Selected Articles.

XXVIII.—Cover Crops in Tropical Plantations.

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THE term "Cover crop" is in this article applied to herbaceous plants and the coppiced growth of shrubs which are cultivated among plantation crops for the purpose of soil conservation and soil improvement.

Uses of a Cover Crop.

A cover crop may fulfil one or more of the following functions:—

(a) Its foliage may protect the soil from the effects of heavy rain or water drip from the plantation crop. This water action can affect the soil in two ways. It can cause soil denudation and it can pack the soil.

(b) The foliage of the cover crop may also check surface wash, by preventing the collection of surface water and by checking its rate of flow when it does collect.

(c) In the case of a young plantation crop where the tree canopy is not complete, a dense cover crop will protect the soil from the effects of the sun's rays, thus checking the loss of humus.

(d) A dense cover crop acts as a "smother crop" and will check the growth of weeds.

(e) The root system of a cover crop may help to bind the soil and thus check surface erosion.

(f) If a cover crop has a deep root system it will assist in the drainage of the soil and sub-soil. This will increase the water-holding and water-absorbing capacity of the soil and will thus enable the roots of the plantation crop to penetrate the soil more deeply.

(g) The natural leaf-fall, or the green dressings made available by cutting back the cover crop, will by the addition of organic matter improve the texture of the surface soil as well as its fertility. If a cover crop belongs to the family Leguminosae, it may enrich the soil in nitrogen, especially if it is turned in or utilized as a green dressing.

Selection of Suitable Cover Crops.

The choice of a cover crop is not a simple matter, and it by no means follows that what is found suitable for this purpose in one country for a particular plantation crop will prove equally suitable in another. Again, what is found to be quite suitable as a cover crop among one plantation crop may not be suitable if tried among another plantation crop. A cover crop may thrive under certain local conditions governed by seasons, soils and elevation, but not under others. The following examples are cited. The cultivation of *Centrosema pubescens* Benth. is favourably reported on as a cover crop in established rubber in the Cochin rubber districts of

S. India, while in Malaya is is stated that this cover crop cannot stand the shade of mature healthy rubber. In the former area there is a natural leaf fall in the dry weather preceding the monsoon, which is followed by "secondary leaf fall" during the heavy rains of the monsoon; thus for a great part of the year there is never that heavy leaf canopy which one sees in Malaya and which there prevents the cover crop from thriving. To follow up the same example, *Centrosema pubescens* is recommended in Malaya for renovating mature rubber which has been allowed to deteriorate by excessive soil erosion, and it is said that its cultivation will restore the leaf canopy, but that *Dolichos Hosei* Craib (the Sarawak Bean) should be grown when once this canopy is restored. Similarly *Centrosema pubescens* makes quite a suitable cover crop for coconut plantations in Malaya, but, as stated above, will not thrive under the heavy shade of mature healthy rubber. Another example may be given. *Tephrosia candida* DC is a recognized "contour hedge crop" for tea in Java, Ceylon, and Assam, but in the tea districts of N. Travancore this dies out when the heavy rains of the monsoon set in. The conditions here, however, are perhaps unique, as the June to August rainfall is over 200 inches following on a dry season.

The Necessity for Further and Continued Research.

It does not follow that the cultivation of a cover crop is in all cases beneficial. Though this may prove quite valuable when grown on a type of soil which is capable of retaining moisture, it might prove even injurious to the plantation crop when this is grown on a light soil in countries where the conservation of soil moisture is of importance. Whether such injury could ultimately be overcome by the addition of organic matter, which the cover crop would supply, and by the increased moisture-retaining capacity of the soil which would necessarily follow, remains to be proved. Recent work at Peradeniya, Ceylon, indicates that this may be the case.

There are other questions also which have to be considered. Many of the plants which have been tried as cover crops have a tendency to climb, and this naturally rules out many of them for use among certain plantation crops. For example, there is little doubt that *Mucuna aterrima* Holland would make an excellent annual cover crop but for the fact that it is such a strong climber that it would very likely choke out a plantation crop such as tea or coffee. Other cover crops have had to be ruled out as they have been found to harbour some disease from which the plantation crop is also liable to suffer. Then again the cover crop may itself succumb to disease or may die out and something else may have to be found to replace it. There is no doubt that land does get "sick" of growing one particular crop, and this appears to be especially the case where legumes are concerned, so that it may prove necessary to have a rotation of cover crops. In any case research on this question of suitable cover crops cannot be allowed to stand still, as one never knows when disaster will overwhelm any which is now being grown, and in many areas it is essential that there should be some form of cover crop.

The majority of cover crops now being grown are plants which have been brought into cultivation comparatively recently, and in some cases a considerable amount of research has been necessary to find out how best these are to be treated. There is usually difficulty in getting seed of the wild Leguminosae to germinate readily. Most of these will yield to a treatment with concentrated sulphuric acid for a varying length of time. Work in this direction has been carried out in Sumatra with a large number

of possible cover and shade tree crops, and a bulletin has been published* giving the results of these trials. In some cases vegetative propagation is the only feasible method, and work in this direction has been carried out at Peradeniya in Ceylon with *Dolichos Hosei* and *Indigofera endecaphylla* Jacq., two of the most important cover crops now being grown there under rubber and tea respectively.

Another line of research is also indicated which up to the present has received little attention. It is that connected with growing mixed cover crops. An instance of this is the mixing of *Centrosema pubescens* with *Dolichos Hosei.* The former is grown in Malaya as a cover crop in young rubber, but is not suited for old rubber as it cannot stand the shade of the latter; there is, however, an intermediate stage when the former cover is tending to die out on account of the increasing shade, and it is then that a mixture of the two cover crops is suggested. In the case of sisal, *Phaseolus lunatus* Linn. has in Java been found to be one of the best cover crops to grow, but this has the disadvantage that it takes a long time to cover the ground and, unless great expense is incurred in weeding, the cover crop may be suppressed before it is fully established. In such a case a mixture of a quick-maturing cover crop with the slower growing *Phaseolus lunatus* might be found to solve this difficulty.

The simplest form of cover crop is one which has only within recent years been introduced, and this is what is now termed "selective weeding." In the early days of plantation industries "clean weeding" was the rule. The disastrous results of this soon became apparent. Soil erosion naturally followed, and the crops showed the effects of this. Recourse was then had to the use of concentrated fertilisers and artificial manures. Many planters then abandoned "clean weeding" on this account and allowed the natural vegetation to remain, keeping it in check by cutting back. As such vegetation consisted largely of grasses, this operation was termed "grass knifing." Then the question was raised whether it would not be better to have controlled growth of some plant which would protect the ground more efficiently than a miscellaneous growth of weeds, and the possibility of some of these being able to enrich the soil with nitrogen led to trials with plants of the family *Leguminosae.* As it is not always practicable to grow a definite cover crop for reasons such as excessive rainfall, badly distributed rainfall, poverty of the surface soil, excessive shade, etc., a system has of recent years sprung up known as "selective weeding," *i.e.*, plants which are considered desirable from the point of view of soil cover are allowed to remain, while grasses and other plants which are liable to choke these are removed.

Though the value of Leguminous crops has been well known to arable farmers for centuries, and though such crops have been used for ploughing in, or composting, the study of cover crops in connection with the plantation industry is of comparatively recent date. At the close of last century the number of plants which had been tried as cover crops was very small indeed, but at the present time a very large number have been tried, and of these probably about a score have been found to be distinctly useful and have been taken up by the planting community and grown for one purpose or another. Even at the present time this line of investigation is mainly confined to the planting countries of the East. Nowhere has this work been carried out so thoroughly as in the Dutch East Indies, and it is from there that most of the cover crops now cultivated in Malaya and Ceylon have been introduced. The results of the work done in Java are described by W. M. van Helten† in a publication of the Department of Agriculture. Recently this

* Med. Alg. Proefstation der A.V.R.O.S. Alg. Serie. No. 27. Germinating experiments with seed of different species of green manures. Dr. Maas.

† Mededeelingen van het Algemeen Proefstation voor den Landbouw. No. 16.

line of research has begun to receive attention in the newer planting countries of Africa, but there so far the work has got little beyond the experimental stage.

An aspect in connection with cover crops which has occasionally been referred to, but which up to the present appears not to have received sufficient attention, is the question of manuring to promote the growth of the cover crop with a view to manuring the plantation crop ultimately, though indirectly. This aspect has received a certain amount of attention in arable farming when growing a green manure crop for ploughing in. It is understood that this used to be a sound agricultural practice among the indigo planters in Bihar, and it is in use in English farming, especially in the manuring of temporary pastures to encourage the growth of clovers and other legumes which enrich the soil in nitrogen. A considerable amount of attention has been paid to the aspect of the question by the Scientific Staff of the Indian Tea Association.

An endeavour has been made to summarise such information as is available regarding cover crops which have been tried and which are in use. These are arranged under the different plantation crops among which they are being grown or tried, and as in some cases the same cover plant has been found of use when grown among different plantation crops, a certain amount of what may seem to be repetition is inevitable. Such an arrangement, however, appears to be advisable as it serves to indicate more clearly the conditions under which such plants will grow, and will thus better serve as an indication as to what, after trial, may be suitable as a cover crop with other plantation crops such as sisal and cacao, about which little information appears to be available.

TEA.

The tea bush in a plantation is an artificial plant in that it is kept cut back, in order to make it produce a flush of leaf which can easily be picked by the pluckers from the ground.

The nature of the crop therefore precludes the cultivation of many cover crops which would be suitable among a tall-growing plantation crop. Nothing which has a strong tendency to climb, and thus smother the tea bush, can be grown.

Cover crops in tea are grown with two main objects in view, firstly to check soil erosion, and secondly to maintain or increase the supply of humus and plant food in the soil.

In Java, where tea is planted on the contour, a method of planting which is beginning to claim attention in Ceylon, the cover crop is grown in contour hedges which alternate with catch drains, and usually there are one or two rows of tea between the contour cover crop and the catch drain according to the steepness of the ground. As the soil and débris which accumulates in the catch drain is always thrown up hill, it can easily be understood that in time terraces are formed with the catch drain at the back and the contour hedge crop in the middle of the terrace. The cover crop is sown or planted in a double line. When well established it is cut back to about nine inches from the ground so as to make it bush out. This is pruned back four or five times a year, and the cuttings are spread on the floor of the terrace where they are hoed in. A description of these Java methods is given by Hope.*

Somewhat similar contour hedges are now used both in Assam and in Ceylon. In the S. Indian tea estates of N. Travancore there is no record of any plant having been discovered for this purpose which would suit the rather unique climatic conditions which are experienced there.

Besides these contour hedge crops there are other plants which are grown as ordinary ground cover crops. In Assam these are chiefly plants

* Agricultural Journal of India. Vol. XI. p. 184.

which are treated as green manure crops and are usually turned in when three to four months old. In Ceylon and S. India, where there is greater necessity to protect the steeper slopes against soil erosion, certain perennial cover crops have been tried and several of these are now being extensively grown. The main object of such cultivation is to lessen the serious loss caused by soil erosion of what might be termed chemical and mechanical soil fertility.

It must always be remembered that complete cover crops such as these are in direct competition with the tea bush in utilising the plant food and moisture in the soil, and it is a question whether the immediate effect of growing such is beneficial to the tea. Recent work in Ceylon, where *Indigofera endecaphylla* has been grown as a cover crop, indicates that its cultivation has not had a depressing effect on the tea. The cultivation, however, of crops of this type opens up a large field for investigation regarding soil management, the manuring, cultivation, treatment and utilisation of the cover crop. In Assam, where cover crops are largely grown for the purpose of turning in when three or four months old, experiments carried out indicate that while these are growing and utilising plant food and moisture from the soil they are in direct competition with the feeding system of the tea bush, and do have a decided depressing effect on the yields of tea plucked, but when they have been turned in a marked improvement is noticed in the amount of tea plucked, as soon as such green dressings have become incorporated with the soil.

The three well-recognised contour hedge crops in Java are *Clitoria cajanifolia* Benth., *Leucaena glauca* Benth., and *Tephrosia candida* DC.

Clitoria cajanifolia Benth. A sub-erect perennial shrub indigenous in Malacca, the Straits Settlements, Java and Tropical America. The plant is propagated from seed which is sown in situ.

Java. This has been used for many years as a contour hedge crop as well as a soil binding crop along the margin of field drains.

Assam. Introduced from Java in about 1915, and has been found to be equally satisfactory here. It has to be cut back three or four times a year.

Ceylon. Introduced from Java in 1922. In a trial cultivation at Peradeniya a sowing in June gave a dense bushy growth 5-6 feet high within six months. Since then this has been repeatedly cut back and soon makes fresh vigorous growth. Sown in March on a bare, washed slope, where many other possible cover crops had been tried and failed it soon became established and in nine months an excellent hedge was formed.

Leucaena glauca Benth. A small tree, probably a native of Tropical America, but common both in the new and old world tropics. This is commonly grown as a contour hedge crop in Java, propagted by stakes and cuttings, and thrives up to an altitude of 4000-5000 feet. It is very suitable for this purpose as its procumbent branches assist in checking soil erosion, but the hedges must be cut back three or four times a year. It is also grown as a wind break and shelter belt among tea and the light shade which it casts is said to be of benefit.

Indigofera suffruticosa Mill. Tropical America and the W. Indies. This has been tried both in Assam and Ceylon and is favourably reported on.

Indigofera arrecta Hochst. A native of E. and S. Africa.

In Assam this is reported to do well in all tea districts and is suitable for contour hedge planting. In Ceylon this has been tried at Peradeniya as a contour hedge plant and it is reported that though it starts well it dies out when about eighteen months old and after three loppings.

Indigofera Gerardiana R. Grah. (*Indigofera dosua* Wall.).

Assam. This crop is grown from seed and is stated to do well in all hill districts; it is also being tried on the plains, treated as a contour hedge crop.

Tephrosia candida DC. India, Malaya, naturalised in Jamaica. "Boga medaloa." A sub-erect perennial shrub. The plant is propagated from seed which is sown in situ. Germination is improved if the seed is soaked in concentrated sulphuric acid for from 10-20 minutes. This has been cultivated now for many years in Ceylon, Malaya, Java and India. It is grown much in the same way as *Clitoria cajanifolia,* but must be cut back before it flowers and seeds if it is to persist for any length of time. If treated in this way it is said to last for from 4-7 years in Ceylon and for 3 years in Assam. In the latter place it is recorded that its cultivation had no effect on the growth of tea for the first two years, but in the third year there was a significant increase. Its cultivation is reported to have met with indifferent success in the tea districts of Palni and Travancore in S. India as most of it died out in the heavy monsoon rains. Details of numerous trials with this in various parts of the Dutch East Indies are recorded by van Helten (l.c.).

Tephrosia Hookeriana var. *amoena* Prain. In Java this is stated to form a compact hedge when grown in lines, but it does not last more than a year or two.

Perennial Ground Cover Crops.

Indigofera endecaphylla Jacq. A spreading procumbent perennial belonging to the Old World tropics.

Travancore, S. India. Reports from the Peermade Tea Station state that this is the most promising cover crop as yet tried but even it may die out during the heavy monsoon rains.

Ceylon. This plant was introduced to Ceylon from S. India and was first grown at Peradeniya in 1921. Planted two feet apart between rows of tea bushes it will make a complete ground cover in about five months. It has been tried with success at elevations ranging from 500 to 6000 feet. Reports on definite experiments with regular planting in tea are all quite recent and, though the tea bushes look well and flush freely, no definite increases in yield have as yet been recorded. All that can be said is that the bushes have not gone back in condition. The method of propagation recommended is to grow this in a nursery either from seed or from cuttings and to cut off the procumbent shoots from the nursery plants when these are about a foot long. Three or four cuttings are planted together at intervals of about two feet between the rows of tea bushes. One acre of nursery is stated to be sufficient to plant up seventy acres of tea garden.

Java. Referred to in Java publications of 1925 and 1926 as most promising not only as a cover crop but also as a fodder crop for live stock.

Desmodium triflorum DC. (*Desmodium heterophyllum* Wall.). A native of the tropics generally.

Ceylon. There is stated to be a certain demand for seed. Probably referring to this species *The Tropical Agriculturist* states that the plant adversely affectes the tea bush when the growth becomes too dense and it should be forked through occasionally to assist soil aeration. Burnett of of Dickova Estate, in a recent article in the same publication, states his opinion that its effect is detrimental to tea as its matted root system prevents soil aeration.

Travancore, S. India. The report on the Peermade Tea Station states that this plant covered the ground during the rains but that it died out in the dry weather.

Desmodium polycarpum DC. (*Desmodium heterocarpum* DC.). Tropical Asia and Australia.

Assam. This is a common plant in grass jungles and is stated to be suitable for planting on terraces and slopes to prevent wash. If sown in the nursery in February, cuttings for plantings can be taken in the following August. When once established it gives no trouble. Suitable for contour planting.

Java. This plant has been grown experimentally here.

Desmodium purpureum Fawcett and Rendle (*Desmodium stipulaceum* DC; *Desmodium tortuosum* DC.). Florida, West Indies and Tropical America.

Assam. Stated to grow well on very poor soils. It can either be sown directly among the tea or can be propagated by means of cuttings.

Desmodium retrofleum DC. Burma and the Himalaya region, Assam. Stated to be very similar to *D. purpureum,* but makes a better cover crop.

Oxalis corniculata Linn. Cosmopolitan.

Travancore, S. India. Reported to be great success as a cover crop. Petch in *The Tropical Agriculturist* also makes mention of this as a possible cover crop.

Another species of *Oxalis* not identified, which has a purple flower is also stated as being successful as a cover crop in Travancore.

Eupatorium pallescens DC. Brazil.

In Java this is stated to be useful in establishing vegetation on worn out slopes where nothing else will grow. It can be profitably utilized by being brought in and buried in trenches among the tea.

Annual Ground Cover Crops.

The practice of growing quick-maturing crops for turning under seems to be largely confined to Assam, where the following have been tried for this purpose. These are turned in when about 12 weeks old.

Cajanus Cajan Millsp. (*Cajanus indicus Spreng*) Tropics and sub-tropics of the Old World. The use of this has given remarkable increases in tea yields.

Glycine hispida Maxim. The native variety of this has been grown with success for many years.

Sesbania bispinosa Steud. (*Sesbania aculeata* Pers.), and *Sesbania aegyptiaca* Poir. Old World Tropics. These are both stated to be useful on "red bank" and light soils.

Cyamopsis psoraloides DC. This has been tried but no information is available as to how far this is useful.

Crotalaria juncea Linn. Tropics. This has given good results on all soils.

Crotalaria striata DC. Tropics. Commonly found growing wild on the sandy flats of the Brahmaputra and on the sandy soils of the Dooars. It grows well on the poorest soils.

Crotalaria sericea Retz. This species appears to be suggested as a suitable crop though it had not been tried (1918). The leaves are larger and appear more succulent than those of *C. striata* DC.

Phaseolus lunatus Linn. Tropics generally. Bush forms of this are being tried for the Mlange tea districts of Nyasaland as a soil cover.

Mucuna spp. Bush types of the imported velvet beans are being tried for the Mlange tea district of Nyasaland as a soil cover.

Crotolaria usaramoensis E. G. Baker, E. Africa. This is grown in Java between the rows of tea for cutting as green dressings. It is somewhat similar to *C. striata,* but is said to give heavier cuttings. It is also being

tried in the same way in Ceylon. It must be cut before it is allowed to seed, otherwise it is liable to die out.

Crotolaria anagyroides H.B.K. Tropical America. This is similar to *C. usaramoensis.*

COFFEE.

The question of cover crops for coffee is more complicated than for tea; for not only are there several species of coffee under cultivation, many of which require special conditions of soil and climate, but the question is further involved by the system of pruning adopted and the necessity and otherwise of top shade. These conditions regulate the intensity of the shade on the ground and therefore the suitability of any particular plant as a cover crop.

In the case of *Coffea arabica* almost every country has its own method of cultivation, varying from the widely spaced unpruned trees as grown in Brazil to the close planted, topped and heavily pruned bushes in S. India. Different systems of pruning also affect the amount of shade. In parts of Central America new wood is encouraged and all coffee is borne on primaries, while in the East, where the tree is trained to a single permanent stem, the coffees borne on secondaries and tertiaries which are encouraged by the system of pruning adopted. This latter method means a much heavier ground shade and one which is much nearer to the ground. This would at once rule out any plant which require full sunlight and which have a tendency to climb. Then again large-leaved species such as *C. excelsa* Cheval and *C. liberica* Hiern throw a much denser shade than do the varieties of *C. arabica* Linn.

Little information is available as to what effect cover crops have on the yield of coffee, but considering that, coffee does not require the same amount of rainfall as is required for tea and that it is always regarded as a surface-feeding crop, it is likely that there would be greater competition between the plantation and the cover crop both for plant food and for soil moisture than there would be in the case of tea.

There can be no doubt, however, that where coffee is planted on land which is liable to surface wash, contour hedge planting on the lines which have been adopted for tea can with advantage be tried—in fact in Java such a system is adopted in the case of *C. robusta,* and the same plants are utilized as contour hedge crops as for tea. Similarly *Leucaena glauca* is used there for light lateral and top shade.

Clitoria cajanifolia Benth. is recommended in the Dutch East Indies as a contour hedge in *robusta* coffee up to elevations of 2,000 feet.

Indigofera arrecta Hochst. has been tried as a contour hedge crop in *robusta* coffee at Peradeniya, Ceylon, and is said to have made good growth.

Tephrosia Hookeriana var. *amoena* Prain is stated also to do well as a contour hedge crop in Java at elevations varying from 600 to 2,000 feet, though it is stated that the plants are not quite so vigorous if planted under half shade. It is said to be very sensitive to heavy rain when young.

Desmodium gyroides DC. A native of tropical Asia. This has been found to be most useful in Java up to an elevation of 2,500 feet and stands cutting back well. It produces numerous leaves and forms a fairly thick humus layer.

Perennial Ground Cover Crops.

Indigofera Anil Linn. Java. This is reported to make a nice bushy growth. Sown in line 18 inches to 2 feet apart, it covers the ground with a dense growth within three months, and the plants can be cut after six months. The plant lives for about two and a half years. A certain amount of difficulty is experienced in weeding the crop when young.

Indigofera endecaphylla Jacq. From the trials made with this at Peradeniya, Ceylon, the opinion has been found that this appears to be suitable as a cover crop for *robusta* coffee.

Centrosema pubescens Benth. Tropical America. Experiments carried out at Ituri, Belgian Congo, have made a favourable impression as to the possibilities of this plant as a cover crop for *robusta* coffee. The points which are emphasised are that the plant is a peremial and never completely sheds its leaves even in the dry weather, that it is deep-rooted and opens up the soil, and that a complete cover is procured in 4-5 months. An objection to this plant which is not raised in the report is its climbing habit.

Trifolium Johnstonii Oliv. E. Africa. A report on the trial of green manure and cover crops at the Scott Laboratories, Kenya, states that this produced a wonderful mat of growth and would stop wash very well on slopes.

Annual Ground Cover Crops.

Cassia hirsuta Linn. Tropical America. This has been tried at the Coffee Station at Sidapur, Coorg, S. India, but without much success. It would only grow in the open and could not stand the shade of *Grevillea robusta* A. Cunn.

Crotolaria semperflorens Vent. Tropical Asia. This is also under trial at the Sidapur Coffee Station but there is no record of its success or otherwise.

Numerous species and varieties of plants likely to prove suitable as green manure and cover plants are beng grown at the Scott Laboratories, Kenya. These include both indigenous and exotic plants, and a full list of these is published in the Annual Report of the Department of Agriculture, 1926. Among these the following appear to be worthy of mention.

Crotolaria intermedia Kotschy. Tropical Africa. "Very promising."

Crotolaria incana Linn. Tropics and subtropics. "Most promising for Coffee."

Vigna unguiculata Walp. (*Vigna catjang* Walp.). Tropics and subtropics of the whole world. A native variety named "Embu," with an erect habit, is stated to be promising for coffee.

Astragalus Aucheri Boiss. (*Astragalus venosus* Aucher.). "Most promising."

Phaseolus lunatus Linn. Tropics and subtropics.

Phaseolus lunatus var. "Madagascar bean" "Promising."

Phaseolus lunatus Linn. (*Phaseolus inamoenus* Linn.) "pois du cap." "Very fine growth."

"New Zealand grass pea." Probablv *Lathyrus sativus* Linn. "Very fine growth. Possibly suited for high elevations."

Lupinus polyphyllus Lindl. "Good growth. Suitable for Coffee."

PLANTATION TREE CROPS.

This name is here applied to tree crops where the growth of the tree is unrestrained, as distinct from such crops as tea and coffee where the growth is usually kept in check bv pruning. Such tree crops would include Para Rubber, Coconuts, Oil palms, Cloves, Nutmegs, etc. The three first mentioned are those which are generallv grown on a large scale. From the nature of these crops the trees have to be widelv spaced, and it is some considerable time before a complete leaf canopy is formed. During the young stages care must be taken to keep noxious weeds in check, such as the Lalang (*Imperata arundinacea* Cyrill.) of the East, and the Para grass

(*Panicum muticum* Forsk.) of the West. In the past very considerable expenditure used to be incurred in weeding charges and there were also large capital losses of soil fertility. Latterly this expense and loss has to a great extent been saved by a system of growing ground cover crops or, as they are sometimes called, "smother crops."

In reading reports of trials of plants which are likely to the useful for this purpose, there are two points which are generally raised: first their ability to keep such weeds as Lalang in check, and second whether they are liable to be dangerous in case of fire when they wither or die. In the case of some plants which are grown for this purpose, they can be made much more effective if they are prevented from flowering and fruiting. For example, *Mimosa invisa* Mart. has a varying reputation. By those who understand how to deal with this cover crop it is claimed that there is nothing to equal it. It must be prevented from seeding either by rolling or by beating it down, which causes it to make fresh growth immediately. If it is left to itself it will die out naturally, and not only become a danger from fire, but will let the Lalang through, which, now that the soil has been made richer by the growth of this cover crop, will grow stronger than ever before.

When tree crops have grown up and formed a canopy, the cover crop is grown more for the purpose of maintaining soil fertility, and though the ground cover crops of the type mentioned above may prove generally suitable for all such crops when they are young, the choice of a suitable cover crop for the grown plantation will depend on the amount of shade which the trees themselves throw.

COCONUTS.

This crop opens up the possibility of a different class of cover crops from those referred to under tea or coffee. In the case of a young plantation, cover crops are grown to all intents and purposes in the open, and therefore shade-bearing cover crops need not necessarily be considered. Some of the pulse crops also which can be grown may, if necessary, be treated as catch crops and harvested for their grain.

In the case of grown plantations the trees of the plantation crop throws a fairly light top shade on the ground. Any plants which are grown under coconuts therefore must be able to stand a certain amount of shade, but as the coconut palm has a clean smooth stem there is not much fear that climbing plants will prove to be objectionable. There is one point, however, to be borne in mind and that is that the leaf drip from the palms may damage a cover crop if it has a soft succulent leaf. The rigid leaf of the palm and the smooth straight leaflets tend to concentrate drip on particular spots, in fact, where coconuts are grown on sandy soils one can often see the outline of the leaf pricked out on the soil by this water drip.

With the wide spacing required, coconuts are usually planted on land which is fairly level, and therefore the question of contour hedge crops has not received much attention. Under special circumstances these may prove necessary. The only mention of such cover crops is from Malaya, where *Clitoria cajanifolia* Benth. is mentioned as being likely to prove suitable for this purpose. This is the conclusion drawn from a trial cultivation on the Castleton Station. *Tephrosia candida* DC. could also be used if necessary. This is a common cover crop under coconuts in Ceylon. On terraced lands something is required to protect the edge of the terrace, but nothing is mentioned in any reports as to any plant having been tried for this purpose. *Indigofera endecaphylla* Iacq. is a possibility. It grows successfully under low-country rubber in S. India and it is said to thrive in Ceylon at elevations varying from 500 to 6,000 feet.

Perennial Cover Crops in Young Coconut Plantations.

Tephrosia candida DC. This thrives in both young and old plantations, but if the land is rich it will, unless lopped, grow too tall and thus adversely affect the young trees by its shade.

Indigofera hirsuta Linn. Old World Tropics. Tried at the Castleton Station, F.M.S., and reported as promising. It covers the ground in four months, grows to a height of two feet and thrives both in and out of coconut shade.

Calopogonium mucunoides Desv. Guiana. First tried as a possible cover crop in Java in 1923. Tried at the Castleton Station, F.M.S., in 1926 and reported to do well among young coconuts, though it has a tendency to climb. Planted three feet by three feet it made a complete cover within three months and a cover two feet thick within five months. It is stated to die out after about 12-18 months, but by that time will in all probability have seeded itself.

As much more attention has been paid to cover crops among young low-country rubber reference should be made to this. It is probable that what would grow among the one will grow among the other provided soil conditions are suitable.

These include a large number of tropical pulse crops of which the following are the more important:—

Phaseolus lunatus Linn.; *Phaseolus calcaratus* Roxb., Tropics of Asia; *Phaseolus mungo* Linn.; *Dolichos biflorus* Linn.; *Dolichos Lablab* Linn., Old World Tropics; *Vigna unguiculata* Walp. (*Vigna catjang* Walp.); *Canavadia ensiformis* DC., Tropics.

As there are many cultivated forms of these different pulses which have been adapted to suit different seasons and varying agricultural conditions, an extended trial of these may bring to light particular strains which would adapt itself to local requirements. There are also "bush" forms of some of these which, if procurable, might prove more easy to deal with.

Crotolaria usaramoensis E. G. Baker. Tropical East Africa. This has been tried with success in Java. It seeds very freely, and if it is to last for any length of time it should be cut back before it can seed.

In addition to the pulse crops named above, the following are referred to as suitable cover crops for coconuts in Porto Rico* for both young and old plantations, especially those on coast sandy soils. In the case of the former emphasis is laid on the necessity for preventing the plants from covering the trees even for a short period, and it is stated that where young trees have been smothered even for three weeks the effects of this are still apparent after six months.

Mucuna capitata Sweet. (*Mucuna velutina* Hassk.). *Mucuna aterrima* Holland (*Stizolobium aterrimum* Piper). These two species are said to make about equal development, and they also make heavier growth and have a longer growing season than the Florida Velvet bean, *Mucuna Deeringiana* Merrill (*Stizolobium Derringianum* Bort), of the Lyon bean, *Mucuna nivea*. DC. (*Stizolobium niveum* Kuntze). *M. capitata* did not mature till nine months after planting. In the case of all these the vines have to be periodically cut back from around the young trees.

Jack beans and Sword beans, *Canavalia ensiformis* DC. and *Canavalia gladiata* DC., have also been tried, and though they grow well they do not

* Porto Rico Agricultural Experiment Station. Bull. No. 19. Cover crops for Porto Rico. C. F. Kinman.

make such a complete and heavy cover nor do they last as long as the two species of *mucuna* recommended above.

Cajanus Cajan Millsp. is also said to make thrifty growth on coconut lands. It is valuable for killing out wild vegetation and for providing wind protection.

Mention is also made of a wild *Canavalia* known as "Mato de la Playa" which is very common on the sandy coast, *Canavalia obtusifolia* DC. This is suggested as likely to be useful for binding loose sand. The same plant is common on the sandy coast of Trinidad.

Vigna marina Merr., known as "Solani," is reported as being a promising cover crop recently introduced into the Philippines, though it is not state with which crop it has been grown. It closely resembles *Dolichos Hosei.*

Perennial Cover Crops in Grown Coconut Plantations.

One point must be borne in mind in deciding what cover crop to grow under coconuts, and that is the method of harvesting the nuts. If these are left on the tree till the nuts are dead ripe and have commenced to fall at harvest, or if nuts are only collected off the ground having fallen when ripe, then a tall-growing cover crop, unless it is kept lopped down, is objectionable, since many nuts which have fallen are likely to be overlooked at harvest. Another objection to cover crops which are inclined to grow tall is that it is very difficult to supervise labour at work.

Calopogonium mucunoides Desv. Trials at Castleton Station show that this will not thrive under shade and therefore it is unsuitable as a cover crop under grown coconuts.

Indigofera hirsuta Linn. At the above station this is reported to thrive under coconut shade.

Clitoria cajanifolia Benth. This is favourably reported on in the Philippines. In Malaya the impression is that it does not make a sufficiently dense cover. The tough leaf of this plant would be an undoubted advantage.

Centrosema Plumieri Benth. Tropical America. First introduced to the East as a possible cover crop by Dr. C. J. J. van Hall, Java, in 1912. This is favourably reported on both in the Philippines and in Malaya, though in the latter country it is stated to thrive only under good soil conditions. Though a climber it does not readily climb the coconut stems.

Centrosema pubscens Benth. Tropical America. Introduced into the Dutch East Indies in 1922. Favourably reported on in Malaya, though it will not thrive on badly drained land. It is excellent where the drainage is good, and far excels *C. Plumieri.*

Tephrosia candida DC. Favourably spoken of in the Philippines. On the Castleton Station, F.M.S., it is reported to have grown ten feet high and, would therefore have to be cut back and be used as a green dressing. In Ceylon the extending use of this plant as a cover crop is reported, and it is stated that the practice of alternating the growing of this with a period of cultivated fallow is finding favour among coconut growers.

Tephrosia Vogelii Hook.f. The "fish poison bean" of East Africa. In the Philippines it is stated that this is a useful cover crop for coconuts. As it is a coarser-growing plant than *T. candida* its growth would probably have to be kept in check by lopping.

Tephrosia Hookeriana var. *amoena* Prain. Trials at Castleton Station, F.M.S., are reported to be promising, and suggestion is made that it should be sown thicker than 3 feet by 3 feet if a complete cover is to be formed.

Leucaena glauca Benth. has been tried at the Castleton Station in Malaya, but its growth was found too open to make a good cover.

Cassia mimosoides Linn. (*Cassia Leschenaultiana* DC.). Tried at the Castleton Station, F.M.S. Growth was very slow when young, but later it formed a dense impenetrable mass 10-12 feet high and therefore cannot be recommended.

Cassia hirsuta Linn. Tried at Castleton Station, F.M.S. It did not do well. (It probably cannot stand the shade, as when tried in coffee in S. India it was found that it would only grow in open spaces).

Mimosa invisa Mart. Tropical America. Tried at Castleton Station, Malaya. Reported to be very good on heavy soil, and when sown three feet by three feet apart formed a complete cover in three months' time. It is inclined to die out when one-and-a-half to two years old, but will last much longer if beaten down or rolled. It is objected to by some on account of the spines and the difficulty of getting labour to work among it.

Mikania scandes Willd. Tropical America. Known in Malaya as the "mile a minute" plant. This is suggested as a possible cover crop in Malaya. One plant planted in the centre of a square of four coconut trees will in a very short time completely cover the ground.

PARA RUBBER.

There are two distinct problems connected with cover crops in rubber. The first is to find suitable plants which will grow under the partial shade of young rubber, and the second is to find something which will grow under old rubber, which in countries such as Malaya, with a well-distributed rainfall, throws an almost complete shade throughout the greater part of the year.

Cover crops grown are very similar to those grown among young coconuts, except that there is not the same fear of climbing plants smothering the trees, since rubber will form a stem in a comparatively short space of time, while the coconut will take anything from three to seven years to do this.

Young Rubber. Annual Cover Crops.

Phaseolus lunatus Linn. (patani). Recommended in the Philippines.

Phaseolus calcaratus Roxb. (palawan beans). Reccommended in the Philippines.

Crotolaria striata DC. In the F.M.S., where this was tried at the Castleton Station, it is reported that within a few weeks of sowing it makes a dense growth and somthers all weeds. At the Moopley Rubber Station, Cochin, S. India, it is reported to do well in the dry weather, but is is not able to stand the heavy rains of the S.W. Monsoon, nor can it stand lopping.

Crotalaria usaramoensis E. G. Baker. Tropical E. Africa. In Malaya this is stated to be very similar to *C. striata* except that its growth is denser and more rapid. It is said to stand cutting back, but presumably this must be done before it seeds, as reports from Java say that it does not last long if allowed to seed. It has also been reported to have done well in Ceylon at Peradeniya, but there it also requires periodic cutting back.

Crotalaria anagyroides H. B. K. Tropical America. Reports from Malaya and Ceylon are similar to those above relating to *C. usaramoensis.*

Dolichos biflorus Linn. Reported to be very successful in young rubber in Ceylon.

Young Rubber. Perennial Ground Cover Crops.

Centrosema plumieri. Benth. Under good soil conditions this has proved very satisfactory in Malaya.

Centrosema pubescens Benth. In Malaya this is said to be much superior to *C. plumieri* on well drained land, and in Ceylon it is reported that it is commonly used in young plantations.

Calopogonium mucunoides Desvi. In Malaya this is found to be very useful in young areas and is recommended for sowing in new clearings. It is specially useful in the suppression of weeds.

Indigofera endecaphylla Jacq. Tried at the Moopley Rubber Station, S. India, and said to be good. At the Tenmalai Rubber Station, S. Travancore, it is found to die out during the hot weather.

Tephrosia candida DC. This as recently as 1926 is referred to as the standard cover crop for young rubber in Ceylon.

Passiflora laurifolia Linn. Tropical America. Mentioned as a cover crop in young rubber in the Philippines.

Passiflora foetida Linn. Brazil. This has been tried in Malaya.

Old Rubber. Perennial Cover Crops.

In Malaya, with its continuous growing season, there appears to be only one Leguminous cover crop which has so far been found to thrive under the shade of old rubber, though one or two of those which do well among young rubber have been found to be useful for renovating old rubber which has been allowed to "go back," and which in consequence does not form a complete shade canopy.

Under the system known as "selective weeding" there are several plants which are now being left to form a ground cover when the plantations are weeded.

In South India, where there is a very different distribution of rainfall, there is not the same permanent shade canopy over the ground. There is also a "secondary leaf fall" which occurs during the heavy S.W. Monsoon rainfall, as well as the normal dry weather leaf fall, and thus the leaf cover is never as heavy as in Malaya. There are several cover crops which are reported to grow here under old rubber which are not suitable for Malayan conditions.

Dolichos Hosei Craib (*Vigna oligosperma* Back.), the Sarawak Bean. This is the standard cover crop for old rubber in Malaya, Ceylon, and the Dutch East Indies. The main difficulty is in establishing the crop. Seed is scarce, and when sown under rubber germination is unreliable. In Ceylon it is recommended that plants should be grown in nurseries in the first instance. They can be established either from seed or by rooted cuttings. The cuttings should be rooted in coconut "sawdust," and when planting out takes place the planting holes should be manured with a little general fertiliser.

Mimosa invisa Mart. Tropical America. Very satisfactory results have been obtained both in the Dutch East Indies and in Malaya with this. It can be propagated by seed sown 3 feet by 3 feet apart. Its disadvantages compared with *D. Hosei* are that it dies out when eighteen months to two years old, and it cannot stand the same amount of shade.

Mikania scandens Willd. is stated to stand the shade of mature rubber well, and it is suggested that in Malaya this might prove a suitable cover crop.

Teramnus labialis Spreng. (*Teramnus mollis* Benth.). Tropics. This is reported to be doing well in one rubber estate in the neighbourhood of Kandy, Ceylon, and it is recommended by the Agricultural Department as useful at higher elevations where it is difficult to establish *Dolichos Hosei.*

The following have been tried in S. India as possible cover crops for old rubber.

Centrosema pubescens Benth. This is reported as promising. It retains its leaf in the hot weather.

Phaseolus Dalzelli T. Cooke. This is reported to make an excellent cover, but the plant dies away in the hot weather.

Phaseolus sublobatus. Tropical Asia. There is no information as to whether this is *P. sublobatus* Buch.—Ham or *P. trilobus* Ait. (*P. sublobatus* Roxb.). It is very similar to the preceding except that it may survive the hot weather if in heavy shade.

Phaseolus mungo Linn. is stated to keep green and grow in the hot weather.

Indigofera endecaphylla Jacq. is spoken well of in old rubber.

Tephrosia candida DC. is also commended.

Uraria Lagopus DC. and *Uraria lagopoides* DC. India and Malaya. These have been tried with some success, but "pink disease" has been found on them. These plants have been quoted under the name of *U. hamosa* Wall.

Smithia geminiflora Roth., India, Malaya and Australia; *Crotalaria evolvuloides* Wight, India, and *Crotalaria quinquefolia* Linn., India, have all been tried with a certain amount of success.

Besides these plants which have been definitely planted and tried there are others which have been encouraged by selective weeding. "Ferns" are reported to be allowed to grow among old rubber to prevent soil erosion on certain estates in Malaya, and as long as these are cut down annually their effect is considered to be good. A similar statement has been made about the growth of ferns on the peaty soils of British Guiana and their beneficial effect on Liberian coffee. Lycopods (Staghorn Moss) are also allowed to grow in the same way on some Malayan estates.

Lotus corniculatus Linn. is mentioned as being similarly useful in the Dutch East Indies.

OIL PALM.

The cultivation of the Oil Palm, *Elaeis guineensis* Jacq., as a definite plantation crop is of so recent a date that such work as has been done on the use and value of cover crops is confined almost entirely to Sumatra.

In young plantations *Calapogonium mucunoides* has been found to be most suitable: for, though it does not kill out the lalang, it effectively checks its growth and prevents it from spreading. In older plantations where there is a leaf canopy this cover crop cannot stand the shade, and in its place *Dolichos Hosei* has been found to be most suitable.

Mimosa invisa is sometimes grown but it is not so popular on account of its spines, which interfere with the work of the labourers nor does it check lalang so well.

CACAO, CLOVES, NUTMEGS.

No information is available about the use of cover crops for Cacao, Cloves or Nutmegs, except that *Cajanus Cajan* is mentioned as being useful as a ground and wind protection for young Cacao.

SISAL.

The question of growing cover crops among sisal is one which has received a certain amount of attention in the Dutch East Indies, and it is understood that the Agricultural Department in Tanganyika is also paying attention to this matter. The main problem in connection with this plantation crop is to supply a ground cover which will smother weeds and thus reduce the cost of maintenance as well as the serious danger that there is

from fire. It is essential, therefore, that any cover crop grown should be able to remain green during the dry season when wild fire is likely to occur. It is also essential that such a crop should be capable of quickly covering the ground after it has been sown, so that it will be able to smother weeds before these become too big, especially such weeds as the rank-growing annual grasses which are such a serious menace to the sisal plantations of East Africa. Further, any cover crops grown must be such that it does not itself tend to over-grow the sisal.

A number of possible cover crops have been tried in Java and of these *Phaseolus lunatus* has proved one of the most satisfactory up to the present.

Indigofera tinctoria Linn. (Indigofera sumatrana Gaertn.). This grows well enough, but when the dry weather sets in the plants tend to become bare.

Crotalaria usaramoensis E. G. Baker. This does not maintain its cover for a sufficient length of time.

Canavalia obtusifolia DC.). *Canavalia lineata* DC. This is not as good as *Phaseolus lunalus* Linn.

Tephrosia Vogelii Hook. f. Grows too tall.

Passiflora foetida Linn. On good soil this is apt to smother the sisal while on poor land the growth is thin, yellow and weakly.

Dolichos Hosei Craib. Cannot stand exposure to the full light and only grows around the base of the sisal plant. Even here it is apt to die out.

Calopogonium mucunoides Desv. has proved satisfactory except that it has a tendency to climb.

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