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SOME INVESTIGATIONS ON COCO-NUT DISEASES ASSOCIATED WITH SOIL CONDITIONS IN NEW GUINEA.

(*Continued.*)

R. E. P. Dwyer, B.Sc.Agr., Economic Botanist.

In the previous instalment of this article (*New Guinea Agricultural Gazette*, Volume 5, No. 3, December, 1939) an account of some investigations and observations on occurrences of physiological disorders of coco-nut palms was presented. Particular attention was paid to investigations of maturation wilts of young coco-nut palms recorded from various parts of the Territory of New Guinea.

A further contribution on the subject is now presented. Some physiological derangements of mature coco-nut palms, particularly from those plantations situated on the deltaic and estuarine deposits on certain areas of the New Guinea mainland, are described, together with the contributory causes. These occurrences are compared with similar diseases recorded from other countries. The chemical and physiological changes, especially as regards moisture requirements and potash movements, which occur on coco-nut palms at various stages of growth are indicated and discussed in relation to the diseases described. An account of several other diseases and derangements of coco-nut palms, associated with unfavorable soil, moisture and nutritional relationships, are also discussed. The employment of proper cultural methods in the control of coco-nut diseases, especially those of physiological origin, is indicated.

CHEMICAL AND PHYSIOLOGICAL CHANGES IN THE COCO-NUT PALM RELATED TO MATURITY.

According to Sampson[24] who furnishes the most complete analyses on the coco-nut from this point of view:—

> In the case of *nitrogen* the heaviest demands are made on the resources of the tree quite late in the development of the fruit, i.e., within the last six weeks or eight months. Nearly 75 per cent. of the nitrogen removed from the tree when the ripe fruit is harvested is to be found in the meat of the nut. Analysis shows as regards *potash* that the demand for this commences early in the development of the fruit. The quantity of potash in the meat seems to be greatest at the time when the meat is being laid down after which it seems to be reduced, when no longer required for this work. The supply of potash seems to be readily forthcoming when it is required. It is probable that this being a more soluble salt than most other plant foods, there is much more elasticity in the supply, it being taken away from other parts of the plant, resulting possibly in the retardation of growth for the time being, and brought to where its presence is essential. (The significance of this in relation to a maturation wilt is self-evident, when the potash is transferred from the fronds to the developing fruits.) Potash is required in large quantities by any rapidly growing part of the palm. Such growing parts are always present. The bud or "cabbage" is continually forming new leaves and these leaves are all the time expanding. In the axis of each leaf a flowering branch is normally formed, and this in its turn has to grow very rapidly until the flowers expand. Even after this it continues to grow rapidly as the fruit which it carries are swelling and the meat within the fruit is forming. All these places show a concentration of potash. In the leaves also large quantities of potash are required especially in the young plant. The plant, however, is able to remove a large part of the potash from any working part of the plant, as this gets past work. Thus in the young tree not yet in bearing, it is seen that there is 41 per centum of potash in the ash of the tender leaf which is growing. In the fully developed green or working leaf there is only 18 per centum.

It has been shown by numerous investigators with temperate fruits and other crops, that the proportions of carbohydrates (sugars, starch and cellulose) to nitrogen (i.e. the carbohydrates/nitrogen ratio) greatly changes at the time of blossoming and fruit setting. How far this is true of coco-nuts does not appear to have been determined, but the indications are that great changes do occur at the first fruiting phase of young coco-nuts.

In most plants the daily rate of water utilization is low in the vegetative stages of growth, but increases rapidly as the plants reach maturity.

The "cabbage" on a young palm, six years old, has easily the lowest percentage of dry matter, but practically double the percentage of ash found in any part of the plant at that age.

In the young palm, of the same age as above, the percentage of dry matter is low in the trunk; about 9 per cent. according to Sampson and increases to 49.30 per cent. in the bearing palm. There is an increase of dry matter also in the leaves but this is not nearly so marked between the two stages as for the trunk.

There is a significantly higher percentage of phosphoric acid in the ash of a young palm than in that of a bearing tree and apparently this element has most use in the young developmental stages. Experiments in this country have shown that it must be seldom that phosphoric acid deficiency symptoms develop in a coco-nut palm here. On some of the western islands, however, where phosphate deposits occur, very high yields of coco-nuts are obtained. In spite of this, single applications of phosphatic manures on old palms here have given no results, which appears to conform with the experiences elsewhere.

Many coral-derived soils under tropical conditions are low in lime content, due to excessive leaching of the surface layers. This is one factor which leads to their stickiness and liability to water-logging. In some places, applications of quick-lime, freshly slaked lime, or coral sand often give excellent results in increasing the yield of coco-nuts. In addition to its direct effect on the texture of the soil, this element has use in replacing potash in the soil and thus liberating this for the use of the crop. The probable significance of this fact in connexion with the disease at Namatanai (New Ireland) is thus clear, if it is known that there is heavier demand on the potash supply at the time the palms are coming into bearing. The soils there are of coralline derivation being acid or lacking in lime, until the actual limestone layer is reached, in addition to having low values for actual potash content.

In Bangalore, India, studies and analyses[33] to determine the plant food requirements of coffee at the bearing stage gave some very valuable results, which may be applicable to the coco-nut palm. A known number of coffee spikes, blossoms, set-buds and berries was collected, month by month, over a period of thirteen months and analysed for the essential plant foods, organic matter and carbohydrates, especially sugars. It was found that a large amount of potash was required and stored in the spike and blossom, prior to setting, and that this potash became distributed as the berry developed after setting.

The phosphorus requirements of coffee seem to be very steady and uniform, being about one-fifth the nitrogen content throughout the course of its development.

Coffee seems to require a steady and increasingly available supply of nitrogen throughout the course of its growth, not only to supply the ordinary nitrogen requirements, but, also, to maintain the nitrogen/carbohydrate ratio, which influences, in no small measure, the successful ripening of the fruit. This shows that the practice of applying complete fertilizers in certain stipulated proportions is well supported by physiological reasons. These experiments, although more specific in their objective, bear a close resemblance to Sampson's results from detailed analyses of different parts of the coco-nuts at varying stages of maturity.

Symptoms of Potash Deficiency.

Eckstein, Bruno and Turrentine[12] in their book on *Potash Deficiency Symptoms* state, " a characteristic of potash hunger signs is that they usually first become noticeable after a certain period of growth of the plant is reached (*see* page 6). After a certain time, where potash is lacking, the plant attains a stage in which its potash content becomes so low that a normal functioning of metabolic (building up) processes is no longer possible and pathological phenomena develop. The symptoms of potash hunger are, therefore, variable with the different ages of the plant. Since the metabolic processes of the plant are also dependent on the weather, light, temperature and humidity, the signs of potash deficiency under otherwise equal conditions will be manifest in variable form and extent under different conditions of climate. Since potash has a very high degree of efficiency, typical potash starvation signs occur only after an extreme degree of potash deficiency is reached."

It will be seen that bronzing, yellowing, leaf spotting and die-back (similar to the appearance of leaf scorch in fruit trees) may represent extreme conditions of nutritional disturbance, whether due to actual manurial deficiency or to insufficient water and contained nutrients reaching the growing portions of the plant.

It is only possible to give a very brief *résumé* of the findings that potash deficiency exerts an unfavorable influence on the water utilization of the plant. This is due to this element causing both impairment of water absorption through the roots and increased loss of water through transpiration, which decreases the ability of the plant to withstand drought.

According to the authors quoted above, " in plants suffering from lack of potash the shoots develop at the expense of the roots; the latter are usually more seriously damaged than the aerial part of the plant. The production of secondary roots and lateral growth of the roots are materially injured. The relationship between transpiration and potash nutrition (supply to the plants) are the biggest factors in the impairment of the water economy of the plant, when potash is deficient. The presence of potassium tends to reduce the loss of water by transpiration and increase absorption. Lack of potash causes greater loss of water and wilting typical of potash starvation results."

Wallace[31] has shown that potash deficiency has a greater influence on the root development of biennial and perennial plants than on annuals. It has also been demonstrated by several workers that the relationship between "potash deficiency" and "parasitism" (disease attack) is especially pronounced in perennial plants.

The general symptoms of potash deficiency in plants are that the leaves lack substance, hang down limply and the general appearance gives an impression of weakness and feebleness. Thus it is seen that such deficiency can lead to a condition closely approaching "leaf droop" without the appearance of outside organisms. It is a curious phenomena that plants suffering from potash deficiency at first go a darker green than in the case of a healthy palm, a phase which lasts for some time.

In more advanced stages, "leaf scorch", "necrotic and dark spotting", with leaves hanging down limply are common symptoms observed. There is collapse of supporting tissues in the leaves, and the root system is reduced. Finally, there is increased susceptibility to diseases, pests and climatic factors.

This discussion on potash deficiency symptoms only touches on the subject, as it has long been known that there must be a proper balance between the manurial constituents present, both in the soil and in the plant. As may be expected, the potash/nitrogen ratio is of the utmost importance in the nutrition of the plant. It is for this reason mostly that the results obtained from the use of balanced and complete fertilizers (applied in certain definite proportions) are much greater than those where single fertilizers only are used.

The degeneration of the midrib cells of the coco-nut fronds showing streaking, at Namatanai, may be due to cell dissociation caused by manurial deficiency (potash relatively low according to analysis), exaggerated by unfavorable water and nutritional relationships at the time the palms were coming into bearing.

Wallace[31] has shown that the nitrogen-potassium ratio is of the utmost importance. A wide ratio increases leaf scorching, while a narrow ratio reduces it.

Bain[2] as a result of analyses of very young palm leaves, from palms growing on both healthy and wilt areas, stated that "any differences which showed up were considered to be secondary to the seemingly more important water factor."

His general conclusion was that there was a high nitrogen status in wilt areas shown by leaf analyses, particularly in relation to phosphate or potash according to soil type. It was important to note that Bain found in some wilt areas that the percentages of potash in the young leaves were greater than in those from the healthy area.

Soil analyses or leaf analyses, considered by themselves, do not give anything like a full picture of the problem. The percentage amounts of potash and other nutrients found in various parts of the palm (especially when it is switching from the vegetative to the productive phase) are not nearly so important as the total amounts required for new growth and fruit production at critical periods. It is the sudden demand for water and nutrients normally required by a young palm, coming into bearing, not being met under unfavorable conditions of soil and climate, which leads to pathological symptoms.

There may be lack of balance of nutrition between nitrogen, potassium, phosphoric acid, and lime (or calcium) and magnesium. It is pointed out that there may be plenty of potash present in the soil, but it is not available to the plant, owing to lack of balance with the other nutrients present, unfavorable water relationships (which may be seasonal), or other causes. The largest proportion of the plant is built up with water, from the soil, and carbon dioxide, found in the air, through the action of sunlight on the green colouring matter or chlorophyll (photosynthesis). In this manner, starches, sugars, celluloses, fats, oils, plant acids and other compounds are synthesized. The direct nutritive effect of the water on the building up of carbohydrates (carbon compounds) and the necessity for respiration is not often stressed in relation to wilting and cell break down. Without recourse to actual figures it is absolutely certain that there is a tremendous increase in the total amounts of carbohydrates (starches, sugars, &c.), and oils synthesized at the time a coco-nut palm is coming into bearing, hence, there is a greater demand for water.

It is obvious that as far as coco-nuts are concerned there is plenty of room for research on the subjects indicated.

Potash Movements Only.

Sampson's Figures[24] (Condensed and Tabulated).

"*Analyses of the different Parts of a Coco-nut Palm about Six to Seven Years Old (not yet bearing) compared with a Bearing Palm*".

—	Root.	Stem.	Stipules.	Petioles. (Leaf stalk).			Leaflets.		
A. Young Palm % K_2O	.14	.50	.051	av. 74 (.12 old, 1.78 tender)			av. 1.08 (.55 old, 2.01 tender)		
B. Bearing Palm % K_2O	.29	.21	.034	av. 26			av. .56		
Percentage of K_2O (Potash) in the ash				Old.	Green.	Tender.	Old.	Green.	Tender.
A. Young Palm ..	3.33	10.89	2.68	3.92	4.24	34.60	13.75	18.13	40.94
B. Bearing Palm ..	8.27	3.91	3.50	av. 4.17			av. 13.08		

In comparing analyses of an inflorescence about to open with a similar inflorescence after the kernel of the fruit is formed, it is found that there is more than double as much potash in all parts of the young inflorescence, as compared with the older one.

The percentage of potash in the inflorescence (Spathe about to open) is, on a "barren" palm, 15.80 per centum, compared with 20.46 per cent. in a bearing palm.

Physiology of the Root System.

In order to give a better idea of the problem a very brief account of the root behaviour of coco-nuts is given. Copeland[5–6] and other authors have dealt with such physiological problems in detail.

All roots of the coco-nut palm have an impervious, rigid shell called the "hypodermis" which protects their structures, and gives them a very strong anchorage in the soil. The main horizontal spreading roots are like stout cords and both they and their larger branches bear numerous fine, much-branching roots which, in turn, may branch into much finer roots. The coco-nut palm has no root hairs, but the life history of their finest roots, like the root hairs of other plants, is very transitory.

The zones through which absorption of water and nutrients takes place is usually limited to the young growing part of the root, which has thinner epidermal or outer layers and thus allows the moisture and soil nutrients to be absorbed by osmosis. This zone is relatively short and is usually seen extending for just a few inches behind the hardened root-cap.

When the new growth of the roots is checked by dryness or other causes, the hardened, rigid shell (hypodermis) present on the older part of the root, tends to grow right up to the root cap and, thus, naturally limits the absorbing zone under unfavorable conditions.

As soon as the soil becomes wet again the roots revive, new root elongation occurs and absorption begins anew, through the thin, epidermal layers of the new portions or replaced roots.

The numerous, raised, light-coloured, outgrowths seen on the surface of all coco-nut roots are breathing organisms ("pneumatophores", really specialized reduced roots), through which the air supply to the roots and low internal system of the plant is maintained. These cannot function below the free water surface or in water-logged soils and, consequently, roots, growing under such conditions, either cease functioning or die altogether.

No roots will grow any distance into water, nor into a level of the soil where free water stands, also a rise in the water-level ultimately kills submerged roots. Sandy soils or pumice soils are naturally drier than heavy clay soils, and, in such free soils, the roots tend to grow deeper and maintain a deeper level than in stiff soils.

Duthie[8] says that, "as coco-nuts normally grow on poor soils (e.g., on sea-shores and coral atolls), it cannot be argued that potash and phosphate are the limiting factors present". This statement refers to a description of coco-nut wilt found on an acid clay soil, markedly deficient in available potash and phosphate, but with adequate nitrogen and organic matter.

It must be argued, however, that where the root system is restricted, manurial deficiencies, such as those indicated, must behave as important contributory, or inter-acting, limiting factors. Where palms are growing on poorer soils and are flourishing, it is because the proportionately greater and deeper root development in the loose sandy soil gives the roots access to a greater "total" of nutrients than where root growth is limited by heavy clays, or a high water-table. Further, in such free, sandy soils, found at the seashore, it is usual to have plenty of water available to the palm, which is charged with nutrients derived from the higher foothills and soil formations further inland. Under all circumstances, lack or exhaustion of nutrients will be felt, but it will have a much more pronounced effect where a restricted root system limits the total amount of moisture and nutrients available in an already deficient soil. That the nutrient content of the soil is most important in maintaining the healthy production of coco-nut palms is well illustrated on Witu Island, where the volcanic soils are very rich. There coco-nut palms are heavy yielders in areas where the soil is no more than 12 inches to 15 inches deep and rests on new volcanic rock which entirely restricts the root-growth below that level. This would not be possible in a soil deficient in nutrients.

Copeland[6] investigated, in detail, the water relationships of the coco-nut palm during drought conditions. It was found that after a prolonged drought in one district of the Philippines, it took palms two years to recover. He commented that "the injury to the palms' vitality during a prolonged drought is so severe that the return of favorable weather conditions is but slowly followed by resumption of normal activity. When adequate rains come the roots must awaken from a defensive rest, in which a prompt response cannot be expected. A constant supply of water must be at the disposal of the coco-nut, or it will protect itself against injurious desiccation by a partial suspense of vitality".

Rooting of the Palms and the Necessity for Root Adjustment.

Soil conditions, such as those described in this article, undoubtedly lead to shallow rooting, except where the soil is well drained by creeks or main drains. Whether the roots go deeper or not they can only take up limited supplies of nutrients below the water surface, also the fibrous roots and smaller roots tend to die off in zones of poor aeration, as aeration is necessary for water and nutrient absorption. Thus, although plenty of water is present, conditions of physiological drought and reduced nutrient supply may occur, even though there are plenty of manurial ingredients present in the soil. If, by any chance, previous cropping with exhausting crops or lack of the main essential ingredients (nitrogen, phosphate, calcium and more particularly potash) is in evidence, this effect may be increased. It is seen that soil analyses are of great assistance in solving disease problems associated with soil nutrition.

Such causes as those indicated above can lead to cell collapse and breakdown, as for example some forms of bud-rot caused by unfavorable soil and moisture relationships, mainly, have been recorded from many sources. In the change-over period from wet to the dry season, where soils are liable to waterlogging and compaction after drying out, there is decided necessity for root adjustment. This often has marked physiological effects which are reflected in the behaviour of the palms. There is too much moisture in the wet season which leads to reduced nutrient intake and loss of roots. It is likely that in the dry season (particularly in abnormal periods), there is too little moisture present which, owing to compaction of the clay and the fact that the clay does not give up water quickly, would also lead to upset of the palms. The roots could be expected to grow and function better as soon as more rains are received, hence, in a plantation subject to a seasonal bearing, the best yield should be obtained from the beginning to the middle of the wet season.

It is feasible to believe that some form of seasonal adjustment is the natural behaviour of all coco-nut palms, excepting where the water-table exists at a relatively constant depth in a friable soil.

This root adjustment only leads to pathological symptoms becoming apparent under abnormal climatic conditions (e.g. too much or too little rainfall), where the soil and water-table do not favour normal root development.

It appears likely that seasonal bearing, nut-fall, leaf-droop, and often loss of palms (such as is found in coco-nuts growing on the Madang coast) may be due to fluctuating climatic and soil conditions affecting the behaviour of the roots and thus the water and nutrient supply to the palms.

Moisture Requirements of Coco-nut Palms.

No work has been done on this problem in New Guinea, but a good deal of investigation has been carried out in the Philippines.[6-11]

In making injection experiments the writer observed when introducing culture solutions through numerous ¾-in. auger holes, which were about 4 inches deep and sufficient to hold 50 C.C. of water at one time, that hundreds of grammes of water were taken up, almost as quickly as they were introduced, on bright, sunny days. In the early morning and on rainy days the rate of absorption was very slow.

During a long wet season, when there are numerous consecutive cloudy days, moisture absorption and utilization by the plant are greatly reduced, despite the abundance of water present. In the dry season the rate of absorption is greatly increased, as is the transpiration. The palms have natural adaptation in the leaves for regulating transpiration to some extent.

The pinnae (leaflets) are adapted for folding longitudinally and thus lessen transpiration by protecting the stomata (breathing organs, found in the leaves) from undue evaporation. There are no water storage organs found in the coco-nut palm, such as are found in numerous other plants.

Espino and Juliano[11] carried out detailed investigations on the absorption of culture solutions by coco-nut palm roots. They showed that the rate of absorption was 233.33 per centum more rapid during rainless days than during rainy days. The wind makes a decided difference in the transpiration of the leaves, but makes a much greater one when the leaves are in full sunshine, as is more usual in the dry season.

Copeland[5-6] reports that a coco-nut palm can absorb 24 litres (54 lb.) of water per day, from root absorption experiments, but from determinations of evaporation from the leaves, he is inclined to place the figures at from 28-45 litres.

Espino and Juliano (*loc. cit.*) from a different set of calculations place the water requirements as 16 litres (36 lb.) per day.

Whatever figures are correct, they are all of a high order and explain why palms flourish so well at low levels (sea-shores and islands) in the tropical zones.

The annual requirements of a coco-nut palm requiring 36 lb. per day would be 13,140 lb. and for one requiring 54 lb. per day would be 19,710 lb. Thus the requirements per unit area (acre or hectare) are constantly very high.

All investigators agree that there is a very close correlation between absorption and transpiration. The absorption of nutrients by the palm depends on two sets of factors—those that occur inside the plant (physiological) and those that occur outside the body of the plant (environmental). Among the important factors determining absorption are the age, the health of the plant, and all of the factors which govern the rate and amount of transpiration.

The amount of transpiration depends upon the temperature and humidity of the air, rain, wind-velocity and the growth activities of the plant.

Where unfavorable moisture conditions occur, and in times of severe drought, the older leaves fall off or die back with unusual rapidity. It has been proved that the older leaves are the ones which would lose the most water; the tree cuts down its water requirements in this way, to a very considerable extent.

In several instances here, when the palms were growing under unfavorable conditions, or during abnormal weather periods, one has seen the ground literally littered with leaves. There is a tendency for this fall of leaves to occur within a very short space of time under certain conditions.

When root growth and absorption are greatly reduced, as usually follows physiological droughts, or dry periods, then the whole of the top growth is reduced proportionately. It may happen that the growth slows up completely or is reduced to such a degree that the fronds fall off altogether. If the conditions are permanently unsuitable, premature ageing of the palms may result, unless the soil conditions are improved.

It seems feasible that "leaf-droop" occurs where the moisture and nutrients supply of the palm are greatly reduced, so that the palms tend to shed a high proportion of their leaves to balance the absorption to the supply available. Where the palms are not sufficiently vigorous to shed their leaves, or where their vigour has been further reduced by other contributory factors, e.g., fungus attack, then these leaves remain attached to the palm in the familiar manner already described in the previous article on coco-nut diseases.(9)

Duthie(8) compared the soil moisture relationships in soils from healthy beds and those carrying palms liable to wilting . In the case of the heavy, clay soils under investigation he concluded that the slow lateral movement and availability of the moisture in compact, clay soils were key factors leading to the appearance of the diseases. It is not the gross moisture present in the soil, but the amount of available moisture which is most important. The wilting point in a clay soil may occur when there is more than 13 per centum moisture present in that soil, especially where there is a high percentage of salts (sodium, magnesium).

Such salts when present in high concentration hinder absorption through the roots. Physiological and chemical analyses of the New Guinea soils are very lacking as far as such data is concerned. It is pointed out that as the percentage of water to dry matter in a young palm is much greater than that in an older palm, the water requirements of a young palm, in proportion to its size, are greater. This helps to explain the greater susceptibility of young palms to drought conditions. Copeland(5) maintains that proper physical composition of the soil is of a great deal more importance than its chemical composition, if only the palms are able to secure sufficient water. It appears that both are important but the physical relationships of the soil are not usually given sufficient prominence.

Restriction of Water Supply Due to Disease and Injuries.

Waterlogged soil and fluctuating climatic conditions which are often not optimum for the growth of the coco-nut palms favour insect and fungus attack.

The bleeding fungus (*Thielaviopsis paradoxa*) does most damage in wet situations and often causes hundreds of lesions to develop on the trunks, some of which become large and deep seated. Even though the palms recover from such attacks a good deal of conducting tissue is destroyed, which naturally reduces the water supply to the palms.

Thread Blight (*Corticium penicillatum*), as a general rule, only assumes serious proportions under wet conditions, in wind-locked areas. This fungus destroys the fronds and reduces water absorption under conditions where maximum leaf area is required for the palms to flourish.

"Frond-fall" and "leaf-droop" which are usually most prevalent in waterlogged and deficient soils, both lead to a reduction of the total number of fronds and reduce the water supply to the palms. Where the fronds fall off prematurely the soft tissues are exposed to beetle attack. After severe beetle attack half the diameter of the trunk may be destroyed and, although the palms recover, the water and nutrient supply to the palms are reduced for all time.

Severe burning off, such as is practised on some plantations here when the undergrowth is out of control, in addition to burning the humus from the soil, destroys the superficial layers of the palm trunks. This greatly reduces the water conducting tissues. The influence of such diseases and injuries as those outlined, greatly aggravates the effects of adverse climatic and soil conditions on the general health of the palm.

MATURE PALM WILTS AND OTHER PHYSIOLOGICAL DISEASES.

There are mature palm wilts and other physiological derangements of coco-nuts present in New Guinea which are due to palms growing on soils with unsuitable profiles, which are subject to waterlogging in the wet season and to drying out and compaction in the dry season. In mentioning instances of this, some very good examples are to be seen on the mainland of New Guinea, in parts of the Markham Valley, near Lae, and in the plantations around Madang, located on estuarine formations. Similar occurrences have been noted in the Kavieng districts, also in Manus, and the Admiralty Islands, on varying classes of soil, but more especially where stiff, clay-soils overlying coralline limestone are present. The question is whether these mature palm wilts are to be classed in the same category as "maturation wilts" where the particular stage of growth and the change in the chemical composition of the plant itself comes so much into play.

The late Dr. H. R. Briton-Jones has clearly recognized the difficulty in classifying wilt diseases of coco-nuts in his second treatise on the subject.(4) He remarked that "the causes of the unsuitability of the conditions for coco-nuts in different soils may be entirely different. In one case, it might be due primarily to the physical texture of the soil, whereas, in another, it might be due to the chemical composition of the soil or even to a combination of certain physical and chemical factors".

This appears to indicate the crux of the position, and, further, it indicates how this problem of wilt diseases is so closely related to deficiency problems as a whole and to the retrogression of coco-nut areas, which is becoming more and more common in plantations here.

It seems a safe deduction that the soil profiles, the climatic environment and the cultural conditions in New Guinea would seldom duplicate those found in the West Indies, hence we may expect different responses from the coco-nut palms under the particular circumstances prevailing here.

It would appear that coco-nut wilts of the "bronze leaf" type are not nearly so severe or prevalent in this country as in the West Indies. Certain of the external characteristics of the diseases described in this article do not seem to correspond with those described by Briton-Jones,[4] Bain,[2] Duthie,[8] and others.

The possible explanations as to why coco-nut wilts are not common here are many, as, for example, most parts of New Guinea are classified amongst the wettest tropical countries in the world. Except on some areas of the mainland, the soils are all geologically new where coco-nuts are grown.

Culturally, in New Guinea, sugar-cane is never intentionally replaced with coco-nuts or vice versa, and interplanting coco-nuts with sugar-cane is not done. In very limited areas coco-nuts planted here may have replaced small areas of native-grown cane for edible purposes or patches of wild canes.

Briton-Jones, in 1928,[4] decided that there were two forms of the root disease (wilting) of coco-nuts recorded by Stockdale[28] and Nowell[17] in Trinidad, which he named, respectively, "bronze leaf wilt" and "yellow leaf" or "tapering stem wilt". In the former the leaves are a highly-coloured yellow to bronze or may assume a reddish-brown colour. The latter is distinguished by a yellow discolouration of the leaves progressing from the tip backwards, while all the leaves, including the central ones, become dwarfed, and it is a chronic malady whose history and effects have not been worked out. His observations in Trinidad and some of the other West Indian islands led to the opinion that the onset of "bronze leaf wilt" is in the majority of cases due to physiological drought, which does not need a prolonged period, but may become evident after a short, dry period under certain soil conditions, especially where the soil is heavy, badly drained, and subject to desiccation in the dry season.

The soils on which the disease is serious were said to be generally heavy, in very bad tilth and constitutionally such that they do not drain well, but dry out rapidly and crack in the dry season. The very definite correlation between lack of drainage and the incidence of the disease indicated that any organism present was a secondary factor, and the primary cause is suggested very strongly as a soil factor.

The general wilting of coco-nut palms often seen after a long spell of dry weather in portions of New Guinea (e.g., the Gazelle Peninsula, New Britain), with usually a subsequent recovery when the rains occur, shows some features in common with the above occurrences. It is, however, usually seen on light, porous soils with poor water-holding capacity. The lower leaves do brown off and wither, but these palms immediately respond to good rains. This browning off after a drought and subsequent recovery is not the same as bronze wilt and does not explain the conditions met with at Kokopo and Namatanai and elsewhere in New Guinea.

Park[19] refers to the effects of "drought" on coco-nuts in Ceylon. He first suspected bud-rot infestation, as one estate of 100 acres contained 600 dead or dying palms. The standard of cultivation on the estate was poor, and it was found that the condition was due to the effects of drought, while the buds fell off from mechanical causes only. He stated that "the condition was comparable with 'bronze leaf wilt' disease recorded by Briton-Jones, in Trinidad".[4] The condition was worst on low-lying land, liable to water-logging in wet weather, due to this water-logging causing the palms to become shallow-rooting. The effects of good cultivation were marked under these conditions, and drainage to induce deep rooting was advocated.

Patel[20] says that, "in the red soils of India, palms suffer through drought in the summer. It is possible that some mineral nutrients available in the soil may not be absorbed by the palms, because of some limiting factors such as moisture".

Briton-Jones[4] experimentally reproduced bronze leaf symptoms in healthy palms, under suitable conditions, by digging trenches around them. Another very interesting experiment was where he induced some leaves on one side of a palm to turn to a bronze-yellow colour by cultivating on that side to a depth of 3 inches, thus cutting the root system within the cultivated area.

According to Bain,[2] "bronze leaf wilt" is considered to be a physiological die-back of the palm, as a result of water deficiency in the plant. After a long investigation, he concluded that "the 'Trinidad wilt' was due to the curtailment of root growth by a high water table at certain times of the year, followed by dry seasons, which the restricted root system could not withstand and function properly".

The close approximation of the soil conditions described and the development of this type of root-growth in palms growing in certain areas of the Madang coast, as described elsewhere, are worthy of note.

It is seen that certain soil factors, particularly water-logging, which militate against the plant producing an effective root system, operate in wilt areas, and it has been clearly indicated that bronze wilt may occur in several types of soil. It would appear, therefore, that the factor to be particularly stressed in this disease is a water deficiency in the plant, the differences in nutrient status being considered as contributory factors. The disease should be extra prevalent in a dry period, following an abnormally wet season, and apparently field observations have confirmed this. It will be shown elsewhere in this article that many other disease symptoms found in coco-nut palms in New Guinea are worst under the particular conditions mentioned, as one may naturally expect.

It was been recorded that,[2-8] "in all plantations where 'bronze leaf wilt' was noted in Trinidad, the palms were planted generally at what appears to be just about half the proper distances apart (about 15 feet and in some cases 20 feet)". The range of spacing of coco-nut palms on the main plantations in New Guinea is from 25-36 feet, and is usually about 30 feet.

Curiously, the occurrence in young palms at Namatanai was on areas where the spacing was rather wider than usual, at about 36 feet. The only places where close planting is resorted to here are on the native groves, where frond choking does occur owing to light competition, but wilting appears to be very rare.

Bain[2] says that "the usual age at which palms die from the disease is from 15 to 18 years". If this is the period at which palms come to the bearing stage there, it seems that the palms come to this stage much later than in this Territory, probably owing to the late planting and the different soil conditions, &c.

Duthie, writing on "Coco-nut Wilt, in the Essequibo and Pomeroon Districts of British Guiana",[8] says that "Bain's findings explained the puzzling fact that trees grow normally for several years, as even a relatively small root system is sufficient to keep young trees in good health, but the strain of bearing is usually the critical point. Trees 15 to 25 years old are affected on the Essequibo coast and the symptoms are almost identical with those in Trinidad. The disease occurs both on clay and sandy soils."

His investigations were confined to the clay soils and he found the wilt occurring on an acid clay, markedly deficient in potash and phosphate, but with adequate nitrogen and organic matter. It was shown that the accumulation of saline substances (magnesia and soda) in the subsoil of the wilt area indicated lack of aeration and drainage, even though the soil was not waterlogged.

The following conditions were listed as leading to wilt in British Guiana:—

The widespread cultivation of sugar-cane led to large areas being changed from bush to sugar-cane—a shallow-rooted grass crop which exploits the top 18 inches of the soil and leaves the lower layers free from roots. The wilt disease of coco-nuts on the heavy, clay soils of the Essequibo coast is probably caused by planting coco-nuts on old cane beds where the sub-soil is too compact and saline to allow easy root penetrations, with the result that the top soil becomes a mass of roots and the percolation of water is greatly hindered. The trees are thus living on the verge of drought, and the effects of physiological drought were also important owing to the high content of moisture and soda even in the top soil. When evaporation from the soil surface is increased by 'clean cultivation' or by the death of a few trees, wilt appears and spreads slowly in the direction of the prevailing winds.

The type of soils in which this wilt occurs, the chemical status and, further, its occurrence after the growing of the exhausting crop sugar-cane should be carefully noted for comparison with New Guinea conditions. Duthie's description also largely conforms with the conditions found in Trinidad.

Mature Palm Wilt on the Huon Gulf.

The nearest approach to an extreme case of "mature palm wilt" resembling the "bronze wilt", such as one has seen depicted from Trinidad, was seen recently on a plantation situated in the Huon Gulf area, on a plain apparently representing the old delta of the Markham and Adler Rivers. The areas planted with coco-nut palms, ranging from 21-27 years old, were covered by a dense undergrowth of grasses and weeds, such as Kunai, *Imperata arundinacea, Saccharum spontaneum* (wild sugar-cane), and many other grass-types, also bananas and cassava, *Manihot utilissima* (which had been previously planted and run wild).

"Leaf-droop" and "leaf-break" were most abundant and were very prevalent, while the palms were stunted and bearing poorly. In many areas, tapering stem, yellowing and bronzing of the fronds, and reduction in the size and number of the fronds, were most noticeable. The erectness of the few fronds left, their feathery, open nature, and poor colour and vigour, showed conclusively that the soil and cultural conditions were at fault (*see* photographs).

Coco-nut Palms—Mature. Affected by unfavorable soil conditions; non-bearing, also "leaf-droop" and "taper stem" present. Two palms with heads missing.

Coco-nut Palms affected by soil conditions.

N.B.—Palms—non-bearing. Fronds—feathery, reduction in size and number. "Leaf-droop"—present.

In some places the very strong-growing, soil-exhausting creeper, *Ipomœa robusta* (sweet potato type), was seen growing over the trunks and into the branches of the palms. Several palms were seen to be left as bare poles only, with the cabbages collapsed and fallen off. Stem-bleeding, due to the fungus *Thielaviopsis paradoxa,* was seen on many of the palms.

The frequent gaps in the plantation showed that the loss of the palms had been high in the past. The general appearance of the plantation suggested unsuitable soil conditions, and extreme manurial deficiency, which from the scorching and bronzing present on the palm fronds was apparently an inter-action of potash deficiency combined with physiological drought. The conditions were undoubtedly intensified by lack of care and attention, probably increased by

Coco-nut Palms, showing dense undergrowth, such as *Ipomœa robusta*, climbing on trunk. N.B.—Stunted and poor condition of palms, also " leaf-break " present.

burning off and the presence of so many strong-growing, soil-exhausting grasses and weeds, most of which have a heavy drain on nitrogen, but particularly on potash. The soil profile, however, showed the main reason for the state of the coco-nut palms here, when the inter-action with the other factors mentioned are taken into account. The surface-soil was a stiff clay loam, liable to waterlogging in the wet weather. The sub-soil was a very compact and small-grained clay, caused by deposition of the fine particles. At varying depths below this clay sub-soil, coarse rubble layers composed of water-worn pebbles were met. In the wet season there is a mass movement of water through these rubble layers from the high hills behind, so that almost a free water surface is presented. The surface layers were liable to waterlogging, with the presence of a superimposed water table in the wet season and to drying-out and cracking in the dry season. Obviously the rubble layers hasten the loss of water from the soil and sub-soil in the dry season. It will be seen that these conditions somewhat approximate the conditions seen in the Madang district. Owing to the presence of grasses, wild sugar-canes, native food crops, wild bananas, &c., which would not be present on a well-kept place, the chances of deficiency and unsuitable water-relationships causing severe symptoms are greatly increased. It is also apparent that this set of circumstances would more closely represent the extreme conditions found in the West Indies, where coco-nuts have been previously grown for several years.

Where unsuitable soil conditions exist, and the plantations are badly treated as concerns lack of drainge and the growing of exhausting crops, there is, in the future, considerable likelihood of many other areas showing "mature palm wilt", some forms of "bud-rot", and related symptoms.

Particulars of Some Areas Where Physiological Derangements of Coco-nuts Occur.

All of the plantations where clay exists hold the surface water after heavy rains, except where creeks and running streams provide adequate natural drainage. The coco-nuts in the naturally-drained areas bear quite well, thereby showing that drainage is essential for all the undrained areas of similar soil type. Some typical soil profiles from waterlogged areas in the Astrolabe Bay area, where palms are very stunted and surface water is often found right to the surface, are now described.

When holes are first sunk, the water is seen at about 6 inches from the surface, but usually fills and runs over at various periods. The ground is very clayey down to 4 ft. 6 in., being slightly freer at the surface. At a short distance from the surface there is usually a hardened pan of deposited clay, blue-grey in colour, showing poor aeration and the presence of unoxidized iron. Even at the surface the clay was very puggy, but much more so in the compacted layers where the very fine-grained, colloidal particles are washed down and deposited. Such soil conditions are totally unsuited for plant growth, or nutrient intake. Under ordinary conditions heavy clay soils give up their nutrients slowly, owing to colloidal attraction. It is almost impossible for a coco-nut palm to take up its food from such a soil under water-logged conditions, or, conversely, when the soil has set very hard in the dry season.

Typical soil profiles in areas liable to forms of "mature palm wilt" vary somewhat as to actual depth of the deposits, but usually conform to the same type. In one water-logged area, the face of a creek showed first a shallow, dark humic layer on top, then a stiff clay loam (about 1 ft. 6 in. to 2 feet deep) overlying a very stiff, clay sub-soil, which reaches to a depth of 5 feet. Then, from the bottom of this clay to 15 feet down, alternating layers of pebbly gravel (rubble) with sandy layers intervening were seen. This type of deposition appears to be associated with the streams running from inland through the plantation, or, in other words, are estuarine deposits. In this particular case, it was derived from the shifting mouth of a comparatively large river.

Underground Water.

The whole of the area subject to the palms dying off has an extensive underlying free water-table, at no great distance from the surface. The level of this main water-table usually corresponds with the level of the water in the running streams present, which are usually quite shallow in the estuarine areas. It seemed practically certain that there is a superimposed, secondary, water-table which is only in evidence in the wet season, or in periods of heavy rainfall. This secondary water-table is only a few inches from the surface, in the wet areas, and is held up by the compacted zone of deposited clay (which acts as a hard pan), assisted by the flatness of the land and the lack of drainage. This raised water-table lies near the surface during the whole of the wet season, but, in the comparatively short dry season, the ground dries up, sets very hard, and compacts. This is especially so in the case of the non-bearing areas, where the water tends to lie all over the place. In the dry season, under these particular conditions, even the grass and weeds stop their growth to a large extent. The change-over period from the wet to the dry season greatly affects the nutrition of the plant and plays a most important part in the development of deficiency symptoms leading to stunted growth, leaf-droop, nut-fall, and so on.

In the bad water-logged areas mentioned, the palms range from 10-20 feet high, while nowhere are they higher than 40 feet, even in the best areas, where the soils are so heavy. Numerous palms in these areas show constriction of the trunks at a few feet above the ground level with evidence of a later recovery of diameter to a limited extent, which illustrates the effect of neglect in the early stages. Where the palms are stunted, with tapering stems, and non-bearing, this is a direct reflection of the soil conditions and related root development.

The high water-table and water-logged state of the soils following heavy rains are very deleterious to the healthy growth of the root system, as this prevents air intake below the water level and interferes with it in the saturated zone. Because of this fact, and despite the excess of moisture present, it is impossible for it to be absorbed by the roots. Consequent on the reduced water supply to the palm is a reduced intake of nutrients and untimely death of the roots.

In many places the palms are reduced to getting their air and nutrient supply from the top 6 inches of soil during the wet period and after prolonged periods of stagnation either the roots die off or become sickly below the water level. In the dry reason the soil cakes and compacts, and the heavy clay soils give up their moisture very slowly to the reduced root system. The palms often show a partial recovery towards the end of the dry season, when new roots develop and cause more water and nutrients to become available from the lower sub-soil layers.

It is pointed out that the presence of the estuarine rubble layers underneath the soil layers assists the water getting away in the dry seasons and leads to a greater contrast, between the wet and dry seasons, of soil conditions than would otherwise occur. Extremely bad cases of unsuitable soil profiles such as those described above may mean that the ground is totally unsuited for coco-nuts, especially where drainage is impossible or uneconomic. The pronounced seasonal bearing in the plantations on this coast is closely related to the fluctuating soil and climatic seasons (*see* graph). The change-over periods from the wet to the dry seasons or vice versa are believed to be critical seasonal periods for the coco-nut palms, and to have a pronounced influence on both seasonal bearing and the occurrence of nut-fall in coco-nuts, where heavy, water-logged soils liable to drying out are present.

Seasonal Variations In Yield.

It is not intended to discuss this problem for New Guinea as a whole, but to relate the seasonal fluctuations in yield of certain plantations with the moisture and nutritional status of the soils already described, and to indicate other reactions of the palms to these particular environments.

The monthly yield of one plantation, in particular, is discussed where the tendency to seasonal bearing is pronounced. In the three years considered November, December and January are usually peak months for production, while March, April, May and June are months of comparatively low yield of copra. If, for the three years, the total monthly yields as bags of copra harvested are compared, the following interesting facts are revealed. The total number of bags harvested in the three high yielding months are as follows:—November (902), December (914), and January (900), giving a total of 2,716 bags. In the three low yielding months the numbers of bags harvested were for April (680), May (624), and June (715), giving a total of 2,019 bags, which represents almost a third reduction in yield compared with the former three months.

This seasonal variation in yield is undoubtedly due to a seasonal inter-action between the soil, climatic factors and the nutrition of the plant, and is what one would expect under the conditions prevailing on most of the plantations around the Madang district, particularly on those properties which are situated on deltaic deposits in the extensive Astrolabe Bay area.

Under the particular conditions obtaining at Kasaragood, India, Patel has shown by mathematical calculations (regression, co-efficients, and significance of yield) that the rainfall of the year previous to and of the year of the harvest is significantly correlated with yield.

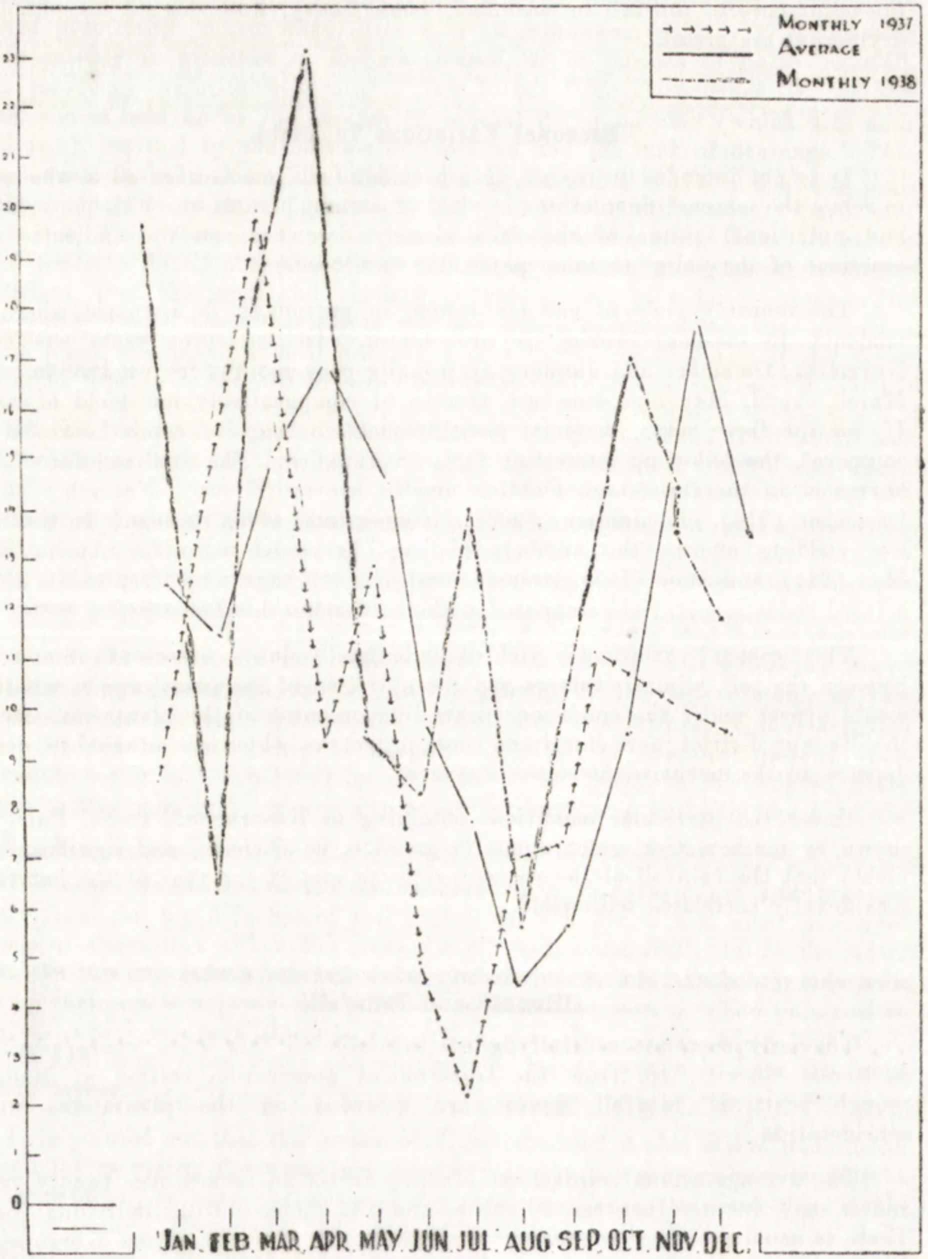
Climate and Rainfall.

The only complete rainfall figures available in this office, concerning this particular district, are from the Government observation station at Madang, though scattered rainfall figures are recorded on the plantations under consideration.

The average annual rainfall at Madang is 136.36 inches over twenty years, and it may fluctuate between 90 inches and 165 inches during individual years. There is usually a long wet season of seven months duration, from November to May, with a short dry season, usually of only five months duration, from June to October.

RAINFALL GRAPH, MADANG.

MONTHLY RAINFALL (1938): AVERAGE FOR 21 YEARS (1917–38): MONTHLY RAINFALL (1937).



The appearances are that both the maximum and low yields are recorded at the beginning and end of the wet season respectively, but this may be misleading as to times at which the causes leading to the actual losses in crop occur. The peak months are March, April and May, while August and September are the driest months and, as seen, the lowest yields are recorded in April and May, which, however, ranges from five to six months after the rainfall season has begun. The fact that this reduction in yield is more apparent at the end of the wet season and lasts into the change-over period is worthy of note.

The period of maximum yield is where regular and moderate rainfall conditions are experienced immediately after the dry season. The high yields seem to commence immediately the dry season is over, when the soil is not water-logged, and sufficient rainfall occurs for the palms to set satisfactory crops.

There may be both immediate and long term effects (or seasonal and annual responses) to seasonal conditions. The effects of drought on reducing the following year's crop is well known. The fact, however, that poor, or optimum, fruit-setting conditions in a particular part of the season may not be evidenced till twelve months later is not often recognized. Where the seasonal effects on yield occur in the same crop, this may be due to either the full crop not being carried to maturity owing to nut-fall, or, conversely, to spathes and already mature nuts being carried down over on the palms and dropped together at a later date. This latter occurrence is not uncommon on poorly vigorous palms.

Nut-fall of the Type Related to Soil Conditions.

Stockdale[29] has briefly described nut-fall from the Kurunegala district, Ceylon, where the rainfall was said to be rather excessive for optimum growth of the coco-nuts and the soils heavy. It was only under these conditions that "nut-fall" and "leaf-droop" proved serious in Ceylon, and under excessive and continuous spells of wet weather proved capable of considerable damage to palms and crops.

Gadd, in 1923,[13] stated that "in Ceylon it was shown that water deficit following on a prolonged drought caused greatly increased fall of the 'female flowers', or 'button nuts'. Such abscission of 'buttons' and youngest fruits may be caused by periods of drought as may the falling of larger nuts".

He indicated, however, that "nut-fall" in Ceylon occurs principally in the rainy season, and in the districts where it was particularly severe the soils were heavy loams which become hard during the dry weather, with a tendency to water-logging in periods of excess rainfall. These particular soil conditions, during heavy rains, become deleterious to the healthy growth of the root system by interfering with the air supply, which despite the excess of moisture present leads to reduced absorption of water, and untimely death of the roots, resulting in nut-fall.

The reader is referred to the New Guinea *Agricultural Gazette*, Vol. 3, No. 1, pages 58 to 70, for a detailed account of nut-fall in coco-nuts where the various kinds of nut-fall are described.[9] The purpose of the discussion included here is to show that nut-fall can be closely related to deficiency of water and nutrients in certain types of soil. The nut-fall problem in New Guinea is elucidated on page 62 of the same article, where it is stated that severe incidences of nut-fall have been recorded only at intervals on plantations in this Territory.

The fall of buttons and of large nuts up to 10 inches in diameter was noted in certain areas near Madang with soil horizons as described previously, and, also, in other plantations in the same district, where stiff clay soil rested on a loose foundation of decomposed coral. In these areas there was no great depth of soil on top, and, owing to an intervening zone of deposition, or probably due to an excessive lime status, the coco-nut roots did not extend far into the coral layers.

In the limestone soils of coral atolls in this Territory (e.g., in the Western Islands) there is generally deposition of secondary limestone hard pans due to the leaching action of the water. The lime is leached out by the water and deposited at certain depths, where it has a typical mortarising effect and firmly cements the fragments of sand.

Brackish underground water is present at relatively constant depths right throughout the coral atolls. The small difference in height from the surface to the water in the various places is more dependent on the slight irregularities of ground elevation present. On the higher ground on the margins it is rarely more than 5 ft. 6 in. to the free-water level, while it rises to the surface in the lagoons, and over wide intermediate areas the water is only at about 1 foot to 18 inches from the surface.

The holding up of the surface water by the lime-impregnated layer would lead to increased water-logging in very wet seasons.

In the lagoons and swampy depressions, however, it is the excess of free brackish rather stagnant water coming to the surface which restricts the root-growth and makes the areas unsuited for growth of coco-nut palms at any time, as is seen where they are dwarfed or lean over.

It was seen from soil profiles examined that underneath some areas it was no distance to a second lime-impregnated layer, below the free water surface of the true water-table, which was practically impervious to water. Below this at varying depths solid coral is usually met with its lime-infiltrated coating, which also prevents the free water level dropping far.

It would be thought that the presence of this underground free water should ensure that any water shortage would be unlikely. This, however, is not the case and the best coco-nuts on these atolls are very prone to seasonal bearing and are affected by seasonal conditions.

The yield of copra falls off badly after long dry seasons.

The shallow rooting of the palms in most areas here and the tendency for them to fall over and show flat plates of hardened mortar-like ground at their bases has been described in a previous article.[10] The superimposed limestone hard-pan mentioned does not entirely prevent root-growth, but below this layer the roots are usually constricted, gnarled and not well developed.

In addition to the restrictive action on the spread of the plant roots, it also causes retention of the surface rainfall, near the surface in the wet seasons, despite the fact that the surface soil is loose and sandy. It is also believed that this layer has the effect of limiting the amount of nutrients available. The loose, sandy, surface soil leads to a quick drying out in the dry season and reduces the water and nutrient supply to a restricted root system. Stunting, deficiency symptoms in the palms and fall of poorly developed and unfilled nuts is common under these conditions as is "leaf-droop" and seasonal bearing. The effect of the physical conditions mentioned are closely inter-related with soil exhaustion and lack of nutrients which has caused the palms on so many of the older areas to retrogress in vigour and production.

In the plantations of New Guinea, there is reason to believe that any physiological upset of the palms and nut-fall which occurs is worse in the change-over period from the wet to the dry season, although a certain amount may occur all the year round.

The occurrence of nut-fall as indicated is undoubtedly a question of unsuitable soil and water relationships. Few insects or fungi could be seen present on the base of the fallen nuts at Madang. It is fairly safe to conclude that physiological conditions are responsible, and the organisms present serve to increase the effect. It appears that a much heavier crop is set at flowering time than is carried to maturity, simply because under unfavorable circumstances the palms cannot carry a full crop.

It is the opinion of Dr. Tammes[30] of the coco-nut experiment station at Manado, Celebes, N.E.I., that "It seems that the number of fruits produced is not limited by the number of flowers nor by pollination, but is exclusively controlled by the physiological condition of the nutrition of the tree. A very important factor is the available quantity of water."

The present author does not entirely subscribe to the above conclusion, but there is no doubt that the water relationships do play a very big part as where there is too little water present, or where too much water in the soil leads to physiological drought owing to root restriction and reduction of water intake.

Influence of Soil-exhausting Crops on Wilt and Disease Occurrences.

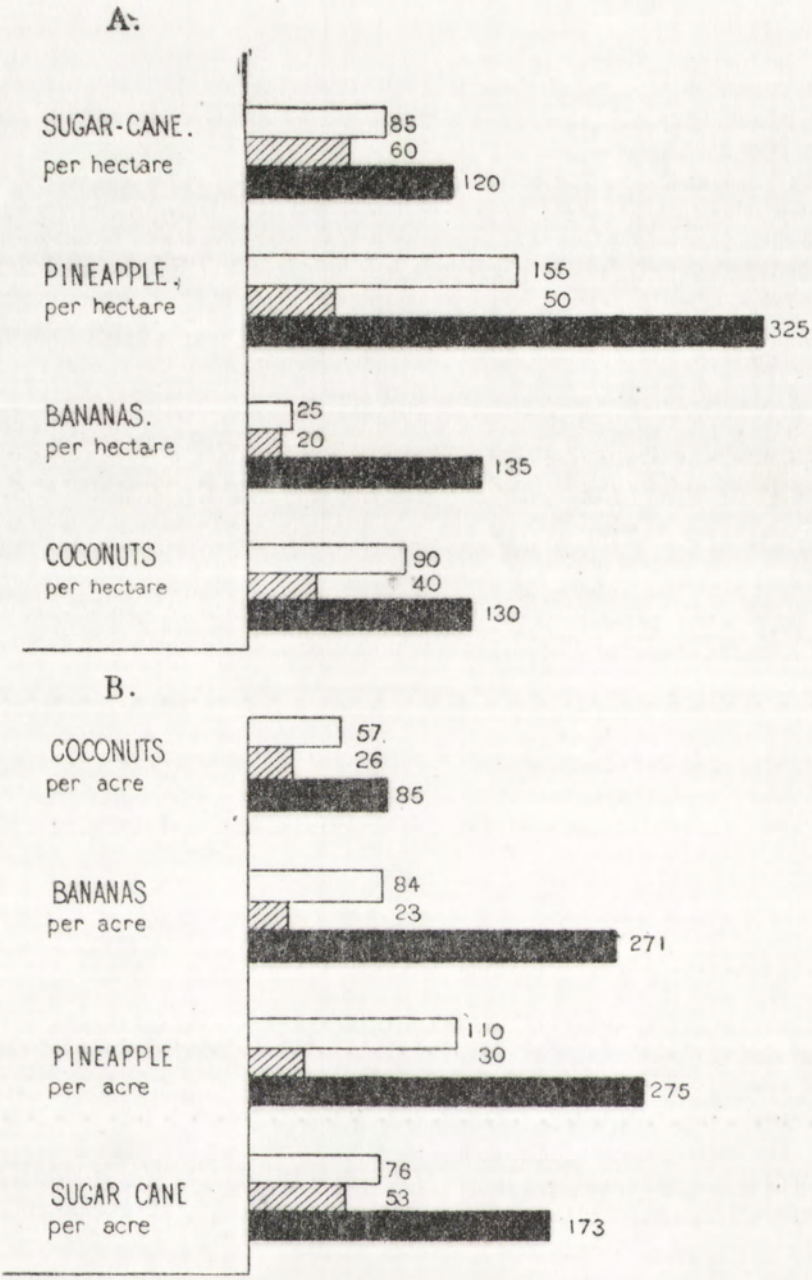
It has been pointed out that the worst manifestations of wilt in the West Indies occur where coco-nut planting follows sugar-cane culture. Reference to the graph, showing the approximate manurial requirements of this crop as compared with coco-nuts, will indicate that apart from the physical effects of this crop on the soil, sugar-cane has a much greater drain on the soil constituents than coco-nuts; this is particularly true of the potash requirements.

It will also be seen that this drain on manurial constituents (especially potash) is even greater in the case of bananas and pineapples, which are normally grown as native food crops in New Guinea. Cassava, taros, sweet potatoes, maize and other crops can be shown to have a similar effect. Some of the native non-leguminous creepers, commonly found in plantations, e.g. *Ipomoea robusta* (a very strong creeper of the sweet potato family), have a most exhausting effect on the soil. Such rampant-growing weeds as *Sida rhombifolia* and Blue Rat's Tail, *Stachytarpheium* spp., have much the same effect.

In ordinary native culture their normal shifting system of cultivation ensures that after one crop is sown it is a long interval before the same ground is utilized again. The exhausting effect of these native foods is thus recognized in a practical fashion.

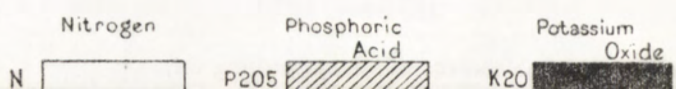
In the past, and even up to the present time, it has been the practice of planters when developing new places here to grow large areas of native crops to feed their native labour or for sale. In numerous instances here, where plantations are just coming to the bearing stage, it has been possible to distinguish the palms growing

QUANTITIES OF PLANT FOOD REMOVED FROM SOIL BY TROPICAL PLANTS.



A. Figures given by Eckstein, Bruno, Turrentine, (12)
= Kilogram per hectare, kg/ha. 1 kg/ha. = 0·9 lb. per acre

B. Figures given by Jacob and Coyle (15)
= lb. per acre.



over old native gardens or on areas previously used for growing native crops. After growing such food crops, the sôil is often left without cover for some time, so that the ground is exposed to the scorching effect of the sun's rays and to erosion and washing by heavy rains.

The young palms growing on such exhausted and previously exposed areas usually appear stunted with a general appearance of debility compared with the surrounding palms. The fronds appear yellowish or yellowish brown in appearance, as contrasted with the healthy green colour of palms growing on normal bush soils. It is rarely that these palms reach an extreme wilted appearance as is apparently common in other countries; nevertheless, this is probably a manifestation of the same kind of growth reaction but in a lesser degree. It is seldom that the palms do not recover when the palms get older and the roots get a greater hold on the soil. There are few plantations in New Guinea where some areas of palms showing similar symptoms to those indicated above do not exist.

It is unfortunate that one cannot present general chemical analyses of the common grasses found in New Guinea plantations. As far as this country is concerned, "kunai" or "lalang" grass, *Imperata arundinacea,* has all the deleterious effects of sugar-cane on the physical texture of the soil. This ubiquitous grass occurs over the whole Territory and its dense growth has a most exhausting effect on the soil. It has a deep matted and intertwined strong fibrous root system which goes down to considerable depths. Analysis shows that this grass has a high percentage of ash which is rich in potash. It is small wonder that palms growing in competition with such a growing and soil-exhausting grass fare badly and become more liable to both fungus and insect attack, besides reacting immediately to unfavorable water-table and climatic conditions. The relationship of the previous strong growth of kunai to the poor appearance of the palms coming into bearing at Kokopo (and probably in Namatanai) is readily understandable.

Coco-nuts Following Sisal Hemp: "Agave Sisalana".

Near Constantinehafen, Astrolabe Bay area, there were formerly old sisal plantations, planted by an old German company. These were later abandoned and coco-nuts planted instead. As would be expected the coco-nuts did not thrive. Over large areas the palms remained stunted, yellowish and poorly bearing; often their tops fell off. About three-quarters of the whole area had to be abandoned. The main reason for this was the shallow stony soil present with deep layers of rubble underneath, allowing the water to get away quickly to the free underground water flowing through the gravels. The conditions were exaggerated by the impoverishing crops of sisal hemp previously grown.

Sisal hemp is a most exhausting crop, as is seen from the analysis quoted, and unless the waste is returned to the soil and heavy manuring carried out the soil may be rendered useless for other crops.

The green leaves of sisal contain in their ash 18.8 per cent. potash, 3.29 per cent. phosphoric acid, .098 per cent. nitrogen (low), 33.40 per cent. lime and 15.37 per cent. magnesia.

As would be expected the palms following such an exhausting crop showed marked signs of deficiency.

In addition to the shallowness and lack of nutrient content in this soil, the prevalence of leaf-droop and yellowing was largely caused by the previous cropping and the attempts to control weeds by burning off.

Curiously the predominant native grass which has now grown over the abandoned areas is a most rampant-growing, soil-exhausting species. The planters in the district usually refer to this area as a "kunai" or "kangaroo" grass plain. In reality, the tall coarse grass present is *Ophiurus megalophyllus,* a common species in the tropics which has no common name here. There are several other species present including the kangaroo grasses, but very little kunai. Based on experiences elsewhere, it is under these extreme conditions that die-backs would be expected in the coco-nut palms.

In addition to kunai and the small areas of true sugar-cane, grown for native requirements, the following indigenous grasses are listed as being amongst those which may produce similar bad effects on coco-nuts to those already indicated for kunai and sugar-cane:—

Saccharum spontaneum—Native sugar-canes.
Saccharum robustum—Native sugar-canes.
Chrysopogon aciculatus—Love or seedy grass.
Paspalum conjugatum—Thurston grass.
Themeda gigantea—Giant kangaroo grass.
Themeda australis—Kangaroo grass.
Ischaemum muticum—Swamp grass.
Sorghum nitida—Native sorghum.
Pennisetum macrostachymum—A native grass, very like elephant grass.
Ophiurus megalophyllus—A very strong vigorous grass, common in certain areas, e.g., at Melamu.

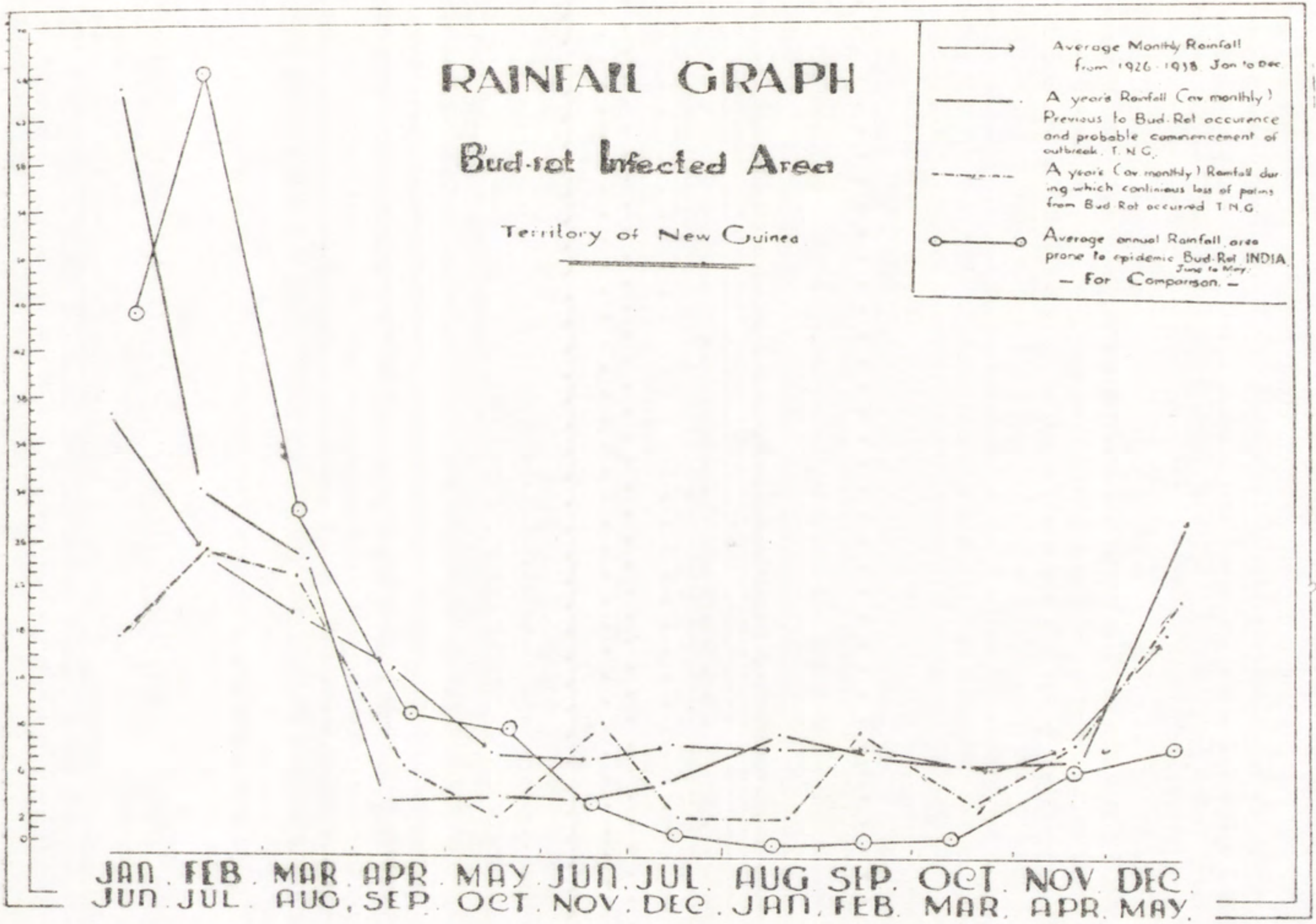
Tobacco.

On the Madang coast and in various other parts of New Guinea, coco-nuts have been planted after extensive trials of tobacco-growing had been carried out. Some of the biggest areas grown in German times were planted at Bogadjim (Stephansort, the first German capital of this Territory), where numerous Chinese were engaged in tobacco production. This may be one of the contributory reasons, apart from soil and climatic conditions, why the later planted coco-nut palms have not flourished.

In recent years tests have been made on growing tobacco leaf for manufacturing native twist or trade tobacco and coco-nut palms do not appear to flourish so well on areas used for this purpose.

SOIL CONDITIONS ASSOCIATED WITH BUD-ROT AND THEIR RELATION TO OTHER DISEASES

Association of unfavorable soil and climatic conditions with the development of true bud-rot, in which the fungus *Phytopthora palmivora* Butler was in evidence, have been recorded from certain New Guinea plantations. It is not intended that the sporadic occurrences of bud-rot be described in detail in this article. Certain contributory factors found in the situations where an outbreak occurred and which are of decided value in illustrating the conclusions of this present article are described. This is the first undeniable diagnosis of true *Phytopthora* bud-rot here and this was arrived at from investigations by the Director of the Department of a loss of several hundreds of palms. This fungus was at first definitely suspected from the macroscopic symptoms present (i.e., from



RAINFALL GRAPH
Bud-rot Infected Area
Territory of New Guinea
Average Monthly Rainfall from 1926-1938. Jan to Dec.
A year's Rainfall (av. monthly) Previous to Bud-Rot occurence and probable commencement of outbreak. T. N. G.
A year's (av. monthly) Rainfall during which continious loss of palms from Bud-Rot occurred. T. N. G.
Average annual Rainfall, area prone to epidemic Bud-Rot INDIA June to May.
— For Comparison. —
JAN. FEB. MAR. APR. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC.
JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.

the visible appearance and symptoms of the disease). This determination was backed up by the opinion of the Director of the Imperial Mycological Institute, based on the presence of fungus mycelium closely resembling *Phytopthora,* and from the descriptions and specimens forwarded to him. Unmistakable spore forms of *Phytopthora palmivora* were later isolated in Rabaul, from the tissue of a diseased coco-nut palm. In the future, a detailed article on the local occurrences of this disease will be presented.

The only losses of palms from bud-rot recorded here are from regions of heavy rainfall and usually occur under abnormal weather conditions. In the most recent records, it was noted that the first appearance of the disease coincided with a period when the rainfall was much wetter, in the wet season, and much drier, in the dry season, than was usual. This gives a much greater contrast of climatic conditions between the wet and the dry seasons (*see* graph). The loss of palms occurred on heavy soils under flat and foothill conditions. Significantly, it is under very similar circumstances that the scattered occurrences of bud-rot in Fiji have been recorded by Simmonds[26-27] and others.

The occurrences of this disease have been almost confined to the wetter portions of the Fiji group, being commonly found on the back portions of the estates, along the foothills. This comprises a region of continuous rainfall and frequently of poor drainage where the coco-nuts grow under unfavorable soil and climatic conditions which favour fungus development, but reduce the vigour of the palms. Palms growing close to the seashore with optimum water-table conditions are affected slightly as was found in the occurrences here.

The environmental conditions prevailing where bud-rot has been recorded here have many features in common with those obtaining where the other diseased conditions, described in this article, have been recorded, but are more extreme.

The heavy soils present are liable to water-logging in the wet season, and to drying-out and compaction in the dry season. This tendency is increased in areas of heavy rainfall and where poor drainage exists.

In a typical soil-profile of an affected area, it is found that there are proportionately large areas with very compact, almost impermeable hard-pan, or clay layers, present, which hold the water at the surface and restrict root-growth. In certain flat areas, where loss of palms, frond-fall and nut-fall were most in evidence, a stiff clay band was present, usually at a depth of 6 inches to 9 inches, but often almost to the surface. It is seen from water lying about in shallow depressions and from other signs that a superimposed water-table exists in the wet season which disappears in the dry season. The evaporation of this surface water continually adds to the humidity of the surrounding atmosphere.

Below the first clay zone there was, in several places, a sandy sub-soil layer present which was loose and porous and extended to a depth of at least 2 feet. Below this again a second impervious clay band is often met with, which is blue-grey in colour (showing the presence of un-oxidized iron) and represents a second zone where deposition of fine particles has taken place.

The root systems of coco-nut palms growing under these conditions are restricted by the relatively impervious layers near the surface, especially as the water stagnates there in the wet season.

Some root-growth does occur below the first clay layer, but is absolutely prevented where a second clay layer or other hard-pan exists.

In the dry season the loose sand, underneath the clay, is believed to reduce the water supply to the palms, which effect would be greatly increased in the dry season. The clay layers present hinder water movements and the access of the roots to the true water-table. It is obvious, without reference to the bud-rotting and other organisms present, that such conditions are not optimum for the growth of coco-nut palms, though they do favour most types of fungus development. The *Phytophora* bud-rot disease particularly can only be exceedingly destructive in a very moist atmosphere.

Where bud-rotted palms are found on the sides of low foothills, the water-table may not be so close to the surfaces, but the soil conditions may still lead to water-logging and restricted root-growth. On one typical area it was seen that the surface soil was a stiff chocolate clay loam, which was stiffer even than those soils found on the flats. The sub-soil was an extremely fine-grained and puggy clay, resting on a compacted layer of weathered parent basaltic rock. This weathered rock formation gradually merges into the unweathered parent rock at a comparatively shallow depth. The soil as described is very puggy in the wet season but sets like a brick in the dry season. Palms growing under these conditions do not flourish. This can be seen from the chlorotic leaves, reduced length and number of fronds, and the grass ground covers present showing a light overhead canopy. It is impossible to think that such climatic conditions, and soil and water-table formations, do not have a great deal to do with the development of bud-rot. Obviously, it is no coincidence that the type of bud-rot found here, and in Fiji, occurs under such conditions.

In the Philippine Islands bud-rot only assumes epidemic proportions in one of the most humid districts of the islands, where the soils are heavy and wet.

The late Dr. Sharples,[25] in 1924, enumerated several instances of where investigators had recorded outbreaks of bud-rot in various parts of the world which were associated with unfavorable soil and climatic conditions. It was resolved at the Imperial Botanical Conference of 1924[25] that the term "coco-nut wilt" be applied to such occurrences as were falsely designated bud-rot, for the reason that the bud, as a general rule, was the last portion of the crown to become affected.

It is the author's opinion that, whether the crown is affected first (as in the instances of true bud-rot given) or last, the soil conditions always warrant very close study wherever outbreaks of wilts and bud-rot occur.

It has been mentioned right throughout this article, that there are several other diseases and conditions of the palm influenced by related environmental conditions. In this regard, it is a significant fact that on some areas where true bud-rot was recorded here, the following series of diseases or symptoms were noted. Leaf-droop, leaf-break, nut-fall (bad), frond-fall (bad), leaf scorch, deficiency spotting, taper stem, *chlorosis*, stem bleeding, *Pestalozzia*, leaf-spotting, thread-blight (*Corticium penicillatum*), *Botryo-diplodia theobromæ* and a condition tentatively named "gummy leaf". It is plain that many of these conditions (especially the first nine listed) are symptomatic of the particular soil conditions prevailing, rather than distinctive diseases.

It is worthy of note that the dynastid beetles (especially *Xylotrupes gideon*) had caused considerable damage under these conditions and probably favoured the spread of the disease.

There may be a number of inter-related and inter-acting factors (working both from within and outside the palm) responsible for palms showing a series of pathological derangements such as those described.

It is very clear from the considerations outlined that cultural practices designed to keep up the vigour of the palms and remedy unfavorable environmental circumstances are of the utmost importance in disease control.

Discussion.

It is necessary to refer to the well-known subject of optima and limiting factors to obtain a true idea of what occurs where there are a number of inter-acting conditions of nutrition and environment necessary for best growth of the palms. Optimum growth is impossible wherever one main limiting factor is present, as this will determine the maximum influence of any other factors present. In plant growth, there is no such thing as the influence of one factor without reference to the effect of other conditions present. It has been shown that water supply and available potash are two of the very important factors limiting the growth of coco-nut palms. Besides acting as simple, limiting factors, they also interact in many ways, as is indicated in various sections of this article. Regardless of the amount of potash present in the soil, only a certain total quantity can be absorbed by the palm if the water supply is checked in any way.

It is, however, reasonable to state that where the water and potash contents of a soil are both too low (or too high) much greater detrimental effects of malnutrition can be expected. Looking at this contention in another way, let us assume that by a series of pot culture or other methods, it is possible to maintain an optimum water supply to young palms all growing in a constant nutrient medium and to vary the potash supplied to them. Then some plants will be found to have lower than the minimum supply of potash necessary for the proper growth of the palms, so that pathological symptoms may result. Some palms will show lesser effects of the deficiency by being only a darker green than others then, within a certain range, other palms will appear quite normal. Other palms, with so much potash supplied as to upset the balance with the other nutrients and moisture present, will either show no increase in growth or else retarded growth.

If the supply was varied in another series of similar cultures, and the potash kept constant, then similar variations in growth responses would be expected. If both the potash and water supply to the palms was varied, it is likely that the palms receiving the larger quantities of water could do with less potash within certain limits. This is an attempt, in a simple way, to demonstrate how limiting factors may work and also indicate one type of experiment necessary to determine the nutrient requirements of coco-nut palms. Obviously, such pot culture experiments are relatively simple with annual plants, such as the tomato, but are difficult with long-lived and bulky perennial plants like the coco-nut palm. It might be mentioned here that annual plants, like the tomato, have been used as indicators as to the nutrient requirements of other plants, in pot experiments.

The subject is very much more complex, however, than is indicated here, when it is considered that such nutrients as nitrogen, phosphates, calcium, &c., all have their effect and that temperature and actual inherent vigour of the plant come into play.

It must also be recognized that the coco-nut palm has very great inherent capabilities of adapting itself to its environment and to varying conditions of moisture and nutrient supply. Sampson[24] and others have indicated that a coco-nut palm shows a much different analysis when grown on a good soil than on poor soil, which means that the plant can and does economize on plant food under unfavorable conditions.

It might be pointed out that there is a growing mass of evidence to prove that when the humus content of the soil is allowed to run down below a certain level, crops become increasingly subject to diseases of all kinds.

It must be stressed that the inter-action of many limiting factors has to be considered when investigating any physiological disease. The genetical constitution of the plant usually interacts with environment and it is found that weaker palms are much more affected by unfavorable soil and water relationships than strong ones.

One would think that when wilting of palms actually occurred, the end point of water or nutrient deficiency was not far away and that there may be several degrees of growth differences between this and a normal palm.

Thus, although palms do not show pronounced deficiency symptoms, they may have their vigour sufficiently reduced to render them liable to fungus attack. Though there are relatively few records of occurrences of severe palm wilts in New Guinea approaching those known as "bronze wilt" in the West Indies, how are we to classify the occurrences which are recorded here? Is the "maturation wilt" described to be classed in the same category as the more permanent "mature palm wilts", such as are described from the Madang coast? It seems that much more detailed work is necessary as regards the actual physiology and nutrition of the coco-nuts, through all stages, before complete understanding of the problems is possible.

It is no coincidence that similar unsuitable soils conditions to those described as causing coco-nut wilts elsewhere, are responsible for similar physiological diseases here. There appears to be a tendency to classify all pathological symptoms due to soil moisture and deficiency relationships as wilts. One should remember that complications are frequent where otherwise harmless organisms attack the plant, once its vigour is lowered. Wilts, bud-rot, nut-fall, leaf-droop and many other diseases are all symptoms which may be due to different causes, but it has been shown that they may be closely inter-related under certain conditions.

As mentioned before, it is probable that wilts are, as yet, not so prevalent in New Guinea, because the soils are newer and, secondly, because the land has not been cleared of its virgin jungle and been in cultivation with soil exhausting crops for so long.

In addition to major nutrient deficiencies, several unfavorable circumstances are listed. These may, or may not, be present, but where found could be expected to produce outward visible symptoms in the growth of the palms, especially if several were found together in the one situation—

1. Stiff soils or soils too porous.
2. Class of subsoil and the presence of hard pans and superimposed water tables.

3. Shallow planting.
4. Poor seed nuts (inherent vigour of the palms).
5. Previous cropping with exhausting crops.
6. Presence of grasses and weeds.
7. Close planting.
8. Overshading.
9. Continuous burning off.
10. Exposure to heavy winds.
11. Excessive rainfall and continuous cloudy weather.
12. Drought.
13. Season of coming into bearing.
14. Cultural conditions, such as lack of cultivation or drainage.
15. Overstocking the plantation with cattle, especially where tramping over heavy soils.
16. Leaching and erosion of the soil.

If deficiencies of other minerals (e.g., rare metals) are involved in some New Guinea soils, as well as any major nutrient deficiencies, the palms would undoubtedly show other distinguishing symptoms. Theoretically, different combinations of limiting factors may lead to distinct types of physiological diseases.

Finally, it is necessary to decide where one is dealing with physiological wilts or with virus diseases caused by ultra-microscopic viruses carried by certain vectors such as sucking insects.

The influences of water relationships and nutrition on fruit setting, nut-fall and disease occurrence in coco-nut palms, show how closely related are soil problems (physico-chemical) and the functions of the plant (physiology). It is also shown how necessary it is to associate chemical findings with botanical studies and considerations. The determinations of the virus and other diseases present are the province of the plant pathologist.

It would be a most valuable contribution from physiological and chemical research to find out, in detail, whether there is a heavy drain on any particular elements, when the palms are reaching the bearing stage and just what changes do occur.

It is the sphere of the chemist to give us much more data on the nutrient status of the soils here, and to give us detailed chemical analyses of the plant itself. The future studies of our departmental chemist are expected to elucidate many of the problems outlined in this article.

Remedial Measures.

A description of the correct agricultural practices in coco-nut cultivation would entail a separate article, hence some of the salient points only are indicated for New Guinea conditions in particular. It is necessary to consider most of the conditions which affect the nutrition and health of the coco-nut palms in determining any suitable methods of prevention or control of coco-nut wilts, or similar physiological diseases. References to suitable measures for control of maturation wilts have been made as the particular conditions were described.

The selection of the original plantation site is most important. When selecting areas for coco-nut planting avoid obviously unsuitable soils and situations by making preliminary soil surveys. Proper attention should be paid to the nature of the sub-soils present. This can be determined by digging deep holes at specified intervals and also studying the soil profiles in exposed banks of creeks, cuttings, quarries, &c., before the planting is proceeded with. Soils liable to watêr-logging, such as in low-lying, swampy areas, should not be planted, nor should those areas with hard-pans or wide stony layers present in the sub-soil strata.

Naturally unsuitable formations such as hard-pans, solid rock too close to the surface, clay belts and similar unfavorable profiles are usually unchangeable circumstances once the palms are planted. If coco-nut wilts occur-when the soils have an impervious hard-pan the condition is irremediable. Proper clearing and planting methods must be followed and it is necesary for the best growth of palms that planting at the right depths, in well prepared holes, be carried out.

Seed and nursery selection are most important procedures rarely followed in this country though commonly urged by this department.

Where it is necessary to plant coco-nuts in wet situations drainage is essential. Deep main drains following a proper fall should be constructed with plenty of smaller lateral drains leading into them. Levels should be taken with a dumpy level, row tracer, or suitable contrivance before the drains are made.

Cattle grazing over wet soils liable to compaction are injurious to the growth of coco-nut palms on such soils. It is not possible to drain soils when they are running in the plantation. They may be beneficial when rotationally grazed in properly sub-divided paddocks where the soils are friable and free working.

Strong growing grasses and other exhausting plants should not be allowed to take possession of the planted areas. Eradicate "kunai", or "lalang", *imperata arundinacea,* also seedy grass, *chrysopogon aciculatus,* particularly. Nothing does this better than where the palms are vigorous growing and provide a dense, overhead canopy, as grasses generally do not flourish under dense shade.

Do not grow soil-exhausting crops such as sugar-cane, bananas and native food crops prior to planting out coco-nuts unless a suitable rotation is used. The graphs showing the high manurial requirements of heavy feeding crops well illustrate the reasons for this. There is legislation in force in Malaya to prevent more than one crop of such plants as cassava, *manihot utilissima,* being grown prior to planting of permanent crops such as rubber.

The use of drier ash, composted refuse, &c., and the provision of complete chemical fertilizers and potash manures to increase the vigour of the palms and remedy deficiencies are indicated. There are economic and other considerations involved which require detailing in a separate study. The use of burnt coral and slaked lime is worthy of much greater trial on some of the stiffer soils in this country.

One of the most important problems on New Guinea plantations is the conservation of humus and organic matter which is very seldom given sufficient attention.

The effects of continuous burning off on the humus supply of most tropical soils is disastrous in the long run. Of course, where pests are bad, occasional burning off of accumulated rubbish is essential. Burning off is usually practised to try and kill off injurious growths and to revive the vigour of palms which should never have been allowed to get into such a state of decline.

The conservation of the humus involves various methods of assisting the dropped fronds, cut weeds and husks to decay without actually being lost from the soil.

Cultivation, ploughing, mulching, circle weeding, hoeing, rolling of dense covers, &c., are all subjects which need separate discourse. It is apparent that clean weeding, hoeing or ploughing should not be carried out in the middle of the dry season, or in times of drought, especially in shallow soils, where the fibrous roots are close to the surface. The palms may suffer badly and show wilting where the water and nutrient supplies to the palm are reduced by the cutting of these roots under such circumstances.

The uses of creeping covers on plantations have already been dealt with in an article by the Director.(34)

In soils greatly depleted of humus, the use of erect, cover crops such as *Leucaena glauca, Tephrosia candida* and *Crotalaria anagyroides,* is recommended. These are cut back at intervals and, if possible, the final objective should be to establish suitable creeping cover crops under them.

Among the great uses of cover crops is that they keep the soils cold and moist over the dry season, reduce severe fluctuations in soil moisture and thus greatly lessen the necessity for root adjustment.

On heavy soils, cover-cropping is recommended providing drainage is adequate. Under wet soil conditions less rampant growers like *Desmodium scorpiurus* or *Dolichos hoseii* are worthy of trial. Cover crops should be kept under control and slashing, hoeing or turning under the rampant cover periodically, say, once in every twelve months or two years, adds humus to the palms and increases their vigour. Where the palms are poorly vigorous circle weeding should be carried on where cover crops are used, as root competition may occur under such circumstances.

This Department recommends *Centrosema pubescens, Pueraria javanica* and *Calopogonium mucunoides* for normal coco-nut soils. It must be remembered that these covers show a high percentage of mineral nutrients on analysis which are returning to the soil in an available form when they are cut back or the leaves drop naturally. They also possess the faculty of adding nitrogen to the soil per medium of the bacterial nodules on the roots. Cost of plantation maintenance and weeding are greatly reduced where cover crops are established.

Phenomenal yield increases are the result often expected from the use of cover crops which are not realized in practice for various reasons which it is not possible to describe here. It is certain that if the plantations in this country had been cover-cropped ten years ago, and proper cultural practices followed, many of the older plantations here would not be approaching the stage of uneconomic production as is the case to-day. Increased yields per acre lessen cost of production and care and attention to the planted areas are usually repaid by the additions to the economic life of the property.

Obviously, the natural rainfall and climatic conditions cannot be changed and the soil profiles are also constant. It is usually possible to improve the vigour of coco-nut palms by methods which prevent water-logging, increase the available depth of soil and the water and nutrient supplies available to the palms. The profound importance of employing proper cultural methods for control and prevention of coco-nut diseases is consequently indicated.

Summary.

An account of some further investigations and observations on occurrences of physiological disorders (wilts, die-backs, &c.) of coco-nut palms in New Guinea is presented.

Special attention is paid to "maturation wilts" of young coco-nut palms at the first bearing stage, recorded from various parts of this Territory.

The symptoms and pathology of the disease at Namatanai, New Ireland, and, also, the detailed investigations and identification of the organisms present by the Director of the Imperial Mycological Institute are given. His comments relating this occurrence to the "cadang cadang" disease of the Philippines, made it necessary to consider the possibility of virus causation.

Reports on soil analyses by the Waite Institute and the comments of their Chemist and Plant Pathologist on the nutrient status and water-relationships of the soils, associated with the occurrences at Kokopo and Namatanai are presented. They indicate the close resemblance between these occurrences and the "bronze wilt" described from Trinidad.

The evidence presented shows that this "maturation wilt" is most probably a physiological disease. During three years, the symptoms made a cyclic appearance in dry periods, and each time disappeared when the conditions became favorable.

Some pathological derangements of mature palms ("mature palm wilts"), particularly from those plantations situated on the deltaic and estuarine deposits of the Huon Gulf and Astrolabe Bay areas of the New Guinea mainland, are described, as are the contributory causes.

Most plantations in this Territory contain areas where palms grow poorly, nevertheless, severe coco-nut wilts are of relatively infrequent occurrence here, probably owing to special local conditions which are discussed.

The occurrences in New Guinea are compared with similar diseases recorded from other countries. These are "cadang cadang" disease, described from the Philippines as a suggested virus disease, "bronze wilts" from Trinidad and Jamaica, coco-nut wilts from Ceylon and derangements of palms coming into bearing described from Malaya.

The pathological symptoms displayed are of physiological origin, excluding possible virus diseases.

The chemical and physiological changes (especially as regards moisture requirements and potash movements) which occur in coco-nut palms at various stages of growth are discussed in relation to the diseases described. Particular attention is paid to the physiology of the root system and its natural adaptations and reactions to such unfavorable circumstances as water-logging and lack of aeration.

Several other diseases and derangements of coco-nut palms present in this country are described (*see* also previous article[9]) as being primarily associated with similar unfavorable soil, moisture, and nutritional relationships to those already mentioned, though the symptoms displayed are often complicated by fungus and insect attack. "Seasonal bearing", "leaf-droop", "frond-choke", certain types of nut-fall, "bud-collapse", "deficiency spotting" and "die-back" appear to belong to this category.

Selected soil profiles showing unsuitable soil, sub-soil, water-table and moisture relationships are described, both in relation to diseases present and their control.

The importance of proper cultural conditions in relation to the control of most coco-nut diseases, but particularly those of physiological origin, is stressed.

The relative importance of physiological disorders of coco-nut palms, as related to fungus diseases, or distinct from virus diseases, is not yet determined. The necessity for chemical and botanical research on the nutrition of the coco-nut palm in relation to the soil conditions obtaining here is clearly indicated.

Acknowledgment.

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The soil analyses published in connexion with the investigations on maturation wilts were carried out through the kind courtesy of Professor Prescott, Director of the Waite Institute, South Australia.

The analyses were made by J. H. Hosking, Soil Chemist, who has since published an article[32] which includes a detailed comparison of the soils from Kokopo with the deposits from the Rabaul volcanic eruption of 1937. His comments and those of D. B. Adam, Plant Pathologist at the Waite Institute, in connexion with the occurrences described, are most valuable and gratefully acknowledged.

F. Henderson, Inspector and Instructor of the Department of Agriculture, New Guinea, carried out useful collaborative work on the disease in New Ireland, being detailed for this work by the Director.

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CONTROL OF COCO-NUT TREEHOPPERS (*SEXAVA* SPP.) BY DUSTING.

B. A. O'Connor, B.A., B.Sc.Agr., Assistant Entomologist.

During the year 1937, a number of laboratory experiments were made to test roughly the comparative toxicity of various dusts to the coco-nut treehopper, *Sexava* spp. These dusts included calcium arsenate, lead arsenate and paris green —diluted in each case with hydrated lime—as well as mixtures of derris, and proprietary mixtures which had as lethal constituents lead arsenate, nicotine sulphate, derris and orthodichlorbenzene. The dusts were applied at a rate somewhat greater than would be economical in the field, the object of the experiments being merely to eliminate the obviously inefficient and uneconomical preparations. Those which appeared most effective were to be tried later in field experiments, using a power dusting machine.

The experiments were carried out as follows:—

Cages of copper wire, 3 feet high and 2 feet in diameter, were constructed, and in each of these from 30 to 50 adult treehoppers were placed, together with food consisting of coco-nut palm leaflets strung on a wire passing across the top of the cage. A hand-duster was used to apply the various dusts, and in each experiment one cage was left untreated, to act as a control. After the first day, fresh, undusted leaflets were placed daily in the cage, the original leaflets being removed. The effectiveness of the treatments was measured by the percentage of treehoppers killed within three days after dusting.

These tests showed that the arsenicals, paris green, calcium arsenate and lead arsenate, were by far the most efficient of the dusts. Paris green was easily the best, but its price appeared prohibitive, and this fact, together with the danger of foliage-burning, caused this insecticide to be passed over in the earlier field trials, though later it was tested out.

Calcium arsenate and lead arsenate appeared roughly equal in toxicity, but as the former was the cheaper, it was the first to be tried in field experiments.

A few results, typical of those obtained in the laboratory tests, are appended. The figures given are the percentage of deaths within three days of treatment—

	Per cent.
Control	10
5 per cent. lead arsenate	97
5 per cent. calcium arsenate	97
5 per cent. paris green	100
Control	10
Proprietary mixture of lead arsenate	100
10 per cent. derris	47
Proprietary mixture of derris	77
Control	16
5 per cent. lead arsenate	100
Proprietary mixture of derris	40
Derris 2½ per cent., orthodichlorbenzene 2½ per cent.	40

The paris green in each case killed about 90 per cent. of the insects in one day, and invariably during the second day all were dead. An interesting point was that the insects did no feeding in any of the cages where paris green was used, showing that death was caused most probably by their ingesting particles of the dust during the process of cleaning their feet and antennae. The effects of the dust must have been very rapid, as dusting was carried out always at about 4 p.m., and yet the treehoppers had lost the desire for food by 6 p.m., when feeding normally begins.

Lead arsenate and calcium arsenate also cause death when ingested during the process of cleaning. For this reason the cages had to be very thoroughly washed after each experiment, as any particles of dust remaining on the wire would affect subsequent tests. On one occasion, cages which had been used for tests with the three arsenical dusts were washed roughly, and treehoppers were placed in them with fresh food, no dust being applied. After three days, the majority of the hoppers were dead, showing that even the traces of poison left on the wire had been sufficient to provide a lethal dose. Percentage mortality in the various cages was as follows:—

	Per cent.
Control	18
Traces of 5 per cent. lead arsenate	88
Traces of 5 per cent. calcium arsenate	70
Traces of 5 per cent. paris green	80

An experiment was carried out also to assess the burning effect of paris green on coco-nut palm foliage, a brief description of which follows: A six months' old potted palm was dusted very heavily with 10 per cent. paris green in hydrated lime, the leaves being first moistened to assist adhesion of the dust. For twelve days the palm was left in the open, but removed to shelter when rain fell, so that the dust would not be washed off. After the lapse of twelve days, it was left permanently in the open. At the end of three weeks, small, scattered, brown patches were noticed on the leaflets, and after six weeks the burnt areas were fairly extensive. This was, of course, a very severe test, and it is doubtful if burning occurs when paris green is used in the field, as the rate of application is much lower, and the dust is washed off by frequent rains. Calcium arsenate, when similarly tested, caused no burning.

Field Experiments.

During the period May to November, 1938, a power duster was used in the conducting of field experiments, the object being to determine the cheapest and most efficient type of dust and rate of application which would achieve reasonable control of the treehopper. In the earlier experiments calcium arsenate was used, and later, lead arsenate and paris green were given a trial. Paris green can perhaps compete economically with calcium arsenate, but lead arsenate, besides being more expensive than calcium arsenate, proved to be much less effective. It was found that diluents could be dispensed with in the case of calcium arsenate, as good coverage of the foliage could be achieved with the undiluted dust. With paris green, however, a filler is necessary, as the rate of application per acre is so low that the undiluted dust would not give even coverage. Hydrated lime was generally used, though trials were made of kaolin and proprietary fillers to determine whether they improved the adhesion of the dust to the foliage. It cannot be said that they were successful, so there is no point in using them except as a diluent. This line of inquiry is not closed, however; it is hoped that a good sticker may be found, thus considerably increasing the effectiveness of dusting as a control measure.

The result aimed at in the field tests was that there should be a mortality of 90 per cent. or more of the pests, when dusting was followed by only one night without rain. Hence, particular attention was paid to the results of experiments in which rain fell after the insects had fed for one night only on dusted foliage, and estimated costs of treatment were based on these results. As the treehoppers feed almost exclusively at night, it is obvious that a fall of rain before their first nightly feed would greatly reduce or neutralize the effect of the treatment, as the dust is easily washed off by rain. This proved, in fact, to be the case. On the other hand, where several rainless days and nights follow on dusting, deaths are more numerous, and where such weather can be counted on, the costs tabulated below can be materially reduced by decreasing the rate of application of the dust.

Unfortunately, owing to the smoothness of the leaf-surface of the palm-foliage, dust will not adhere well to the under surface of the leaflets, where it would be sheltered from the rain.

It seems opportune at this juncture to explain why dusting was decided on instead of spraying. The latter method calls for the use of a smaller quantity of poison, and has the great advantage of causing the spray material to adhere to the leaf surface, even during periods of heavy rain, provided that the film of spray material has had time to dry before rain falls. However, conditions on a local coco-nut plantation make the use of sprays quite impracticable, except in some cases on low palms. Because the spray has to be applied to foliage 50 to 60 feet from the ground, and applied thoroughly, in the form of a mist, a powerful and heavy spraying machine would be necessary to treat an affected area in a reasonable time. The difficulties of operating such a machine in a plantation need no stressing. Large quantities of water would be required (about 200 gallons per acre for each spraying) and the mixing and transporting of the spray material from a depot to all parts of the plantation would be a very big task. Moreover, the time taken for treatment would be several times that taken in dusting. Hence it is clear that spraying is not suitable for local coco-nut plantations.

Dusting, on the other hand, is a comparatively simple process, as a light and low-powered machine, which can be carried by natives or drawn on wheels, will treat 10 acres of palms per hour. Further investigation of dusting machine types is required to determine that most satisfactory for plantation conditions in this Territory.

Technique of Experiments.

For each experiment, a block of 64 palms (1 1/7th acres) was selected, having eight palms on each side. Each block of palms was well separated from the others, so that dust could not drift from one to the other during treatment. Then the fronds were cut from a palm in the middle of the plot, normal in height, foliage and extent of attack by *Sexava*, and the treehoppers counted. The plot was then dusted, and after seven or eight days a similar palm was defoliated, and the remaining *Sexava* counted. Difference in the two counts was taken as the mortality. This figure would naturally be only approximately correct, but satisfactory, as palms in a given locality seem always to have much the same population, and inaccuracies are reduced by comparing the results of a number of experiments. Cutting of fronds and counting of treehoppers thereon, incidentally, is the only really satisfactory way of determining the severity of *Sexava* attack on a plantation. The appearance of the fronds is no guide, as badly chewed palms may have few treehoppers, but show the effects of previous severe attacks, while healthy-looking palms may harbour large numbers of the pests, constituting the vanguard of a heavy infestation. Collecting of adults at night is a good guide to the most severely-affected portions of a plantation.

When the population of a palm is being determined, a native is sent aloft with a bush knife or hacksaw and a long rope. He cuts off the fronds, and lowers them one by one onto a sail spread at the foot of the palm. Here they are examined by several natives, under supervision, and the treehoppers caught and counted. During the day they are almost invariably found on the under-surface of the leaflets, and careful scrutiny is necessary to find them all, particularly the young nymphs. Examination of a palm by this method takes from one to three hours, depending largely on the efficiency of the boy who cuts and lowers the fronds.

To prove that the insects were killed by the dust, and did not merely migrate elsewhere, large sheets of bagging were placed under certain dusted palms, and on these numbers of dead *Sexava* were found during the few days following on dusting, their condition showing that they had been poisoned.

In almost every case, dusting was carried out between 4 p.m. and sundown, because at that time of the day, it was possible to forecast fairly well whether rain would fall overnight or not. As regards wind, a steady air-drift or light breeze is desirable, at it carries the dust steadily in one direction. When the direction of the air current is changing rapidly, dispersal of the dust is unsatisfactory. This is especially so when two or three rows of palms at a time are being dusted. It appears that successful dusting can be carried out even with quite a strong breeze, as results obtained under these conditions have been good, even though most of the dust appears to be swept away underneath the foliage of the palms. At present, it appears that the most satisfactory combination of speed and efficiency can be achieved by treating two rows of palms at a time. This makes possible the dusting of about 10 acres per hour, except in unusually rough country.

In all, over 30 experiments were carried out on small plots, and two 10-acre plots were also treated. On the large plots it was intended to carry out the full programme of two dustings at an interval of about 100 days. Consequently, they had to be reasonably large, so that results would not be unduly affected by immigration of *Sexava* from surrounding untreated areas, during the six or twelve months needed to show the effects of the treatment on yield and health of palms. Two dustings will almost invariably be needed to achieve reasonable control of the treehopper, the first dusting being designed to kill those already on the palms, and the second to deal with those which have hatched out after the first dusting. The interval of 100 days allows time for the most recently laid eggs to hatch, but not for the earliest hatchings to reach the adult stage and lay a further batch of eggs.

It is extremely difficult to present the results of the experiments in a concise form, so that it has been thought better to give those of some typical successful experiments. These will give a good idea of the killing capacity of the dusts used:—

1. 11½ lb. of undiluted calcium arsenate per acre.
   Dusted three rows at a time.
   One night only without rain.
   Population before dusting—98 (36 adults, 62 nymphs).
   Population after dusting—1st row nil, mortality 100 per cent.; 2nd row nil, mortality 100 per cent.; 3rd row 2 adults, mortality 98 per cent.
2. 8 lb. calcium arsenate per acre, diluted with 9 lb. lime.
   Dusted two rows at a time.
   Three nights without rain.
   Population before dusting—75 (18 adults, 57 nymphs).
   Population after dusting—1st row nil, mortality 100 per cent.; 2nd row nil, mortality 100 per cent.
3. 3 lb. paris green per acre, with 21 lb. lime.
   Dusted two rows at a time.
   Five nights without rain.
   Population before dusting—105 (27 adults, 78 nymphs).
   Population after dusting—1st row 4 nymphs, mortality 96 per cent.; 2nd row 4 nymphs, mortality 96 per cent.

Paris green has not been tried as thoroughly as calcium arsenate, but, at present, it appears that the latter gives somewhat better results on a cost basis, and it has the advantage that it does not need the addition of a filler such as hydrated lime to make it of sufficient bulk to give a good cover of the foliage. A filler is necessary with paris green, which is very heavy, and mixing entails extra time and labour. There is also some evidence that calcium arsenate has a delayed action, causing deaths weeks after being eaten by the insects, but this needs further investigation. The cost of material for two dustings with calcium arsenate at a rate of 12 lb. per acre is about 9s., and the same expenditure would allow of two dustings with 3½ lb. paris green and 9 lb. lime. All costs, except for hydrated lime, are based on pre-war American quotes, as prices of arsenicals in Australia are prohibitive. Moreover, the calcium arsenate from the United States of America has proved superior to the Australian article. Manufacture of commercial calcium arsenate in the United States of America has reached a high pitch of efficiency, owing to the vast quantities used annually in the control of pests like cotton boll weevil.

It is anticipated that the total costs of dusting an acre of palms twice will not exceed 11s., including cost of material, depreciation on machine, oil and fuel, labour and supervision. On some properties, where treehopper attack is consistently extensive, it would seem economical to treat the whole plantation first, and during the succeeding years promptly treat any local outbreaks, so that the pest never regains a hold. Complete eradication by artificial means is scarcely possible, and an attempt would be extremely costly, so that the object to be aimed at should be reasonable control.

The economics of the subject are, of course, of paramount importance, for, where dusting might show a profit with copra at £10 per ton on the beach, it might not be profitable at the £5 mark. At the latter price level, only the heaviest losers from *Sexava* attack might find it worth while to conduct a dusting campaign. In this connexion, the following calculations may be of interest.

A plantation known to the writer is 600 acres in area, and has been severely attacked by *Sexava* for a number of years, production at times falling as low as 6 tons of copra per month. When this property was taken over from the Expropriation Board, its average monthly production over a period of years had been 32 tons. For the five years 1933 to 1937 inclusive, the average has been 16 tons. This may not be due solely to the activities of the treehopper, but the many severe attacks by the pest have undoubtedly been the major factor in the decrease.

The cost of two complete dustings of this plantation at 11s. per acre amounts to £330, so a reasonable estimate to cover unforeseen eventualities would be £400. Probably, during the remainder of a five years' dusting campaign, it would be necessary to dust only isolated areas, as signs of renewed infestation appeared. Two dustings of 100 acres in each of the five years would seem a generous estimate, though only experience will show what is actually necessary. These dustings, at 11s. per acre, would cost £275, so one might budget for £350, making the total cost for five years' control of *Sexava* £750.

In assessing the gain due to increased copra production, it must be remembered that the price received for the extra copra is nearly all clear profit, apart from the cost of dusting, because the increased output is achieved without an increase in capital charges. Bags and twine must be allowed for, and possibly some increase in labour strength, the cost of which items, estimated at £1 10s. per ton, must be deducted from the beach price of copra. At the time of writing, the latter is about £6 10s. per ton, so that each extra ton of copra produced as a result of dusting represents a profit of £5. Hence, to pay for the cost of the dusting campaign, plus interest on the £750, about 170 tons of extra production would be needed during the five years, that is, a little less than 3 tons per month. Any increased production over and above this would represent clear profit due to dusting, apart from the long-range effect of protecting the palms from injury. If copra were only £5 per ton during the five years, 4½ tons per month of extra production would be needed to cover the cost of dusting, and, if it were £10 per ton, a little over 1½ tons extra would be required.

In the case of the plantation mentioned, it is obvious that everything points to a large increase in revenue as a result of a dusting campaign. A calculation along these lines should indicate to any planter whether it would be worth while to embark on such a venture. In the case of less severely infested plantations, dusting of the whole area at one time might not be economical or necessary, the main principle in successful control of the pest being to treat localized outbreaks promptly and thoroughly, thus preventing the spread of the pest over a wide area.

Since the completion of this article, the results of dusting experiments carried out by W. R. Carpenter & Co. Ltd. are to hand. Using lead arsenate diluted with kaolin containing a sticker, and checking results by counts of *Sexava* before and after dusting, they claim great success. The experiments were conducted at Agita Plantation in the western islands.

PLAN AND SPECIFICATIONS FOR A SMALL HOT AIR DRIER.

By F. O. Moody.

A native-operated half-ton hot air drier in the vicinity of Rabaul, which has been kept under observation for some considerable time, has yielded such consistently good results that we have caused plans and specifications of the building to be prepared by the Department of Public Works and these are published herewith for general information.

The plans and quantity estimate speak for themselves and the following additional notes are appended:—

Flue pipes.—The pipe from the fire-box into the heating unit and chimney is of 12-in. diameter cast-iron piping, while the heating unit consists of a number of 42-gallon oil or benzine drums fitted into each other and, if possible, riveted together.

Draught.—The pipes of the air-inlets are continued to just under the heating unit; the exit vents for moisture-laden air end just under the iron roof of the drier.

Trays are built of wooden frames reinforced at the corners by galvanized iron binding and cross-straps of the same material; a further strip can also be placed across the centre and bottom of each tray.

Fire-box and chimney-flue are entirely separated from the drying chamber to eliminate the risk of fire.

Method of drying.—The 40 trays carry each almost 56 lb. of green coco-nut meat, loosely laid in the trays in a single layer, so that, as far as possible, the pieces are not piled in on top of each other, thus ensuring perfect draught.

This drier should successfully deal with 1 ton of green meat, or approximately ½ ton of copra every 24 hours, allowing in that period for the time required to remove the dried batch of copra and refill the trays with the succeeding charge of green meat.

Temperature should be maintained at a constant 120° to 140° F. throughout the drying process.

MATERIALS FOR HOT AIR DRIER.

Item.	Description.	Size.	Quantity and Remarks.
	CONCRETE WORK.		
1	Cement	Casks 19	
2	Stone	½"	5½ cubic yards
3	Stone	¾"	5½ cubic yards
4	Sand (clean, coarse)	..	5½ cubic yards
5	Mild steel rods	½" diameter	350 feet—235 lb.
6	Bricks, fire	..	600
7	Rag bolts, nuts and washers	6" x ¾"	40
8	Furnace grate and door	..	1 only
9	Sheet steel	15" x 15"	1 only

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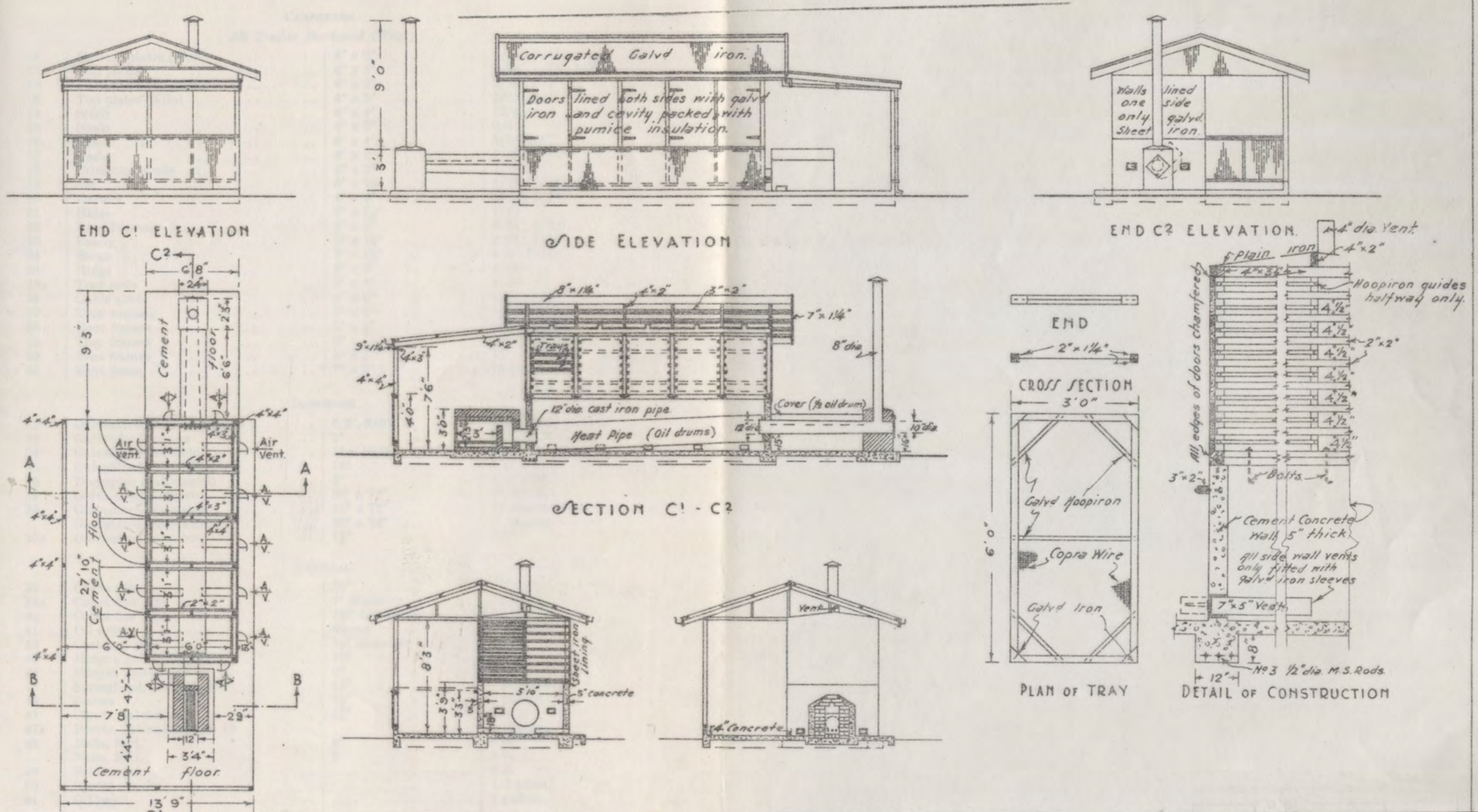
SMALL HOT AIR DRIER



MATERIALS FOR HOT AIR DRIER—*continued.*

Item.	Description.	Size.	Quantity and Remarks.
	CARPENTER.		
	All Timber Hardwood (Wrot).		
10	Bottom plates (Wall)	4″ x 2″	1/18′, 1/15′
11	Top plates	4″ x 3″	1/18′, 2/15′, 1/13′
12	Bottom plates (Kiln)	4″ x 3″	2/18′, 6/7′
13	Top plates (Kiln)	4″ x 3″	2/18′, 4/7′
14	Studs	4″ x 4″	12/5′
15	Studs	4″ x 2″	6/5′
16	Posts	4″ x 4″	3/7′, 4/8′
17	Rails	4″ x 2″	1/18′, 1/14′
18	Trimming studs	4″ x 2″	2/7′
19	Sill	5″ x 1¼″	1/18′, 1/14′
20	Rafters	4″ x 2″	12/9′, 5/11′
21	Ridge	8″ x 1¼″	1/21′
22	Roof battens	3″ x 2″	8/21′, 4/13′
23	Fascia	9″ x 1¼″	2/21′, 1/13′
24	Barge	7″ x 1¼″	4/9′, 2/11
25	Ridge	4″ x 2″	1/18′
25A	Tray rests	3″ x 2″	1/18′
26	Gable studs	4″ x 2″	1/16′, 2/4′
27	Tray runners	2″ x 2″	80/7′
28	Door frames	3″ x ½″	5/10′, 5/14′
29	Tray frames	2″ x 1¼″	80/7′, 80/13′
30	Vent frames	5″ x 1″	53′
31	Vent doors	7″ x 5″ x 1″	14 pieces
	IRONWORK.		
32	Galvanized iron, corrugated	6/5′, 9/6′	22/8′, 8/10′ x 24 G.
33	Galvanized gutters	5″	10/6′ x 24 G.
34	Galvanized brackets	1″ x 16 G. ..	20
35	Galvanized ridge capping ..	18″	4/6′ x 24 G.
36	Downpipe (galvanized) ..	3″	4/6′ x 24 G.
37	Galvanized plain iron	30″ x 72″	16 sheets
38	Galvanized plain iron	24″ x 72″	10 sheets } 24 G.
..	Galvanized plain iron	36″ x 72″	5 sheets
38A	Galvanized hoop iron	1¼″	280″
	GENERAL.		
39	Copra wire	36″	242 feet
39A	Copra flue pipe	8″ diameter	11 feet }
40	Copra flue pipe	10″–12″ diameter	10 feet }
41	Oil drums	40-gal.	8
42	Cast iron pipe	12″ diameter	24″
43	Hinges, galvanized tee ..	12″	5 pairs
44	Hinges, galvanized tee ..	6″	7 pairs
45	Springhead, galvanized ..	2¼″	7-lb. packet
46	Screws	1¼″	1 packet
47	Clouts, galvanized	1¼″	3 lb.
47A	Rivets, galvanized, No. 10 ..	.. .. ..	1 packet
48	Nails, R.H.	4″	4 lb. }
..	Nails, R.H.	3″	8 lb. }
49	Solder	.. .. ..	4 lb.
50	Spirits of salt	.. .. ..	1/3 pints
51	Oil paint	.. .. ..	1 gallon

One European and two trained natives should build job in three weeks.

A HANDY AND INEXPENSIVE " CEYLON TYPE " KILN DRIER.

By E. Caulfield-Kelly.

Building.

Fifty-two feet long by 22 feet wide, of native material, with kunai or sac-sac roof, having a covered vent in the ridge, after the fashion of a "jack-roof". No flooring is necessary.

Fire-pit.

This may be dug as deep as 3 feet below ground level, or less, according to the nature of the ground and the height of the water-table, and should be 46 feet x 16 feet in dimensions, with a hard dry bottom of either cement or firebricks, or even tamped earth or coral. Its position in the building should be with one end against the back wall and one side along one of the side walls.

Drying-bed.

Forty-eight feet x 18 feet, made with timber and strong wire mesh—rabbit wiring is quite suitable—the frame to be strongly re-inforced to carry about 5 tons. This is supported immediately over the fire-pit on posts of mangrove or other native hardwood, so that the bottom of the tray is at least 7 feet above the floor of the fire-pit. The space from ground level above the pit to the level of the bed should be enclosed on three sides by galvanized iron nailed on to the inside of the supporting posts, so that the heat and gases ascend from the pit directly under the bed. The fourth side, which should be the end of the bed at the entrance end of the building, should be enclosed by sliding or hinged doors to provide an entrance to the pit to lay and tend the fires. The bed, being directly over the pit, will, of course, have one of its ends against the back wall of the building, and one of its sides along one of the side walls. This will allow an operating space of 4 feet at the entrance end of the building and 4 feet along the length of the drying-bed.

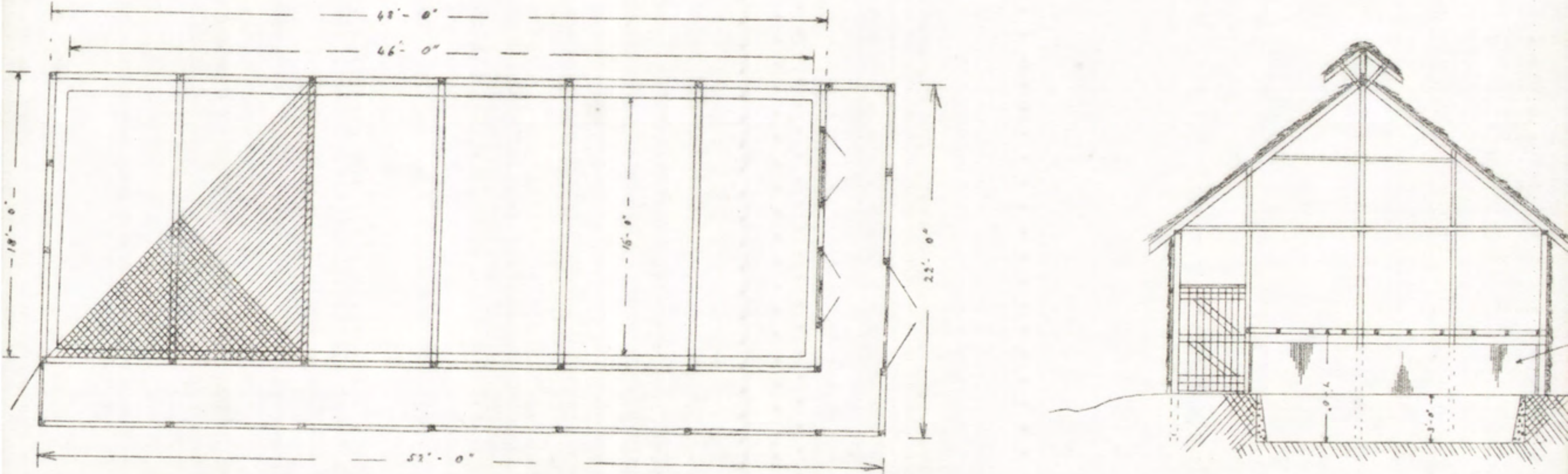
Firing.

Perfectly dry half-shells, quite free from husk, must always be used. Ten double lines of these, cupped into each other, should be laid down across the width of the fire-pit. These double lines should be 4 feet apart, and, leaving a space of 1 foot at each end, should therefore be 14 feet long. The double lines should be laid side by side and touching, but not over each other. Each line should be lit at the opposite end from the preceding line, i.e., each alternate double line is ignited at the same end. Ten of these double lines will be sufficient to fill the pit and will constitute one charge. Each line will burn for about four hours and fires must be kept well up for the first eighteen hours.

Process.

Seventeen thousand nuts are husked and placed convenient to the drier. Each nut is split in two and laid aside, concave side downwards, for an hour or so to thoroughly drain. If possible, the meat should then be sundried (concave side upwards) for the first day and drying then completed in the kiln for three further days. On the first day in the kiln, the half-nuts are either placed or "lined"

A HANDY CEYLON DRIER



concave side upwards and stacked to a height of 10 inches to 1 foot in such a manner that the heat and gases from the pit may circulate freely through them. On the second and third days in the kiln the half-nuts need not be so carefully placed, but may be thrown haphazardly on the bed, the lower nuts each day alternating with the upper ones. If sun drying on the first day is not possible owing to weather or other conditions, a further twelve hours in the kiln may be necessary to ensure full drying.

Notes.

Kilns of this type have been operated successfully on the Madang coast on a group of properties which turn out 1,000 tons of copra per annum.

Husking nuts is a task at which native labourers become quickly proficient and an average task for a day-unit is to collect and husk 500 nuts.

The most useful husking apparatus is a sharp-pointed piece of 1-in. flat iron, fixed in a plank, on which the labourer can sit to steady it, but a piece of pointed mangrove or hardwood driven into the ground is also quite effective.

Six half-shells cupped into each other will cover a foot of fire-line so that the shells of 960 nuts will be sufficient for a charge of ten lines. No knives or shovels are required in the drier as the meat will drop out of the shells, or can easily be removed by hand when quite dry, and the copra, being in large pieces, can be handled without shovels.

Wastage in copra cutting and loss of small pieces will be entirely eliminated.

No firewood gangs are necessary with this process as the shell from each batch of copra cured will be more than sufficient to dry the succeeding batch and, incidentally, will be quite dry.

Constant attention to every detail will be necessary for a month or so until the labourers thoroughly understand their tasks. This applies especially to the firemen, but the process will be found eventually to be more economical than ordinary hot, air drying, whilst a really first-class copra can be turned out with reasonable care.

The half-nut pieces of copra can be again halved or even quartered if desired when bagging in order to reduce the number of bags per ton required.

The proportions of the drier can be reduced or increased in proportion to the output of a property.

The shell fires will provide a smoke-free heat and hot gases only, provided that no husk is left adhering to the shell and that it is quite dry and free from dirt.

To obtain the first batch of good clean shell it would probably be worth while to dry the first 17,000 nuts by ordinary smoke fires and treat the first batch of copra cured as smoke dried.

A further advantage of this would be that the interior of the building, especially the roofing material, would be protected to a certain extent by the smoke against subsequent insect attack.

Until the labourers are quite proficient it may be necessary to pick over the first few batches of cured copra for smoke tainted or discoloured pieces and submit these as smoke-dried copra.

BRUS TOBACCO FOR NATIVES.

George H. Murray.

Increased prices and irregularity of transport have added to the difficulties of the planter with regard to the issue of rations to native labourers. Part of that issue has been stick tobacco imported from the United States of America and as attempts to produce a similar article in the Territory, acceptable to natives, have proved a failure, " brus ", or air-cured tobacco, is recommended as issue instead of the manufactured article. This is accepted by the natives, even preferred by many bush natives who have not become accustomed to the manufactured article. Planters, if they choose, can produce " brus " on their plantations and thus reduce costs considerably and the following instructions have been written for their benefit. Although ordinary air or open barn-cured " brus " is sufficient for the purpose, the final section in the article deals with further fermentation of the leaf to improve the bouquet and reduce the " bite " which are not objectionable to natives, but, nevertheless, this would increase the value of the ultimate product for the planter who may eventually desire to produce tobacco for the open market.

Tobacco requires a well-drained soil but not too sandy and good cultivation is essential for success. The ground should be thoroughly broken up, reduced to a fine tilth and all weeds and grass removed as any check in the growth of the plant will have an adverse effect on the quantity and quality of the leaf.

In preparing seed beds every care must be taken to ensure good drainage and it is therefore necessary that they be raised fully 6 inches higher than ordinary ground level. There need be no limit to the length of the beds, but they should not be more than 4 feet wide for ease in weeding and watering. The ground should be sterilized before sowing the seed and the simplest way of doing this is to pile broken-up dry bushwood to a depth of 5 or 6 inches on top of the seed beds after all preparatory work has been completed. This should be burnt and when the fire has died down all partially burnt sticks, twigs and charcoal should be carefully removed and all the ashes incorporated with the soil by raking deeply backwards and forwards. The fire will destroy all ground insects, fungus spores and most noxious bacteria. I have found even large millipeds 6 inches from the surface all scorched up by this method, while potash and other elements in the ashes act as fertilizers to the soil. Even natives realize the advantage of this treatment as they frequently sow their tobacco seed where logs or stumps have been burnt.

After the ashes have been thoroughly incorporated with the soil the surface of the bed should be levelled off with a piece of straight-edged timber and by the time the bed is thoroughly cooled down, three or four days later, it will be ready for receiving the seed.

The seed is very minute and it is best to mix it with ashes as its distribution, if sown broadcast, can be more readily noticed. Personally, however, I prefer sowing even tobacco seed in rows about 3 inches apart in the shallowest of drills and pressed down with a smooth board as the seed is so minute that it must not be covered deeply. The beds must be kept continually moist but not wet and if allowed to dry out for a single day the sprouting seeds or seedlings will be killed. The seed bed must be kept shaded against the rays of the sun and this is easily done by having well plaited bomboms the width of the bed. The bomboms should not be more than 6 or 9 inches above the seed bed until after the young plants appear when the shade should be gradually raised as the plants increase in size. If bomboms are not easily obtainable, a good shade can be provided by laying lengths of kunai flat on frames with thin laths of bamboo or similar plant to keep the kunai leaves in place. This latter method is the one used in the tobacco Proefstation, North-East Sumatra, and it served the purpose quite well. Every care must be taken in the way the shading operation is handled for if kept heavily shaded too long the young plants will become leggy and weak. Some recommend the use of cheese cloth but this is quite unnecessary for ordinary tobacco, although highest quality of tobacco is raised even to maturity under such shade in Cuba.

When the seedlings have developed two pairs of leaves they should be pricked out and planted in a nursery bed 4 inches apart to make sturdy plants, so that they will not feel the shock of transplanting to the open field when 5 or 6 inches in height.

The distance of planting is somewhat variable according to the type of tobacco desired, but under New Guinea conditions rows of 3 feet apart and 18 inches in the row are satisfactory, as there is no mechanical cultivation in the Territory which would require wider spacing.

The plants should not be permitted to develop side-shoots, all of which should be nipped off as soon as seen. When the plants have developed twelve to eighteen leaves, they should be topped, but due care must be taken that this is not done too soon, otherwise it will encourage side-shoots—the leaves should be well developed before the plant is topped.

To obtain leaves of the best quality they should be harvested separately when fully ripe, which can be judged by the appearancee of the leaves, which will become dull in colour. For cheaper grades of tobacco the whole plant can be cut off close to the ground when the greater number of leaves are ripe.

The curing of tobacco requires special training and experience, and those contemplating the production of "brus" tobacco would be well advised to adopt a simpler method common amongst many small growers even in many parts of America to-day. If leaves are to be picked separately, the harvesting can be done when the plant is about four months old, commencing with the lower leaves, which are the first to ripen. Experience is required to know just when they are ripe enough for harvesting, as individual plants vary to a certain extent in ripening. Besides, judgment in the appearance of the leaf ripeness can be tested by bending the midrib, and the snap will give an idea whether the leaf is still too green or ripe.

Whether the leaves are picked singly or the whole plant is cut all the crop should go into a curing shed (a good kunai roof gives sufficient covering) to protect the crop from sun, dry-air currents and excessive humidity.

Hung on sticks suspended horizontally in racks, the leaves in pairs, if picked singly, or the whole stem, undergo a slow curing process, or dry fermentation, gradually turning yellowish brown and becoming tough. The length of curing depends on the kind of leaf and temperature, but from three to six weeks is sufficient to develop the nicotine content and correct leaf texture. In rainy weather fires made of dry coco-nut shell, free of coco-nut fibre, as used in a Ceylon copra drier, will prevent damage from excess moisture in the leaf. In North-East Sumatra, which produces the highest-priced tobacco in the world, the curing sheds are of great size, but are built entirely of atap, i.e., sak sak, or preferably nipa palm leaves, with ventilators in roof or on the sides that may be raised or lowered as required.

The elaborate curing sheds used for pipe tobacco are quite unnecessary for "brus".

Due care must be taken that the crop is grown in the right season, otherwise the crop will prove a complete failure. Naturally, the leaves should ripen in the dry season, so that the seed should not be sown more than about two and a half to three months before the wet season is over.

Fermentation.

After being air-cured the tobacco leaves can be taken off the frames and made into small bundles, when they can then be stored for a few months if necessary. Complete fermentation can be commenced almost immediately after air-curing has ceased, and to do so a simple method is as follows:—

The bundles of leaves are spread on the floor in layers forming piles 10 or 12 feet long, about 5 feet wide and 6 to 7 feet high, which will contain roughly half a ton of leaf. If the leaves appear too dry it may be necessary to give them a slight sprinkle of water to start fermentation. A close watch must be kept on the temperature, which should not be allowed to go higher than about 125 deg. to 130 deg. It will be necessary to break down the heap and rebuild several times to get an even temperature, but fermentation should be complete in about six weeks. The leaves are then ready for baling prior to shipment to the manufacturers. However, as stated in the earlier part of this article, full fermentation is not necessary for "brus". The above particulars are given for the planter who desires to reduce the "bite" and improve the bouquet, thus producing a finer article, and, when he has had sufficient practice, details can be given for producing a higher-quality tobacco.

THE VALUE AND USES OF METEOROLOGY.

By B. G. Challis.

This article is an explanation in simple terms of the practical uses and benefits to be derived from meteorology, which may be defined as that part of natural science dealing with the factors influencing weather and climate.

The study of weather and climate is important to people in many spheres of activity. At first sight it may appear that such people as agriculturists, aviators and mariners are the only ones vitally concerned with this subject, but merchants, engineers, contractors, medical officers, insurance men, caterers, leaders of defence forces and many others are among those who find a knowledge and the study of weather conditions essential in their respective callings. A few instances will be cited to illustrate the importance of meteorology and the correlations between meteorology and the various interests operating in this Territory.

At the chief town in each of the various administrative districts of the Territory there is a climatological station where barometric pressure, temperature, humidity, wind, visibility, cloud and other weather phenomena are recorded. In addition, there are some 60 stations which forward to this office in Rabaul, immediately after the close of each month, particulars of their rainfall records on a form, which also makes provision for notation of wind direction and force, cloud scale and any other available information, such as thunderstorms, dew, &c. When received by the central bureau at Rabaul these particulars are transferred to a permanent register and are then available on application.

For historical purposes it is interesting to note that climatic changes have occurred from one geological epoch to another. Geology teaches us that there have been great changes in the world's climatic conditions since its earliest formation (in pre-Cambrian period) through the various geological epochs—Palaeozoic, Mesozoic, Tertiary and Quaternary.

Remains of plant and animal life are amongst evidence of these climatic changes. The presence and disappearance of ice-fields and the transformation of forest and desert also support such changes.

Many theories are propounded regarding the causes of climatic changes, but so far a satisfactory solution is still awaiting authoritative acceptance. However, these changes become scarcely appreciable within our own life-cycle unless we can refer to records registered by instruments.

Through the courtesy and assistance of various observers stationed throughout the Territory it is possible, where the records cover a sufficiently lengthy period, to determine the climate of the different localities and its effect on agriculture and other kindred callings.

There is, of course, a difference between weather and climate. Weather is the meteorological condition for the 24 hours ensuing. Climate is the average weather condition over a number of years. The weather changes so frequently and is notoriously capricious in its behaviour during the course of a year, but its constancy or average over a period of years will enable a description to be made of the "climate" of a selected place, and at the same time act as a guide to what may be expected of the average behaviour of the weather. Accurately recorded weather conditions for a month or so are practically valueless, and the recordings must be continued over a lengthy period to have any marked value.

Meteorology is not an exact science. The movement of the various atmospheric factors follows no set plan, so that a vast field of research and future study lies ahead for students of meteorology, particularly in its application to this Territory.

As climatic factors vary in different localities it is obviously necessary to record them at as many places as possible, and wherever private rain gauges are installed the central bureau would greatly appreciate receipt of such further records as observers may care to submit.

It is a natural function and duty of this office to publish from time to time such information as it is able to collect by the co-operation of observers, and it should be noted that already considerable climatic data has been published in previous issues of this *Gazette*. It is hoped that the published information proves its usefulness and will lead to a more accurate knowledge of the various climates to be found in this Territory.

Agriculture.

Dr. Bryce, formerly Director of Agriculture in New Guinea, and now directing the agricultural welfare of Nigeria, stressed the importance of climate on agriculture in the following words:—

> The influence of climatic factors on the crop yield is of course recognized by everyone. Of equal and in some instances of greater importance is the influence of climatic factors on the incidence of fungus diseases and insect pests. It has been stated by Sir E. J. Russell that the loss to agricultural crops in Britain through the ravages of fungi and insects is probably at least 10 per cent. of the total value of the crops, or some £12,000,000 per annum. 'The saving fact seems to be that the pest does harm only when three sets of conditions happen to occur together: the pest must be present in the attacking state; the plant must be in a sufficiently receptive state; and the conditions must be favorable to the pest.' The chief conditions that favour the pest or otherwise are climatic, and a sound knowledge of the local climate is frequently of great aid in devising means of combating the pests and diseases. For example, 'in the Sudan some degree of control over the cotton thrips has been effected by giving the plant protection against the drying north wind and so maintaining a rather more humid atmosphere—a condition in which the plant flourishes more than the pest.' A knowledge of the climatic and essential seasonal conditions which favour the boll weevil of cotton in the United States has led to alterations in the cultivation of the crop in order to obtain a quick-growing and early-maturing variety in infested districts, a line of investigation which seems at present to offer the most hopeful means of controlling the pest.

A perusal of the article submitted by the economic botanist in this issue will reveal to the reader the stress laid on the particular weather conditions in relation to the diseases of coco-nuts. Similar importance is attached to the welfare of other crops in relation to rainfall and other climatic factors, for unless the planter is aware of the climate of a particular area it would merely be gambling with his fortunes if he ventured on a planting scheme in which the generally known weather conditions are likely to have an adverse effect on the particular crop chosen.

Some varieties of crops require a short growing season and others a long one. For instance, to cite the case of cotton, which may prove a particularly remunerative crop now war has broken out, it is possible to grow long stapled cotton successfully where the crop has a long growing season or where it can be irrigated when rain has ceased falling. So that a prospective planter of this crop would choose the variety of cotton best suited to the particular climate of his settlement.

When reliable information is available for a particular district for reference at a central bureau the intending settler may be supplied with advice on the suitability and prospects of any particular crop with a greater degree of accuracy and certainty. For instance, in the Gazelle Peninsula he would not sow a grain crop in October when he knows the length of time it takes to mature will require it to be harvested in the middle of the wet season. Any experienced planter will, therefore, make good use of his available climatic records and their variability.

The Governments of Germany, Holland and the United States of America in particular make a keen study of climate and use this knowledge to the best advantage, and we might well follow them in this respect.

An examination of the rainfall records of Rabaul and Manus indicates, at a glance, that the latter town receives nearly twice as much rainfall as Rabaul, and that Rabaul has a distinct dry season which is essential to the success of some crops, whereas it would be detrimental to attempt to cultivate a similar crop at Manus, which experiences no regular dry season.

To cite another instance, a case has just come to notice of a plantation on the mainland which was recently abandoned simply because of unsuitable soil and climatic conditions in that district. The coco-nuts on this plantation thrived at first but later succumbed. Had inquiries been made and advice sought regarding the average climatic conditions of this area over a period of years such a costly mistake could have been averted.

Generally speaking rain is essential for growth of leaf and wood and sunshine for profuse blossoming and good setting of seed. Many insects are badly affected by excessive rain, particularly bees and flies, which become fungus-ridden and perish under such conditions, while lack of rain or sunshine retards vegetative growth and causes the plants to wither and die.

Aviation Weather Service.

Aviation services regard as essential a knowledge of weather conditions along the route over which they operate, especially prevailing weather at landing places. In response to the writer's questions when discussing the value of weather advices with a flying-boat captain, he emphatically stated, "It is sweet music to our ears to hear the actual prevailing weather conditions." Weather, apparently, has a marked psychological effect on aviators, and it greatly relieves their minds to receive aeradio advice of the weather they are likely to encounter and especially that prevailing at their next landing place.

It is interesting to note that at all airports of call on the air mail route from Sydney to Rabaul trained officers are stationed to make available weather messages for the information of aircraft. Prior to departure from each aerodrome *en route* the pilot signs a form on which is indicated weather conditions between points of departure and ports of call.

As a guide to the most favorable altitude at which to fly weather observers inform the pilots of the strength and direction of winds in the higher atmosphere. These are ascertained by the aid of pilot balloon observations, which are carried out by tracing through a theodolite and noting at fixed intervals of time the track and movements of suitably coloured rubber balloons filled with hydrogen. These balloons are so light in comparison with their size that they immediately adjust themselves to the speed and direction of wind flow in the various layers of the atmosphere. By taking advantage of favorable winds not only is there a saving in time gained by an increase in speed but also a great saving in petrol consumption.

On all aerodromes it is of paramount importance that a pilot should know the exact direction and approximate velocity of the wind at ground level, particularly when landing, and a wind direction indicator is always installed for this purpose. This may take the form of the usual wind sock which blows out from a pole in the direction of the wind, or in more modernly equipped airports, a wind vane is attached to a large white arrow which is easily visible from the air to mark the wind direction. Smoke fires are also of assistance at actual ground level itself, especially on aerodromes which have only a one-way runaway.

Aeroplanes usually land into the wind, but on narrow runaways it sometimes becomes necessary to land partly or completely across wind. In these cases drift has to be counteracted by depressing the wing tip of the machine into the direction from which the wind is blowing, thereby offsetting the possible drift by a corresponding amount of side-slip into the wind, hence the necessity for knowledge of direction and velocity.

Although not within the scope of services provided by this Territory, it may be mentioned that at many air force depots a special 'plane, which co-operates with weather bureaux, is sent up daily to a height of 25,000 feet to ascertain atmospheric conditions at various altitudes.

In passing it may be noted that, since we have so many aerodromes and landing places at high altitudes in this Territory, with decreased barometric pressure associated with increasing height and a more rarified atmosphere, an increased runaway is required for taking off and landing. The length of the run for take-off is increased by 15 per cent. at 2,000 feet, 25 per cent. at 3,000 feet and 50 per cent. at 5,000 feet.

The information given by weather observers for the benefit of aircraft comprises—

- (*a*) Barometric readings (essential for night flying or when flying "blind" through cloud or fog).
- (*b*) Humidity.
- (*c*) Direction and force of surface wind.
- (*d*) General remarks upon present weather.
- (*e*) Total amount of cloud in tenths of sky cover.
- (*f*) Type and amount of low clouds with direction of movement.
- (*g*) Type and amount of middle clouds with direction of movement.
- (*h*) Estimated height of the base or underside of low clouds.
- (*i*) Horizontal visibility.
- (*j*) Upper winds.

This information can be condensed, coded and transmitted by radio to aircraft in flight.

The most feared factors as far as aviation is concerned are thunderstorms and fog. Low clouds over a landing place often present difficulties to aviators, and in this respect observers can proffer welcome advice by giving information as to the location of any clear spaces where the 'plane might come through.

Vast amounts are spent annually on aviation meteorology, and from press reports within the past few months we learn that Pan American Airways, in conjunction with their Trans-Pacific Air Service, provided for over 100,000 francs expenditure on their aviation meteorological service at Noumea in our neighbouring territory.

In the United States of America, the Department of Agriculture, which controls the weather services of that country, has submitted $990,000 as their requirements to be expended on research, while its actual cash appropriation to maintain the existing aviation weather service for the fiscal year ending 30th June, 1940, is $3,700,000.

In connexion with the Trans-Atlantic Air Service it may be mentioned that the French steamer *Carime* (6,400 tons) was engaged cruising in the Atlantic Ocean during 1937-38 specifically as a meteorological and radio station collecting valuable information on the atmospheric conditions of the Atlantic, and just prior to the outbreak of hostilities a co-operative plan was arranged for exchange of weather data collected by various ships crossing the Atlantic for the benefit of shipping and aviation.

Health.

A knowledge of climatology in relation to different localities is essential to the medical profession not only from a general public health point of view, but to aid its officers to diagnose causes of ill-health and which places to recommend to their patients requiring either a bracing or sedative sanitorium.

In selecting healthy or unhealthy localities the general concern of the medical officers regarding a place is to obtain information as to the exposure, elevation and drainage.

Exposure refers to what degree a particular locality is open to or sheltered from the sun or winds and the influence of modifying forces such as sea or mountains and the effects of these forces on a locality. The penetration of the sun's direct rays assists the bactericidal powers, whereas low-lying, inland valleys will be liable to mists and perhaps produce detrimental effects on the patients.

Elevated altitudes are usually associated with purer air and feelings of personal buoyancy as a result of the rarer atmosphere and its lesser moisture content than stations on the littoral or sheltered valleys where there is usually a greater range of temperatures.

Porous soils are a factor tending towards a healthy locality, whereas impermeable soils are generally unhealthy and in such cases an engineer may be called in to suggest a suitable drainage scheme to overcome the difficulty.

Meteorology teaches us that the atmosphere is like a blanket preventing the penetration of ultra violet rays so that the higher the elevation and more rarified the air the greater the healing power of such rays. Although Zulus know nothing of the principle of ultra violet rays, they have learned from experience their healing virtues, and it is customary for them to go to the tops of their highest mountains to expose wounds to the sun with beneficial results. At lower levels the ultra violet rays have a beneficial effect from dawn to about 8 a.m., but after that the effect is negligible.

It is therefore necessary for the Health Department to have a knowledge of the various climatic factors including sunshine, rainfall, humidity and temperatures to enable them to deal satisfactorily with matters coming under their jurisdiction.

Engineering.

Meteorology has also many applications to engineering. It may be noted that in connexion with air-conditioning purposes to arrive at an ideal indoor temperature the builder would ascertain the average outdoor temperature and in the case of many coastal New Guinea stations he would probably strive for about 71°F. as an ideal indoor temperature.

Recently an electrical engineer conferred with the department's bureau to ascertain the minimum shade and maximum solar temperatures experienced in Rabaul. This information was necessary to enable him to make allowances in the stress on electric light wires which his company propose to lay in a single span of half a mile from the vulcanological observatory site to a base at the foot of the hills encircling Rabaul.

Ballistics.

At present most people in this Territory are military minded, and from our knowledge of the theory of gunnery and small arms we know that weather conditions have a decisive bearing on the motion of the projectiles during flight from muzzle to target.

Before leaving the factory, .303 service weapons are tested for certain standard conditions which include—

(*a*) Still air—at all points of the projectiles' trajectory.

(*b*) Ground pressure of 30.00 inches of mercury at 32° F. in latitude 45 degrees.

(*c*) Ground temperature of 60° F.

Allowance must therefore be made for any departure from these standard conditions. The longer the range being used the more necessary it will be for adjustments to suit the particular prevailing weather.

For naval gunnery and artillery such other climatic factors as relative humidity and lapse rates must receive consideration.

The effect of wind on the trajectory of a bullet or shell, especially that of a cross-wind, is a factor for which due allowance must be made.

For accuracy of shooting with anti-aircraft and long-range guns, it is necessary to know the equivalent constant wind, which may be defined as the average velocity and direction of wind from the firing point to the top of the trajectory.

The velocity and direction of surface and upper winds are ascertained daily at Rabaul and Salamaua by means of pilot balloon observations. If the presence of cloud prevents a speedy pilot balloon observation, the weather observer may ascertain the strength and direction of ballistic winds by firing a shell to burst at a known height into a patch of clear sky and tracing its smoke drift through the weather observer's theodolite.

Where instruments such as anemometers, wind vanes or pilot balloons are not available to measure the direction and force of surface winds, a due appreciation on the wind's direction and force may be gained by a study of its effect on trees, grass, smoke and other objects rather than on physical sensations. The annexed universally adopted Beaufort Scale Wind Force Table will enable the observer to discriminate between the various types of wind.

So far as our records show in New Guinea, there is nothing to indicate that winds greater than force seven on the Beaufort Scale have been experienced near ground level, although a wind of 60 miles per hour was registered near the 18,000 feet level a day after the departure of the tourist ship *Strathnaver* from Rabaul—28th August, 1939—when it may be remembered that during this vessel's stay we experienced perhaps our most severe squall for many years. However, this squall was of very short duration.

As altitude increases there is a noticeable rarity in the air which corresponds to a decreased atmospheric or barometric pressure. As the barometer falls, less air resistance is thus offered to a projectile so that at hill stations such as Wau, Edie Creek or Upper Ramu, a rifleman must take into account the rarity of the atmosphere and deduct from his range $1\frac{1}{2}$ yards for every 100 yards. It should be noted that the barometer falls about 1 inch for every 1,000 feet altitude.

Every degree the temperature registers above or under 60° F. the rule is to deduct or add $^1/_{10}$ yard for every 100 yards of range. The following may be quoted as an example. At Edie Creek the range finder reports the distance to the target at 1,600 yards. Barometer records 23.00 inch and thermometer 80° F.

		Deduction.
Barometer	$7 \times 1\frac{1}{2} \times 16 =$	168
Temperature	$20 \times {}^1/_{10} \times 16 =$	32
Total deduction		200

Corrected elevation sight will therefore be 1,400 yards. Corrections may appear negligible for actual skirmishing conditions likely to be encountered in this Territory with small arm weapons, but it is obvious that for naval gunnery and artillery purposes, when the shell passes through a greater stress of weather factors, a knowledge of barometric pressure, ballistic temperatures and strength and direction of equivalent constant winds will be essential to accuracy of shooting, and in this respect the services of a weather officer or meteorologist can be of great assistance to a gunnery unit.

Summary.

In conclusion it may be stated that meteorology is so closely associated with health, habits, pleasure and various vocations in life that it warrants universal attention.

Meteorology covers such a wide field, and the factors which govern it are so variable in character that a net-work of weather observers is necessary to act as a guide for any intelligent discussion on climate and the probable behaviour of weather.

Illustrations have been given in this article to show the importance and value attached to this branch of science; also the necessity for observers in the various parts of the Territory continuing to submit weather data to a central bureau at the Department of Agriculture in Rabaul.

To quote John Ruskin on meteorology—

One following this science will find himself part of one mighty mind—a ray of light entering into one vast eye—a member of a multitudinous power, contributing to the knowledge and aiding the efforts which will be capable of solving the most deeply hidden problems of nature, penetrating into the most occult causes, and reducing to principle and order the vast multitude of beautiful and wonderful phenomena by which the wisdom and benevolence of the Supreme Deity regulates the course of the times and the seasons, robes the globe with verdure and fruitfulness and adapts it to minister to the wants and contribute to the felicity of the innumerable tribes of animated existence.

TABLE OF THE BEAUFORT SCALE OF WIND FORCE.

Beau-fort Number.	Descriptive Title.	Abbreviated Descriptions.*	Specification for use on land.	Average speeds in the open.		
				Miles per hour.	Metres per second.	Feet per second.
0	Calm ..	Calm ..	Smoke rise vertically ..	Less than 1	Less than 0.3	Less than 2
1	Light air ..	Light wind	Direction shown by smoke but not by wind vanes	1–3	0.3–1.5	2–5
2	Light breeze ..		Wind felt on face; leaves rustle; ordinary vane moved by wind	4–7	1.6–3.3	6–11
3	Gentle breeze ..		Leaves and small twigs in constant motion; wind extends light flag	8–12	3.4–5.4	12–18
4	Moderate breeze	Moderate wind	Raises dust and loose paper; small branches are moved	13–18	5.5–7.9	19–27
5	Fresh breeze ..	Fresh wind	Small trees in leaf begin to sway; crested wavelets form on inland waters	19–24	8.0–10.7	28–36
6	Strong breeze..	Strong wind	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	25–31	10.8–13.8	37–46
7	Moderate gale		Whole trees in motion; inconvenience felt when walking against the wind	32–38	13.9–17.1	47–56
8	Fresh gale ..	Gale ..	Breaks twigs off trees; generally impedes progress	39–46	17.2–20.7	57–68
9	Strong gale ..		Slight structural damage occurs (chimney pots and slates removed)	47–54	20.8–24.4	69–80
10	Whole gale ..		Seldom experienced inland; trees uprooted; considerable structural damage occurs	55–63	24.5–28.4	81.93
11	Storm ..		Very rarely experienced; accompanied by wide-spread damage	64–75	28.5–33.5	94–110
12	Hurricane ..	Hurricane	.. ..	Above 75	33.6 or above	Above 110

* The abbreviated list of descriptive terms is often used in plain language reports and forecasts.

EASTERN STANDARD TIME* OF SUNRISE AND SUNSET FOR THE YEAR 1940—RABAUL.

(Lat. 4° 12′ S. Long. 152° 11′ E.).

1. These times are for the upper limb of the sun and may be taken as correct to within one minute for Rabaul.

2. Subtract four minutes per degree of longitude for any place east of Rabaul. Add four minutes per degree of longitude for any place west of Rabaul. (Accuracy still being approximately within one minute of time.)

3. An additional correction must be made for latitude, for which the following table may be used:—

—	For Every Degree of Latitude—	
	South of Rabaul.	North of Rabaul.
	minutes	minutes
January	Subtract 1.5	Add 1.5
February	Subtract 0.9	Add 0.9
March	Subtract 0.1	Add 0.1
April	Add 0.7	Subtract 0.7
May	Add 1.4	Subtract 1.4
June	Add 1.7	Subtract 1.7
July	Add 1.6	Subtract 1.6
August	Add 1.0	Subtract 1.0
September	Add 0.2	Subtract 0.2
October	Subtract 0.6	Add 0.6
November	Subtract 1.3	Add 1.3
December	Subtract 1.7	Add 1.7

After this correction time should be correct to within approximately 2 minutes.

—	Rise.	Set.	—	Rise.	Set.	—	Rise.	Set.
	h. m.	h. m.		h. m.	h. m.		h. m.	h. m.
January—			February—			March—		
1 ..	5 44	6 05	8 ..	5 58	6 12	7 ..	..	6 07
2 ..	..	6 06	10 ..	..	6 13	8 ..	..	6 06
3 ..	5 44	..	13 ..	..	6 12	9 ..	..	6 05
4 ..	5 46	6 06	15 ..	..	6 13	10 ..	..	6 04
5 ..	..	6 07	17 ..	..	6 12	12 ..	5 56	..
9 ..	5 48	6 08	19 ..	..	6 11	15 ..	5 57	..
12 ..	5 50	6 09	20 ..	5 59	6 12	16 ..	5 56	..
16 ..	5 51	6 11	21 ..	..	6 11	17 ..	..	6 03
18 ..	5 52	..	22 ..	5 58	..	19 ..	..	6 02
20 ..	5 53	6 12	24 ..	..	6 10	21 ..	5 55	..
24 ..	5 54	6 13	26 ..	5 59	..	22 ..	..	6 01
28 ..	5 55	..	29 ..	5 58	6 9	23 ..	5 54	..
30 ..	..	6 12				25 ..	..	6 00
31 ..	5 56	..	March—			26 ..	..	5 59
February—			1 ..	5 58	6 08	27 ..	..	5 58
1 ..	5 56	6 13	3 ..	5 57	..	28 ..	5 53	..
5 ..	5 57	6 14	4 ..	5 58	..	30 ..	5 54	..
6 ..	..	6 13	6 ..	5 57	..	31 ..	5 54	5 58

* Data supplied by C. L. Anthony, Survey Office, Rabaul.

—	Rise.	Set.
	h. m.	h. m.
April—		
1 ..	5 53	5 57
3 ..	5 52	5 55
6 ..	..	5 54
8 ..	5 51	..
11 ..	..	5 53
14 ..	..	5 52
16 ..	..	5 51
18 ..	5 50	..
21 ..	5 49	5 49
23 ..	..	5 48
24 ..	5 50	..
26 ..	5 49	..
30 ..	5 49	5 48
May—		
1 ..	5 48	5 47
4 ..	5 49	..
5 ..	..	5 46
7 ..	5 50	..
8 ..	5 49	5 45
9 ..	..	5 46
13 ..	5 50	..
14 ..	5 49	5 45
17 ..	5 50	..
20 ..	5 49	..
21 ..	5 50	..
24 ..	..	5 46
25 ..	..	5 45
27 ..	..	5 46
28 ..	5 51	..
30 ..	..	5 45
31 ..	5 51	5 46
June—		
1 ..	5 52	5 46
6 ..	5 53	..
7 ..	..	5 47
8 ..	5 53	5 46
9 ..	..	5 47
10 ..	5 54	..
11 ..	..	5 48
12 ..	..	5 47
14 ..	5 55	5 48
16 ..	5 54	..
17 ..	5 55	5 49
18 ..	..	5 48
19 ..	..	5 49
21 ..	5 56	..
23 ..	..	5 50
24 ..	5 57	..
25 ..	5 56	..
27 ..	..	5 51
28 ..	..	5 50
29 ..	..	5 51
30 ..	5 58	5 51
July—		
1 ..	5 58	5 51
2 ..	5 59	..
3 ..	5 58	5 50

—	Rise.	Set.
	h. m.	h. m.
July—		
4 ..	..	5 52
5 ..	5 59	..
6 ..	5 59	..
7 ..	5 59	5 53
9 ..	6 00	5 54
10 ..	5 59	5 52
11 ..	..	5 54
12 ..	6 00	..
13 ..	5 58	..
14 ..	6 00	..
16 ..	..	5 55
17 ..	5 59	5 54
19 ..	6 00	5 55
21 ..	..	5 56
22 ..	5 59	5 54
23 ..	6 00	..
24 ..	..	5 55
25 ..	..	5 56
26 ..	5 59	..
27 ..	6 00	..
30 ..	5 59	..
31 ..	5 59	5 56
August—		
1 ..	6 00	5 56
3 ..	5 58	5 55
7 ..	..	5 56
8 ..	5 57	5 55
10 ..	5 58	5 56
12 ..	5 57	..
13 ..	5 56	5 55
18 ..	5 55	..
22 ..	5 54	..
24 ..	5 53	5 54
25 ..	5 52	5 53
30 ..	5 51	5 52
31 ..	5 51	5 52
September—		
1 ..	5 51	5 52
2 ..	5 50	5 52
4 ..	5 49	..
6 ..	5 48	5 51
7 ..	5 47	..
9 ..	5 46	..
10 ..	..	5 50
12 ..	5 45	..
14 ..	..	5 49
15 ..	5 44	..
17 ..	5 43	5 48
18 ..	5 42	..
19 ..	5 41	..
21 ..	..	5 47
22 ..	5 40	..
24 ..	..	5 46
25 ..	5 39	5 47
27 ..	..	5 46
29 ..	5 38	..
30 ..	5 37	..

—	Rise.	Set.
	h. m.	h. m.
October—		
1 ..	5 37	5 45
2 ..	5 37	5 45
3 ..	5 35	5 44
6 ..	5 34	..
7 ..	5 35	5 45
8 ..	..	5 44
9 ..	5 34	..
11 ..	5 33	..
12 ..	5 32	5 43
15 ..	5 31	..
17 ..	5 30	..
18 ..	..	5 42
19 ..	5 29	..
24 ..	..	5 43
27 ..	5 28	..
28 ..	..	5 42
30 ..	5 27	..
31 ..	5 27	5 42
November—		
1 ..	5 27	5 42
2 ..	5 27	5 42
3 ..	5 28	5 44
4 ..	5 27	5 43
7 ..	5 26	..
10 ..	5 27	5 44
16 ..	5 28	5 45
17 ..	..	5 46
19 ..	5 27	..
21 ..	5 28	5 47
24 ..	..	5 48
26 ..	5 29	5 49
28 ..	..	5 50
29 ..	5 30	..
30 ..	5 30	5 50
December—		
1 ..	5 31	5 51
2 ..	5 31	5 51
5 ..	5 32	5 53
9 ..	5 33	5 54
10 ..	..	5 55
11 ..	5 34	..
13 ..	5 35	..
14 ..	..	5 57
16 ..	5 36	..
17 ..	5 37	5 58
19 ..	..	5 59
20 ..	5 38	..
21 ..	5 39	6 00
23 ..	..	6 01
25 ..	5 41	6 02
28 ..	5 42	6 04
30 ..	5 43	..
31 ..	5 43	6 04

THE CHIEF CHARACTERISTICS AND USES OF SIX NEW GUINEA TIMBERS.

J. L. d'Espeissis, B.Sc., B.Sc.For., Dip.For.

Several New Guinea timbers have achieved a certain prominence during the last two or three years. The most outstanding of these is Laup, or New Guinea Walnut (*Dracontomelum mangiferum*). This walnut is the mainstay of the timber industry at present and it comprises the bulk of the timber exported. It is now creating a considerable amount of interest for veneer purposes in the United Kingdom, the United States of America and also in Australia. In fact exporters find it hard to cope with orders. The main difficulty with regard to the marketing of this species is one of supply. This is due to several reasons, namely, the scattered occurrence of the species, which calls for selective logging which, in order to be economic, requires greater mobility on the part of the logging organizations than the present conditions would appear to permit, a lack of sufficient shipping space, which temporarily prohibits an increase in output, while lastly, susceptibility to damage by internal borers, which necessitates the rejection of many logs for export purposes. However, in view of the increasing demand for walnut, it may be confidently expected that these difficulties will be overcome in time.

Erima (*Octomeles sumatrana*), which is suitable for veneers, plywood and general purposes is, after walnut, probably the best known New Guinea timber. It is being exported in small but steady quantities. Another fine cabinet type of timber, which is just beginning to receive attention, especially for veneers, is Irotu, or Bush Calophyllum (*Calophyllum* sp.). These three timbers, particularly walnut and erima, may be said to have been exported more than any other species.

Two timbers well known here, Kwila (*Afzelia* (*Intsia*) *bijuga*) and Kamarere (*Eucalyptus deglupta*) are the most favoured local hardwoods for constructional purposes throughout the Territory. These timbers, due to sea freights, cannot stand competition with equally good, if not superior, hardwoods overseas. Consequently, it would seem that the future for these timbers would lie in the supply of the local demand and, even for this purpose, it is probable that conservation of existing supplies will be necessary.

A widely spread and well-known timber deserving greater attention is Toan (*Pometia pinnata*). Due to the more frequent occurrence of this species as compared with others, throughout the coastal forests of the Territory, this timber must some day be of considerable commercial importance. Already limited quantities have been used locally and exported to Australia. It is not to Australia, however, with its plentiful supply of some of the world's best hardwoods, that one must look for the establishment of Toan as an export timber, but rather to New Zealand, South Africa and the East. Toan is somewhat similar in its main characteristics to Philippine Mahogany, or red Lauan, and consequently in time, with careful treatment, it must build up for itself a reputation as a fair general utility type of medium hardwood.

The following notes on the characteristics of these timbers will serve to give some idea of their real and potential uses:—

LAUP OR NEW GUINEA WALNUT (*Dracontomelum mangiferum*, Blume).

Colour ..	.. Sapwood white; truewood grey-brown.
Grain ..	.. Generally interlocked.
Figure ..	.. Attractive black stripe on the quarter, and also ribbon, due to interlocked grain; on the back face often without particular distinction.
Texture ..	.. Fairly coarse; slightly more open than Queensland walnut.
Weight ..	.. Approximately 47 lb. per cubic foot at 12 per cent. moisture content. Logs sometimes sink.
Seasoning	.. Seasons rapidly without degrade.
Workability	.. Light and easy to work under hand or machine tools. Nails easily; glues readily; suitable for both peeled and sliced veneers.
Finishes ..	.. Fairly coarse texture, requires filling, gives an attractive finish in natural colour.
Sizes ..	.. Available in full range of boards and joinery sizes and as veneers and plywoods.
Uses ..	.. A valuable walnut type for all high-grade cabinet manufacture. Particlarly suitable for sliced veneers.

ERIMA (*Octomeles sumatrana*, Miq.).

Colour ..	.. Sapwood light yellow; truewood light brown to greyish yellow.
Grain ..	.. Generally interlocked.
Figure ..	.. Striped figure due to interlocked grain on the backsawn face; ribbon figure on quarter-sawn face due to the same reason, also fine flakey figure. Similar to white Lauan or white Pacific Maple.
Texture ..	.. Fairly coarse.
Weight ..	.. Approximately 23 lb. per cubic foot at 12 per cent. moisture content.
Strength..	.. A fairly soft timber. Modulus of rupture about two-thirds that of Douglas Fir and about half as stiff. Compressive strength a little lower than Douglas Fir. Low in impact strength.
Seasoning ..	Seasons rapidly without degrade.
Borer susceptibility	Pore size and starch content of sapwood suggest probable susceptibility to Lyctus attack.
Workability	.. Light and easy to work under hand or machine tools. Nails easily; glues readily; suitable for rotary peeling.
Finishes ..	.. Treatments suitable for Pacific Maple should be applicable.
Sizes ..	.. Relatively large size of logs yields full range of boards and joinery sizes, particularly wide boards. Is available as veneers and plywood.
Uses ..	.. Should be suited to all purposes now served by white Pacific Maple. It should find use for carpentry, coffin boards, corestock, furniture, mouldings, plywood, veneers, shelving and box manufacture.

IROTU (*Calophyllum* sp.).

Colour ..	.. Pink.
Grain ..	.. Fairly straight.
Figure ..	.. Attractive figure on the backsawn face, or rotary peeled veneer, due to fibres interlocked in bands tangentially—similar to *Calophyllum costatum* of Queensland, which is known under the name of Red Touriga. On the quarter it is without distinction.
Texture ..	.. Fairly coarse.
Weight ..	.. Approximately 40 lb. per cubic foot at 12 per cent. moisture content.
Seasoning	.. Seasons readily.
Workability	.. Relatively easy to saw and dress; nails and glues readily. Suitable particularly for peeled veneers.
Finishes ..	.. Attractive finish in natural colour.
Sizes ..	.. Should be available in full range of boards and joinery sizes, and as veneers and plywood.
Uses ..	.. Appears to have possibilities for interior finish, such as moulding, skirting, architraves, and for joinery, such as doors and stairways. In the furniture trade it should be suitable for cabinets, tables and chairs. It makes particularly attractive plywood when peeled and logs of this species are symmetrical and of suitable form for this purpose.

KWILA (*Afzelia bijuga*, A. Gray).

Colour ..	.. Yellow-brown when fresh, turning dark brown with age; sapwood light buff to pale yellow.
Grain ..	.. Slightly cross-grained.
Figure ..	.. Without distinction.
Texture ..	.. Moderately coarse; pores large, some contain conspicuous sulphur-yellow deposits.
Weight ..	.. Approximately 58.7 lb. per cubic foot at 12 per cent. moisture content. Logs sink.
Strength..	.. A hardwood with static bending strength greater than Teak and Douglas Fir. Modulus of elasticity greater than that of oak; compression strength also greater.
Seasoning	.. Seasons readily with little degrade.
Workability	.. Easy to work, saws well, mortises cleanly.
Finishes ..	.. Takes glossy finish under tools, and high finish when polished.
Sizes ..	.. Available to order, locally, in full range of boards and constructional sizes.
Uses ..	.. Very resistant to insect and fungal attack, therefore durable when exposed to weather and in the ground; not, however, very resistant to teredo attack, therefore unsuited for marine work unless protected; corrodes steel. Particularly suitable for high-grade heavy constructional work, also for furniture and cabinet making.

KAMARERE (*Eucalyptus deglupta*, Blume).

Colour ..	.. Red brown.
Grain ..	.. Generally straight.
Figure ..	.. Characteristic stripe or ribbon on quarter-sawn face due to interlocked grain; back-sawn face without character.
Texture ..	.. Fairly coarse.
Weight ..	.. Approximately 52 lb. per cubic foot at 12 per cent. moisture content.
Strength..	.. A moderately hard wood, with static bending strength slightly greater than Toan, as also are its modulus of elasticity and its compressive and impact strengths.
Seasoning	.. Readily seasoned.
Workability	.. A firm timber relatively easy to saw, but difficult to dress on the quarter-sawn face without tearing the interlocked grain. Mortises cleanly and produces sharp edges in moulding or shaping. Nails easily.
Finishes ..	.. Gives attractive finish in natural colour resembling a red Pacific Maple when quarter cut.
Sizes ..	.. Available in full range of boards and joinery sizes.
Uses ..	.. It should prove to be a substitute for red Pacific Maple for many purposes. Appears to have possibilities for all forms of interior finish such as flooring, lining, moulding, skirting, architraves; for joinery such as doors, stairways, and also for house frames. In the Territory of New Guinea it is the most-used local hardwood for general building purposes. In the furniture trade, also, it should be found useful. It is too hard, however, for satisfactory veneering.

TOAN (*Pometia pinnata*, Forst.).

Colour ..	.. Pink to light red brown.
Grain ..	.. Usually straight, but may be interlocked.
Figure ..	.. Usually without character, but sometimes has attractive broken stripe due to interlocked grain; pores prominent.
Texture ..	.. Fairly coarse.
Weight ..	.. Approximately 41 lb. per cubic foot at 12 per cent. moisture content.
Strength..	.. A moderately hard wood with static bending strength slightly less than Douglas Fir Modulus of elasticity about equivalent to that of oak. Compression strength about equal to oak. Impact strength low.
Seasoning	.. Readily seasoned.
Workability	.. A firm timber relatively easy to saw, but sometimes difficult to dress without tearing the interlocked grain. Mortises cleanly and produces sharp edges in moulding or shaping. Bends particularly well. Nails easily. Glues readily.
Finishes ..	.. Gives attractive finish in natural colour, somewhat resembling Queensland Maple. Amenable to the same range of finishing treatments as Queensland Maple.

Sizes	Should be available in full range of boards and joinery sizes and as veneers and plywoods.
Uses	Should prove a substitute for Lauan (red Pacific Maple, or Philippine Mahogany). Appears to have possibilities for all forms of interior finish such as floorings, lining, moulding, skirting, architraves; for joinery such as doors and stairways, and for house frames. In the furniture trade it should find use in cabinets, tables, chairs, household furniture, and especially in bent work. It makes attractive plywood.

New Guinea coastal forests, like most tropical rain forests, are characterized by the great number of tree species represented. The six species dealt with above are by no means the only species with commercial possibilities. Several other species have proved themselves to be most satisfactory for local use; while in addition to these, without considering the highland species, numerous other timbers of potential value occur in the more accessible coastal areas. However, the timber export industry is a comparatively new one, and due to the difficulty of placing new untried timbers on a fastidious market in competition with well known established species, the six timbers described here are the only ones to have obtained any prominence as yet. There is the possibility now, however, since war-time conditions have seriously restricted the importation of softwoods from America and Baltic countries, that the demand for this type of timber in Australia will give this Territory an opportunity to develop its light-coloured, light-weight timbers of the coastal forests as softwood substitutes. So far they have received little attention; and due to difficulties, such as blue staining caused by fungal attack, the small quantities exported in the past have not been favorably received. These difficulties, however, can be overcome; and it is hoped, with the demand which has arisen, and which is increasing, that these types will come into their own, and that the New Guinea timber trade will become firmly established; for it is only by more thorough utilization, that the present expensive selective logging can be avoided and the industry established on a really economic basis. Incidentally, such a development would give the newly inaugurated forest department greater opportunity to establish sound forestry practice in this country.

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AVOCADO CULTURE.*

(FARMERS' CIRCULAR 1.)

By F. G. Galang, of the Horticulture Section, Bureau of Plant Industry, Manila.

In its native home, tropical and semi-tropical North and South America, the avocado (*Persea americana* Mil. and P. *drymifolia* Ch. and Sc.) is an important food of the inhabitants. In the Philippines, however, it is still considered a luxury fruit since the present price is not within the reach of many. Of the many species and varieties of fruit trees introduced into the Philippines, none has gained so wide a reputation within a short time as the avocado. Although it is said to have been brought into the Philippines from Mexico in 1890, yet it was not successfully grown here until 1903 from planting materials received from Hawaii, Costa Rica, and the United States of America. The Bureau of Agriculture (now the Bureau of Plant Industry) began the distribution of avocado in the Philippines in 1913, and with the co-operation of the College of Agriculture of the University of the Philippines, it is able to produce many avocado trees bearing fruits in many provinces. Approximately, 22,000 trees are now found growing in the Philippines, 4,500 of which are already bearing fruits.

Varieties.

Avocado trees vary in habit of growth; some are tall with short lateral branches while others have spreading branches. The leaves are usually medium thick and leathery, and they vary in shape and size. The flowers are borne in compact panicles generally at the end of the twigs. The fruits are variable in shape, size and colour. The surface colour of the fruit, when ripe, varies from light green to dark green, purple, brown, red, crimson, or maroon. The rind may be thin and delicate to thick and leathery and enclosing a large seed. The pulp is very nutritious, rich in fat, appetizing, with nutty flavour, and of a buttery consistency. There are three avocado races, namely, the West Indian, the Guatemalan and the Mexican types. Each of these types requires a different elevation for its development and possesses different characteristics, as follows:—

West Indian.—The fruit of this type has a poor shipping quality, loose-fitting, and with rather large seed. According to Stahl they contain from 4 to 7 per cent. fat. The skin is medium thick and is always smooth and leathery. The seed coats are usually separated, and the cotyledons are rough on the surface. The fruit stems are short. The Philippines grow varieties under this type as the Pollock, Family, Cardinal, Wilson, Waldin, Wester, and Baldwin.

Guatemalan.—This type has a thick woody rind, producing dull, large and rough fruits. The seed is small and invariably tight-fitting; the fruits are of good shipping quality, the meat of which is drier than that of the West Indian. The surface of the cotyledons is smooth. It contains more fat (from 10 to 13 per cent.) but less carbohydrates. The fruit usually is borne on long fruit stem. The young leaves are frequently reddish or bronze in colour instead of green. The Dickinson, Lyon, Tertoh, Taft and Tumin are the varieties of this type already cultivated in the Philippines.

* Reprint from Farmers' Circular No. 1—"Avocado Culture" by F. G. Galang—of the Horticulture Section, Bureau of Plant Industry, Manila.

Mexican (Persea drymifolia).—The foliage is anise-scented, small, and sharp at the apex. The fruit is small with thin, smooth rind which generally adheres to the pulp and is of purplish black in colour. It contains a higher percentage of fat (from 12 to 15 per cent.). The seed is large with thin coats which are either separated or adhering to the cotyledons. The surface of the cotyledons is smooth. The varieties under this type that are already grown in the Philippines are Ganter and Puebla. Seeds of the Gottfried and Northrop were successfully introduced in 1924.

In planting avocado, one of the most perplexing problems is the choice of the right varieties, and this is due to a considerable variation in the productiveness of avocado trees. Some trees profitably bear fruits every year; others only in alternate years; others do not bear any fruit at all. Many varieties fail to bear fruits satisfactorily owing to lack of pollination brought about by the failure of the flowers to open at the proper time or to the incompatibility of the pollen itself. Generally, fruit bearing in avocado will be more successful if compatible varieties are interplanted and if their flowers open at such time as will permit cross-pollination, or if self-compatible varieties are planted, the opening periods of flowers overlap. However, the varieties to be interplanted should have approximately the same flowering time—early varieties should not be interplanted with late varieties and vice versa. The mid-season varieties can be interplanted with either the early or late varieties.

Of the hundreds of varieties now planted in the United States of America, not a single one has so far been selected that gives all the desired qualities. Each has some defects. And these varieties will have to be replaced eventually by a more desirable variety, or strain. In the Philippines, numerous seedlings and named varieties have already been imported and planted. Of those that have so far fruited, some are good, while others produce small fruits of poor quality. Moreover, many had failed to maintain themselves under local conditions. Altogether not less than 100 varieties and strains of avocado have already been introduced, out of which about 40 varieties are surviving and seventeen are bearing fruits. However, according to the list of avocado varieties given in the 1929-30 annual report of the California Avocado Association, there are 342 varieties, classified as follows: 62 Mexican, 78 West Indian, 152 Guatemalan and 50 unclassified. In addition, a score or more varieties and strains are fast developing in the United States of America and elsewhere. Therefore, aside from the varieties already found growing in the Philippines there are many more varieties and strains which merit further planting and introduction. Nevertheless, until new varieties, or strains, have proven to be superior and especially adapted to local conditions, the Philippine grown avocado varieties, which have fruited for several years, should be given preference in starting an avocado orchard. Of the many varieties that have been introduced and distributed, only a few have so far gained popularity. The Cardinal, Pollock, Lyon, Wester, Tertoh, Family, Cummins, Commodore, Cyrus, Quality, Douglas, Vega and Miami have fruited successfully in Lamao, Bataan and elsewhere in the islands. But due to the limited extent of their trial, their selection should not be considered final. The Cardinal has predominated, however, probably because of its productive habit under certain soil and climatic conditions.

When selecting the varieties to be planted, one should be guided by the following points: the trees should be hardy, productive, regularly bearing, disease and pest resistant, early or late bearing; the fruit should be of good flavour, quality and size; and the seed should be comparatively small. It should be borne in mind that the fat content does not indicate a good quality, for in the United States of America the most prized varieties are poor in this respect.

Requirements.

The avocado is distinctly tropical and subtropical in its requirements. There are now avocado trees growing in widely separated localities in the Philippines, and the behaviour of these trees clearly indicates that the plant is at home in this country. In localities where the dry season is not too long, they thrive with very little attention. However, when the dry season extends for four or five months, they require some irrigation unless the soil moisture is within the reach of the roots during the driest part of the year.

The tree is not exacting in its soil requirements so long as good drainage is afforded. It is very intolerant of standing water, and cannot endure it for any length of time. Deeply and well-drained soil, which is rich in organic matter, is the best for avocado, but well-drained heavy soil of average fertility will also grow good avocado, especially in moist regions. Any soil where citrus trees thrive will produce good avocado trees.

Like most other fruit trees, the avocado does not thrive well in places exposed to strong winds. Its leaves cannot quite resist excessively hot, dry winds. Besides, winds increase the evaporation of water which in turn may cause a heavy dropping off of immature fruits. Also the fruits are liable to suffer injury through rubbing against the branches or against each other, and the danger of the breakage of limbs, especially those heavily loaded with fruits, is increased. However, this is not a limiting factor in avocado culture, because it can be remedied by planting windbreaks in places where there is no natural protection from the winds. Windbreaks reduce the air movement and so diminish evaporation. Windbreaks should be planted around the orchard; if the plantation is large, windbreaks should be planted in every hectare lot.

The West Indian varieties are very tender, and are best adapted to low and medium elevations up to 900 metres above sea level. The Guatemalan varieties are rather intermediate, and have wider range of adaptability. They can be grown from sea level up to an elevation of 2,500 metres, but an elevation of not more than 700 metres is the best. The Mexican varieties are the hardiest with respect to cold weather, and have a wide distribution. They thrive best from 600 metres upwards.

Propagation.

The avocado is propagated by seeds, by budding, grafting, inarching, or marcotting, but preferably by budding or grafting. Inarching and marcotting are too laborious and expensive. Grafting sometimes gives a better result than budding. The grafted plants are oftentimes more vigorous than the budded ones. On the other hand, trees grown from seeds usually do not come true to type. The chances of obtaining a fruit of better quality than that produced by the parent tree are very slim. It is the experience of avocado growers that seeds are unreliable means of reproducing a variety. However, if seeds have to be depended upon for the propagation of avocado, the seed of some avocado varieties may be carefully halved so as to produce two plants from each seed. The resulting plants, however, should be given a reasonable dose of fertilizer in order to produce good growth. Generally, the whole seed germinates earlier, and the resulting seedlings are more stocky and have more number of leaves than the halved seed.

The first step in the production of budded or grafted trees is the raising of the stock plants. In the United States of America the varieties of the Mexican type are commonly used as stock plants because of their greater hardiness against frost than the large-seeded and hard-shelled varieties in spite of the greater amount of plant food in the seed of the latter. But this type possesses a wide range of variability, and caution should, therefore, be taken in using it as a stock plant in the Philippines. On the other hand, the West Indian seedlings, being generally more vigorous than the other types, may prove good stock plants at lower altitudes in the Philippines, although they were proven less successful as scion for the Mexican stock. The Guatemalan type will succeed both the West Indian and the Mexican stocks. This type is vigorous and thrifty, but somewhat tender, although less so than the West Indian. Fuerte, a hybrid between Guatemalan and Mexican types, is much used as stock plant in the United States of America nowadays.

As the seed of the avocado loses its vitality quickly, it should be planted while it is still fresh. And if the seeds cannot be planted at once, they should be stored in properly moistened sand, sawdust, charcoal, or sphagnum moss. The seeds may be planted directly in bamboo pots or in seed beds with the pointed end up. About one-fourth of the seed should be left exposed so that the resulting sprouts can be thinned out, leaving the strongest one. Set the seeds 40 or 50 cm. apart in the seed beds. In potting, the soil should contain one-third each of sand, loam, and well-rotted compost. If sown in seed beds, the soil need not be so rich—a sandy loam soil being sufficient. It is sometimes advisable to grow the seedlings for budding or grafting in the seed beds although it will require more labour to remove them properly when transplanting them in the field. Seeds should not be allowed to dry out, otherwise they will lose their viability.

Budding or grafting is done in the same way as in citrus or other fruit trees. It can be done any time the stem of the stock plants has attained the size of a little larger than a lead pencil provided it is not raining and that the seedlings are in condition, that is, the sap is flowing freely. The scion should be selected from the best tree of the desired variety, should be well matured, preferably from twigs which are just ready to send out a new growth, and should contain plump and well-developed buds.

Avocado stem is very brittle so that in forcing the bud to grow, a notch should be made of a few inches above the bud instead of cutting the stem half-way into the wood of the stock for lopping as in the case of other fruit trees. In lopping never bend the stock as in other fruit trees in order to avoid a premature breaking.

When the scion is already well advanced the top of the stock may be cut off entirely about 10 cm. from the bud. After the bud has grown to a length of about 25 cm., the stock should be cut off clean just above the union of the stock and the scion, and the cut surface should immediately be painted with white lead or other suitable materials. This will protect the wood from decay.

Planting.

When the plants are about 50 cm. high or more, they can be transplanted in the field at the beginning of the rainy season, at a distance of about 8 to 10 metres apart in holes large enough to accommodate the plants. Set the plants as deep as they grow in the nursery, and use good surface soil for refilling the holes. The soil should be packed firmly around the plant. It is well to pour in water while firming the soil. If water is available, planting may, of course, be done late in the rainy season, and even during the dry season. In transplanting, great care should be taken so as not to injure the root system, which is very delicate, and the roots should never be exposed to dry, or else the plants will die. To avoid the least injury to the roots, the plant should be dug from the nursery with a ball of earth. In planting balled trees, it is necessary to remove the sack or wrapping materials from around the ball of earth, as the sack will decay in due time. However, to facilitate the rotting and the penetration of water, two or three cuts should be made at the sides with a sharp knife. Split and remove the pot in transplanting the potted plant. Cut one-half of the leaves or young twigs of the plant previous to transplanting. The newly-transplanted plants should be watered and mulched from time to time as may be necessary. In watering, a basin should be made around the tree to hold the water. Shedding the newly-transplanted plant is necessary if planting is made during the dry season. Care should be taken that varieties are planted together, which will provide for each other at the time when each is ready for pollination.

Orchard Management.

A modern fruit orchard should be well cultivated, irrigated, fertilized, cover-cropped, pruned and mulched from time to time. The cultivation of young avocado orchard is done in the same way as in citrus, that is, deep ploughing is advisable at the beginning; but when the trees are already big, deep cultivation should be avoided as much as possible, otherwise there is danger of destroying part of the root system and exposing the soil. At this stage the tree can be kept clean by occasional hoeing of the ground near its trunk. Mulching the trees and planting cover crops between the spaces are beneficial for the upkeep of the trees, since both prevent soil erosion and replenish the nitrogen and organic matter of the soil. Legumes have the power of gathering free nitrogen from the air and storing it in their nodules, and are, therefore, more valuable as cover crops than non-leguminous plants.

In order to get the most profit from the trees, it is always a good practice to maintain the fertility of the soil. To accomplish this, fertilizers should be applied regularly to bearing trees. There is a wide diversity of soil in the Philippines, so that to give advice regarding the kind and amount of fertilizer without knowing the condition of the soil is almost futile. However, the kind of fertilizer needed by avocado is probably not very different from that needed by other fruit trees, although the amount may differ. And in the absence of experimental data no definite and specific information is given. The condition of the tree and of the soil should be determining factor as to the kind and quantity of fertilizer to be used.

A young tree requires very little, if any, commercial fertilizer until it begins to bear fruit heavily. Animal and poultry manure and nitrogenous commercial fertilizers are, however, beneficial to young avocado trees. A complete fertilizer which is low in nitrogen and high potash is good for fruit-bearing trees. In the United States a mixture containing 5 per cent. nitrogen, 7 per cent. phosphoric acid and 2 per cent. potash, the nitrogen being derived from organic materials, has given good results on young trees when applied at the rate of 1 lb. per tree, three or four weeks after planting, and 8 to 10 lb. on five-year-old trees. The percentage of potash is increased while the trees come into bearing—5–8–3 or 6–6–3 in spring, 4–8–10 in the fall, and 4–7–5 or 5–5–5 in summer.

As a general rule, avocado requires little or no pruning at all after each tree is properly established. However, inasmuch as the avocado plant is naturally weak and brittle, the pruning of forking branches and shortening of young and spindling twigs may be done to strengthen the stock and the framework of the growing trees. This is to be done at their dormant stage. The mere pinching of undesirable shoots may induce the growth of other buds where an extension is needed in order to make the trees more or less symmetrical in growth. Tall-growing trees should be pinched back. Again, some thinning of the branches should be done from time to time so as to permit sunlight to the inside foliage. Of course, any heavy pruning should be avoided, as this will greatly accelerate the vegetative growth and delay the fruiting period. Only dead and undesirable branches should be removed after the fruits have been harvested. All wounds should be painted with white lead or other suitable materials to avoid rotting.

In places where there is a uniform distribution of rainfall, the avocado need not be watered at all, but in places where there is a prolonged dry period watering is necessary unless the ground water is high or is within the reach of the roots. The water may be distributed in the way which is most convenient, economical, and effective. The furrow system of irrigation should be practised on big plantations whenever it is practicable for the sake of economy, and the bucket system may be used for watering the individual trees around the house. Where there is lack of water in the soil, the trees may shed much of their foliage, flowers or fruits.

It is often advisable to top-work undesirable trees in the orchard to a good variety. This can be done by cutting the tops back, including the big branches. Of the numerous sprouts which appear, only a few good ones should be left for budding or grafting with selected scions. The cut surfaces and the trunk should be painted and whitewashed in order to protect them from decay and sunburn.

Pests and Diseases.

There are comparatively few insect pests and diseases which at present affect the avocado in the Philippines. Among the insects, the borers and the scale insects, including mealy bugs, are found destructive to our avocado trees. Other pests are the thrips, caterpillars and white ants.

The borers are found to attack the trunk, pith and twigs. They work their way downward, destroying all growth thereby, and may eventually kill the tree. Limewash may lessen the infestation.

The caterpillars attack the leaves and flowers. They can be controlled by spraying either with lead or calcium arsenate.

The thrips attack the flowers, but they can be prevented by dusting with pyrethrum, derris powder or tobacco dust.

The scale insects suck the sap of twigs, leaves and fruits. Heavy infestation weaken the tree, and sometimes cause premature falling of fruits. Oil emulsions and soap-suds are usually effective in controlling the scales.

The important diseases of avocado are die-back and anthracnose. The anthracnose is a disease of the leaves, bark, and fruit. The affected portions turn black with sunken spots, usually circular in form. It can be controlled by spraying with Bordeaux mixture. The infected parts should be cut and burned.

The die-back is a disease of the twigs. The infected parts become dry. It can be prevented by spraying the trees with lime sulphur or Bordeaux mixture. These sprays should be applied periodically once every two weeks at least, as the new flushes appear until they mature.

Other diseases of minor importance which may also be controlled are the scab and the leaf spots.

Harvesting and Yields.

The avocado season in the Philippines is from January to March and from June to September, depending upon the climate of the locality. In humid districts the season is rather early. There are, therefore, only two short periods in the year during which avocado fruit is not obtainable in the market—from April to May and from October to December. However, by planting varieties which fruit at different times of the year, it is possible to produce avocado fruits all the year round. In the United States the Fuerte variety is said to be fruiting from November to May; Verde from March to May; Puebla from November to December; and Taft from May to November.

Avocado trees grown from seedlings begin to bear fruits when about four to eight years old, six being the average. On the other hand, vegatively-grown trees sometimes begin to bear fruit the first year in the nursery. At this age, however, and probably up to three years, they should not be allowed to fruit at the expense of the future growth and vigour. The annual yield of a full-bearing tree ranges from a few to 500 fruits—sometimes from 800 to 1,200 fruits. An average of 500 fruits a year per tree is considered a fair yield. Generally the yield varies from one season to the next, partly depending upon the size of the previous crop, rainfall, winds, and the condition of the tree at the flowering season.

The avocado fruits are very perishable and should be handled with care. In harvesting, the fruits should be carefully clipped off, leaving a short stem on them for handling purposes. A fruit-picker provided with a knife similar to that one used in picking the mango fruits should be used in harvesting the fruits of tall-growing trees. Furthermore, the avocado should be harvested when fully matured, and not allowed to ripen on the tree. The maturity of the fruit is indicated by its colour. For example, the appearance of reddish streaks in the case of purple-fruiting varieties and the change of colour from green to a lighter green in the case of green varieties are indications of maturity. In the thin-skinned forms the ripeness of the fruit can be determined by external pressure, but in the very thick-skinned varieties this cannot be done. The ripeness of the fruit of the latter vareties can be determined by the stems when it is easily pulled out of the fruit, and when a toothpick can be easily pushed through the stem it indicates that the fruit is ripe enough for eating. If the fruit is picked before reaching maturity, its flavour is poor, while, if left too long on the tree, the keeping quality is impaired. The fruits should be placed in a basket or box lined with packing materials, such as dried straw, banana leaves, &c., when intended for short distances shipment; when the fruits are to be shipped long distances they should be wrapped individually with soft tissue paper.

Uses.

The avocado fruit is rich in fat and protein, but low in sugar content. Its oil is similar to olive oil, and can be used for the same purposes. It has been known in countries where avocado has been long grown that its fruit is a wholesome and highly-digestible food. Wolfe and others said that an ounce of avocado contains about 73 calories, which is nearly three times that of banana, one and a half times that of beefsteak and other meats, and three times that of several kinds of fish. And, because of this and its low carbohydrate content, it is a good food for diabetic people. Its iron content is about three times that found in other common fruits, and, therefore, it is a good food for anæmic people.

In the Philippines the fruit is eaten with sugar and milk, or in frozen form, or as ice-cream ingredient. Few people eat the meat offhand. In the United States it is extensively used as a salad fruit, because of its delicate, nut-like flavour, and its smooth, buttery consistency. The avocado should not be considered merely as a salad fruit, but as a substantial food which may be used in a great many combinations. For it is also eaten offhand, with the addition of lime or lemon juice, or salt, or sugar only. Mashed and seasoned, the meat is used as sandwich filling or is spread on salted crackers. Often it is also added to soup just before serving. A number of recipes on how to eat avocada fruit have been published from time to time.

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COCO-NUT OIL—PROPERTIES AND COMPOSITION.*

By R. Child, F.I.C., B.Sc., Ph.D. (Lond.), Director of Research and Technological Chemist, Coco-nut Research Scheme (Ceylon).

Coco-nut oil as ordinarily prepared in Ceylon and other tropical countries is a colourless to pale brownish yellow oil. In temperate climates it appears as a greasy, somewhat crystalline white to yellowish solid fat, which has a melting range of between 20° and 26°C. (68° to 79°F.). Unless refined it has a more or less pronounced odour of the coco-nut.

2. Composition.

Coco-nut oil is composed of the glycerides of volatile and non-volatile fatty acids with between 0.2 and 0.8 of non-saponifiable constituents. The latter, which are mostly of the nature of sterols, have not been recently investigated and will not be further considered here. Whatever the country of origin, coco-nut oil seems to vary surprisingly little in composition and is regarded as the least variable of the commercial fats.

Several analyses giving the percentage composition of the fatty acids (present as glycerides) have been published since 1925, when the modern technique of such analyses was first developed, and these show good agreement, the following table giving the range of figures obtained:—

	Per cent.	
Caproic acid	0.2 – 0.5	Saturated acids about 91 per cent.
Caprylic acid	7.8 – 9.0	
Capric acid	4.5 – 6.8	
Lauric acid	44.7 – 51.0	
Myristic acid	16.5 – 18.5	
Palmitic acid	7.5 – 9.0	
Stearic acid	1.0 – 3.0	
Oleic acid	5.0 – 8.2	Unsaturated acids about 9 per cent.
Linoleic acid	1.0 – 2.6	

Coco-nut oil, like palm kernel oil and the fats from certain other *palmoe* species, is thus characterized by the presence of a high percentage of lauric and myristic acids and notable proportions of the lower acids. This makes the oil eminently suitable as a butter substitute in margarine and the like.

3. Technical Analysis.

It is not possible to apply the exhaustive method of analysis, such as those leading to the above composition figures, for commercial purposes, neither is it necessary. Commercial methods of analysis are required for the purpose of confirming the identity of an oil, for detecting adulteration, for determining the quality of a sample (e.g., whether it is rancid or acid), and consequently for assessing its value for any particular technical purpose. Such methods are thus routine ones for specific purposes and must be quick and easily reproducible. More refined methods are usually only employed in fundamental research.

It is not the purpose of this article to go into details of methods of examination, but it is necessary to discuss briefly the principles of some of them.

* From *Journal* of "Coconut Industries", Vol. 3, No. 2, June, 1939, pp. 86–91.

Physical methods of examination include the determination of the *density* of the liquid oil and of its *refractive* index, the latter being an optical measurement of the amount of bending (or refraction) of a ray of light passed through the oil. Such figures are often characteristic of particular oils. Thus the determination of the refractive index would detect in a few minutes the admixture of 10 per cent. of parings oil to white coco-nut oil.

Saturated and Unsaturated Fatty Acids.—It will be observed that in the table above the first seven acids are grouped as saturated, and oleic and linoleic as unsaturated. All of these fatty acids are chemical compounds of carbon, hydrogen and oxygen, differing, however, in the proportions of these three elements.

The acids grouped as saturated contain the maximum of hydrogen possible—they are "saturated" with respect to hydrogen. The unsaturated acids are capable by suitable chemical processes of taking up more hydrogen. Thus oleic acid can absorb hydrogen to be converted into the saturated acid, stearic. The unsaturated acids can absorb, besidese hydrogen, other elements, such as oxygen, chlorine, iodine, &c., and in practice their capability of absorbing iodine is used as a measure of their unsaturation, the iodine value of an oil being the number of parts of iodine which 100 parts of the oil can absorb under certain standard conditions. Thus pure oleic acid can take up about 90 parts of iodine per 100 parts; some samples of linseed oil can take up as much as 200 parts or twice their weight of iodine. Coco-nut oil has the lowest iodine value of all the oils in common use, the iodine value being between 7.5 and 9.0 for the majority of samples.

The iodine value indicates, then, the degree of unsaturation of an oil which, in turn, indicates broadly the technical use to which an oil may be put. Thus oils with value over 100 are classed as "drying oils", owing to their applicability in paints and varnishes; such oils rapidly absorb oxygen and are converted into hard, glossy films. Coco-nut oil falls into the non-drying class.

Saponification.—When oils are treated with alkali—say caustic soda or caustic potash—the fatty acids are set free from their combination with glycerine and combine with the alkali to form soap, the glycerine also set free forming a by-product of the soap industry.

Different oils require different characteristic amounts of alkali for this saponification. The number of parts of caustic potash required for complete saponification of 1,000 parts of an oil is known as its saponification value. Oils like coco-nut oil, which contain large proportions of lauric and lower acids (caproic to lauric in the case of coco-nut oil), have high saponification values. Coco-nut oil has, in fact, the highest saponification value (255 and over) of all the oils in common use, rape seed oil (170 approximately) being the lowest. The majority of common oils have values round 195.

The lower fatty acids, caproic to lauric, are somewhat volatile, particularly when treated with steam, and special analytical methods (*Reichert Meisel value* and *Polenske value*) have been based on this for dealing with oils containing lower acids, particularly coco-nut oil, palm kernel oil and butter fat.

Coco-nut oil, owing to its cheapness, is seldom adulterated and the latter methods are seldom required for coco-nut oil itself. It is, in fact, with a view to detecting the addition of coco-nut oil to more expensive fats, especially butter, that they have been developed.

Free Fatty Acids.—One determination which is usually required in a technical examination of a fat is that of its free fatty acid content. All oils consist essentially of glycerides of fatty acids. These glycerine compounds can be split into their components—fatty acids and glycerine—in various ways. Saponification with alkali is one which has been mentioned. In the process of digestion of fats, the first stage is this splitting, which is affected by a digestive ferment or enzyme known as "Lipase". Such enzymes are present in the oil seeds themselves from which oils are derived; they are also secreted by moulds, &c. Consequently oils pressed from stale, mouldy copra or seeds, or which have been allowed to deteriorate in the presence of moulds or in other ways, are found to contain fatty acids in the free state, i.e., set free from their combination with glycerine.

The presence of free fatty acids is undesirable, particularly in edible oils; acid oils have to be refined for edible and some other purposes which results in losses amounting to about twice the weight of free fatty acids present. Note also that whilst the development of free fatty acid in an oil is not the same thing as rancidity, the two often go side by side, and an acid oil is likely to be a rancid one.

The determination of the percentage-free fatty acid in an oil is thus an essential one in the examination of technical oils. Older text-books refer to coco-nut oils coming into the market containing as much as 25 per cent. free fatty acid. Such low-grade oils are seldom met with to-day.

Ceylon-milled oil has the advantage of being pressed in the country of origin, i.e., of having available supplies of fresh undeteriorated copra. It is marketed in two grades, white oil and mill oil. (Parings oil is mentioned later.) Mill oil usually averages about 2 per cent. of free fatty acid; samples do not commonly exceed 3 per cent. White oil is usually below 1 per cent.—all percentages calculated as lauric acid.

British Standard Specification.—The British Standards Institution has issued a specification for coco-nut oil (B.S.S. No. 682—1935) which includes standards for moisture, colour, refractive index, iodine value (7.0-9.5), saponification value (not below 255), acidity (not above 5 per cent. as lauric) and unsaponifiable matter.

Edible Coco-nut Oil.—Has usually to contain below 0.10 per cent. free fatty acid (lauric), to be free from suspended impurities, to be sweet and neutral in taste and odour, and to meet fairly stringent standards as to colour. Further details are given in an article of the writer's in the *Tropical Agriculturist* (Ceylon), vol. 89, No. 5, 1937.

4. Parings Oil.

In the manufacture of desiccated coco-nut, the brown skin of the nut is removed. Drying and pressing of the skin or "parings" produces an oil differing somewhat from ordinary coco-nut oil. As usually produced, the iodine value lies between 19 and 25, and the saponification value between 237 and 244. The free acidity is usually rather higher than that of mill oil and, as would be expected, parings oil is usually darker in colour.

As would be deducted from the higher iodine value, parings oil has a higher content of unsaturated acids. No complete analysis of the component acids has, however, been made for commercial parings oil.

Parings oil sells at a slightly lower price than mill oil. Its annual production in Ceylon can hardly exceed 2,000 tons, and with the exception of the Philippine Islands it is probably not produced elsewhere.

5. Food Value of Coco-nut Oil.

The essential factors for maintenance of health and for satisfactory growth, besides water and oxygen, are proteins (which vary in biological value), fats, carbohydrates, certain mineral salts and vitamins.

Fats are either stored in the tissues or oxidized to produce energy, having from the latter point of view a value expressed in calories exceeding both carbohydrates and proteins.

All fats consist, as has been pointed out in the previous section, essentially of glycerides of fatty acids.

In general, any fat or mixture of fats which melts at about human body temperature is absorbed by the human organism with little difficulty. A very hard fat melting at, say, 50 deg. C., is not readily assimilated when ingested alone, but is so when blended with a soft fat in such quantity that the mixture is liquid at 37 deg. C.

There is no evidence that different glycerides have different food values. The mixtures of fats employed in margarine are blended to give a product whose melting point and consistency resemble butter, and, broadly speaking, there is no difference in the food value* between one such mixture and another, and from this point of view all fats or mixtures of fats may be regarded as equivalent if the limitation imposed by melting point be observed.

Recent work on the rate of digestion of fats has been published by Miss Hartwell, of King's College, London (*Biochem. J.* 1938, 32, 462), which seems to favour coco-nut oil in this respect. The rate of digestion of various fats by pancreatic lipase was measured, the fat being prepared in the form of "reconstituted creams" so that it was in the form of minute globules and the conditions comparable with those of actual digestion in the organism. The results are of particular interest and some of the conclusions worth quoting *in extenso*—

> "Coco-nut oil was digested more rapidly than any other fat, including butter. Almond oil, ground-nut, bacon fat, beef fat, oleostearine, cocoa butter, cod liver oil, cotton-seed oil, lard, mutton fat, olive oil, premier jus, soya bean oil, hardened whale oil and hardened ground-nut oil, were digested at a much slower rate than butter and all at approximately the same rate.
>
> It seems possible that if margarines contain this fat (coco-nut oil) they may be more rapidly digested than butter." Coco-nut oil "may prove a more valuable food than has hitherto been supposed."

VITAMINS.—Coco-nut oil has been reported to contain traces of vitamins A and E. It is, however, not a good source of vitamins and it is at least doubtful whether edible coco-nut oil which has undergone processes of refining contains any effective amount of any vitamin.

On the other hand coco-nut oil as a source of fat in the diet is *more satisfactory than other fats in economizing vitamin E,* some other fats such as lard apparently having an antagonizing effect on this vitamin. A similar statement has been made that coco-nut oil *"economises" vitamin B.*

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* That is, as fats. No consideration is given to accessory food factors such as vitamins, &c.

6. Rancidity of Coco-nut Oil.

Space does not permit of a detailed discussion of this subject. It will suffice to say that, contrary to statements in old text-books that coco-nut oil readily becomes rancid, it is when refined of good keeping qualities.

It is, however, under the action of moulds, liable to develop a type of rancidity common only to oils containing fatty acids below lauric, with the development of odoriferous ketonic substances. This type of rancidity is, therefore, known as "ketone rancidity", a "perfume rancidity". It cannot develop in oils kept free from moisture, sediment and moulds.

COCOA POD AND COCOA BEAN.*

The period of hardest work for the cocoa grower begins with the approach of the main crop. The ripe pods have to be picked and gathered and the cocoa beans, the actual material of the crop, have to be removed from the pods and prepared for the curing. As the pods ripen at different times, which means that the picking, i.e., of the main crop as well as of the mid-crop, lasts over several months, the working process is often repeated. Careful picking of the pods at the proper moment assures to a certain extent the quality of the final product, for only properly ripe pods can yield properly ripe beans.

The picker must have a good knowledge of the degree of ripeness of the pods in order to correctly distinguish between the over-ripe and unripe fruits.

The first work of the crop is the picking of the pods, i.e., cutting them off at their stems. The pods on the lower branches are cut off with a bush knife; for those on the higher branches cocoa knives are used (these vary in shape in the different centres) which are fastened to long sticks.

Great care has to be exercised in this kind of "picking"; there must be no damage to the trunk and branches or to places where flowers (and pods) begin to develop, for such damage would be injurious to future flowers.

The pods drop to the ground, and are then gathered and put in heaps; they are sorted, and, right on the spot, they are opened either with bush knives or sticks or by beating them on a stone.

This breaking of the pods lays open the seeds of the cocoa tree, the universally appreciated cocoa beans. From 20 to 70—on an average, however, 40 beans—lie in five, or at the utmost seven or eight, orderly rows from end to end, embedded in a thin film of soursweet, soft, white or pale pink pulp. The beans are about 2 to 3 cm. long and 1 to 1½ cm. thick. They are almond-shaped, and their colour varies between pale pink and pale brown tints.

The inside of the cocoa bean—the nibs—covered by a thin shell, consists almost exclusively of irregular, rather rifted-looking folds of seed-leaves—cotyledons—of a whitish or darker tint, which in some cases is even as dark as purple. The cocoa bean has no nutritive tissue, as met with in the seeds of other plants. This only appears in the form of a thin, colourless membrane, stunted in its growth, which surrounds the seed-leaves. The mass of the kernel is thus made up of the cotyledons, the seedbud of the cocoa bean. They contain all the nourishment which makes cocoa a most valuable product of tropical agriculture, a product which captured the world markets in a very short period. The production of cocoa, the trade in the article, the working-up, and finally the sale of the finished goods, has created an organization that is of utmost importance to the economy of all countries that share in it.

The cocoa beans are removed from the opened pods either by hand or with a scoop or with a wooden spatula. They are freed superficially from the sticky pulp and put into baskets or other suitable containers to be taken to the next stage of the work, the curing plant. The larger plantations even use a portable railway for this purpose.

At the curing plant the cocoa beans are turned into the commercial "raw cocoa". The large number of pods left over after the removal of the beans are dug into the soil to serve as manure. Pods which show any signs of disease (black rot) are generally burnt very carefully.

* From *Gordian*, Hamburg, 10th June, 1939., XXXXV. Jahrgang, Heft Nr. 1059.

PRACTICAL COMPOSTING.*

A Plea for Adapting the Technique to the Raw Material and the Environment.

By G. B. Masefield, M.A. (Oxon.), A.I.C.T.A., Agricultural Officer, Uganda Protectorate.

The subject of making compost manures has received a good deal of attention lately, and a number of excellent accounts have been published describing systems of composting. The danger of these methods is that they tend to become too systematic; and, as one who has had experience of composting under varied climatic conditions, I feel that a word of warning against this tendency is desirable.

It is evident that composting cannot satisfactorily be reduced to rule-of-thumb methods. A system which is advocated for one place may be of little use in another with a different climate, and even from one season to another, with differences in rainfall, the same system will not prove satisfactory. For this reason, all systems which gave a "time-table" of composting operations are to some extent a snare and delusion. The experienced composter will vary his methods from season to season, and even from day to day. This is one reason why, to get the best results in large-scale composting, it is essential to have adequate expert supervision and not to rely upon unskilled native labourers only.

Pits or Heaps?

As an example of the need for flexibility, we may quote the much-vexed question of whether compost is best made in pits or in heaps. Pits are, of course, best under dry conditions, as the evaporation is much reduced; but they fail in wet climates or seasons. I have seen compost made in concrete pits without any provision for drainage; in a very wet season there was standing water in the pits and the lower layers of the compost putrified and became noxious. On the other hand, in very dry weather heaps may become so dried out that decomposition almost ceases and some of the material is actually blown away.

There are, of course, means of getting round both these disadvantages. I have made successful compost with garden refuse in a pit, the floor of which sloped down slightly to a drainage channel at one end. During a very wet season in Uganda, the rainfall just served to decompose the compost nicely without any addition of water, and the compost never became water-logged.

Heaps, on the other hand, can be conveniently protected from evaporation during dry weather by laying a few coco-nut palm leaves along the top to form a thatch. During the wet season a good idea is to build them with the top sloping inwards to a central hollow so that all rainwater is caught and collected. Whether compost is best made under a roof or in the open depends on the climate, and also on whether the water supply is sufficient to compensate for the rain lost by using a roof.

An experienced composter again will vary the size of his heaps, building them bigger in dry weather and smaller in wet. Another factor in which flexibility is desirable is the frequency of turning. In dry weather, excessively frequent turning leads to far too much loss of moisture. As an extreme example, I may

* From *Tropical Agriculture*, May, 1939, Vol. XVI., No. 5, p. 99.

quote an experiment in which two compost heaps were built, each containing at the outset 9 cwt. of fresh material. The experiment ran for three and a half months, during which one heap was turned weekly and the other not at all. At the end of that period, the unturned heap weighed 8 cwt., but the turned heap only 3 cwt.

This matter of control of moisture content is probably the most important single factor for success in composting, and too much insistence cannot be laid on frequent visits to the compost heaps and a flexible system which will take advantage of weather conditions.

The Fly Menace.

Another point to which great attention must be paid is the control of fly breeding in the compost. In most composts a sufficiently high temperature is reached in the interior of the heap to kill fly eggs and maggots. But the material at the edges does not reach this temperature, and, therefore, periodical turnings are necessary to ensure that this material is mixed up in the centre of the heap. In the case of the common house-fly, which is probably the commonest breeder in compost, the period from the laying of the eggs to the emergence of the fly averages about twelve days in the tropics. It is therefore essential that the heaps should be turned at least every ten days as long as the compost is fresh enough to attract egg-laying flies.

In any locality, it may be found that other species of flies are commonly breeding in compost. For example, in Trinidad *Leptocera ferruginata, Chrysomyza ani,* and an unidentified Tachinid fly were found to be of very common occurrence. Where this is so, the length of time from egg to emergence for each species should be ascertained, and the turning programme arranged accordingly.

Since flies breeding in compost may become a serious nuisance and in some cases a menace to the health of people or livestock, this is another reason for insisting that operations such as the turning of compost should be responsibly supervised. For the same reason, composting cannot be altogether recommended as an occupation for uneducated native peasants.

Materials for Composting.

In examining the suitability of different materials for composting, the chief consideration is to get the right degree of aeration in the mass. For example, maize stover for composting is better chaffed than uncut; but the chaff-cutter should not be set to cut too short, as this again leads to excessive compaction in the heap. Sugar-cane tops, being shorter, may be composted without chopping up. Rice straw, if composted by itself, becomes too compact and does not decompose. Pea and bean haulm are rather too open for composting by themselves, but are a good lightener for cereal straws. In composting garden refuse, care should be taken not to include too high a proportion of lawn-mower cuttings, as these tend to compact themselves and lead to anaerobic fermentation and acidity. Weeds are difficult to decompose if too much earth is included with their roots; but Beckley[1] has overcome this difficulty by growing beans on the compost heaps, which assists rotting.

In general, it may be said that there are few types of agricultural refuse which cannot be composted if the right degree of aeration is obtained. Probably all of them rot better if mixed with other suitable ingredients than in the pure state, a fact which seems to have been too much overlooked in estate methods of composting. One of the exceptions seems to be tobacco stalks, which are very hard to induce to decompose. I have also had poor results with plantain leaves and peelings, both of which are a common type of habitation refuse in Uganda.

In cases where adequate aeration of the compacted mass is hard to obtain; this may be achieved artificially by placing ventilating tiled (Lambert and Davis[2]) or lengths of bamboo pole under the heaps. Here again there is plenty of scope for ingenuity and flexibility of programme.

Experiments on Composting.

The technique of composting experiments has its own difficulties, which make it very hard to obtain results that are convincing to the modern statistically-trained critics. In a series of experiments carried out in Trinidad at the Imperial College of Tropical Agriculture on the effect of adding various substances such as dung, sulphate of ammonia, lime, and an inoculum of "activated compost" to composts with the object of accelerating decomposition, no results were obtained which reached statistical significance as to the benefit of any of these treatments.

One reason for this position is the difficulty of obtaining from a large and often heterogeneous mass of compost a small sample for chemical analysis which shall be representative of the whole. The statistically-minded may be interested to note that on two occasions, when taking six samples from the same point in the same heap for measurement of carbon dioxide evolution, the sampling error proved to be 190 per cent. and 227 per cent. of the mean respectively.

Another difficulty lies in finding a suitable means of measuring rates of decomposition. After some experience in endeavouring to assess this by such methods as temperature records, chemical analyses, degree of humification, carbon dioxide evolution, and fungus and bacterial counts, I have come to the conclusion that there is no better criterion than judgment by eye and hand. A very useful technique is to take a few fibres from the compost mass in one's hand and roughly feel the breaking strain, by which means one soon becomes quite proficient in judging the degree of the rotting. Eye and hand can take in the whole of the heap in a way in which sampling methods cannot, and can often deliver judgment which cannot be translated into figures.

Although it appears, therefore, that experiments in composting are apt to be disappointing, I think that there is a danger in the fact that most of the writers who have advocated different systems of composting have worked these out quite empirically, have not compared them side by side with other systems which have proved good, and have not investigated a number of variations which might have greatly improved the process. It seems desirable that a much greater number of field trials in composting methods should be made, which may at present be of great assistance to the practical man, but from which accurate scientific results should not be looked for too soon. In estate practice, it is better for every composter to make his own experiments rather than to follow too slavishly methods which have been worked out for other localities and climates.

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LIVESTOCK—ITS PLACE IN ESTATE PRACTICE.*

By R. Paton.

It is an axiom as old as the land itself that "you can't farm without muck" and never was this truth being more forcibly driven home than it is to-day. Throughout the length and breadth of Britain one is confronted with the depressing spectacle of derelict land, worn-out and impoverished pastures, former good hill grazings overrun with bracken, gorse and brambles rampant in what once were arable fields; and as a concomitant one hears the same tale on all sides of dwindling livestock. The cold blast of economic depression which has assailed the agricultural industry ever since the few prosperous years following the war has completely upset the established rules of farming practice, and farmers have been forced to adopt methods of working their land which are quite opposed to their natural instincts of good husbandry. As I heard it aptly described not long ago, "good farming no longer pays", but the man who said that did so with his tongue in his cheek, knowing full well that the account would have to be squared some day.

Tractors have taken the place of horses on many farms, mechanized transport has almost completely driven the horse from the roads, uneconomic prices for beef, wool and mutton have resulted in a great diminution of cattle and sheep, while pig numbers have also dwindled under pressure of imports of pig products from foreign countries. The net result of all this so far as the land is concerned is a colossal decrease in the amount of humus and urine, which constitute the very life-blood of the soil.

Now, with the shadow of war overhanging the world, the Home Government has awakened to the fact that the fertility of the land has been allowed to sink to such a low ebb that it could not possibly respond to intensive production of food crops, such as would be required in war-time, and so subsidies have been offered for treatment with slag and lime, and now a further grant of £2 per acre is being made for the ploughing up of worn-out grassland; not with the object of bringing it into immediate crop production, but with a view to improving the pasture and getting livestock back on to the land so that its fertility may be restored against the day when heavy demands may have to be made upon it. So far as I know this is the first time that the importance of livestock as a means of promoting and maintaining fertility of the soil against a national emergency has been given the official recognition it deserves. To make the scheme complete proposals relating to subsidies and marketing are either in hand or under consideration to ensure remunerative prices for all classes of livestock.

There may be a vast difference between farming practice at home in the temperate climate of Britain and estate practice in Malaya, but the principle governing soil fertility is exactly the same. The methods whereby fertility is obtained and maintained may also be different, but they boil down to the same thing in the end—humus. Centuries of farming practice have established the irrefutable fact that fertility cannot be maintained for any appreciable length of time without livestock, and I venture to predict that the same truth will be brought home to agriculturists in Malaya, sooner or later.

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* From *The Planter*, No. 7, Vol. XX., July, 1939.

That there are drawbacks, and prejudices, to livestock on estates, I am very well aware, but in this connexion, I would suggest that I speak from experience, that most of these drawbacks and prejudices arise from the haphazard methods under which cattle have been tolerated on estates up to the present time. Cattle and goats which the labourers may be allowed to keep, as a sop to the Labour Department or under the necessity of retaining a labour force, are a vastly different proposition as compared with herds which are maintained by the keenness and under the supervision of the manager for the benefit of the estate. Whether they are owned by the labourers or the estate makes little difference; it is the methods under which they are kept that count, and if their value to the estate is recognized to the extent that the manager takes a direct interest in them, it follows that they will be of correspondingly more value to the labourers. Livestock owned by the estate are not likely to show any direct profit at the present time on the livestock account, but with careful management they should show no loss, and properly worked there should certainly be an increase in soil fertility, with a resultant profit from increased crops.

Cattle, pigs, sheep and goats are all suitable for this country, but not all of them are suitable for every estate. Pigs, for instance, might be difficult on an estate with Malay or Javanese labour, and goats are a pest on an estate with young clearings.

Cattle.

The two chief reasons I have heard put forward against the keeping of cattle are—

(*a*) lack of grazing grounds;
(*b*) damage done by uncontrolled grazing.

As regards (*a*) I think that too much importance is placed on the necessity for grazing grounds. If fields could be provided with good pasture grasses, we would have the ideal conditions for cattle, but as the pastures simply do not exist, and our main object in keeping cattle at all is to provide manure, it follows that they should be stall-fed as much as possible under conditions that will ensure the maximum conservation of dung and urine. All that is necessary, therefore, is a shed having a good concrete floor, with channels to collect the dung and urine and convey it to a concrete pit, a small area set aside for exercising purposes with a good supply of drinking water, and an area for the growing of guinea grass. This latter can be either an area set aside for the purpose, or the guinea can be grown successfully on the edges of drains or terraces, thereby preventing soil wash as well as providing fodder.

Under these conditions cattle will keep well and healthy, uncontrolled grazing and its attendant evils will not exist, and the manure can be utilized to the best advantage. Where composting is being practised, the addition of manure and urine to the heap will both expedite the breaking down process and enhance the value of the compost. From a manurial point of view the urine is most important, and great care should be taken to see that this is not wasted. If it cannot be applied to the land direct, compost heaps are the best means of "banking" it, but such heaps should be protected from rain otherwise a lot of the value will be washed out of them. The greatest value is obtained from the manure if methods of handling it are directed towards the production of the biggest possible volume of humus, with the minimum of waste, and in actual practice many ways and means of achieving this object present themselves. The following suggestions, however, are put forward for what they are worth :—

(*a*) Collection of dung and urine in concrete sumps and direct transport to the field. In this case the liquid manure should be poured into trenches which have been filled with vegetable matter such as grass and weeds, cover crop, coco-nut husks, &c., and then covered over with soil. This method can be applied also to the planting hole in the case of young rubber.

(*b*) Collection as above and daily application to compost heaps which are afterwards dug into the soil.

(*c*) Composting in the cattle shed after the manner practised at home in the "reeds" and courts of the cattle-feeding countries. This is the ideal method of making farmyard manure, but so far I have not tried it in this country, and so I cannot say anything about it.

On coco-nut estates under grass and mixed covers the cattle need never be housed at all. A method which I have employed with a herd of cattle for the past few years, and which has given very good results, is to move them systematically through selected areas, tethering them to individual palms at night, ten successive nights at each palm. During the day the cattle graze in the same area, and the driving to and fro from cattle sheds to grazing grounds, which is the usual routine with herds belonging to the labourers, and which is a potential source of damage and trouble, is entirely eliminated.

A good way to start off an estate herd is to purchase from 15 to 20 of the best young heifers available, and these can be picked up at about 20s. to 30s. a head. When they are two years of age a selected bull should be added to the herd, and thereafter the normal increase should be one calf per cow per annum. Bull calves should be castrated, unless required for breeding purposes, and all the calves should be allowed free access to their dams. A good cow at home will produce enough milk to rear two or even three calves, but in this country the average cow has barely sufficient milk to make a good job of one. And even then, in the hands of native dairymen and estate labourers, the calf has to be content with what it can get after the cow has been milked very nearly dry. It will be appreciated, therefore, that estate herds allowing the calves all the milk would very soon effect a great improvement in the standard of cattle throughout the country.

A herd started by the purchase of young animals need not entail a very big outlay, and after the first year or two the capital value should more than double itself. For about 30 animals, one or two herdsmen, according to whether the cattle are stall-fed or not, are sufficient, so the monthly expenditure is the amount of their wages only, and after a few years there should be sufficient revenue from sales to more than cover this. The handling of the manure, of course, is a direct charge to manuring, and the amount of labour required will depend on circumstances. That this will pay for itself, however, in terms of increased fertility leaves no room for doubt.

Pigs.

As compared with cattle, pigs require much more supervision and management if they are to be reared successfully. Here again manure should be the main consideration, but during periods of very low prices there is apt to be a deficit in the working account which will make the manure look rather expensive. It must be borne in mind, however, that where the pigs are properly fed the manure is much more valuable than that obtained from cattle, on account of the high proportion of concentrates included in their rations. A good feeding mixture contains broken rice, rice bran, coco-nut cake, and ground-nut cake, whereas cattle, as a rule, get no concentrates at all.

A herd based on 20 to 30 breeding sows will mean about 200 to 300 animals of all ages always in stock, and this a unit which can be handled efficiently by three coolies for the actual cooking, feeding, cleaning, &c., and attention to sows at farrowing.

Cross-bred animals, viz., strains obtained by mating pure-bred boars to local sows in the first place, and then breeding from the cross-bred sows again with a pure-bred or suitable cross-bred boar, pay best as they inherit the virtues peculiar to both in respect of stamina, rapidity of growth, prolificacy, abundant milk and resistance to disease. It has been proved by experiment and confirmed in practice that litters of cross-bred pigs are considerably heavier than Chinese pigs at time of weaning, and that the live weight gain thereafter brings the cross-breeds to a killing weight of about 120 katties anything up to two months earlier than the Chinese breeds, with a much better carcase.

It has been proved also that sows of the European breeds are not such good milkers in this country as Chinese sows, hence the necessity for retaining a proportion of native blood. Cross-bred sows of large white, middle white and large black strains, all of which have been in this country, are usually prolific breeders and good milkers.

Exercise is essential to keep breeding stock in good condition, and it is advisable to let young pigs and weaners have free range for an hour or two each day until they are four months old. If due consideration is given to this requirement when the site for the piggery is being selected, no great harm or trouble should result, and a small herd-boy put in to look after the pigs while they are out can keep them from straying into areas from which it is desirable that they should be excluded. Young clearings and nursery areas should be definitely forbidden, but there is very little damage that pigs can do in old rubber. When tapping is in progress, and the cups are fairly low down on the trees, pigs, of course, should not be let out until after the latex has been collected, otherwise a certain amount of crop is liable to be lost.

With training and close supervision Tamils make excellent pig-men, so there need be no difficulty on account of labour. A certain amount of foodstuffs, such as tapioca roots and sweet potatoes, can also be grown if land is available, and it may be possible to give such land out in the form of allotments to the labourers and then buy the produce from them. This provides work for dependants and enables them to earn a small income, thereby easing the strain on the family budget and at the same time contributing something towards improving the position as regards locally-produced foodstuffs.

One method whereby a herd of pigs can be started easily is to purchase, say, ten to fifteen in-pig gilts, preferably of a good cross-bred strain and in pig to a pure-bred boar. This forms the foundation of a good herd which can be built up to whatever size is desired. The gilts should all farrow within two or three months of taking delivery, and when the young ones are ready for weaning a suitable boar should be purchased with which to carry on the breeding.

The manure from the piggeries should be conserved in as concentrated form as possible and to this end a concrete sump should be provided to receive all the washings from the pens. Rain water from the roof should not be allowed to enter the sump as otherwise the manure will become too highly diluted. The pigs too, particularly the fatteners from which the best manure is obtained, should be housed fairly intensively so that the manure is not overdiluted by the washing of the pens. By this it is not meant that the animals should be overcrowded but the buildings should be designed so that the biggest possible concentration of manure is conveyed to the sump with the minimum of washing. One hundred and twenty fattening pigs housed in ten pens, each pen having a floor space of 10 feet by 8 feet under cover and 15 feet by 8 feet uncovered, will keep a sump 6 feet square full of good rich manure. The sump should be allowed to fill up and thereafter the quantity removed each day should be just more or less the amount which goes into it.

The manure as it comes from the sump is, of course, in semi-liquid form, and it has, therefore, to be transported in drums or buckets. In this form it is very suitable for applying direct to coco-nut and oil palms by pouring it in a circle at a radius of about 8 feet around each palm. The quantity required will depend on circumstances, but it is better to err on the side of being too liberal than otherwise.

Other ways in which this manure can be usefully applied are—

(*a*) *Nurseries.*—Periodic waterings with a fairly dilute mixture applied between the rows, preferably after a light chipping of the soil, will keep the seedlings making good healthy progress. Heavier dressings will promote rapid growth when it is desired to force on the seedlings for any special purpose.

(*b*) *Basket Seedlings.*—Two or three applications of a fairly weak mixture spread over the time between planting in the basket and removing it to the fields will ensure good, strong plants which will go ahead without any check.

(*c*) *In the Planting Hole.*—By filling the holes with soil to within 9 inches of the top and then applying a bucket of manure to each hole about two weeks before completely filling the holes and planting, some very fine results have been obtained both from basket seedlings and budded stumps.

(*d*) *Young Rubber.*—Seedlings and budded rubber will both rapidly respond to applications made in the field, and care has to be exercised to avoid over-manuring as it is likely to promote a bigger development of branches and foliage than the young plant can support. Unfortunately, a luxuriant growth of weeds is also encouraged, but can be depressed by planting a mulch of bush prunings or other cover crop around the plant, at the same time the mulch rapidly breaks down under the influence of the manure to form a rich, crumbly mould.

As regards the economics of pig-keeping it must be emphasized that present-day prices allow of no margin of profit on the pig-keeping account. Anyone who adopts this form of livestock must concentrate, therefore, on making revenue as nearly as possible equal expenditure and be prepared to charge any loss there may be to enhanced fertility of the land. It must be emphasized also that any cutting of expenditure in regard to feeding and the production of manure can only result in disappointment. In this connexion I cannot refrain from remarking that, in my opinion, it is a pity the Government does not do more to encourage this form of animal husbandry by restricting the import of pigs from other countries.

Sheep.

Where conditions are suitable, that is to say, wherever there are areas under grass, sheep do very well and are well worth keeping. They exhibit no tendency to stray, are very easily herded and therefore constitute no menace to growing crops.

A flock of Kelantan sheep was started on this estate some 25 years ago, and it is still going strong. Numbers are maintained round about 100 and for the past ten years Calcutta rams have been used for breeding purposes. Some difficulty exists now, however, in getting rams from India and some other breed will have to be tried.

Of all the animals with which I have had experience in this country, sheep are the least troublesome, and the following few points are the only ones which have to be observed:—

In the first place, they must be housed at night in a shed raised 2 or 3 feet above ground level and the floor of the house must be slatted to ensure that all the dung and urine will drop through. The ground beneath should be concreted and sloped to a concrete tank in which all the manure is collected.

The second important point is that the sheep should not be turned out in the mornings until well after the sun is up, and they should not be also housed again until just before dark in the evenings.

One or two rams only should be retained, according to the size of the flock, and allowing one ram for about 30 to 40 ewes. All other ram lambs should be castrated while they are still very young. From the age of one year all the sheep should be clipped periodically. The wool also is a valuable manure and should not be wasted.

No feeding of any kind is required other than grass, but a trough of good clean water should be available near the shed. Wet or swampy grazing grounds should be avoided and conditions around the shed kept clean and dry.

The amount of manure produced by a flock of 100 sheep is surprising and it is very highly concentrated and therefore of considerable manurial value.

With a Tamil labour force a flock of sheep is a decided asset also from the point of view of supplying fresh mutton on occasion and revenue from this source is generally sufficient to cover expenditure.

Goats.

Generally speaking, goat-keeping should follow the same methods as those outlined for sheep, but special pens should be provided for the entire males. Bunches of green bushwood should be hung up in the sheds at night, otherwise the animals are inclined to gorge themselves when they are turned out in the morning and suffer colic and other digestive troubles in consequence. Grazing grounds are essential and for this purpose light "belukar" or abandoned areas are ideal. Wet and swampy places should be avoided.

In the case of both cattle and goats the animals may be all owned by the labour force, but to get the benefit of them the sheds should be provided by the estate so that the manure may be properly conserved. The advantages of this system are apparent to any manager who realizes the importance which the ownership of livestock plays in the establishment of a settled labour force.

Having dealt now with a brief outline of how these four classes of livestock may be kept to the benefit of any agricultural holding, there remains one other point—disease. This must always be a risk where livestock is concerned, but with common-sense methods of housing, feeding and attention there is no reason why undue losses should occur on this account. Cleanliness and the avoidance of over-crowding are of first importance, and these are both possible of attainment on any estate. Immediate isolation of any animal which appears to be off colour is also easily arranged, and is only a common-sense method of avoiding trouble. To the same end any new animals which are being added to the herd should be kept apart from the others for at least three weeks. Digestive disorders all arise from faulty feeding and supervision alone will prevent this.

Overcrowding is a source from which various ills arise. Not least of which is infection from intestinal parasites. Badly designed houses also give rise to ailments such as rheumatism, particularly in the case of pigs, for which a dry sleeping place is absolutely essential.

More serious diseases, such as foot and mouth disease and swine fever, must not be lost sight of, but the risk of these is also minimized by strict adherence to the rules of cleanliness and quarantine. In case of doubt or definite outbreak, the Veterinary Department can be relied upon to take the necessary steps for treatment and control. In all cases, however, prevention is better than cure, and if this is borne in mind from the outset, the risk of disease should not prevent anyone from going in for livestock.

As regards housing, feeding and general management, the Department of Agriculture has already issued some excellent articles and anyone following these will not go far wrong.

In conclusion, I would emphasize the point that cattle manure alone will not work miracles, nor will it oust artificial fertilizers from their place in agriculture. Used in the proper manner, however, under conditions of correct soil management, it will so enrich the soil in humus and bacterial activity that the response to any other form of manuring or cultivation will be materially increased. The bounty of the "good earth" is there for our winning, but only as we nurture it shall we reap the reward.

AGRICULTURAL AND FORESTRY RESEARCH IN LATIN-AMERICAN REPUBLICS.

Scientific research is being recruited to the aid of the United States Government's programme of advancing its announced "good neighbour" policy in its relations with the other republics of this hemisphere to the status of mutual helpfulness among them in the fields of agriculture and forestry.

Of the approximate $1,000,000 designated for the promotion of closer cultural relations with our neighbours to the south, more than a third—or $350,000—has been allotted to the Department of Agriculture, for the purpose of a long-range research looking toward increasing the production in tropical America of raw materials needed in this country and now obtained principally from the Old World tropics. Some of the most important of these, notably rubber and quinine, actually originated in South America, but their present production is controlled by other countries in south-eastern Asia and the East Indies.

Preliminary steps will be discussed at the Lima conference, and in the meantime Department of Agriculture scientists are developing an agenda of projects to be undertaken. Expenditure of the $350,000 breaks down into support of several lines of activity, all regarded as highly important.

For four new Department of Agriculture attaches, $120,000 a year will be needed. At present this country has only one agricultural attache in the entire Latin-American area, with an office in Buenos Aires. The new men will be located in Mexico City, Havana, Rio de Janeiro, and Panama.

A survey of hardwood forest products of tropical American republics calls for $65,000 a year. At present virtually nothing is known about the economic possibilities of tropical American forests. A similar survey of soils, vegetation, climate and other factors affecting agriculture will take another $65,000 a year. Rubber and quinine will receive special attention under this project. The sum of $75,000 is set aside for the development of a tropical forest experiment station in Puerto Rico to work out problems and serve as a research centre for the Caribbean region. The United States Weather Bureau will be given $15,000 to make possible the training of meteorologists from American republics interested in special lines of weather forecasting technique. Particular attention to problems connected with hurricanes will be called for in this work. Finally, $10,000 is made available for the printing of scientific bulletins and other publications after translation into the three languages of Latin-America, Spanish, Portuguese and French.

Other lines of activity for which additional appropriations are not at present needed are the loan of agricultural officials to the American republics, co-operation with radio companies for the transmission of information, and promotion of the early completion of the Inter-American Highway as far as Panama.

Although the whole subject is only now being formally broached, informal inquiries by representatives of certain other American republics indicate their keen interest, and even eagerness to co-operate by placing their scientific facilities and tracts of land at the disposal of the scientists, both American and from among their own nationals, who will take part in the work.—FRANK THONE.

* From *Science*, Supplement, 16th December, 1938, p. 9. Vol. 88, No. 2294.

TABLE OF PLANTING DISTANCES.*

The following table shows the number of plants to the acre at distances of 1 to 50 feet apart, and the area in square feet available for each plant:—

Distance apart in feet.	Area for each plant in square feet.	Number of plants to acre.	Distance apart. Feet.	Area for each plant in square feet.	Number of Plants to the acre.
1 by 1	1	43,560	15 by 15	225	193
1½ by 1½	2¼	19,360	16 by 16	256	170
2 by 2	4	10,890	17 by 17	289	150
2½ by 2½	6¼	6,970	18 by 18	324	134
3 by 3	9	4,840	19 by 19	361	120
3½ by 3½	12¼	3,556	20 by 20	400	108
4 by 4	16	2,722	22 by 22	484	90
5 by 5	25	1,742	24 by 24	576	75
6 by 6	36	1,210	26 by 26	676	64
6 by 7	42	1,037	28 by 28	784	55
7 by 7	49	889	30 by 30	900	48
8 by 8	64	680	32 by 32	1,024	42
9 by 9	81	537	35 by 35	1,225	35
10 by 10	100	435	37 by 37	1,369	32
12 by 12	144	302	40 by 40	1,600	27
13 by 13	169	257	45 by 45	2,025	21
14 by 14	196	222	50 by 50	2,500	18

For numbers not given in the above table, divide 43,560 by the square of the distance apart the trees are required to stand, in feet; the result is the number of plants required per acre.

HOW TO DESTROY RATS.

Rats, at times, do get into a house or an outhouse, however carefully kept, and the housewife is naturally keen on keeping the pests away, or of getting rid of them when they appear.

Here are a variety of ways found useful, and such as can be dealt with by all womenfolk.

When a house is infested with rats which refuse to be caught by cheese and other baits, a few drops of the highly-scented oil of rhodium poured on the bottom of the trap will be an attraction they cannot refuse.

Place on the floor, near where rats' holes are, a thin layer of moist caustic potash. When the rats travel on this it will cause their feet to become sore, which they lick, and their tongues become likewise sore. The consequence is that they shun this locality, and seem to inform all the neighbouring rats about it, and the result is that they soon abandon a house that has such a preventive.

Cut some corks as thin as wafers and rub them in grease. Place the same in their tracks; or a bit of sponge dipped in treacle or honey, with a small quantity of oil of rhodium, will fasten to their coats and cause them to depart.

If a live rat be caught and smeared over with train oil, and afterwards allowed to escape in the holes of other rats, it will soon cause all to take their departure.

* Extract from *Tropical Planting and Gardening*, by H. F. MacMillan, page 51.

Take a pan about 12 inches deep and fill it with water; then sprinkle some bran on the water and set the pan in a place where the rats most frequent. In the morning you will find several rats in the pan.

Make two parts of common squills (well bruised) and three parts of finely-chopped bacon into a stiff mass, with as much barley meal as may be required, and then bake in small cakes and put for the rats to eat.—*The Planter* and *Tanganyika Advertiser*, April, 1939.

HOW WEATHER NEWS IS COLLECTED.*

One of the many duties of the British Royal Air Force of which the general public is not aware is the maintenance of a special flight of pilots, known as the Weather Flight or, more ceremoniously, the Meteorological Flight. These pilots ascend daily to heights of about 25,000 feet to gather information of vital importance to the Air Ministry's experts when they work out their weather forecasts.

A knowledge of the weather conditions he is likely to meet is essential to the pilot who has to keep to a time schedule on regular routes, and the highly-organized weather service now operating co-ordinates information received from a network of ground stations observing weather conditions on land, from ships as they move about on the oceans, from pilotless balloons, whose behaviour as they rise in the air is being observed and interpreted by meteorological experts, and from aircraft reporting what happens in the upper air.

The Royal Air·Force Meteorological Service Branch was established in 1924, since when the flight has carried out almost continuously its onerous duties; the occasions when the pilots have been prevented by bad weather from going up have been extremely rare. The last occasion when they had a "day off" was in November, 1936, when all Britain was hidden in a blanket of fog and not a single aerodrome could be seen from the air. Since then the flight has completed 1,500 high-altitude flights in unbroken succession, soaring to heights where in winter time they often encounter temperatures of 80 degrees below freezing point.

NOTES ON COPRA.†

Copra dried to 6 to 7 per cent., if stored in a well-ventilated dry store at an even temperature, will not seriously deteriorate. It is apparent that there is little to gain by drying copra much below 6 per cent. moisture content, although in the past much more stringent recommendations have been made.—*The Tropical Agriculturist*, Vol. 89, No. 5, 1937.

As usually shipped in the East, copra is attacked in transit by moulds and insects, resulting in serious losses and deterioration. Experiment had shown that it can be dried to such an extent that moulds and insects do not touch it, and that the resultant short weight is amply compensated by the absence of loss. This is not yet fully appreciated, but undoubtedly will be in time.—Supplement to *United Empire*, August, 1938.

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* Extract from W.740, Weekly London Letter by Andrew Blackmore, 1939.
† From *Agricultural Journal*, Department of Agriculture, Fiji, Vol. 10., No. 2, 1939.

PHASES OF THE MOON, 1940.

RABAUL.

January	2—Last Quarter	2.56 p.m.
	9—New Moon	11.53 p.m.
	18—First Quarter	4.21 a.m.
	25—Full Moon	9.22 a.m.
	14—Apogee	10.0 p.m.
	26—Perigee	9.0 p.m.
February	1—Last Quarter	12.47 a.m.
	8—New Moon	5.45 p.m.
	16—First Quarter	10.55 p.m.
	23—Full Moon	7.55 p.m.
	11—Apogee	12 noon.
	24—Perigee	8.0 a.m.
March	1—Last Quarter	12.35 p.m.
	9—New Moon	12.23 p.m.
	17—First Quarter	1.25 p.m.
	24—Full Moon	5.33 a.m.
	31—Last Quarter	2.20 a.m.
	9—Apogee	3.0 p.m.
	23—Perigee	8.0 p.m.
April	8—New Moon	6.18 a.m.
	15—First Quarter	11.46 p.m.
	22—Full Moon	2.37 p.m.
	29—Last Quarter	5.49 p.m.
	5—Apogee	7.0 p.m.
	21—Perigee	5.0 a.m.
May	7—New Moon	10.7 p.m.
	15—First Quarter	6.51 a.m.
	21—Full Moon	11.33 p.m.
	29—Last Quarter	10.40 a.m.
	3—Apogee	9.0 a.m.
	19—Perigee	5.0 a.m.
	31—Apogee	3.0 a.m.
June	6—New Moon	11.5 a.m.
	13—First Quarter	11.59 a.m.
	20—Full Moon	9.2 a.m.
	28—Last Quarter	4.13 a.m.
	15—Perigee	1.0 a.m.
	27—Apogee	9.0 p.m.
July	5—New Moon	9.28 p.m.
	12—First Quarter	4.35 p.m.
	19—Full Moon	7.55 p.m.
	27—Last Quarter	9.29 p.m.
	10—Perigee	5.0 a.m.
	25—Apogee	3.0 p.m.
August	4—New Moon	6.9 a.m.
	10—First Quarter	10.0 p.m.
	18—Full Moon	9.2 a.m.
	26—Last Quarter	1.33 p.m.
	6—Perigee	1.0 p.m.
	22—Apogee	8.0 a.m.
September	2—New Moon	2.15 p.m.
	9—First Quarter	5.32 a.m.
	17—Full Moon	12.41 a.m.
	25—Last Quarter	3.47 a.m.
	3—Perigee	4.0 p.m.
	18—Apogee	6.0 p.m.
October	1—New Moon	10.41 p.m.
	8—First Quarter	4.18 p.m.
	16—Full Moon	6.15 p.m.
	24—Last Quarter	4.4 p.m.
	31—New Moon	8.3 a.m.
	2—Perigee	2.0 a.m.
	15—Apogee	8.0 p.m.
	30—Perigee	2.0 p.m.
November	7—First Quarter	7.8 a.m.
	15—Full Moon	12.23 p.m.
	23—Last Quarter	2.36 a.m.
	29—New Moon	6.42 p.m.
	12—Apogee	2.0 a.m.
	27—Perigee	10.0 p.m.
December	7—First Quarter	2.1 a.m.
	15—Full Moon	5.38 a.m.
	22—Last Quarter	11.45 a.m.
	29—New Moon	6.56 a.m.
	9—Apogee	6.0 p.m.
	25—Perigee	4.0 p.m.

N.B.—Apogee—the point in the Moon's orbit farthest from the earth. Perigee—the point in the Moon's orbit nearest the earth.

There will be a transit of Mercury across the disc of the Sun on the 12th November, visible in the eastern portion of Australia between 7 and 11 a.m.

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