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COFFEE IN THE HIGHLANDS

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THE high prices that have been obtained for good quality arabica coffee over the last few years have greatly stimulated Territory interest in this plantation crop. This article applies specifically to coffee cultivation in the Highlands of New Guinea and is intended to meet, as far as possible, the immediate needs of intending coffee producers in this region. It is not intended to discuss in detail aspects of a highly technical nature but to concentrate more on the agronomic fundamentals of correct plantation establishment and management for the successful owner-manager.

It is fairly evident that coffee seed was first introduced to the Highlands by the Lutheran Missionaries some years before the war. The seed was introduced from the Finschhafen area and was the green-tipped bourbon arabica coffee. Some of the earliest Highlands planting are still surviving at the Lutheran Mission station at Asaloka some miles from Goroka. These trees have grown to approximately twenty feet in height and have continued to thrive and crop well despite the fact that they were entirely neglected during the war years and for some time after. They are typical green-tipped bourbon arabica coffee.

Since the introduction first of bourbon coffee to the Highlands various other species and varieties have been introduced. Blue Mountain Jamaican arabica coffee introduced from Wau was planted at Aiyura in 1937. Small quantities of robusta seed were introduced by the Lutheran Mission. Later still a number of other arabica varieties were introduced and planted at Aiyura for observational and experimental purposes.

The Botany of the Coffee Plant.—

The coffee plant belongs to the Genus *Coffea* and the Family *Rubiaceae*. Although there is some doubt among botanists regarding the classification of the Genus *Coffea*, the more recent publications list four species of economic importance. In order of world importance these are :—

1. *Coffea arabica* Linn.
2. *Coffea canephora* Pierre ex Froehner.
3. *Coffea liberica* Bull ex Hiern.
4. *Coffea excelsa* A. Chev.

Coffea robusta is included as a form or variety of *Coffea canephora*.

As *Coffea arabica* is the only species of economic importance in the Highlands it is not proposed to deal with the remaining species in any further detail.

The species *arabica* is indigenous in Abyssinia and possibly part of Arabia. In Abyssinia, it is found mainly in the southern mountains between latitudes 7 and 9 degrees north, among fringing forest growths and along the shaded banis of streams at altitudes from 4,500 to 6,500 feet.

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Botanically the plant is a glabrous, glassy leaved shrub or tree. The flowers are white or creamy and are borne in clusters at the nodes on new lateral wood. Self-pollination is usual although cross-pollination may be effected by wind or insects.

The fruit which resembles a cherry, is a two-seeded drupe, normally containing one seed in each locus.

It is proposed to discuss the agronomic aspects of coffee cultivation in the Highlands under the following headings :—

1. Varieties.
2. Soils and Climate.
3. Land Preparation.
4. Plantation Management.
5. Pests and Diseases.
6. Harvesting.
7. Processing.
8. Marketing.

Varieties.

Almost all of the arabica coffee plantings in the Highlands are derived from seed introduced to Aiyura in 1937. The bulk of the plantings consist of the two botanical varieties;

(a) *Coffea arabica* L. var. *typica*, usually referred to as " typica " coffee.

(b) *Coffea arabica* L. var. *bourbon*, usually referred to as " bourbon " coffee.

The proportion of planting are approximately 80 per cent. typica and 20 per cent. bourbon.

Odd plants are noticed of several other varieties or types of the arabica species. Among these is the " maragogipe " coffee with the large, bold bean but rather poor yield, plus " mocha " coffee, and several other types of uncertain designation.

Of the two varieties, bourbon and typica, the bourbon coffee appears to be the more suitable for the Highlands. Although the cherry size is slightly smaller than that of typica, the bourbon trees appear to be the higher yielding variety.

The two varieties are readily recognized in that the new leaf growth of typica coffee is a light bronze or brownish colour, and a light greenish colour in the bourbon variety.

Typically the main branches of the bourbon variety grow stiffly upwards at first at an angle of 45 degrees from the trunk, but later curve outwards and downwards under the weight of the crop. The internodes are more closely spaced on the laterals, thus the clusters of fruit are closer and more numerous on the bearing branches. The leaves of the bourbon coffee are generally broader than those of the typica variety. With regard to crop maturity time, it is noticeable that the cherry on typica trees matures more quickly than on bourbon coffee trees.

Apart from its apparent higher yielding capacity, bourbon coffee is preferred because of its obviously more vigorous and sturdier growth, and its greater tolerance under drier and unshaded conditions in the Highlands. When grown under little or no shade, particularly in the more marginal rainfall areas, typica coffee is prone to develop a bunchy and compact shape, and to crop heavily and prematurely. This applies more particularly to the Eastern Highlands where more severe and protracted dry seasons may be expected. Premature heavy cropping usually predisposes the coffee tree to " die-back ". Bourbon trees, however, do not appear to be as adversely affected by premature heavy cropping, and do not suffer from " die-back " to the same degree as neighbouring typica trees.

Overseas experience has indicated that bourbon coffee requires certain environmental factors for optimum growth. In Brazil, bourbon coffee is now much sought after by planters, because of its higher yields and reputed high liquoring qualities. In East Africa, however, bourbon coffee is said to be weaker in stamina than the variety typica, although it is recognized as a coffee of fine quality and liquor. Judging from observations in the Highlands the writer would venture to say that the Highlands environment does seem conducive to optimum bourbon coffee growth.

In the lower rainfall areas of the Highlands it may be that some of the more compact, and reputedly drought-resistant arabica varieties may prove to be more suitable than either typica or bourbon.

Soils and Climate.

Arabica coffee is fairly tolerant to a wide range of soil and climatic conditions, but prefers a fertile, friable, well-drained soil, and a cool temperate climate free of frost, without strong winds, and with a well-distributed annual rainfall of not less than 75 inches. Overseas authorities maintain that arabica coffee prefers altitudes between 4,000 to 7,000 feet. However, New Guinea experience has shown that arabica coffee can be grown quite sucessfully at 3,000 feet and that above 6,500 feet the general growth rate and vigour of the plant is rather less than at the more optimum altitudes.

Coffee Soils of the Highlands.—

Generally the coffee soils of the Highlands are very heteorogeneous in that they vary greatly in apparent fertility, texture, depth and ease of drainage. Even at this early stage of development it is obvious that some of the Highlands soils are good coffee soils and others are only fair, or unsuitable for coffee culture. A coffee soil should be slightly acid, pH values between pH4.5-pH6.0 are considered optimum. Most of the Highlands soils would be within this pH range.

Good drainage is a primary prerequisite in determining the suitability of a soil for coffee growing. It is becoming increasingly evident in the Highlands in soils where drainage is impeded, due perhaps to the presence of laterite layers, or impervious clay subsoils underlying shallow topsoils, that such soils are not very suitable for coffee.

With respect to fertility, most of the coffee soils appear to be average to good. Variations appear in apparent fertility in all areas and over most plantations, but very few of the soils could be considered as too infertile for coffee growing. Other soil factors being conducive to successful coffee culture, apparent low fertility may be remedied by fertilizing.

Apart from drainage and fertility, the depth of friable topsoil and permeable subsoil are also major factors in deciding coffee soil suitability. In general, coffee has a short taproot, penetrating the soil for a distance of usually two to three feet. In addition to this there is the network of fine feeding roots close to the surface, plus the moisture-seeking roots which grow downwards in the soil under the surface-feeding roots. It is axiomatic that a deep, friable, free-draining soil will be more conducive to the maximum development of the root system than shallower and not so well-drained soils. The soil depth and coffee growth response relationship is well illustrated in any area of coffee plantings where the plantings extend from sloping land on to fairly level land. It can be seen that almost without exception, the coffee trees improve in growth and vigour the closer they are to the bottom or the top of the slope. On undulating areas of coffee plantings, growth patterns soon become evident with the bigger and more vigorous trees being in the lower-lying and more level areas. The obviously more vigorous growth observed with plantings is almost correlated with the greater depth of topsoil and a higher soil moisture content, especially during the dry season.

It is suggested that, where slope plantings are made, it is most important that the plantings be on the contour, and that the area be adequately and permanently mulched to conserve soil and moisture. The mulching should also be across the slope rather than up and down the slope.

In the Highlands the deep, friable free-draining, red-loam soils of the upper Asaro Valley are proving to be excellent coffee soils.

On the grassland areas, other than areas of Giant Kangaroo Grass, *Themeda gigantea*, the soils are shallower and generally heavier in texture. The coffee growth response on these soils has not been as promising as on the friable, red-loam soils. Drainage is of paramount importance on the grassland soils, as many of the soils overlay impervious clay subsoils. Lateritic formations, impeding drainage are also more common in the shallower grassland soils.

The darkly coloured, semi-peat soils, characterized by a dense growth of *Phragmites* sp. and *Saccharum* sp. (pit-pit) are proving to be very good coffee soils. However, it is stressed that these soils first require extensive draining before being suitable for successful coffee planting.

Throughout the Highlands, several endemic grass species are reasonably reliable

indicators of soil types, particularly with regard to depth and drainage. It is noticeable particularly where the grass species, *Arundinella furya,* and to a lesser extent, *Capillepidium parviflora,* is the dominant species in the grass flora, that the soils are shallow or poorly drained. These soils are proving unsuitable for coffee culture. However, where *Themeda gigantea* is the dominant species, the soils are generally deep, fertile and free-draining, and very suitable for coffee.

Climate.—

The Highlands climate is on the whole regarded as favourable for coffee production.

It does appear that the dry season, particularly in parts of the Eastern Highlands may be more protracted than experienced in other world coffee producing centres. The general concensus of opinon in most of the successful coffee growing regions of the world, is that the rainfall be no less than 70 inches per annum and fairly evenly distributed throughout the year, with a few months, two to three, of drier weather, but not without occasional showers.

Throughout the Highlands coffee districts, the rainfall ranges from approximately 55 inches in the drier grassland areas to over 100 inches per annum in parts of the Wahgi Valley. In the drier areas it is important that the deficiency in annual rainfall be compensated for by irrigation, mulching, adequate permanent shade, and other moisture conserving practices.

Temperature control is very necessary for successful coffee production. Temperatures that are above the optimum for coffee induce a rapid early growth, premature cropping and exhaustion of the young plant —all of which predisposes the plant to " dieback ". Overseas authorities contend that the average temperatures in arabica coffee producing regions are 55 degrees F. minimum, 80 degrees F. maximum and a mean of 70 degrees F. In the Highlands of New Guinea it is considered that optimum temperatures can be regulated by mulching to lower the soil temperatures and the judicious control of shade to mitigate air temperatures.

When the temperatures are too cold, arabica coffee has little vigour. It grows slowly and is stunted. Cold winds and light frosts are liable to blacken and distort the young growing tips. In the Highlands the majority of coffee plantings are between the 4,500 and 6,000 feet contours. Some Native plantings are between 7,000 and 8,000 altitude. Although the plants at the higher altitudes appear healthy, they are slow-growing and lack vigour compared with the lower altitude plantings. It is also evident that the crop matures more slowly—about ten months as compared with six to nine months up to the 6,000 feet level.

Frosts are rarely recorded as low as 7,000 feet.

Land Preparation.

When preparing land for coffee planting, it should be borne in mind that although the soil and climatic conditions are favourable, there are other local factors which if intelligently recognized may considerably enhance the future potential and ease of management of the plantation.

Firstly it is an asset if the land be flat or only gently sloping. A relatively flat area of land will greatly facilitate irrigation, drainage, and other cultural operations.

The direction of the prevailing winds, especially during the drier months, should be noted. The importance of protecting coffee plantings from winds cannot be stressed too greatly. Every effort should be made to utilize natural land or vegetative wind barriers, or if adequate, to plant windbreaks. The use and importance of windbreaks will be discussed in more detail later.

A plentiful and permanent supply of clean water is essential, both for processing operations and for domestic use. The lie of the land may determine if the water can be obtained by gravitational or mechanical means. The possibilities of utilizing any available waterways for the generation of electric power should not be overlooked.

Clearing.—

With few exceptions, the majority of coffee plantings in the Highlands are situated on land which had as its natural cover a dense grass flora. The clearing of the grassland is in most cases a fairly simple operation.

In grasslands where the grasses are not more than about waist height, areas can be quickly cut and cleared by gangs of labourers using bush knives. In some cases, burning of the grasslands is practised. After the initial clearing, either by cutting or burning, the cleared area may be quickly cultivated and cleared of the grass roots and crowns either by mechanical cultivation with disc ploughs, or by large Native labour gangs using spades and shovels. It is recommended that the work of clearing and cultivating the land in preparation for planting should be commenced at least six months prior to planting. This means that the land should be completely cleared and prepared by the end of the dry season.

In some cases, particularly on lower-lying areas of deep, permanently moist soils, dense stands of tall-growing, vigorous *Saccharum* and *Phragmites* sp. commonly referred to as pit-pit, are found. The work of clearing and preparing such areas is considerably greater than the grasslands. After the initial cutting by hand of the dense pit-pit stands, grubbing operations are then necessary to dig and cut out the firmly rooted stumps of the pit-pit. It is essential that the grubbing operations be very thorough in order to ensure that all of the proposed planting area be well cultivated to a depth of at least 12-15 inches, and that most of the extensive root system of the pit-pit species be removed or killed. Careless clearing of such land will result in a persistent regrowth of the pit-pit species.

Lining.—

Once the lands has been cleared it is desirable to line and hole the area without undue delay. By completing these operations early it is then possible at the beginning of the wet season to concentrate the labour force on getting the temporary and permanent shade established.

The combined operations of lining, holing and establishment of shade, entails much time and labour. Growers are advised not to overestimate their labour potential but to concentrate their efforts and attention on a manageable area in order to complete the operations quickly and successfully.

The lands may be lined out either on the square or triangle. The latter system is preferred as it results in 13 per cent. more trees per acre. For lining out a non-stretchable wire is necessary. Piano wire is quite suitable for this purpose.

The recommended spacing is 9 feet x 9 feet. For multiple-stem coffee it may be better to allow for a slightly larger spacing, perhaps 10 feet x 10 feet. In higher rainfall areas, or areas of very fertile soils, the spacing could possibly be slightly closer. In lower rainfall areas, however, the tendency should be to increase the spacing between the trees to allow each individual tree a wider soil area on which to draw moisture.

With a view to mechanised plantation management in the future, it may be practical to increase the spacing between the rows and decrease the spacing between the trees in the row. For example, rows 13 or 14 feet apart with the coffee trees 6 feet apart in the rows would allow the passage of vehicles through the plantation, without loss of space or plantings. This could be of practical benefiit in the future with respect to mulching, fertilizing and weed and pest-control spraying programmes.

Holing.—

Once the land has been cleared and lined, holing should commence immediately.

Although there is quite a variance of opinion among growers as to the size of the planting holes, large holes, 2½ feet x 2½ feet are recommended. It is of interest to note the results obtained from experiments in Kenya with regard to the size of the planting hole and the subsequent coffee yields.

During the digging of the holes the top-soil and subsoil are separated, being thrown to opposite sides of the hole. It is desirable that the sides and bottom of the hole not be cut with a smooth finish as this will tend to decrease moisture penetration and the rate of weathering. The bottom of the hole should be loosened when the holes have been dug to full depth.

It is recommended that the holes be dug at least three months prior to planting to permit weathering and moisture penetration. Three to four weeks before planting is due the holes should be refilled with

topsoil only and a small mound formed over each hole to allow for sinkage of the soil. After the holes have been refilled the mounds of subsoil are levelled over the surface and a general relining of the planting pegs is completed.

Establishment of Shade and Windbreaks.—

The coffee plant in its natural habitat is a forest plant and as such it requires some form of protection from wind and exposure to direct sunlight for prolonged periods.

Whether the protection from direct sunlight be from cloud formations or provided vegetative cover is immaterial. The important fact to be borne in mind with respect to coffee plantings in the Highlands is that the coffee plant must be provided with some form of shelter, particularly during the drier months of the year. The provision of ample shade and correct shade manipulation during all stages of growth of the coffee plant is a prerequisite for successful coffee production in the Highlands.

The amount of shade necessary is determined to a degree by the environmental conditions on each plantation. In the lower rainfall areas of the Highlands it is natural that a greater density of shade would be required in comparison with the higher rainfall areas. Also plantings at lower altitudes would require more shade than plantings at higher altitudes. Furthermore it should be remembered that the shade provided should be manipulated. More than purely a matter of shade provision, it is a matter of shade control. Controlled so that the shade may be thinned out by pruning during the wet months of the year when the coffee plant is actively growing and increased in density during the hotter, drier months. Local experience and observation are necessary to determine the optimum shade requirements for each area. The amount of shade necessary may also be influenced by cultural operations, particularly mulching and irrigation. It is noticeable that well-mulched plantings exhibit a greater degree of tolerance to wilting and exhaustion during the drier months.

The lack of adequate shade in most parts of the Highlands, especially below the 5,500 foot contour, results in premature cropping or overcropping of the coffee plant. Overcropping is primarily the cause of "die-back" and consequently biennial or triennial bearing. Wherever shade is used it affects flowering and tends to produce even crops in successive seasons.

Where the temperatures are too high and prolonged and the rainfall too low, the trees overbear their strength. The result is a bumper crop one year followed by exhaustion and "die-back", and at least two years of low yields. Shade has the effect of reducing the numbers of flowers produced to within the bearing capacity of the tree to crop without exhaustion.

In the Highlands the unshaded coffee plant rather than developing vertically tends to develop more of a compact shape. The spacing between the internodes become closer and the number of primary laterals arising from the main stem becomes greater. The increased lateral growth in itself presents an additional pruning problem that is not encountered on the shaded coffee tree. The numerous pairs of closely spaced primary laterals in turn develop a vigorous growth of secondary laterals close to the main stem, rather than developing in length and vigour as is expected with the primary lateral growth of shaded coffee trees. It is the excessive growth of primary and secondary laterals, particularly on immature trees, which predisposes the tree to exhaustion and "die-back". The coffee plant has not developed sufficiently to mature such a heavy crop. Part of the crop fails to mature and ripen and dies on the tree.

Where the coffee tree is grown with ample shade, or where the environmental conditions are not conducive to over-cropping, there is not such a profuse lateral growth. Also the internodal spacings are wider, and the primaries tend to develop more in length and vigour, rather than developing a premature excessive growth of secondaries and tertiaries. Thus in the early bearing years particularly, the tree has not an excess of bearing wood and so does not carry too heavy a crop to mature. Furthermore the trees will tend to bear an average crop each year, rather than developing a triennial cropping cycle of heavy and light yields.

To prevent overbearings and "die-back" with unshaded trees, crop stripping and

judicious and fairly constant pruning are necessary. Good plantation management aims at regular crops and a minimum of labour. Intelligent shade management will aid this aim and obviate the practice of crop and flower stripping, and undue pruning when the crop is considered too large.

It is recommended that both the temporary and permanent shade be planted as soon as possible after clearing and holing. The temporary shade will help to depress weed growth. Also it is desirable that the temporary shade provide sufficient shelter for the coffee seedlings when planted, otherwise shade shelters are necessary for each seedling.

Growers should bear in mind that it is much easier to remove shade from an area rather than establish shade in an area of established coffee plantings. Hence in the Highlands, when planting the larger tree species, an initial spacing of 18 feet x 18 feet is recommended. As the shade trees mature and the overhead canopy develops the trees may be thinned out and pruned to give the optimum amount of shade. The final tree spacing may be in the order of 54 feet x 54 feet. It is recommended that the permanent shades species be planted in the coffee rows, so as to allow easy access between the coffee rows.

Qualities of a Permanent Shade Tree.—

When selecting a suitable permanent shade tree it is desirable that the tree :

1. Have a long life.
2. Be leguminous.
3. Be strong wooded and not liable to wind damage.
4. Have a spreading habit and provide a filtered shade.
5. Be easy to propagate and able to stand pruning and lopping.
6. Should not be a tree which is a host for any of the serious pests or diseases of coffee.
7. Be resistant to insect pest and disease attack.
8. Have a tall growth habit to clear the coffee bushes, and a deep root growth system so as not to compete with the coffee bush for soil nutrients.

There is no tree available in the Highlands which fulfils all of the above desired requirements. The following descriptions cover the tree species used in the Highlands for coffee shade.

Albizzia stipulata is the Departmental recommendation and appears as the most suitable of the current shade species. It is fast-growing, leguminous species, with a spreading habit, fairly deep rooting and providing a filtered shade. It is relatively resistant to disease and insect pests, and stands lopping and pruning well. Easily propagated from seed and cuttings. However, it requires protection from strong winds as it is fairly susceptible to wind damage.

Observations indicate that the endemic *Albizzia* sp. commonly referred to as the Wabag Albizzia, is not very suitable. The trees have a massive and rather shallow root system, are inclined to be brittle, are subject to defoliation by mealybugs (*pseudococcus* sp.) and leaf-eating caterpillars during the dry season, and provide a dense rather than a filtered shade.

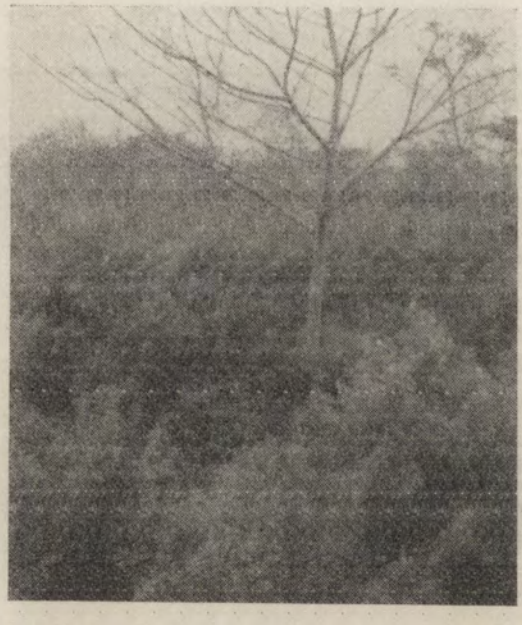
Another of the endemic *Albizzia* sp. occurring in parts of the Bena area appears preferable to the Wabag Albizzia. The former is feathery-leafed, very quick-growing, and it not at this stage subject to defoliation by the same insect pests defoliating the Wabag Albizzia sp.

The *Erythrina* species are not recommended as they lose their leaves during the dry season and are periodically defoliated by caterpillars.

Although some plantings of *Grevillea robusta* have been made, none of the plantings has developed sufficiently as yet to allow assessment of their value as a potential shade species. It is noted, however, that *Grevillea robusta* is a fast-growing species in the Highlands.

Although *Leucaena glauca* does well in the Wau district, altitude approximately 3,000 feet, it has failed to produce similar growth in the eastern and western Highlands. About 16 feet in height appears to be the limit of its growth. The growth rate is very slow compared with that at lower altitudes. Inoculation of *Leucaena* seed with strains of *Rhizobium* isolated from

Development of permanent shade "Albizzia stipulta" in coffee block. Shade 2½ years old.



Wabag "Albizzia" sp. as permanent shade defoliated by mealybugs and leaf eating caterpillars.

Leucaena at Keravat, apart from providing an initial growth response, has not improved the general growth rate of *Leucaena glauca*.

The common Highlands *Casuarina* sp. appears to be a suitable shade tree for coffee, especially after the coffee has become reasonably well established. In the Highlands wherever mature coffee is found growing under established *Casuarinas* the coffee bushes in most instances are very vigorous in growth and healthy in appearance. It is recommended, however, where *Casuarinas* are to be used as a coffee shade species, that there should be adequate soil moisture throughout the year, either from natural sources or irrigation.

Coffee seedlings in nurseries under, or in close proximity to *Casuarina* trees, make slow growth in the early stages of development. This is believed to be due mainly to the strong competition from the *Casuarinas* for soil moisture.

There is substantial evidence to indicate that some *Casuarinas* possess soil nitrogen-fixing properties. Also that the nitrogen content of the leaf fall is comparable with that of many leguminous tree species. Root nodules have been noticed on the Highlands *Casuarinas* species, believed to be *Casuarinas equisitifolia*.

Temporary Shade.—

For a temporary shade species the desirable characteristics are :

1. Leguminous.
2. Rapid growth rate of at least six feet.
3. Free seeding habit and seed easy to harvest.
4. Ease of establishment.
5. Ability to persist for at least eighteen months.
6. Resistance to pests and disease.
7. Ease of eradication when necessary.
8. Resistance to wind damage.
9. Not a host plant for serious coffee pests or disease.

Crotalaria anagyroides is the accepted temporary shade species in the Highlands. It is a quick-growing, leguminous shrub, with a prolific seeding habit, easy to establish, and is rather resistant to wind damage. Given moist conditions it will provide satisfactory shade and shelter within three months, and will persist as an effective shade and shelter plant for at least eighteen months. It is very susceptible to attack by Black Scale (*Saissetia nigra*) and the Crotalaria Leaf Mosaic virus.

Tephrosia candida is a woody shrub growing to a height of 12 to 14 feet. It is slower growing than *Crotalaria* but will persist for at least three years. It has not been used to any extent in the Highlands because of its slow growth and rather poor seed set for the first year or two. There is also evidence to indicate that it competes strongly with the coffee plant for soil moisture. This competition may have a retarding effect on the coffee plant during the drier months of the year.

Tephrosia vogelii is smaller than *Tephrosia candida* but has a more sprawling habit of growth. It is slow-growing and does not appeal as a temporary shade species.

Cajanus indicus (Pidgeon Pea). This plant grows very rapidly, attaining a height of five to six feet. It is not recommended as it is short lived compared with *Crotalaria* and *Tephrosia* and is very susceptible to insect attack.

Bananas are not recommended as a temporary shade species. They compete for moisture and soil nutrients, require extra management and are troublesome to eradicate once established.

Planting the Temporary Shade.—

The *Crotalaria* seed should be planted as soon as possible after the end of the dry season. If planted during October it will be eight to ten feet in height by the beginning of the following dry season, May-June. The recommended method is to plant the *Crotalaria* in parallel lines between the coffee rows. Shallow drills are made running parallel to the lines of coffee holes and the *Crotalaria* seed sown thickly in the prepared drills. It is advisable to dust the drills lightly with an insecticide prior to sowing to minimise attack by cutworms on the germinating *Crotalaria* seed. Aldrin No. 5 dust has proved very effective.

In some cases, every second row only of the *Crotalaria* is planted. Then as the *Crotalaria* begins to weaken towards the

end of its second year, the previously unplanted alternate lines are planted. The older *Crotalaria* rows are then removed and used for mulching between the coffee rows. This latter system of planting has proved quite successful and is gaining in popularity. Usually the *Crotalaria* is planted in a north-south direction so as to obtain the maximum shade benefit. However, should there be prevailing winds from a southerly or northerly direction it is advised that the *Crotalaria* rows run east-west, that is at right angles to the prevailing wind. Priority is thus given to the windbreak factor rather than the shade factor.

Previously in some plantings the *Crotalaria* was planted in the same row as the coffee and the permanent shade. This method of planting proved unsatisfactory as a result of the heavy incidence of Black Scale infestation on the *Crotalaria*. The waxy exudate from the Black Scale, by fall-

FIGURE 1 SHADE PLANTING DIAGRAM

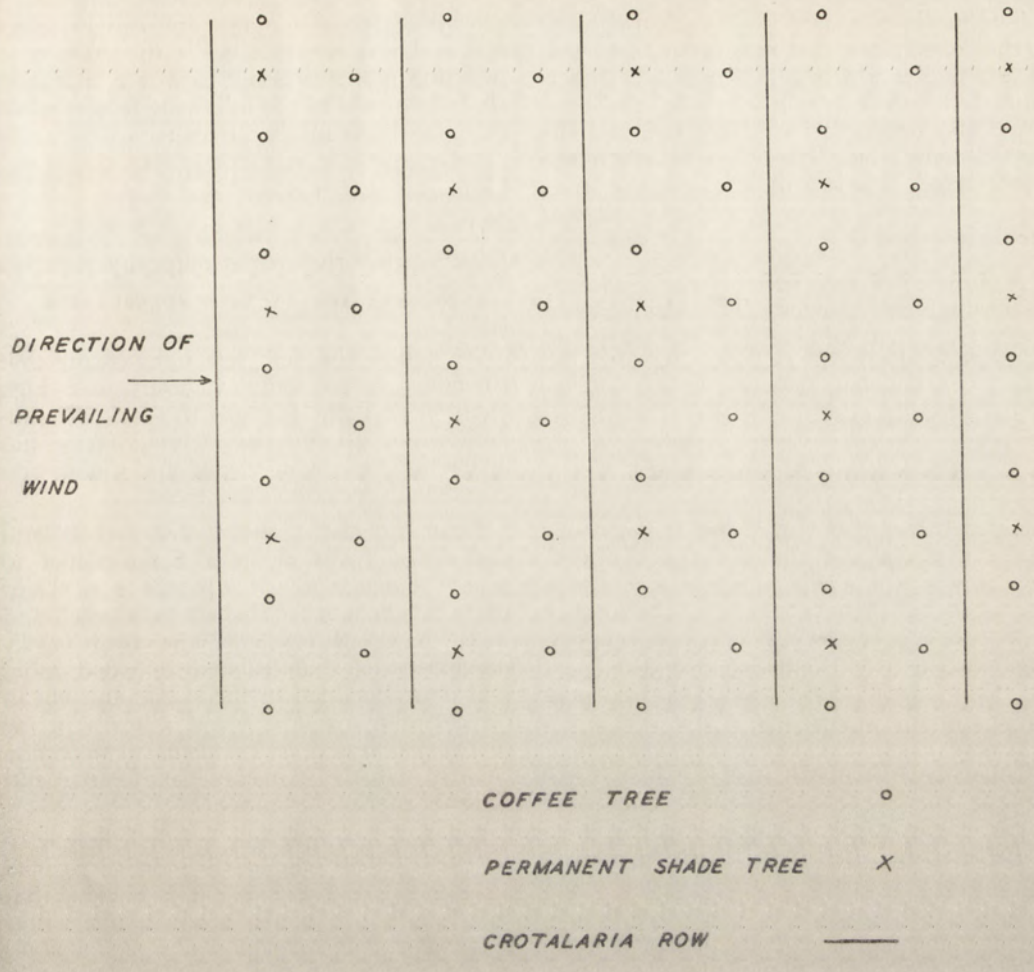


FIGURE 2 ALTERNATIVE SHADE PLANTING DESIGN

ing on to the leaves of the young coffee plants, resulted in the appearance of the Sooty Mould fungus on the leaves of the coffee plant. To a lesser degree Sooty Mould formation may also occur as a result of the presence of Green Scale (*Coccus viridis*) on the young coffee growth. As the *Crotalaria* ages and weakens it becomes heavily infested with Black Scale. The *Crotalaria* overhanging the coffee plant allows the exudate from the Black Scale to fall on to the coffee leaves, hence the attendant Sooty Mould formation.

The Sooty Mould by forming a surface film on the upper epidermis of the coffee leaves, minimises photosynthesis by the coffee leaf. In response the coffee plant tends to produce a spasmodic growth of numerous chlorotic suckers on both the main stem and laterals. The Sooty Mould disappears on removal of the *Crotalaria* or the Green Scale.

By planting the *Crotalaria* in between the coffee rows it can be trimmed so as not to overhang the coffee plants. This greatly minimises the incidence of Sooty Mould.

Windbreaks.—

Many coffee plantations in the Highlands are exposed to strong, prevailing winds at certain times of the year. The use of substantial windbreaks is strongly recommended in all such cases.

The mechanical and physiological damage to the coffee plant that may occur as a result of strong winds should not be underestimated. In extreme cases it has been noted that strong winds have stripped the new flowers from the coffee plant on the unprotected windward side of the tree. Hot, dry winds cause excessive wilting of the coffee leaves.

A number of tree species appeal as suitable windbreak species. The local *Casuarinas, Grevillea robusta* (Silky Oak), and *Eucalyptus deglupta* (Kamarere), are preferred. All are fast-growing, erect species in the Highlands.

Plantation Management.

Allowing that all the phases of the land preparation have been carefully and correctly completed, the foundations of a successful plantation are laid in the nursery and the growth of the tree during its first few years in the field. Correct nursery management and intelligent cultural practices in the field are the key-notes of successful plantation management.

Selection and Preparation of Seed.—

Propagation from seed is the commercial method of establishment for coffee plantings in the Highlands. The Department of Agriculture, Stock and Fisheries, has demonstrated methods of vegetative propagation. However, the high degree of self-pollination in coffee plants, plus the need for more testing of clones, indicates that it is unlikely that vegetative propagation will be used for commercial plantings for some time at least.

For a more detailed account of the current experimental work being conducted by the Department of Agriculture, Stock and Fisheries, with regard to the vegetative propagation of coffee, see "The Vegetative Propagation of *Coffea arabica* L." by A. J. H. van Haaren, *Papua and New Guinea Agricultural Journal*, Volume 10, No. 2, October, 1955.

Usually the seed is obtained from the Department of Agriculture, Stock and Fisheries. In some cases growers prefer to select local seed. In such cases it is usual to obtain seed from selected mother trees. As the coffee plantings in the Highlands are all of recent vintage, one cannot select old and proven trees, as is the custom in selecting mother trees. However, attention should be paid to the following factors when selecting local mother trees :

1. Select trees which are high yielding and have large beans.

2. Select trees which are vigorous. Observe that the tree is naturally vigorous.

3. Select trees which appear true to type.

In making the field selections ensure that the tree is naturally vigorous and high yielding and not because the lack of competition or some other helping factor has given the tree extra vigour and yield compared with neighbouring trees.

Fully ripened cherries are picked and pulped by hand or in a hand pulper to avoid damage to the parchment. Light beans are floated off and all malformed and small beans discarded. The fresh sticky parchment is then rubbed in wood ashes and partially dried in the shade and not in direct sunlight. The wood ashes adhering to the parchment skin, forms a protection coating which prevents hardening and splitting of the parchment.

For best germination results the coffee seed should be planted as soon as possible after the partial drying. It is obvious that the viability of coffee seed declines after some weeks of storage. The germination of old seed can be improved by soaking in water for twenty-four hours prior to planting.

Preparation of the Nursery.—

A flat or only gently sloping site, with a deep, fertile soil is recommended. Good drainage is essential. It is important that the nursery site be in a sheltered position but not under trees or permanent shade.

It is recommended that the nursery beds be five feet in width and of any convenient length. The five foot width is selected as it allows ample space for four rows of seedlings to develop fully in the nursery beds and be root-pruned prior to transplanting. Table 3 illustrates the planting designs for the seed-beds.

The ground should be well dug and freed of weeds, tree roots and stones, but care must be exercised not to bring the heavier

subsoil to the surface. For convenience the beds should be separated by three-foot wide pathways. To facilitate drainage the beds are raised about six inches above the path level using the top soil from the paths.

Protection of the seedlings from direct sunlight is essential. For convenience a framework of posts and crosspieces sufficiently high to allow the workers to stand underneath is recommended. The actual shade is then arranged by placing pit-pit, and other grass materials over the top of the framework and securing so as to prevent it from being blown away. The shade may be easily regulated by either removing or adding further shade material.

In cases where rough building materials are in short demand adequate shade shelters, no more than two feet high may be constructed directly over each nursery bed, leaving the pathways quite free. It is desirable that the shade shelters be completed prior to the planting of the seed.

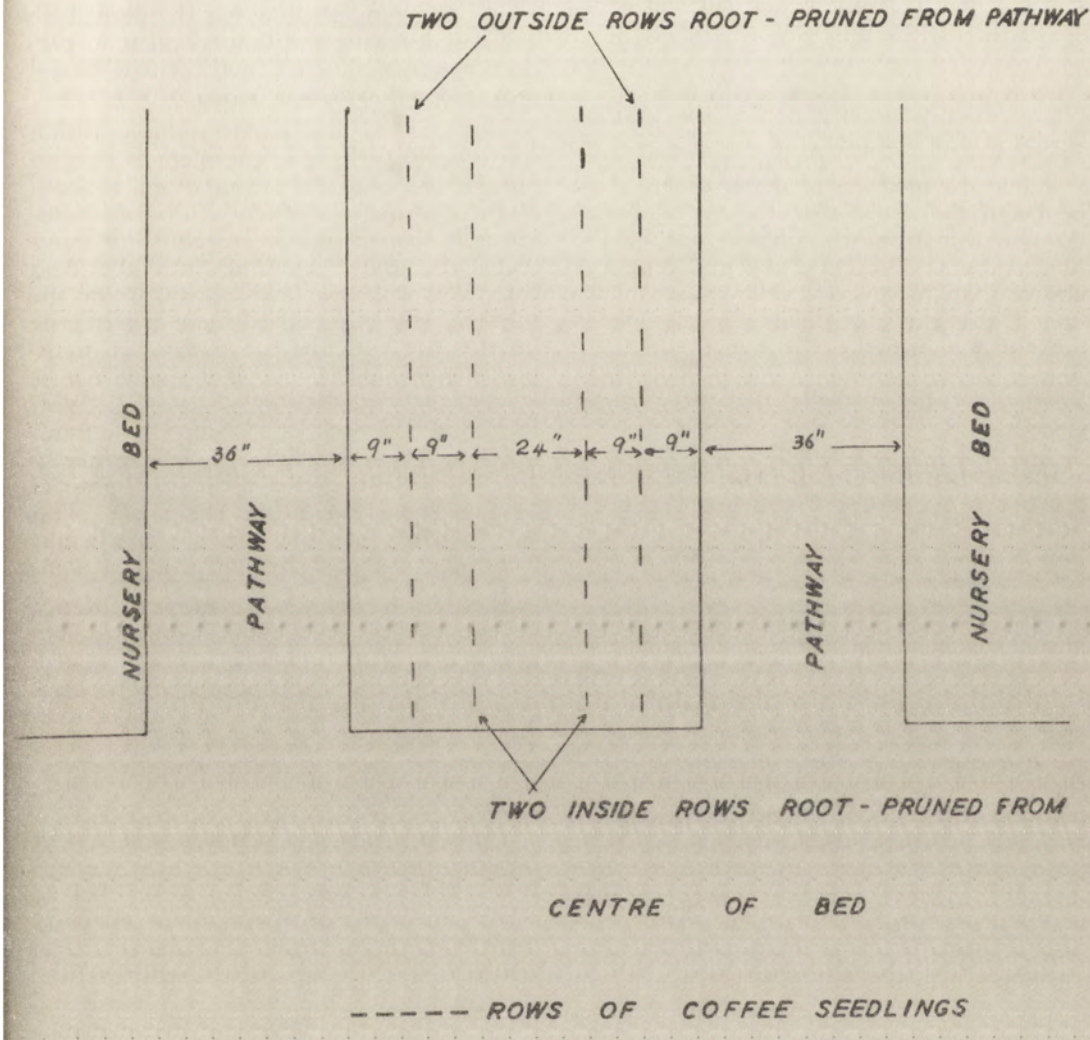


FIGURE 3 DESIGN FOR COFFEE NURSERY BEDS

Nursery Practice.—

The seed should be sown in drills with an interval of nine inches between the drills and the seed six to nine inches apart in the drills. The surface soil must be loose and the coffee seed should not be planted more than about half an inch deep. Too deep plantings result in delayed and spasmodic germinations.

Whilst the seed is germinating it is important that the nursery beds not be allowed to dry out. A complete mulch of fine grass will prevent drying out and packing of the surface soil. When the seedlings begin to emerge the mulch should be removed and the overhead shade increased. Germination normally occurs six to nine weeks after planting.

When the seed has germinated care must be taken to ensure that the young plants do not wilt from the drying out of the nursery beds. Watering and mulching will ensure that moist soil conditions are maintained. As the young plants develop, weed out any malformed or " off-type ' seedlings. Retain only normal, vigorous seedlings. Keep the nursery beds free from weed growth.

In East Africa and Hawaii the normal practice is to sow the seed thickly in the drills and transplant the seedlings to seedling beds as soon as the first pair of true leaves appear.

Whilst the seedlings are developing in the nursery close attention should be paid to the regulation of shade. Overshading will result in long, whippy seedlings, whilst the lack of adequate shade results in retarded growth, sunscorch and yellowing of the leaves. About two months before transplanting the shade should be gradually removed by stages until there is no overhead shade for a short time preceding transplanting. This is to harden-off the seedlings in readiness for field planting. The seedlings are usually left in the nursery for from twelve to eighteen months.

Six to eight weeks prior to field planting it is recommended that the seedlings be root-pruned by root-snapping. This practice was demonstrated by Y. Baron Goto during his visit to the Highlands coffee areas and is considered to be a procedure that should be adopted by all coffee growers, as it avoids the all too common complaint of " bench tap-root ". To root-prune, a spade is inserted into the ground about four inches from the base of the seedling. The handle of the spade is then tilted downwards slightly until a distinct snapping sound is heard from under the coffee seedling. The sound is the complete snapping of the root system of the seedling. The spade is withdrawn and the ground firmed down around the base of the plant.

The severance of the root system of the actively growing seedling has the immediate effect of inducing the injured plant to produce a tremendous regrowth of new lateral roots from the severed roots.

The mass of new roots produced within six to eight weeks is so complete as to completely bind and hold the sod of soil enclosed by the growing root system. On transplanting it is then a simple procedure to transplant the coffee seedling into the field complete with the sod of soil from the nursery. By this method there is very little interference with the root system on transplanting, wilting of the plant should not be evident, and the seedling should suffer very little initial setback as a result of the transplanting. Serious wilting of coffee seedlings after transplanting is a common feature of new coffee planting in the Highlands. This is due mainly to the varied transplanting techniques adopted by individual growers.

Should it be intended to adopt the Kenya system of either single-stem or multiple-stem pruning, it is recommended that the seedlings be capped in the nursery. The seedlings should be capped at no higher than fifteen inches from the ground and at least one month prior to transplanting.

Transplanting.—

The importance of careful and correct transplanting cannot be stressed too strongly. It would be no exaggeration to say that no other single phase of plantation establishment is more important than the successful transplanting of the coffee seedlings from the nursery to the field. For successful transplanting the following recommendations are of importance :—

1. Do not delay in transplanting.

Plant during the early part of the wet season to allow the coffee seedlings to

become firmly established before the onset of the dry season is expected.

2. Eliminate as much as possible the time lag involved in moving the seedlings from the nursery to the field.

The shorter the time lag the less likelihood there is of the seedling wilting and receiving a temporary growth set-back. Hence the advantage of siting the nursery as near as possible to the proposed planting area.

3. Ensure that the seedling root system is covered by wet hessian bags or something similar, during the time that the plant is out of the ground.

Do not on any account allow the young roots to be exposed to either sun or wind.

4. Prune any long tap-roots or lateral roots prior to planting. If planting in the sod, prune off any roots extending more than a few inches outside the sod.

Bench tap-root condition of young coffee plants.

By cutting back the tap-root the common fault of "bench tap-root" is eliminated. Bench tap-root is the direct result of the bending, at an acute angle, of the lower part of the tap-root when planting the seedling in the field. It is largely a result of hurried and careless plantings. Coffee seedlings so planted do not develop into vigorous trees. Outwardly they may appear to develop quite normally for some time but quickly wilt and evince signs of "die-back" during a dry spell or when bearing the first full crop.

5. Do not plant too deeply. This has been a rather common fault with coffee plantings in the Highlands. The result is usually debilitated, stunted plants or premature "die-back" of young bearing plants.

The coffee plant is essentially a surface feeder and when planted too deeply the surface feeding roots are poorly developed or may even be lacking altogether. Over-deep plantings can usually be detected in a plantation by their debilitated appearance and by shaking the main stem of the tree. In the case of over-deep plantings, there is quite a free sideways movement of the main stem when shaken. This is due to the poor development of the surface feeding roots after transplanting. Consequently the tree becomes undernourished and is loosely anchored in the ground.

6. Plant on a dull day.

Dull and calm weather is advised for planting. If the days are hot and sunny it is wiser to plant in the late afternoon.

7. Reject any weak, stunted or atypical seedlings and seedlings with a malformed root development.

8. Provide shade and shelter for the seedlings immediately after transplanting.

Immediately after transplanting, seedlings should be shaded and mulched and protected from winds. Should the temporary shades species be insufficiently developed, then temporary shelters of grass or pit-pit material should be erected for each seedling. A circular shelter giving wind protection is preferred to the roof-top or overhead shelters.

Pruning.—

Careful and correct pruning is a most important cultural practice for successful plantation management. Improper pruning can materially reduce yield and subject trees to biennial or triennial bearing, often resulting in "die-back". It behoves the grower therefore, to prune correctly for efficient annual production and healthy trees.

In the Highlands both the single and multiple-stem pruning systems are practised. Growers are adopting the Kenya and Hawaiian pruning systems, with various modifications, for both single and multiple-stem coffee.

Single-Stem Pruning.—

The important thing to be kept in mind during the first three to four years of the life of the coffee tree is that every care should be taken to ensure that the young growing tree develops strong lateral branches and a strong main stem. If the laterals are strongly developed in the early years of growth, then providing they are well cared for, they should bear a good average crop for many years.

Should the lower side branches (primary laterals) die right back to the main stem, they can never be rejuvenated or replaced at that spot. It is the lateral branches which bear the crop, hence every care should be observed in preserving these bearing branches and ensuring that they become strongly developed as they are the fruiting framework of the bearing tree.

Shaping the Single-Stem.—

1. The young seedling is capped at about fifteen inches above ground level. It is recommended that the capping be done in the nursery about one month prior to planting. At the same time it is advised that the two top primary laterals be cut back to just beyond the first pair of mature leaves. If this is not done the weight of the two top branches may cause the main stem to split at the top.

2. Capping the tree induces it to produce suckers. To ensure maximum development of the main stem and laterals, these suckers should be removed.

3. When the lower side branches have developed satisfactorily, one sucker is then allowed to grow up from the top of the capped tree. On reaching waist height, this stem is capped as before and the two top laterals cut back to the first pair of mature leaves.

Again it is recommended that no suckers be allowed to grow up after capping until the young primary laterals in the middle of the main stem are well developed. In East Africa is is recommended that no suckers be allowed to grow up for at least six months after capping.

4. Once satisfactory development of the upper side branches has been attained, then one sucker should be allowed to grow up as before. This is capped at approximately five feet from the ground.

Remember—

(*a*) Do not allow the tree to carry too heavy a crop while it is still immature—while the young root, stem and leaf systems are insufficiently developed to bear and mature a heavy crop.

(*b*) It is wiser to adopt a long term attitude and have a tree which has the strength and vigour to bear a good crop for many years, rather than a weak, low-yielding tree.

(*c*) Have sharp pruning implements and prune fairly close to a bud so that the wound heals quickly.

Pruning the Single-Stem Tree.—

(*a*) *Remove—*

1. All secondary laterals which grow out from the primaries within at least one hand's span of the main stem. This is to allow adequate aeration and light into the centre of the vegetative framework of the tree.

2. All branches that are growing in towards the centre of the tree or are not growing in the right direction.

3. All deadwood and all thin and whippy branches.

(*b*) Where secondaries grow out in pairs from the primaries remove one secondary so that at each node on the primary one secondary grows out alternately.

(*c*) Where tertiary branches grow out in pairs from the secondaries, remove also each alternate tertiary branch.

(*d*) Remove suckers before they become too big.

(*e*) It is recognized that the best framework for a single-stem tree is one that has widely spaced horizontal branches. If the primaries are too closely spaced, remove alternate ones to allow for ample light and aeration of the interior of the tree. This will also help to prevent certain insects from harbouring in the trees.

(*f*) During the wet season remove all new suckers and new secondary branches growing out close to the main stem. No other pruning is recommended for this time.

Pruning of the single-stem tree should have as its most important objective the preservation of the strength of the primary

branches as the tendency is for them to weaken with each successive crop and to lengthen their bearing tips too far from the main stem. If they are permitted to do this they grow spindly and droop. Successive prunings should aim at cutting back the overlong primaries to strong secondaries, thus arranging for secondaries to replace the primaries that have grown too spindly. Meanwhile, all the sucker growths that sprout from the main stem are pinched away at regular de-suckering intervals which should be sufficiently frequent to prevent these growths being more than a few inches long.

Hence it can be seen at once that the selection and thinning of secondary growths becomes a somewhat complicated pruning procedure, necessitating the use of intelligent and skilled pruners. Also it is a costly procedure since careful pruning may take upwards of ten minutes per tree for some trees.

Multiple-Stem Systems of Pruning.—

In the Highlands several multiple-stem pruning systems are being followed. Growers are adopting mutiple-stem systems, according to their individual preferences, based on either the East African multiple-stem system, a modified Agobiada system or a form of multiple-vertical pruning as practised in Hawaii.

East African Multiple-Stem Pruning.—

The vertical framework is developed by capping the young seedling at about fifteen inches from the ground, in the nursery or after planting in the field. Two suckers then develop on either side of the capped stem and usually other suckers will appear below. These suckers form the vertical growths.

The usual practice is to obtain three or four sturdy upright growths and have them growing up together about the same size and of equal strength. Should only two verticals develop from the capping, either one or both of the verticals may be topped to produce three or four verticals as desired.

As the verticals develop upwards the branches will be interlaced in the centre of the tree. However, as the verticals become taller the weight of the crop on their upper branches and the pulling of the pickers to reach the fruit soon forces the vertical stems to bend away from each other. Thus the centre of the tree is opened up and the interlacing branches are pulled apart.

As the upright stems become taller the lower laterals bear crops, become exhausted and are of no further use to the tree. They are then pruned away flush with the main stem. Hence as the uprights become taller they will become bare of growth further and further up the stem as the exhausted laterals are progressively removed. Only unproductive and dead wood is removed. Pruning is therefore quite simple and well within the scope of unskilled pruners, once they have been shown the fundamentals of the multiple-stem pruning.

In the multiple-stem pruning as distinct from single-stem, the main stems (verticals) are not capped. If the stems are capped they will tend to become too strong and woody. This is to be avoided as the stems cannot bend easily when carrying a heavy crop and may snap off under windy condi-

A nature single stem coffee tree showing excessive vegetative growth.

"Die back" of single stem coffee showing lack of shade, excessive lateral growth and dry immature cherries on leafless branches.

tions or when the crop is being harvested. As also with single-stem coffee, care must be exercised to ensure that the trees do not overcrop. Overcropping can be easily controlled by pruning further up the verticals.

After the stems have begun to bend away from each other with the weight of the crop, harvesting may be done with a short step-ladder or by pulling down the branches within reach. However, there comes a time when by the use of foresight and experience it will be seen that the old stems have grown too tall and spindly. Meanwhile, it may be seen that young sucker growths have begun to sprout from near the base of the tree. Those suckers that originate from too high up on the main stems should be pinched away. Of those growing near the base, one or two of the best may be selected to grow in succession to replace the old main stems. As these mature and grow upright in the centre of the bush, they will in turn begin to form laterals and it is at this time, that one or more of the older stems may be sacrificed and cut back to near the base, so that the younger verticals may take their place.

The aim is to cut back the older stems in succession, perhaps one each year, so that the younger verticals also replace them in succession, thus simplifying the pruning schedule. If sucker growth does not sprout of its own accord, then one of the main stems can be cut back a little earlier so that sprouts are obtained from its stump. Until new sucker growth does appear, it is advised that the main stem be only partly severed at the base by sawing about half-way through the stem and bending it over slightly. This will have the effect of inducing a more rapid sprouting of suckers. The main stem may then be completely removed by sawing right through the stem.

A young well developed multiple stem coffee tree.

Should it be desired to produce suckers on one side only of the vertical then remove nearly all the primary growth on that side only of the vertical. Suckers will then sprout from the bare side of the vertical. This method of sucker formation has been adopted in the Highlands to form new suckers on the eastern side of the stem. The young suckers are then not liable to leaf scorch as they are protected from the hot mid-day sun by the parent tree.

Agobiada Multiple-Stem System.—

The difference between Agobiada system and East African multiple-stem system is that the seedling is bent over and not capped to produce verticals for the first cycle.

In the Agobiada system the young uncapped seedlings are planted in the field and allowed to grow to about waist height. The tip of the main stem is then bent over and pulled down until it touches the soil and is fixed in this position either by being pegged down by a stout, hooked stake, or is secured to a peg fixed in the ground. Before bending over it is recommended that the lower laterals be pruned away, so that the sturdier portion of the bent arch is bare of growth.

It does not take long for new uprights to sprout from eyes along the bent portion of the stem. Three of the best that grow from where the arch begins and are evenly spaced, are selected to form the multiple-vertical tree. The growth of the new uprights is rapid and by the time they have in turn developed laterals, the arched stem of the original seedling has thickened and become set. It will not then spring back into an upright position when released. The original stem will also have grown longer and may have begun to curve upwards at the tip. Some of its laterals may have begun to bear a "fly" crop of fruit and under the true Agobiada system the tip would be released and would be allowed to remain as part of the tree. Usually, however, the old stem at this stage is cut back to where one of the new uprights has grown.

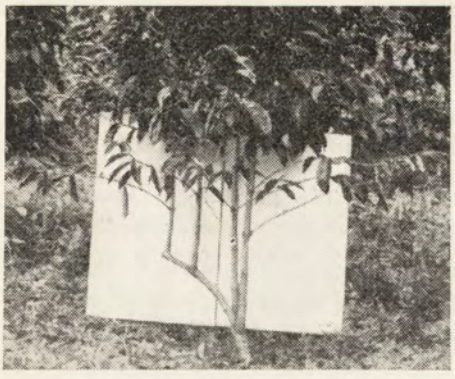
Subsequent pruning for the Agobiada system is identical with that for the East African multiple-stem system.

Hawaiian Multiple-Vertical System.—

The Hawaiian method of developing the multiple stem framework is somewhat similar to the Agobiada system. However, the Hawaiian practice is to plant the seedling in the field at an angle of 45 degrees. This has the effect of promoting a growth of verticals from near the base of the main stem. Thus the verticals for the first cycle of the multiple-vertical system are initiated.

Four verticals evenly spaced around the main stem are selected. All other verticals are then removed. When the selected verticals have developed sufficiently, the top of the original main stem is then cut back to the nearest upright.

Early development of a tree pruned to the Agobodia system.



Advanced development of a true pruned tree to the Agobodia system.

The four verticals are cropped for several years, then the least vigorous of the four is removed at the base. A new vertical is allowed to come up as a replacement. Basically then the pruning consists of removing one of the older verticals each year and allowing a new upright to come up as a replacement. This means that the tree is cropped and pruned to a four-year cycle, thus completely renewing the tree every four years.

An alternative system allows for six verticals in the framework. This system is recommended for areas favoured with higher rainfall and more fertile soils. The older verticals are replaced as in the former system but in the six vertical method, two verticals are replaced every other year and one each alternate year, so that the tree is again completely renewed every four years.

Other systems of multiple-stem pruning are practised in various coffee producing countries, but appear to be only of local importance and are not conducive to high average yields and good quality.

In theory the multiple-stem system of pruning is preferable to single-stem because the tree and its root system are constantly given vigour by the continued formation of new verticals. At the same time all weak and exhausted branches are removed so that they do not deplete the tree of its strength. This should lead to more regular yields and to heavier yields than single-stem trees.

Irrespective of the foregoing remarks, the multiple-stem methods of pruning are easier and far more economical to carry out, especially when pruners are not highly trained. Regular pruning is an essential phase of correct plantation management. It requires a certain amount of skill, plus time and labour. Hence serious consideration should be given to adopting a pruning practice that requires a minimum of labour and skill—one that is easily adaptable to the indigenous labour.

Conversion of Single-Stem to Multiple-Stem.—

Single-stem trees may be converted to multiple-stem by stumping-back.

Normally there will not be any laterals low down on the stem of the single-stem tree. Hence to convert such trees to multiple-stem, the tree should have all the primary branches removed except for a few at the top and no crop should be allowed on the branches that remain. The top branches will help to feed the roots until suckers have grown from the main stem, encouraged by the shock given to the tree by the removal of most of its primaries. To encourage suckers to sprout from the basal part of the tree, a fairly deep saw cut is made in the main stem just above where it is desired that the new suckers appear. In due course a healthy bunch of suckers appear around the basal part of the main stem. When these begin to form primaries the top part of the tree is completely removed by sawing through at the partly severed point on the trunk. Stumping should not take place until after the beginning of the wet season. At the same time

Advanced stage of development of first cycle of Hawaiin system of multiple stem pruning.

any surplus suckers are removed, leaving the three or more selected verticals spaced around the stump. A slanting cut is advised when stumping-back a thick trunk.

In this manner an old plantation of single-stem trees may be converted to multiple-stem in the safest way. Any one of the afore-mentioned multiple-stem pruning systems may be used after the verticals are established.

Basically then, the single-stem system relies on preventing a rapid upward growth of the main stem to final height and pruning to carry the crop on the secondaries and tertiaries, rather than on the primary laterals. On the other hand all multiple-stem systems rely on a rapid growth of the verticals and the crop to be borne mainly on the primary laterals.

When to Prune.—

There is quite a degree of variance among overseas authorities as to which time is considered the correct time to prune coffee.

In both East Africa and Hawaii it is maintained that pruning is most profitably and effectively done immediately after harvesting or during the semi-dormant period

Advanced development of a tree after conversion from single to multiple stem pruning.

Mulching of coffee showing bundles of grass being carried into the block.

following the harvest when rainfall is lowest. In regions where the harvesting period may continue throughout the year, as in cooler higher rainfall areas, it may be necessary to prune at various times. The alternative opinion is that the coffee tree be pruned shortly after the main flowering, when the trees have formed small, immature fruits. However, all authorities agree that trees suffering from "die-back" should not be pruned until the onset of regular rains.

It is recommended when pruning both single and multiple-stem coffee, that only light prunings are required, except perhaps in the case of trees that have not been pruned for several years. Heavy pruning is apt to upset the balance of the tree. In single-stem trees particularly, if the tree is topped and the lower primaries always pruned severely, then they respond by producing extra leaf and lateral growth, at the expense of flower and fruit formation. Hence the need to prune carefully and as little as possible.

In the Highlands the time of pruning would appear to be one of trial and experiment for the present and may even vary slightly for different centres in the Highlands. Perhaps the best time for pruning would be after the heaviest cropping period and before the main flowering. Although this time may vary slightly throughout the Highlands, present indications are that it would be between the months of June and September.

Mulching.—

Mulching of coffee plantings in the Highlands is strongly recommended, particularly in view of the protracted dry season that may be experienced in Highlands coffee areas.

Mulching combines the functions of suppressing weed growth, maintaining a cooler soil temperature, prevention of soil erosion, addition of plant nutrients to the soil, conserving soil moisture and assisting the penetration of moisture at depth and so replenishing the subsoil reserves. Compact and eroded soils resist moisture penetration but mulching tends to renew soil structure and to create absorbent properties in the soil.

Experience in East Africa has indicated that while it is essential that there be sufficient moisture in the subsoil all the year round, it is also beneficial to the coffee plant that the topsoil be dry for part of the year. An indication of this is that alternate row mulching has been found to give better returns and healthier trees than complete mulching. In alternate row mulching each alternate row is mulched once a year and the remaining rows the following year. A repeat procedure is followed in succeeding years.

The surface roots of the coffee tree appear to favour drier conditions for part of the year to permit the nitrogen content of the surface soil to be stepped up and to slow up growth, ripen the wood and initiate flower buds. In alternate row mulching this object is achieved without allowing the soil to become fully dried out.

The coffee pulp itself is a very valuable mulch and fertilizer and should always be returned to the coffee field as it is rich in the essential plant foods, nitrogen, phosphoric acid and potash. It is suggested that the coffee pulp be placed around the base of the coffee plant. The parchment skin has some use as a mulch but no value as a fertilizer.

In the Highlands several grass species appeal as being very suitable for mulching. *Themeda gigantea* (Giant Kangaroo Grass) is excellent for mulching purposes. It is very vigorous, easy to cut and provides a large bulk of mulching material. It also does not tend to break down as quickly as some of the less vigorous grass species.

Pennisetum purpureum (Elephant Grass) introduced from Kenya is a suitable mulching grass. It is quick and vigorous in its growth habit and can be cut back several times a year. It prefers rather moist conditions for best growth and should be allowed to dry out well before being laid as it grows readily from cuttings.

Imperata sp. (Kunai) is useful for mulching, although it does break down very quickly after being cut and laid in the field.

Banana trash, where available, is a useful mulching material, as banana trash contains

a high percentage of potash which is generally considered necessary for fruit formation.

The best time to apply the mulch is during the first few months of the wet season, October to January. Then by the beginning of the dry season the subsoil has adequate moisture reserves for the dry season, with the mulch forming a retentive layer on the surface. It is estimated that approximately three acres of grassland are required to mulch one acre of coffee adequately.

Cover Cropping.—

In the light of overseas experience plus limited local experience, it would seem that cover cropping is not to be recommended in coffee plantings, particularly where the annual rainfall is below 75 to 80 inches per annum, as it then becomes very necessary to implement more rigorous moisture conservation practices. There is little reason to doubt that in the Highlands cover crops would seriously compete with the coffee plant for soil moisture during the dry season.

As a matter of interest, the following results were obtained with extensive experiments carried out in both Brazil and East Africa, designed to compare the value of cover crops, clean cultivation, mulching and non-weeding in coffee plantings. In both instances mulching gave substantially greater yields than any of the other cultural practices. In sequence clean weeding was superior to permanent cover cropping and this in turn was superior to weed growth cover.

Weed Control.—

The problem of weed control in Highland coffee plantings presents a major problem, particularly during the wet months of the year. A vigorous, luxuriant growth of fleshy annuals such as *Galsinoga parviflora* and *Bidens* sp. presents a constant weeding problem.

As mentioned previously it is positively known that weeds compete with the coffee plant for moisture and plant nutrients. Coffee is a surface feeding plant, consequently weed growth offers serious competition to the coffee tree. It is illogical to assume that weeds can benefit the crop, even when the weeds are periodically cut and mowed and left in the field. Nutrients from the weedings or mowings become available rather slowly. On the other hand when fertilizing coffee plants, the ground covering weeds will absorb the bulk of the fertilizers before the coffee plants can benefit appreciably. Fertilizing weedy plantations will benefit the weeds more than the coffee.

Some of the more selective weedicides, particularly Dalapon, have been proved very effective in controlling weed growth in the Highlands and do not appear to be injurious to the coffee plantings. However, as weedicides are rather expensive to purchase, including Dalapon, it is doubtful at this stage whether herbicide weed control would prove to be more economical than hand weeding or any other means of mechanical or manual weed control. The effectiveness of mulching in suppressing weed growth has already been emphasised.

Fertilizing.—

Observation to date indicate that fertilizing of coffee plantings in the Highlands does produce appreciably increased yields and more vigorous trees even on the best coffee soils. The most marked responses have been obtained from complete fertilizer applications. The mixture currently being used is a Shirley's mixture containing 10 per cent. nitrogen, 5 per cent. phosphoric acid and 20 per cent. potash, 10-5-20.

Departmental fertilizer trials conducted on three plantations in the Goroka area confirmed the above observations, namely, that the most pronounced growth responses were obtained from complete fertilizer separately with the exception of nitrogen, applications. The major elements used did not produce marked responses.

Where coffee trees are suffering from exhaustion and " die-back " it is evident that the application of complete fertilizer or sulphate of ammonia hastens rejuvenation of the tree. Experience in East Africa and Hawaii has demonstrated that a nitrogenous fertilizer applied shortly after the beginning of the wet season and again near the end of the wet season, has proved to be of sound economic value. In the former case the coffee tree is growing vigorously and requires ample nitrogen to support and carry the leaf growth and to mature the crop. In the latter case the tree has matured the crop

and is usually in a weakened or exhausted condition. The application of a nitrogenous fertilizer at this stage enables the tree to survive the dry season more easily and so prevent "die-back". The above nitrogenous fertilizer applications are supplied in addition to the normal complete fertilizer applications, but not at the same time. The continued application of sulphate of ammonia is liable to increase the soil acidity and so reduce the availability of minor nutrients. This danger may be averted by using substitute nitrogenous fertilizers alternately with sulphate of ammonia. Nitro-chalk, sodium nitrate and urea can be used instead of sulphate of ammonia.

The coffee tree in production is a heavy feeder on the major elements required for plant growth. Tests conducted in Brazil have shown that one ton of green coffee removes from the soil approximately—

95 lb. of nitrogen.
18 lb. of phosphorous.
101 lb. of potassium.

These figures in fertilizer equivalents are—

475 lb. of sulphate of ammonia.
90 lb. of superphosphate.
203 lb. of sulphate of potash.

The economies of fertilizer costs and current coffee prices justify rather heavy fertilizing. In the event of coffee prices becoming appreciably lower the margin between input costs and output returns may on some of the Highlands coffee soils at least, make fertilizing a doubtful economic proposition.

Irrigation.—

In the lower rainfall areas of the Highlands and in seasons when severe dry months are experienced, irrigation of coffee plantings should prove beneficial.

The amount of irrigation necessary will be determined to a degree by the nature of the soils and other moisture conserving practices, including mulching and shade intensity. Irrigation should be regarded as a means of replenishing the reserves of subsoil moisture and not the surface soil moisture.

Overseas authorities contend that if it is possible to dispense with irrigation, then it is best avoided. The time of application of the irrigation is rather important as irrigation may induce out of season flowering. However, in low or marginal rainfall areas where it is essential for the continued health of the trees, results in Brazil have shown that irrigation may give significant yield increases.

Pests and Diseases.

Fortunately for the coffee industry in the Highlands no serious insect pests or diseases of major importance have appeared to date. The main insect pests and diseases present in the Highlands and causing some damage to coffee plantings and shade species, are :

1. Coffee Stem-Girdler Weevil. (*Cryptorrynchus* sp.).
2. Defoliating Weevils. (*Oribius destructor*), (*Oribius hostis*).
3. Coffee Leaf-Roller Moth. (*Homona coffearia*).
4. Scale Insects—
   (*a*) Black Scale (*Saissetia nigra*).
   (*b*) Brown Scale (*Saissetia haemispherica*).
   (*c*) Green Scale (*Coccus viridis*), (*Pulvinaria* sp.).
5. Brown Eye Spot (*Cercospora coffeicola*).
6. *Crotalaria* Leaf Mosaic Virus.

Coffee Stem-Girdler Weevil. (*Cryptorrynchus* sp.).—

The small greyish-black coffee stem borer weevil is potentially the most serious coffee pest recorded to date. Damage to the coffee tree is caused by the larvae tunnelling under the bark of the main stem in a circular direction so as to completely girdle the tree. In some instances the larvae tunnels just under the bark, whilst in other cases the tunnel extends right into the heartwood of the tree. Usually the stem is attacked between ground level and the first pair of primaries, although attack may extend further up the main stem so that the tree may be girdled a number of times.

The top part of the tree immediately wilts and in some cases dies. Because also of the ringbarking, the main stem is weakened and may snap off at the point of

Damage caused by the coffee Stem-Girdler Weevil with resultant growth of suckers below the damaged area.

ringbarking. Usually the main stem below the area of attack remains quite healthy and vigorous and produces a growth of suckers as the top part of the tree wilts and often turns yellow in colour. The tree can be rejuvenated by selecting one or more of the suckers and allowing them to grow up and form the framework of the new tree. Not many trees are killed outright as a result of attack from the Stem-Girdler Weevil. However, attack does result in a serious setback in growth and consequent loss in yield.

Departmental investigations to date have indicated that a fair degree of control and prevention of attack from the Stem-Girdler Weevil may be obtained by applying 0.5 per cent. Dieldrin spray to the main stem of the coffee tree, particularly at the beginning of the life cycle when the larvae are less than two millimetres long.

Defoliating Weevils (Oribius destructor, O. hostis).—

These are small, black, grey-striped weevils, the adults of which cause severe shot-hole damage to the coffee leaves. Infestation by these weevils is usually greatest where areas of fences of pit-pit (*Saccharum* sp.) are near the coffee plantings.

The adult weevils are highly susceptible to 0.2 per cent. D.D.T. spray.

Coffee Leaf-Roller Moth (Homona coffearia)—

The adult of this moth lays its eggs on the surface of the coffee leaf and then rolls the leaf over to protect the eggs. The larvae on emergence feed on the coffee leaves. As the larvae prefer tender, young leaves, heavy infestation by this pest may cause extensive damage to the young vegetative growth of the plant.

The larvae are effectively controlled by spraying with 0.25 per cent. D.D.T. or 0.05 per cent. Dieldrin.

Scale Insects.—

Green Scale (*Coccus viridis*), (*Pulvinaria* sp.).

Brown Scale (*Saissetia haemispherica*).

Black Scale (*Saissetia nigra*).

Infestation of coffee plants by either the Green Scale or Brown Scale is not very

serious, as the scales are fairly effectively controlled by the three predatory Coccinellids (ladybirds).

Callendra sp., *Orcus* sp., *and Menochilus 6 maculatus*.— L

Black Scale rarely occurs on coffee. It is important because of its heavy infestation of *Crotalaria* and the attendant Sooty Mould formation on the coffee leaves. Although the Black Scale is parasitised by two ladybird species of the genus *Orcus*, infestation of *Crotalaria* by *Saissetia haemispherica* is steadily increasing.

Brown Eye Spot (Cercospora coffeicola).—

Attack by this fungus is typified by brown circular spots, with concentric rings, appearing on the leaves of the coffee plant. The incidence of Brown Eye Spot attack is greatest either where the coffee plants are in a weakened or debilitated condition, or where there is little or no shade. Brown Eye Spot is easily controlled by providing edequate shade and shelter and by improving the general health and vigour of the plants.

Crotalaria Leaf Mosaic Virus.—

Although not a disease of coffee the leaf mosaic virus is worthy of mention because of the increasing incidence and severity of attack on the temporary shade species, *Crotalaria anagyroides*.

The occurrence of the leaf mosaic virus is appreciably reducing the shade usefulness of *Crotalaria* as it reduces the leaf size, growth rate, life span and general vigour of the *Crotalaria* plant and renders it more susceptible to heavy infestation by Black Scale. The leaf mosaic virus is much more serious in the Goroka area than in other areas of the Highlands. In the Goroka area the expected life span and shade usefulness value of *Crotalaria* has been reduced by at least one year as a result of the heavy incidence of the leaf mosaic virus. It is suspected that a species of *Thysanoptera* or one of the aphid species may be the vector of the virus.

Harvesting.

For top quality coffee it is most important that the harvesting and processing operations of plantation management be carefully and correctly carried out. The producer, therefore, must aim for the best quality fruit that can be produced. Only carefully applied cultural practices can achieve this end. Once harvested, the quality of the bean cannot be improved by subsequent processing, although it may be reduced in quality through improper processing.

The most important point to remember with harvesting is that only full rope cherries should be picked. Immature and over-ripe coffee is of inferior quality and cannot be improved by processing. As the coffee crop does not mature and ripen at the same time in all centres of the Highlands coffee picking at one centre or other continues more or less throughout the year. There is, however, a flush period in which the bulk of the coffee crop is harvested. The flush period does appear to be during April and May. Over the three-monthly period, April-May-June, most of the Highlands coffee crop is harvested.

Yields vary considerably from one locality to another and even on different areas of the one plantation. Bourbon trees appear to be higher yielding than typica trees, and the multiple-stem trees higher yielding than single-stem trees. Although no long-term yield figures are available, authentic yields from fifteen to eighteen hundredweight per acre have been recorded. The average yield for the Highlands over a number of years is expected to be considerably lower.

Processing.

As mentioned in the remarks pertaining to harvesting, it is of paramount importance that the ripe cherry be carefully and correctly processed from the cherry to the green coffee stage. For Territory producers to command a premium price for their product, either in Australia or on the world market, it is essential that they establish a name as producers of high quality coffee. Processing more than any other phase of plantation management is responsible for the finished product, the green coffee bean.

Pulping.—

For high quality coffee it is strongly recommended that the picked cherry coffee be pulped on the day on which it is harvested, not later than twelve hours after picking if possible. Delays in pulping may

result in a slight fermentation of the cherry pulp. This in turn may result in discoloured sour beans—characteristics that are detrimental to coffee quality.

It is considered advantageous for the cherry coffee to be dumped into a well-filled receiving tank prior to pulping. This is referred to as the flotation method and allows the grower to separate dried coffee, immature coffee and over-ripe cherries, which will float, from the better quality ripe cherries which will not float. The floaters can then be processed separately.

The pulped bean will always have a percentage of cherry skins and smaller sized imperfectly pulped cherries which often contain peaberries. This material is passed on to smaller pulper which is more closely adjusted and usually referred to as a re-passer. The bean from the re-passer may contain a high percentage of peaberry. As peaberry coffee demands a higher price it is advisable to process and market the peaberries separately.

It is important also that the pulper be adjusted correctly, so that it is not too tight or some of the beans may be nicked and damaged during pulping.

Fermenting.—

There are a number of ways in which the mucilaginous layer covering the parchment skin may be removed. These include natural fermentation, chemical or mechanical demucilaging, enzyme action, and hot water demucilaging. However, as natural fermentation is the only method of mucilage removal used commercially in the Highlands, it is not intended that the alternative methods be discussed in any further detail.

Natural fermentation consists of placing the freshly pulped coffee in a fermentation vat where fungi and bacteria decompose the mucilage to a soluble material which is readily washed off with water. The fermentating vats are usually made of either timber or concrete.

It is important that a relatively large volume of pulped coffee be placed in the vat, at least two feet in depth, so that heat from the fermentation process will not be readily lost and so increase the time of fermentation. The length of time required for fermentation depends upon the prevailing temperatures. In the Highlands it may be from 36-72 hours at least. Fermentation is faster if the fermenting vat is not full of water. Most of the water should be drained away so that the pulped coffee lies in its sticky state.

Great care should be taken to ensure that the coffee is not over-fermented and that it is washed and drained of moisture as soon as fermentation is complete. This can be determined by washing a handful of beans from the fermenting vat. If the beans are no longer slippery and have a gritty feeling, then fermentation is complete. In over-fermentated coffee a sourish or vinegary odour is perceptible.

It is very important that the coffee be washed immediately with clean water as soon as fermentation is complete, otherwise improper drying may result. However, should the coffee be washed before all the mucilaginous matter is removed, then the parchment tends to become dirty and discoloured. It is still somewhat sticky and is liable to pick up a taint or a slightly different taste derived from the juices of the pulp as is continues to ferment and ultimately dries on the parchment skin, giving a liquor that is designated at " under-fermented ".

Hence the necessity for strict cleanliness in the pulping operations, careful supervision of the fermenting process and thorough washing of the coffee at the correct time. Every means should be taken to see that unripe, over-ripe or light coffee cherry is pulped separately from the good, sound ripe cherry. Pulp skin which passes through the pulper should not be allowed to flow into the fermenting tanks with the parchment.

Drying.—

As soon as fermentation is completed and the wet parchment thoroughly washed, the coffee beans are dried. This may be done either by sun-drying or in artificial hot-air driers, or a combination of both methods may be used.

Until fairly recently it was considered that the highest quality coffee could be obtained only from sun-drying. In the light of more recent experiments and experience and improved techniques, it seems that good quality coffee, as good as sun-dried, can be

obtained from a combination of both machine and sun-drying. Machine drying by rotary driers is quicker than sun-drying but care must be exercised to ensure that each batch of dried coffee is uniform and that it is neither under-dried nor over-dried.

As the coffee bean dries it changes colour to a dull dark colour, then finally to a bluish-green colour. Hence the name green coffee. As the bean dries it shrinks within the parchment shell and the silver skin loosens. The beans may be tested for hardness by biting. If they are not quite dry, they will give to the bite. If they are dry they will break when bitten hard enough. When the parchment is completely dry it may be kept in dry storage without harm, either bagged or in bulk, to await hulling. The parchment coffee should not be kept too long in warm humid climates. Also the bagged coffee should not be in direct contact with a concrete floor. It should be stored on a wooden floor, preferably a few inches above the ground. The usual loss in weight from draining to drying coffee is about 40 per cent. The final moisture content of the dried bean should be between 11-13 per cent. Beans with a high moisture content will turn an opaque white colour upon storage. Such beans are unacceptable for good quality coffee.

Sun-drying should take from six to nine days. It should be done slowly at first to avoid a bleached bean colour. It is better to have the drying area situated on high ground, where the air is dry and breezy and sunshine is plentiful. Raised drying trays are preferable to barbecues. The parchment should always be protected from showers of rain and heavy dews.

The ultimate colour of the beans depends upon thorough and even drying. If the beans are wetted or re-absorb moisture during drying, loss in colour and quality will result. The dried beans may have a spotty appearance.

With sun-drying the parchment coffee should be turned frequently so that it dries uniformly. It should not be laid more than one inch thick when placed on the drying trays. As the parchment dries the depth may be increased slightly.

In artificial drying the temperature factor is most important, particularly if the temperatures are too high. Overseas authorities maintain that the temperature should not exceed 80-85 degrees centigrade and that slow drying up to 48 hours is preferable. The usual practice is to sun-dry for several days and then complete the drying in a hot-air drier. Alternatively, the parchment may be partially sun-dried, then machine-dried, and then dried off for one day in the sun afterwards to complete the drying process. Immediately after drying, the parchment coffee should be allowed to cool down before it is bagged or stored and before it is hulled.

In the Highlands, although weather conditions will usually favour sun-drying it would seem a sound policy for growers to make provision for mechanical drying facilities, should unseasonable weather conditions prevent adequate sun-drying. Also sun-drying entirely, on a large plantation, would mean that a very large drying area would be required. Semi-dried coffee is subject to moulding and even fermentation, if the moisture content is not low enough, thus resulting in a poor quality coffee.

Hulling and Grading.—

The hulling of parchment coffee is called shelling or peeling, and is the process in which the parchment and silver skin covering the green bean are removed. There are several types and sizes of machines for these operations. The parchment and the silver skin are removed and the bean is polished, either at the same time or in a second machine working in tandem. Adjustment is necessary for different kinds of coffee, so that two machines are normally used, one for shelling and the other for polishing.

Polishing is aimed at removing all traces of the silver skin and imparting a shine to the coffee bean. A shiny surface gives the bean a more attractive appearance, though coffee is sold more on cupping and roasting qualities to-day than on appearance.

Once the coffee is hulled and polished, it is graded to size in mechanical graders. The peaberry beans are also separated from the flat beans. The coffee can then be further graded through machines designed to separate out the lighter and heavier

beans. Much the same result may be obtained by hand sorting after the mechanical grading. On the world market the size of the bean is not so important. Rather, what is required is a uniform sample of beans with a few imperfections in the sample. In the United States trade the grades range from No. 2 to No. 8. Coffee grades lower than No. 8 are not permitted into the country.

With respect to the Territory coffee production. which to date has been disposed of in Australia, grading has not been a very necessary phase of processing. The Highlands arabica coffees, because of their limited supply and good raw beans and whole roast appearance, have commanded premium prices. Australian buyers have not discriminated to any degree with the different grades of Highlands coffee. However, should world coffee prices drop appreciably and Territory production increase considerably, there may come a time when New Guinea arabica coffees will not be in such demand on the Australian market, unless they are of a consistently high quality and grade. This should point to a greater emphasis by Territory growers on correct processing techniques, and more thorough grading and sampling of the coffee bean.

Marketing.

After the coffee has been processed and graded, it is then bagged and labelled for marketing. Double bagging is recommended as a worthwhile insurance against careless handling and storage during shipment. The filled bag should not weigh more than 180 pounds. Bags should be numbered and marked clearly with the name of the plantation and the grade of the coffee. This is a trade mark and may be of considerable value to the owner if it is favourably recognized.

Territory arabica coffees to date have been sold privately or through agents, to buyers in Sydney and Melbourne. Before being purchase by the buyers, the coffee is sampled and tasted for qualities, by liquorers. The raw coffee is first examined and although its weight and evenness are taken into consideration, the colour is considered most important. Australian buyers prefer a bluish good even green colour, with no indication of brownness, which is indicative of faulty drying or humid storage. The bluish-green colour is preferred as it is reputed to be indicative of high liquoring qualities.

It is of interest to note that recently liquorers in both Australia and overseas have advised that the use of B.H.C. (benzene-hexachloride) insecticides, for example, Gammexane, in coffee plantations, is liable to result in a " bricky " flavour in the liquor of the processed bean. This may result in a downgrading of quality.

Australian importers consider that the well-processed Highlands coffee has a good raw bean and whole roast appearance. The former means that the colour is good and generally of even appearance. The good whole roast appearance indicates a very even colour in the roast, with the absence of light or pale beans. The liquor is considered fairly coloury compared with the good quality Kenya bean but is said to lack the full-body of the Kenya coffee.

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