * * The best corn I ever grew followed these peas.

James Munro makes the following statements regarding the use of pigeon peas:

Pigeon peas have been used on this ranch (Molokai) since 1910, first as a windbreak and later as a soil renovator in worn-out corn fields. The crop was found to be a good soil renovator, but expensive when bringing the land back into cultivation on account of the rank growth, which left very heavy stumps to be disposed of. The pigeon peas are planted at 800-foot elevations in rows 4 feet apart in clean cultivation, either in the fall or spring, giving preference to the fall because there is more time available then. Rainfall averages about 32 inches yearly and the fields are favored with the trade rains in March and April, during which months there is an average rainfall of 5 to 6 inches. Under these conditions pigeon peas make a rank growth, and so long as the soil does not get too hard they will last through a dry summer with stocking after the grasses have failed.

The fenced, 60-acre lot used for the soil renovation test was used at the same time for fattening steers for market. Not more than 60 head were allowed on the lot at one time. These got very fat and the field could have carried more. Pigeon peas should not be pastured until the plants have flowered and the pods are beginning to set, because it is on the pea pods that the cattle graze. They will also eat the leaves when hard up for feed, but in this case they will break down and destroy the plant.

The freckled variety has proved an excellent chicken feed. The chickens were turned out in the peas, and the bushes beaten in dry weather to thrash out the peas. Two varieties have been grown together here without seeming to cross.

The great thing about pigeon peas is, like corn, to get it through its early stages without its being destroyed by caterpillars.

Although the Hawaii Experiment Station had advocated the possible value of the pigeon pea as a field crop as early as 1907, and had been instrumental in getting under way the field plantings above noted, little or no progress was made in Hawaii with it as a field crop, so far as can be determined, until the establishment of the Haiku demonstration and experiment farm on the island of Maui in 1914. Land on that island that failed to produce 25 bushels of

corn per acre after receiving the best cultivation produced a very fine crop when it was planted to pigeon peas under the same conditions. In the succeeding three years 20 acres was planted to pigeon peas, which were regularly harvested as a seed and forage crop. Five tons of seed has been distributed for planting, 100 tons of hay cured, and half the above-mentioned amounts of hay and grain have been milled and fed, either alone or in combination with other feeds to all kinds of live stock. In 1918 and 1919 fully 500 acres was planted to the crop on the island of Maui, and by the end of 1920 more than 1,000 acres was growing in the Haiku district alone. During 1919 one Haiku ranch harvested more than 10 tons daily from 350 acres planted to this crop. This was cured and milled in an up-to-date milling plant, and formed the basic constituent of hundreds of tons of mixed feed turned out during the past year. The managers of a Lanai ranch have become so favorably impressed with the possibilities of this new crop that they have under way plantings covering an aggregate of 2,000 acres.

A Molokai ranch has marketed some of its best conditioned steers from pigeon-pea pasture. At the Haiku demonstration and experiment farm, work mules, horses, milk cows, swine, and poultry were fed pigeon peas as a large part of their ration covering a period of four years. Corn, in 100-bushel crops, and pineapples, in 20-ton crops, were grown on lands that were renovated by the culture and turning under of pigeon peas after the peas had served well their purpose first as a harvested crop, then as a pasture, and finally as green manure.

BOTANY AND AGRICULTURAL HISTORY.

The pigeon pea (*Cajanus indicus* or *C. cajan*) is an erect leguminous shrub, attaining a height of 3 to 10 feet under ordinary culture in Hawaii. The leaves are 3-foliate, the racemed flowers either yellow, or red and yellow, and the ovary is subsessile and has few ovules. The pods vary greatly in size and shape in the different varieties, but are usually 3, 4, or 5 seeded and constricted between the seeds by oblique linear depressions. When not crowded, the plants branch freely well to the base. The stems are slender but heavily foliaged in most varieties, and especially so after the plant has been cut back in the first harvest.

The generic name Cajanus is derived from the Malayan name, Katjang, and the only species is *C. indicus* or *C. cajan*. Some doubt exists as to whether this species was originally a native of India or of tropical Africa. It is extensively cultivated throughout India, even up to an altitude of 6,000 feet. In Porto Rico, whence the first seeds planted in Hawaii came some 20 or more years ago, two prin-

cipal varieties are recognized. The variety now known at the station as No. 218 (probably *C. indicus flavus*) produces rather small seed similar to that of the Iron or Clay cowpea (Pl. I, fig. 1). It is a heavy seed bearer and very much liked by Porto Ricans as food, either as green peas, or as dry-shelled peas, which are prepared very much the same as cowpeas are in the Southern States. Station variety No. 219 (probably *C. indicus bicolor*) has yellow flowers tinged with red (Pl. I, fig. 2). These are in direct contrast to the pure yellow flowers borne by No. 218, and the pods are streaked or blotched with red on a green background. The seeds are light gray and faintly speckled. They are also somewhat larger and more spherical than the solid red seeds of variety No. 218. The main economic agricultural distinction, however, as now recognized, is that No. 218 is early maturing and very heavy seeding, yielding a heavy crop of seeds within seven or eight months from the time of planting, but attaining in the second year a height of only 3 or 7 feet. On the other hand, variety No. 219 does not begin to yield its maximum crop of seed until the second year, but since it is heavily foliaged and attains a height of from 6 to 10 feet, it is valuable as a temporary windbreak as well as for forage and green manuring.

Special reference should be made to the root system of the pigeon pea. The plant is furnished with a long taproot and many branching lateral roots that are abundantly supplied with large clusters of nitrogen-storing nodules. These nodules in some instances exceed the number found on any other of the many legumes studied at this station. No case has come under observation where the seed of pigeon peas required artificial inoculation. The root nodules seem to be present naturally and without exception.

The pigeon pea shows considerable tendency to cross-pollinate when several varieties are grown together. This results in the formation of numerous crosses showing a greater or less variation in characters. Comparatively few of these appear to be constant, although several superior types have been established and are new being propagated with a view to wider distribution. While only slightly variable within the old-established varieties, such as that known as No. 218, careful selective breeding has established a superior and very uniform strain of an early maturing, heavy seeding type which the station has designated "New Era." A field of 5 acres of this strain is being grown for seed.

Alonzo Gartley, of Honolulu, called attention to four well-established varieties of the pigeon pea, which he designates as (1) the Oahu type (apparently station variety No. 218 before its present improvement); the Maui type (apparently station variety No. 219); (3) the Hawaii type (apparently the small-seeded India variety which was first introduced by the experiment station of the

Sugar Planters' Association, and the seed given some years ago to the writer by H. L. Lyon; and (4) the Kauai type (which is similar to the Maui type, excepting that the seed is larger and lighter colored than the Maui type).

CLIMATIC AND SOIL ADAPTATIONS.

The pigeon pea is primarily a dry-land crop, especially when it is considered mainly for seed production. The heaviest yields of seed have been produced at Haiku during warm, dry seasons. Where the soil is of reasonable depth and fertility and in fair tilth the plants thrive remarkably well even during protracted droughts such as prevailed in the Haiku district during 1918 and 1919. A fine crop planted March 15, 1919, and photographed October 15, 1919, developed to perfect maturity on a total of less than 20 inches of rainfall. (Pl. II, fig. 1.) Only one cultivation was given the crop after the intercrop of corn was harvested in July. (Pl. II, fig. 2.) No other crop is known that would prove so successful under like conditions. Doubtless many people will recall having seen neglected pigeon pea plants thriving as well in dry, stony places as though they were being cultivated in a garden. Although suited to dry conditions, the pigeon pea adapts itself to many and varied conditions. Adequate moisture merely adds to the luxuriance of its growth and if, in addition, the soil is rich, the seeding period will merely be delayed to a time when the plant is unable to bear more foliage. Excessively wet districts, for example, Glenwood, on the island of Hawaii, and Nahiku, on the island of Maui, are, however, not adapted to the profitable culture of the pigeon pea, nor is the crop adapted to irrigation farming. As stated before, its great value rests upon its ability to produce abundantly and most economically a nutritious herbage under semiarid conditions. Such conditions at best would be adverse to most other forage crops.

Its range of adaptability to the seasons, to varying altitudes, and to an almost unlimited variety of soil conditions is one of the striking characteristics of this unique field crop. At the Haiku demonstration and experiment farm spring and fall plantings have been equally successful. When planted in February, March, or April the plant begins to bear its first crop of seeds from August to October and continues to flower and fruit well into midwinter, provided the pods are kept picked. No treatment other than that of keeping the maturing pods continually picked will cause heavy fruiting and large yields of seed. Spring is considered the most favorable time for planting pigeon peas, because the plants then start growth rapidly and branch rather freely. Furthermore, at this season of the year a wide selection of crops is available for intercropping with the pigeon pea.

Planting in August, September, or October, to follow the corn or other summer harvests, is practicable when the ground contains sufficient moisture to germinate the seed. However, no intercropping should be attempted with fall planting of the pigeon pea. If the fall planting is followed by either an excessively dry or wet fall and winter, the crop will, as C. G. White has stated, "loiter along" for awhile and then start off vigorously at the coming of warm weather. Such plantings often produce the strongest legumes. They may begin to flower as early as May and yield seed abundantly by early July, especially in the more protected lowlands where the soil is light and well drained. Under such conditions the fruiting season may continue for a period of six months, from July to December. The following year, both from spring and fall plantings, two distinct fruiting seasons, the spring and summer crop and the fall and winter crop, will have established themselves. Under unusual conditions the plants may continue to flower and bear seed throughout the year.

In its adaptation to a wide variety of soils, the pigeon pea is equalled by few other crops. A deep, well-drained, medium rich loam is conducive to the best development and longest life of this crop; however, it thrives in light, loose, sandy soils having scant moisture from the gravelly and stony type to heavy clay loams of close texture and considerable moisture content, provided there is no standing water on the ground. Furthermore, the crop seems to be tolerant of salty soil conditions, plants having been noted to thrive in soils containing fully 0.0005 gram of sodium chlorid per gram of soil. In soils containing twice this amount of salt they were dwarfed and failed to seed freely, while a content of 0.005 gram of sodium chlorid per gram of soil seemed to be wholly destructive to growth. It is thought that many of the extensive barren sandy wastes bordering the seashore might be reclaimed and made of great use by planting them to pigeon peas. Seed stocks are being widely distributed at present with a view to testing further the adaptability of the crop to these conditions.

It has already been shown that the crop finds a natural habitat in the lowlands, but it is by no means confined to low elevations. It is stated that in the Himalayas, the pigeon pea plant thrives at an altitude of 6,000 feet. In Hawaii thriving plants have been found at an elevation of 3,000 feet.

PLANTING.

It is advisable to prepare the land thoroughly before planting it to pigeon peas. After the crop is established, little or no cultivation is required to get good results from it, but the young plants start off slowly and make only a spindling growth for the first month or

FIG. 1.—MATURE SEEDS AND FRUITED BRANCHES OF PIGEON PEA VARIETY NO. 218, PROBABLY CAJANUS INDICUS FLAVUS. (ONE-SIXTH NATURAL SIZE.)

FIG. 2.—MATURE SEEDS AND FRUITED BRANCHES OF PIGEON PEA VARIETY NO. 219, PROBABLY CAJANUS INDICUS BICOLOR. (ONE-SIXTH NATURAL SIZE.)

FIG. 1.—PIGEON PEAS INTERPLANTED WITH CORN. THE CORN WAS REMOVED AND CROP SHOWN BELOW IN FIGURE 2 WAS PRODUCED.

FIG. 2.—PIGEON PEAS GROWN FOR SEED. YIELD 1 TON OF SEED PER ACRE.

two. During this period it pays to run a one-horse cultivator between the rows to keep down the weeds, and for this reason the rows should be spaced evenly. This can easily be done if a "marker" is used. A marker can be made by spiking three 2 by 6 inch runners, 24 inches long, to the underside of a 2 by 12 inch plank, 10 feet long, one runner being placed at each end of the plank, and one in the center. A light wagon tongue should then be fastened to the plank and a steady team used to drag the marker. The one-horse seed drill will have an accurate guide to follow. A skillful driver should mark off 20 acres a day. If the planting is to be done in rough ground where plowing and tillage are impracticable, holes can be dug approximately 5 by 5 feet apart and several seeds dropped in each hill.

When pigeon peas are grown for seed purposes it is recommended that the rows be spaced 4 or 5 feet apart, depending upon the fertility and moisture conditions of the soil. Naturally the more favorable the growing conditions are, the larger the plants will be and the more space they will require for best development. At Haiku, the seed is planted in rows 5 feet apart and intercropped with some quick-maturing crop such as corn, beans, potatoes, peanuts, and the like. By the time these are harvested, the pigeon peas begin to occupy the intervening space. If the crop is wanted for green manuring, it is advisable to space the rows only half as wide as when the crop is to be grown primarily for seed; that is, they should be 24 to 30 inches apart.

The best and most economical method for planting the seed found so far is the use of a one-horse seed drill adjusted to drop the seed approximately 6 inches apart. This is considered the most favorable distance in the row for seed production. With this equipment a skilled workman should readily plant from 4 to 5 acres per day. From 8 to 10 pounds of seed will plant an acre. The seed may also be broadcasted, but such a practice is not recommended. Weeds are likely to smother the young seedlings, and if the plants are overcrowded, seed production will be seriously curtailed. Furthermore, light seeding is essential to make the scant available moisture adequate for even so drought resistant a crop as the pigeon pea.

THE HAY CROP.

HARVESTING.

The best time to harvest the pigeon pea crop for hay is when a large percentage of the pods is mature because a large part of the nutritive value of the plant is contained in the seed. So heavily do some strains seed that fully one-fourth of the forage is made up of grain. One great advantage of the pigeon pea over many other

leguminous seed crops is that its pods do not shatter their seeds even when they are roughly handled.

Since the pigeon pea produces a stiff, woody stem, it has been found desirable to harvest not more than the upper third, or, at most, the upper half of the plant, unless the plants are very spindling and sparse, as they sometimes are on poor thin soils during a dry season. It has been the practice at Haiku to cut back about one-third in the first harvest and a third to a fourth in subsequent harvests, depending upon the growth made by the plants. The stems in such cases do not exceed the thickness of a lead pencil, and they bear practically all the pods on the plant at that time.

The greatest problem thus far encountered is in the mechanical part of the harvesting. No ordinary mowing or harvesting machine now on the market will handle the crop as it is being grown at present. A short-knifed wheat header, such as is used in harvesting wheat and barley in California, if especially strongly built, has been suggested as a practicable contrivance. The Haiku ranch, which has several hundred acres in pigeon peas, has had underway, with some likelihood of success, the modification of a modern corn harvester. Doubtless, when the acreage becomes large enough, implement manufacturers will become sufficiently interested to undertake the manufacture of a suitable implement. In the meantime, the most practical way thus far devised is to cut the stems by the use of the short, strong-bladed, Chinese grass hook, or sickle. The workman grasps a cluster of stems with his left hand and readily cuts through the stiff stems with a strong, swift, drawing motion of the sickle blade. The handful of fodder is then laid upon the cut surface of the plant from which it was just harvested. The plants thus serve as an admirable support for wilting of the fodder preparatory to loading it on the curing trucks or stacking or for holding the fresh-cut material for immediate gathering by the crew following the cutters. These temporary supports are usually about waist high.

Loading the crop on the curing truck, or on wagons for haulage, presents another difficulty, and as now done by hand, is slow and uneconomical. The present methods of loading the green pigeon pea stems are shown in Plate III, figure 1. Bundles making an armful for a man weigh about 40 pounds. They can not be handled with a pitchfork because the mass does not well hold together. The California grain-header idea might help to solve this problem, since the crop as harvested would be elevated directly into the accompanying wagons.

CURING.

The most practical and efficient way to cure the crop is by means of portable curing trucks and stationary raised platforms, the latter built at convenient places in the field. Under this system, the mate-

rial to be cured is supported a foot or more above the ground. The floor is slatted, and all four sides are open to free circulation of the air and wind. It is the action of the wind even more than that of the sun which makes for a well-cured stack of hay. At Haiku it is the practice to load as soon after the forage is cut as is practicable, often within an hour after harvesting. However, if no wind is blowing, which is seldom the case at Haiku, and the fodder is exceptionally lush or succulent, it may be left lying on the plants as above described for a half day or so. If the sun is bright, fully half of the free moisture in the forage will have evaporated in this time. Ordinarily, however, the crop is loaded within an hour or two of harvest, and where sound judgment is exercised no spoilage results from the practice.

When excessive rains occur during the 7 to 10 days required for curing under favorable conditions, tarpaulins are thrown over the top of the stack, but not over the sides, because as free a circulation of air as is possible is needed to prevent overheating and consequent spoilage. Some drawbacks were found to the use of impervious coverings when they were placed over a freshly stacked load of pigeon peas; and it was feared that spoilage would result if such coverings were left on too long. This would undoubtedly be the case were a protracted wet spell to occur while the coverings were on. To overcome this difficulty, Dr. W. D. Baldwin, of Haiku, suggested the use of grass-thatched coverings or roofs, which, while they allowed free circulation of air, at the same time provided perfect protection against the heaviest rains. Through Dr. Baldwin's interest in advancing this work, it was possible to construct the experimental structure shown in Plate III, figure 2. It was first thought that the thatched "blanket" could be used as a tarpaulin, but it was found too cumbersome for this purpose, and it was placed over a frame of bamboo as a permanent structure. It was of just the right dimensions to permit the loaded curing truck to pass under. After having been used for a year or more with the utmost satisfaction, this protection, unfortunately, was wrecked by a severe windstorm. Its total initial cost, mainly for labor, was about $40, and there is no doubt that it saved five times that amount in preventing loss when hay was being cured in bad weather. This method is recommended for trial to all who are interested in the curing of any kind of forage in rainy districts.

The Haiku ranch is now curing hundreds of tons of pigeon-pea hay in large, open sheds, and from these the cured hay is either baled or ground. This method is apparently proving entirely satisfactory.

Hay-curing truck.—Of the two types of hay-curing trucks in use at the Haiku demonstration and experiment farm, the one illustrated

in Plate IV, figure 1, is the simplest, least expensive, and most serviceable. More complete description is given elsewhere.[2] The method is adapted to all forage crops grown in Hawaii and is recommended to farmers for trial.

This truck can be built by any farm blacksmith in two or three days at a total cost not exceeding $30. The bed of the illustrated truck is 12 feet long and 7 feet wide, and holds from three-fourths to one and a quarter tons of cured pigeon pea hay, depending upon the skill of the loaders. The truck body is supported by two 20-inch iron wheels, which have 4-inch tires and run on an axle placed about 4 feet from the rear end of the V-shaped frame shown as A. A 2-inch reinforced pipe makes an excellent axle. When the loaded truck

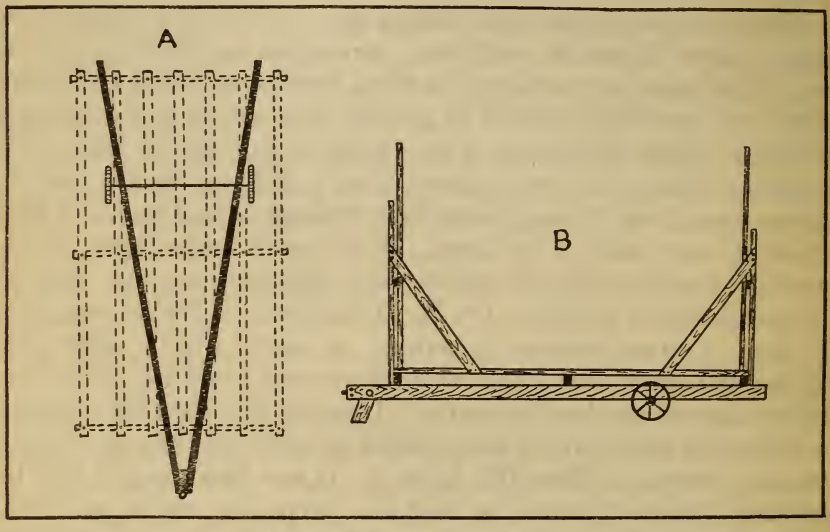

FIG. 1.—Hay-curing truck. Main frame of truck (A), with rack indicated by dotted lines, and side view (B) showing trigger and position of wheels.

is at rest, as when left in the field for the hay to cure, or when it is being loaded, or baled from, the front end is supported at the point of the V by a prop to keep the truck level. This prop is hinged so that it swings easily backward when the truck is being hauled. The standards at each end run to a point at the top, where a notch is cut to receive a 2 by 4 inch ridgepole that supports the canvas when used as a protection from rain. The floor of the truck is made up of seven 2 by 4 inch scantlings, 12 feet long and evenly spaced to allow the air to circulate freely from the bottom. A coupling device is fastened to each end of the truck. The front running gear of a low-wheeled wagon, furnished with a pole and doubletrees for two horses, is coupled to the front of the truck and

[2] U. S. Dept. Agr., Farmers' Bul. 956 (1918).

FIG. 1.—PORTABLE TRUCKS USED IN HARVESTING PIGEON PEAS.

FIG. 2.—GRASS THATCHED SHED FOR CURING PIGEON PEA HAY. PROTECTS FROM RAIN BUT ADMITS FREE CIRCULATION OF AIR.

FIG. 1.—PORTABLE HAYCURING TRUCK. CAPACITY 4 TO 5 TONS GREEN PIGEON PEA FORAGE. CURES IN 7 TO 10 DAYS. TARPAULIN USED AS COVER IN RAINY WEATHER.

FIG. 2.—PERMANENT CURING SHED 8 BY 16 FEET. BUILT OF BAMBOO POLES WITH ELEVATED PLATFORM. CAPACITY ABOUT 2 TONS CURED PRODUCT. COST ABOUT $5.

another, or several additional trucks, may be coupled on behind and thus hauled from the field.

Permanent curing platforms.—In addition to the portable truck described above, several permanent curing platforms have been erected at convenient locations in the field (Pl. IV, fig. 2). These may be constructed to any length desired, but experience has shown that the width should not exceed 7 or 8 feet, since a mass of green forage of not more than this width will cure with little danger of spoiling, especially if the longest axis is set at right angles to the prevailing wind. The principal advantage in these permanent curing platforms is their low initial cost. Strong bamboo poles, or eucalyptus saplings, if available, make admirable platforms at a very low cost.

THE SEED CROP.

HARVESTING.

The pigeon pea may be harvested for seed in two ways: Either the pods may be hand-picked from the growing plants and then thrashed, or the pod-bearing stems may be harvested in the same way that they are harvested for hay. In the latter case, the forage passing through the thrasher will become shredded to such an extent that it will be more palatable. Of course, such shredded material will be devoid of the nutritious grain, and should therefore be classed as straw rather than hay. During the past two years it has been the practice at Haiku to pick by hand all seed intended for planting. This, while it may be slightly more expensive than the other method, insures better developed seed and considerably enhances the total yields of seed, at least doubling the production in most cases. By this method the plants are picked over three or four times per crop, the intervals between picking being from two to four weeks.

All hand-picking of pods is done on contract, originally at a cost of 75 cents per 100 pounds of pods,[3] but during the past year the price was raised to $1.50 per 100 pounds. The work is well suited to women and children, and an active adult may pick 100 pounds or more of pods in eight hours. The pods are picked and dropped into common grain bags. No heavy lifting is required for this work because a well-filled barley bag weighs only 25 pounds. Groups of four and five persons doing this work have earned $5 a day without undue effort.

The tenacity with which the plants hold the pods and the pods their seed is remarkable. At the Haiku substation observations have

[3] Theoretically, prime pods yield approximately 60 per cent of their weight in seed. In thrashing about 50 per cent of total weight of pods is recovered.

shown mature pods to adhere to the plant for fully 60 days without shattering any seed. Continued rain for a considerable period is required to cause the seed to mold within the pod. This is explained by the fact that the pods are borne at the extremities of the upright branches, where they are enabled to dry off rapidly. The pods themselves are practically impervious to water.

THRASHING.

Thrashing the seed directly from the stems requires a rather strongly constructed machine. For this purpose a double-cylinder bean and pea thrasher has been used with much success at Haiku. This thrasher has a capacity of ½ to 1 ton of seed per day when all conditions are favorable. It is important that the stems and pods be well cured and that sufficient power be available before attempting to thrash. An even smaller and simpler pea huller is used for thrashing simply the pods, and the strain on all working parts is very much lighter than when the seed is thrashed directly from the stems. The pods alone thrash very readily when they are thoroughly dry, and about 1,000 pounds can be thrashed within nine hours by a two-horsepower engine. Two men, or a man and a boy, are required to do the work most efficiently.

Whether thrashed from the vine or the pod, the seeds should be recleaned and graded. This is best accomplished by the use of a good fanning mill equipped with suitable sieves and riddles. Unless the seed has become discolored or moldy through improper handling, no further manipulation will be necessary. However, it may sometimes be desirable to hand-pick the seed to make it a merchantable product. This is an expensive process and adds considerably to the cost of the seed. As high as $2 per 100 pounds has been paid to have the work done properly. There are on the market foot treads and power types of bean picking and sorting tables which would greatly facilitate this work.

Most leguminous seeds, such as cowpeas, soy beans, and the culinary beans, are subject to weevil infestation to some extent, and the pigeon pea is possibly as susceptible as any to these ravages. The grower of this crop should provide for it an air-tight storage chamber which can be periodically fumigated. At the Haiku substation a suitable compartment has been built by constructing double walls, floor, and roof of tongue-and-groove lumber laid crosswise with a layer of tarred felt between. The door is beveled and made to fit snugly against a felt face and is fastened with a strong refrigerator door clasp. A compartment 6 by 6 by 6 feet is a convenient size for ordinary requirements, as it holds about 2 tons of bagged seed. The best fumigant to use is carbon bisulphid, the usual dose being 1 to 2 pounds of carbon bisulphid to every 1,000 cubic feet of space

to be fumigated. The compartment described above would therefore require about one-fourth to one-half pound of carbon bisulphid per fumigation. The chemical should be placed in a shallow dish and set on top of the pile of seed to be fumigated. As the liquid volatilizes, the vapor flows over the sides of the container, and being heavier than air seeks the lower levels. Fumigation should be continued from 24 to 36 hours. Those doing the fumigating should use every precaution not to inhale the gas or to bring a light near the vapor, which is very inflammable.

In another publication [4] mention has been made of the opportunity for enterprising and suitably equipped farmers to grow standard varieties of seed, especially the seed of the pigeon pea, the demand for which now greatly exceeds the supply. It is desired to again emphasize this fact. The very best seed strains may deteriorate rapidly in careless or inexperienced hands, but the seed business is, or should be, a highly specialized undertaking. It is likely that there will be an increasing demand for the pigeon pea once its exceptional merits become well known.

PIGEON PEA AS FEED.

FEEDING VALUE.

The feeding value of a product depends not alone upon its composition and digestibility, but to a very large extent upon its palatability to the animals fed. While there have been received some reports indicating reluctance on the part of certain animals to consume pigeon-pea feed, the majority of feeders have found that all classes of live stock readily learn to eat it without the admixture of other feeds. This seems to be the case especially when live stock has access to the growing crop as pasturage. At the Haiku substation no animal has yet been found which does not browse freely upon the growing plant. At the Haiku ranch, on the island of Maui, the dairy herd of 50 cows has been maintained in excellent condition on pigeon-pea "tops" constituting the upper third of the plant, which is the heavily podded portion. The tips and pods are usually eaten first and then the more woody parts, only the thick stems remaining uneaten. Work mules will chew up even a large part of the woody stem. Poultry will jump as high as 3 feet to get at the pods, and they are very fond of the blossoms. Bees apparently gather nectar freely from the flowers. It has already been remarked that the Molokai ranch has marketed some of its best carcasses of beef direct from pigeon-pea pasture. The Haleakalea ranch, on the island of Maui, has likewise pastured a 100-acre field of growing pigeon pea,

[4] Hawaii Sta. Bul. 23 (1911), p. 5.

maintaining, with very satisfactory results, 250 head for a period of 100 days, the plants being stripped to mere stiff basal stems.

The greatest value of the pigeon pea as a feed seemingly lies in its possibilities for replacing a large portion of the imported grains, millstuffs, and hay. These are still brought into Hawaii from the mainland at great expense and heavy consumption of carrying space on the already congested steamship lines.

The accompanying table shows the average percentage composition of pigeon-pea products.

Average composition of the pigeon-pea products.

[Based on all available analyses made in Hawaii to Feb. 15, 1920.]

Character of material analyzed.	Moisture.	Ash.	Crude protein.	Carbohydrates.		Nitrogen.	Fat.
				Crude fiber.	Nitrogen-free extract.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fresh green forage [1]	70.00	2.64	7.11	10.72	7.88	1.13	1.65
Whole plant cured as hay and ground into meal	11.19	3.53	14.83	28.87	39.89	2.37	1.72
Seed and pod meal	11.45	3.85	17.65	30.73	34.53	2.82	1.49
Seed meal	12.26	3.55	22.34	6.44	53.94	3.57	1.46
Thrashed pod meal [2]	13.30	2.66	8.75	35.44	39.22	1.40	1.03

[1] Upper third of plant with seed in pod. [2] By-product in seed production.

MILLING AND MIXING FEEDS.

It is believed that the milling of pigeon peas bids fair to do away entirely with imported feeds in the not distant future. The combined stems, pods, and seeds cured as hay can be milled into a meal similar to the extensively used alfalfa meal; the ground pods and seeds can be used in the same way as corn-and-cob meal; or the grain alone, either whole, cracked, or finely ground, can be mixed with other Hawaiian-grown feeds and supplemented with refuse molasses. As a matter of fact, the Haiku substation has, during the past four years, grown, milled, and fed to half a dozen head of live stock the entire amount of feed consumed, fully 25 per cent of which was pigeon-pea product. This feed has been fed in comparison with the best imported feeds, with a distinct advantage, both in cost and general well being of the animals, in favor of the home-grown feeds. A mill has been established at Haiku which grinds and mixes 10 to 25 tons of feed each working day of the year. From 10 to 20 per cent of this feed is made up of milled products of the pigeon pea.

In many instances the grinding of feeds has been found unprofitable, but this is not always the case. After careful observations it would seem that the extra cost of milling the pigeon-pea plant should, in the majority of cases, more than pay for itself in view of the in-

creasing cost of feeds and the consequent advisability of utilizing many of the coarser stuffs that were once wasted; and also because the most rapid and efficient gains are frequently made by bringing feeds to a uniform degree of fineness, particularly where several kinds are to be mixed to balance the ration and to give variety. Handling the feeds at feeding time as well as in storage is likewise greatly facilitated either by shredding or chaffing the roughage or converting the more concentrated portions to a coarse or fine meal. Now that refuse molasses is being used so commonly, it becomes practically imperative that those feeds with which the molasses is to be mixed be reduced to as uniform-sized particles as possible. The above applies especially to the pigeon pea when the stems and pods are to be utilized. Unground peas are likely to pass undigested through the animals.

The grinding of pigeon-pea hay does not differ materially from the process used in milling alfalfa hay and other cured fodders. However, it is desirable to cut the material into short lengths before it is placed in the hammer-throw mills for the final reduction to meal. If the recutting type of comminutor is used with a small screen, no preliminary cutting and no regrinding will be necessary. Grinding in a burr mill does not seem practical, and the use of the hammer-throw mill after a preliminary cutting apparently is the most efficient method. The cost of milling by this process is estimated at between $3 and $5 per ton.

A word of caution is in order concerning the woody and fibrous nature of the basal portions of the stalks of the mature pigeon pea. Rough or careless grinding leaves small, jagged splinters in the feed, and unless these are guarded against, the coarse, sharp-pointed material may cause irritation in the digestive tract of the animals. It would be a comparatively simple matter to sift all feed through a one-eighth inch mesh sieve to remove this objectionable material before the feeds are used, either mixed or when fed alone, although the station has not heretofore resorted to such practice.

Once the feeds are ground to a uniform fineness, it is an easy matter to mix thoroughly the several ingredients. In the earlier experimental work at Haiku, mixing was done by hand. A tight, smooth floor 12 feet square is convenient for mixing 2 or 3 tons of ordinary feed. The finer and dustier meals, such as pigeon pea, are first spread out in a thin layer. The less dusty meals or "chops" are then spread in subsequent layers. The molasses is added last. This should not be diluted with water, as fermentation and excessive heating with consequent spoilage will result. However, the molasses, if especially thick, may be heated to the boiling point to advantage and then spread over the surface layer of feed by the aid of a

sprinkling can. The mass may be thoroughly worked over first with a rake and next with a scoop shovel. By following this method a man can mix 2 or 3 tons of feed per day. During the past year the Haiku substation installed a mixing machine that had been improvised from a continuous cement mixer. It is furnished with a measuring device so arranged that the concentrated grain feed can be definitely proportioned to the less concentrated and bulkier pigeon-pea hay meal. This machine mixes 4 or 5 tons of feed in a day and seems to work very satisfactorily.

Two milling plants have installed large, powerful mixers similar to the type used for mixing fertilizers. These mixers have a capacity of 20 to 25 tons per day and very thoroughly mix the molasses with the grain feeds. The entire cost of the milling and mixing machinery installed at the Haiku substation, not including engine and buildings, was about $500; the recutting and grinding mill and repaired parts costing $150; the wagon elevator or bagging attachment for the mill, $50; the feed mixer, about $100; the tank, which was connected with the steam boiler for heating molasses, $100; and incidentals, $100.

SUGGESTED FEEDING RATIONS HAVING A BASE OF PIGEON-PEA PRODUCTS.

A series of Hawiian-grown and mixed feeding rations, having as a base pigeon-pea forage in some of its various forms, is given below. The simplest possible ration is given first. This is followed by the more complex and specifically balanced rations for some definite purpose and by explanatory notes.

Ration No. 1.—This simple ration consists of pigeon-pea tops cured as hay or fresh forage in full seed used as a soiling crop. It would be suitable for mules, horses, dairy cows, cattle, and sheep having a run of good pasture while on light work, or for dairy cows that are dry. However, in a recent feeding experiment with cows in full milk, the straight pigeon-pea hay ration produced a better flow of milk than fresh cane tops and sorghums supplemented with a standard grain ration. This might properly be termed a "maintenance" ration. It would be classed as a "narrow" ration because the proportion of crude protein is large in comparison with that of the carbohydrate and fat. When the reverse is true, as in ration No. 2, it is termed a "wide" ration. Convenient designations for "narrow" and "wide" rations would be the terms "nitrogenous" feed and "carbonaceous" feed, respectively. The feeding would best be done from slatted overhead racks, each of which is provided with a tight, shallow trough at the base to collect falling seeds and leaves. In this way loss of this valuable portion of the feed would be prevented.

Ration No. 2.—This ration consists of two-thirds pigeon-pea hay meal and one-third cane molasses. It is a very cheap feed, and costs

not more than $20 or $25 per ton. This ration would be classed as a "medium narrow" one for the reasons outlined above. It would be especially suitable for maintaining cattle in the dry lot, or preferably on good grass pasture, but it would be better still if fed in conjunction with fresh green alfalfa. Should the ration be found too laxative when fed with alfalfa, the alfalfa should be allowed to wilt for several hours before it is fed.

Ration No. 2 and those given below should be fed for best results from wide shallow troughs set about 24 inches from the ground.

Ration No. 3.—This ration consists of equal parts of pigeon-pea hay meal, corn-and-cob meal, and cane molasses. It contains the uppermost limit that could be recommended of both pigeon peas and molasses, except under special conditions. It is a wider one than No. 2, and should be fed in conjunction with fresh green alfalfa. It would then make a first-rate growing and fattening ration for cattle at a cost not exceeding $30 per ton.

Ration No. 4.—This ration consists of equal parts of pigeon-pea hay meal, corn-and-cob meal, algaroba meal, and cane molasses. In the kind and variety of its constituents, ration No. 4 would be considered an improvement on the former rations. It would make an excellent concentrated ration for work mules, horses, dairy cows, and growing cattle, especially if leguminous roughage, for example, alfalfa, cowpeas, and velvet-bean hay or green forage, were fed in conjunction with it. Its feeding value about equals that of imported barley. Its cost should not exceed $40 per ton, which would mean a saving in the cost of feed of at least $20 per ton.

Ration No. 5.—This ration consists of equal parts of pigeon-pea hay meal, corn-and-cob meal, algaroba meal, peanut-hay meal (that is, the entire plant, with all seeds and pods retained), and cane molasses. While somewhat "wide," it is especially rich in fat on account of its peanut-meal constituent. As it stands it would make an excellent feed for fattening swine and cattle. To make it suitable for growing swine and for cows in full milk, 5 per cent of the molasses could be substituted with corn-and-cob meal and 5 per cent additional of the molasses with an equal amount of peanut-hay meal. This would considerably narrow the ration and consequently enhance its value for milk production or for growing animals. For either purpose and for either class of live stock it would be advisable to supplement this concentrated feed with fresh green alfalfa as roughage. Furthermore, in the absence of animal protein such as dried blood or tankage, it is strongly urged that, when fed to pigs, this ration be mixed into a slop with skim milk. This would make a medium-priced feed of excellent quality. For both swine and dairy cows, but especially for the former, sweet potatoes and their tops, and cassava roots

either raw or cooked, would aid still further in reducing the cost and making the ration more efficient. In feeding ration No. 5 to swine and milk cows, it is advised that the mixture be passed through an eighth-inch mesh sieve to remove inert pieces of corncob and pigeon-pea stems; these add nothing to the feeding value and merely tax unduly the digestive organs of the animals. While work mules and cattle can better utilize this coarse material, it would be better to remove it from the ration for reasons previously stated.

For feeding poultry, no more effective Hawaiian-grown poultry grain ration is known than cracked pigeon peas and cracked corn in about equal proportions, supplemented occasionally with a little sunflower, peanut, or soy-bean seed to supply the necessary fat. For either a dry or wet mash, ration No. 5 may be slightly modified by the addition of rice polish, cassava flour, more corn meal (without cob), or other products that suggest themselves. These will make good growing and laying rations. The only element lacking in these feeds is animal protein, and therefore, as recommended for swine, the free use of skim milk is strongly urged, this preferably to be clabbered. In a feeding experiment covering the past two years with Hawaiian-grown feeds for poultry, the use of skim milk proved to be the greatest single factor in egg production.

The quantity of pigeon pea to feed the various classes of live stock should be left to the observation and judgment of the feeder rather than to any set of rules. The best rule known is to feed the animals as much as they will eat in a reasonable time.

PLOWING UNDER OF PIGEON PEAS.

On account of the rather large growth it makes, the pigeon-pea plant may be difficult to plow under, and all plows will not do the work satisfactorily. A large single-disked plow having a subsoiler attachment will do good work either for pigeon-pea stubble or where most of the crop has been pastured down. (Pl. V, fig. 1.) Deep-tilling machines can also be used or the work can be done with any of the several kinds of disk gang plows having wide clearances. Where the plant has made good growth it is essential that it be left standing during the time of plowing rather than be broken down before plowing, as some have suggested.

PIGEON PEA AS A COVER AND GREEN-MANURING CROP AND FOR ROTATION.

Good farming means, or should mean, both permanent and profitable agriculture. No agriculture can be either permanent or profitable where the outgo of fertility from the land is greater than the return. For the maintenance of soil fertility, no agricultural prac-

FIG. 1.—SINGLE DISK PLOW WITH SUBSOIL ATTACHMENT. ADAPTED TO PLOWING UNDER PIGEON PEAS FOR GREEN MANURE.

FIG. 2.—FIELD OF PINEAPPLES FOLLOWING PIGEON PEAS. THIRD CROP PLOWED UNDER. PINEAPPLE YIELD 20 TONS A NO. 1 FRUIT PER ACRE.

tices have longer or better stood the test of time than green manuring and the systematic rotation of crops. In Hawaii no other crop is known that will lend itself more readily to a large variety of conditions than the pigeon pea. On account of its ready adaptability to soil and climate, its drought-resistant properties, deep-rooting habit, heavy production of rich nitrogenous vegetation, perennial nature, and thrift under neglect, the pigeon pea is peculiarly well suited to follow the pineapple and sugar-cane crops after these have spent themselves. Resting the land is said to restore fertility, but a more effective means of restoring fertility is to change the use of the land by practice of rotation of crops. The cropping cycle of sugar cane, pineapples, and pigeon peas in terms of time is quite similar. On an average, the two great staple crops of Hawaii have a cropping cycle consisting of a plant crop and two ratoon crops, covering approximately five years. This is likewise true of pigeon peas. Not only is it good theory but actual experimental practice has demonstrated that worn-out pineapple lands may be restored to their original, or to improved, fertility by allowing a crop of pigeon peas to occupy the land for a period equal to the time such lands were cropped to pineapples, the pigeon peas then being turned under as green manure. This was demonstrated in a pineapple field two years old which yielded 20 tons of A No. 1 fruit during the 1919 season. (Pl. V, fig. 2.) Pigeon peas were grown on this field for three years and the entire crop was then turned under. The tonnage of vegetable matter, including the roots, woody trunks, and foliage, was approximately 50 tons per acre. In addition to this final green-manuring crop, much leafy matter was shed on the ground beneath the plants, so that in places a leaf mold an inch or two thick had accumulated. This leaf mold was difficult to estimate, but in three years it must have yielded fully 5 tons per acre of the richest kind of organic matter. Just before the pigeon peas were planted, the pineapple crop on the same land collapsed at the end of the first harvest. While the present crop (second, or first ratoon, crop) of pineapples succeeding the pigeon peas is only just now maturing, there is every indication that the crop will carry safely into the second ratoon crop. If this proves to be the case, then there has been evolved an extremely simple cropping system, the rotation of pineapples with pigeon peas, an 8 to 10-year rotation, allowing 4 or 5 years to each crop. In this rotation each of the "crops" is a dominating factor for a permanent and profitable agriculture and therefore good farming. It is believed that what is apparently proving so beneficial to the pineapple crop will prove equally beneficial to the sugar-cane crop. Sugar planters will doubtless welcome a dependable cover crop that is not only suitable for green manur-

ing, but one that also requires no irrigation and very little tillage. Such a crop would mean only little extra time and expense over the time-honored custom of leaving the fields fallow.

No doubt it would be practicable for many of the sugar and pineapple plantation owners to seed their otherwise fallow lands to pigeon peas. This practice would not only result in preparing the soil for the subsequent crop of sugar cane or pineapples, but it would enable the plantation owners to maintain considerable herds of dairy cows and other live stock; these in time would do much to increase the local food products and the importance of this can not be overestimated in a scheme of permanent and economical agriculture.

PESTS AND DISEASES.

Thus far the pigeon pea has been comparatively free from pests, with the exception that, as already noted, the seeds in storage are subject to weevil attack, as are the cowpea and a number of other leguminous seeds.

In common with all young seedlings, the pigeon-pea crop may be considerably injured during the first few weeks of its development, especially in certain seasons, by the attacks of cutworms and army worms. However, seasonable planting has made it possible to escape these pests in extensive plantings at the station. Again, as it develops from spring plantings, the young terminal growth may, when conditions are favorable, be attacked by plant lice or aphids. However, like the cowpea, the pigeon pea does not seem to suffer any permanent injury from such attacks. Occasionally the Japanese beetle and other leaf-eating pests attack the foliage, but such injury, particularly in extensive plantings, is negligible.

As the plants make dense, mature growth, especially in sheltered areas, they may be infested with both the cottony cushion scale and the mealy bug. These pests, however, are kept fairly well in control by parasites and the common ladybirds. There is some evidence that the myna bird also feeds upon clusters of the cottony cushion scale.

During the past year harvesters experienced some annoyance from the common wasp. This insect builds its comb in densely growing shrubs, and when disturbed by harvesters in cutting the upper branches of the infested pigeon pea for forage, it retaliates with a more or less formidable sting.

In addition to the Coccidæ already mentioned, several other scale insects have been found to infest the pigeon pea. The most serious of these (*Coccus elongatus*) has been under observation during the past year as it has been the cause of much concern. In at least two extensive plantings on the island of Maui, large areas have become

infested with the pest. As the scale matures it gives to the surrounding surface of the stem the striking appearance of a fungus affection. In a very dry season, for example, such as that experienced in Hawaii during the summer of 1920, the plants, which were severely infested, succumb. However, when the first rains came, most of the infested plants revived and again produced a normal amount of foliage and pods. During the dry season it is recommended that the infested plant areas be grubbed up and the brush burned. It is possible, however, that, by cutting the plants, burning the cut portions, and spraying the stubble with a scale oil, beneficial results can be secured and the stand can be saved.

One pest of the pigeon pea, well known because of its prevalence wherever the plant grows, is the bean-pod borer, the larvæ of the common blue butterfly (*Lycæna boetica*). This pest lays its eggs on the outer parts of the flower or leaves, and the emerging larvæ attack the growing seed within the pods. Only when a few plants are grown in a place has this pest been found troublesome. In none of the extensive plantings have any depredations by this pest been noticed.

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