FALL OF MATURE COCO-NUT PALMS IN NEW GUINEA, DUE TO SOIL CONDITIONS.

(*R. E. P. Dwyer, B.Sc.Agr., Economic Botanist.*)

Falling of mature coco-nut palms due to soil conditions, bad drainage, and so on, is not an uncommon occurrence in some plantations in New Guinea. The bending over of palms on water-logged, low-lying situations, or in peaty soils, so that they almost touch the ground, is a common indication that palms are growing on such soils. Often, though not invariably, such palms fall completely to the ground. They usually remain stunted or low in height, chlorotic and poorly bearing, until drainage is improved.

On one plantation in Buka Island (Small Buka),* coco-nuts are grown under very wet conditions, where extensive drainage has been found necessary. The low-lying nature of the ground, as seen where the water is always slowly running in the shallow drains and around the roots of the palms, has caused many of them to fall over, due to their restricted rooting system. Some of these palms still continued to grow upwards from the tip. The roots at the base are not wholly severed, and such palms may grow on for years, and even produce moderate crops of coco-nuts. Similar areas to those mentioned are known in New Britain and other parts of the Territory, but the example quoted in Buka is an extreme case, where a large area of coco-nuts was planted under wet conditions.

On another plantation in Bougainville Island, a different set of soil conditions is found which has also led to the fall of mature palms over a fairly extensive area. In this case, the surface soil is light and relatively sandy over a large flat area of country. The plantation is a very good, heavy-yielding place, and the coco-nuts generally look strong and healthy, although the planting is closer than usual (probably about 27 feet spacing).

The light soil at the surface does not, on first appearance, appear rich, but under the sandy layer a distinct retentive, clay layer exists at a little distance below the surface. Water is continually moving from the high foothills behind. Through and above the clayey layer there is a continuous slow movement of water, probably carrying dissolved nutrients in it. In the plantation, the water comes almost to the surface during the wet season, and thus drainage under such conditions was found necessary. It is not in the frontage areas, however, that the fall of palms occurs. It is at the back of the plantation, where the soil is lighter on the surface with more pumice mixed in with it, that a proportion of the mature palms fall, though, of course, the silt or clay layer still persists underneath. In the worst areas there is some evidence of swampy conditions in the near past. In such areas the soil is stiffer at the surface, and clay bands have reduced the natural drainage, which in turn has restricted the root area of the palms, and thus, in heavy winds, there is a decided tendency for the palms to fall.

The palms which have fallen on this plantation show a distinct ball of roots and earth at the base. The broken roots appear to have died and decayed owing to lack of aeration, and, in some cases, the fungus *Fomes* spp. was seen to be present. This was not the cause of the trouble, however, as the fungus was not always present. It appeared that the light upper soil could not hold the roots firmly, where the shallow-rooting tall palms had not penetrated far into the

* Buka Island or Small Buka is north of Bougainville Island, one of the Solomon Islands Group, and is only separated from it by the narrow Buka Passage.

sub-soil, or else the roots had rotted off due to excess water and bad aeration. In several localities, shallow planting on heavy, clayey soils appeared to be the main cause of the mature palms falling over.

SHOWING AREA OF FALLEN PALMS, WITU ISLAND.

N.B.—Growth continues vertically at their extremities.

In the Witu group, it was noticed, in some areas, that tall palms planted in 1912, and now aged about 26 years, fell down after heavy winds. These palms were fully bearing and appeared quite healthy, prior to falling. The fronds were dark green in colour and there was no sign of chlorosis, tapering stem, or other deficiency diseases. The palms fell over, particularly in a high wind, and though no detailed counts were made at least a couple of hundred of palms had fallen, particularly in one belt on a large, low-lying area.

FALLEN COCO-NUT PALM.

Showing growing point vertically and at right angles to the fallen trunk.

The fallen palms have a peculiar and distinctive appearance, as they do not die altogether, but continue growing from the head, which turns at right angles from the ground and the main trunk as it lies. The size of the fronds becomes noticeably smaller than on mature palms or compared with fronds which would be seen on palms of comparable age and size (*see* photographs). The

diameter of the upright portion of the trunk is decidedly smaller than the main trunk. These growth habits indicate that less nutrients are taken in, which is accounted for in the reduced rooting surface and feeding area, after the palms

ROOT SYSTEM OF FALLEN COCO-NUT PALM.
Close view showing Root Plate of Matted Roots, taken at Witu.

ROOT SYSTEM OF FALLEN COCO-NUT PALM.
Same subject as above, taken at a greater distance away.

have fallen down. The fallen palms do continue to flower and fruit, but never thrive satisfactorily, as could be expected, when the reduced leaf area and nutrient intake, and the shading from the surrounding palms, are taken into account. The nuts produced are smaller and fewer when they do commence bearing. It should be noted that the palms do not fall until fully grown, and some of those which had fallen were probably 40 to 50 feet long.

An examination of the root system of a fallen palm is most illuminating (*see* photographs). The roots do not break off as would be the case where a normal palm falls, due to other causes, such as washaways, &c. Except at the outside periphery of the palm roots, more than two-thirds of the base is entirely flat and compressed, though there were some exceptions which are described. In these exceptional cases, the centre of the palms has roots protruding as an ovate or round ball, at the base of which the roots are severed. The explanation of why this ball of roots occurs in the central basal portion of some palms appears to be associated with the size of the original planting holes. Where the holes were made larger than usual, the roots were able to penetrate deeper in an area corresponding with the size of the hole. A great proportion of the palms showed no evidence of this secondary bole whatsoever.

The flattened roots which had not been broken at all, except at the periphery, showed every evidence of a "soil-bound" condition, or an effect similar to that which is brought about where large plants are grown in small earthenware pots in the garden or nursery, and the roots are compressed into a small space. The great mass of compressed roots at the base were curled and twisted into a labyrinth of matted roots, which were almost as flat as a plate where they had been in contact with the ground surface. This interwoven mass of twisted roots could be termed a "root plate" caused by enforced restriction of the rooting and feeding area. It was apparent that a detailed examination of the soil profile was necessary to solve the reasons for the flattened appearance at the base of the palms.

Soil sections which were exposed in gullies, exposed foreshores, cuttings for small railway trucks, &c., were examined. The appearance of the actual soil conditions at the base of the palms was most instructive. The first 12 to 15 inches of soil was a reddish-brown chocolate and very friable, volcanic loam which, on appearance, seemed to be chemically and physically a rich soil. The chemical richness of the soil is easily confirmed, as the plantations there yield well over a half a ton per acre per annum (in the vicinity of 14 cwt.), which must be classed as good, high-yielding property. It appeared that so far there was practically no evidence of soil deficiency, and the only weak palms present were hereditarily or genetically so, and such palms can be seen on almost any plantation. The next underlying layer extends for more than 8 inches in thickness, and is definite hard-pan, which is found under a fairly wide area of ground. This layer is very hard and proved difficult to pierce, even with a crowbar. When dug out the hardened material breaks into a fine palpable mass, when pounded, or else comes off in definite flakes or layers in much the same way as shale does. The next underlying layer to the above, when reached, proved not quite so compacted as the above, being composed of a matrix of greyish ash comparable with the hardened layer, but mixed with volcanic scoria. The scoria and rocks found in this matrix appear to be very variable in colour and composition. This

last layer is very deep but variable, being composed of several layers apparently as the result of many upheavals. Curiously, in many sections, a second hardened layer, comparable with that described previously, is met at about 4 feet depth. This appears very similar in appearance to the top hardened layer, but may not be the same in composition. It is the first hardened layer met with which is responsible for the plating and compaction of the roots at the base of the coco-nuts, as it was practically impenetrable to root growth, even by roots so hardened as those of coco-nuts. A native boy had considerable difficulty in digging through this layer when soil samples were being taken, as it was extremely fine-grained and very hard. Semi-weathered, flat pieces of this hardened ground (mud-stone) up to about ½ inch in thickness were seen, in numerous instances, to be attached to the flattened basal roots, and sometimes very fine roots had penetrated partially through this material. The compacting of the roots against this hardened layer explains the origin of the basal plate of roots.

When one walked along the roads and paths where the washing away had exposed this hardened layer at the surface, it was found to be very slippery and very hard. As far as could be gathered it was almost impervious to water, especially when flowing quickly and in quantity, and the loose surface soil was easily eroded away from it, indicating that cover cropping would be valuable. Wherever any low-lying areas are present, the water tends to collect in wet seasons and thus the root system becomes even more restricted in such places from this cause. The topography is, however, usually undulating, with a moderate grade towards the beach which provides a ready get-away for the water through the pervious, rich top-soil. Owing to the presence of this hardened layer, no deep gullies or creeks are present, which limits the available water supply. The ability of such a relatively shallow depth of soil to support such good coco-nut palms is testimony of its richness. It is also plain that coco-nuts can flower and give good production with a very limited root-system, providing the soil is really good.

The palms under the conditions where the hard-pan exists are entirely lateral rooters. This habit offers an interesting comparison with deep-rooting palms seen in washaways or sections exposed by the heavy rains after the volcanic eruption in the soft, deep pumice soils close to Rabaul. Here it was seen that the roots of a young palm (about eight years old) reached a depth of at least 30 feet.

The explanation as to why the palms fall only when they are fully grown and have reached a good height appears to be a question of increased leverage, which is assisted by strong winds, where the root-hold is weak. The soil, as said before, is sufficiently good as to maintain a heavy leaf growth, plus a heavy yield of nuts. It is probable that the tops of the palms reach a maximum weight at a particular height and curve backwards and forwards through a greater number of degrees in heavy winds, when they are tall, than when they are short and carrying even the same or may be a heavier crop. The root anchorage is not deep because of the hard-pan mentioned, so that in heavy winds there is a tremendous strain placed on the roots. It becomes heavier and heavier until eventually a breaking point is reached and the palms fall down. The roots at the edge of the hole on the side closest to the ground are not even severed, and they continue to supply a certain amount of nutriment to the fallen palm, leading to its eventual re-growth at the growing point. Soil and rubbish are sometimes heaped around the unsevered roots to assist the continued growth.

It is evident that, although such palms continue to grow, the roots can never supply enough nutriment for the fallen palms to enable them to become heavy bearers again, though they might conceivably assist in shading the soil.

The reason for certain low-lying areas being more liable to the fall of palms is associated with less aeration and weaker root development where the water is close to the surface, and not moving quickly. The soil is also softer when wet, which leads to an earlier fall of the palms.

It appears likely that the area, where this fall of mature palms occurs, may extend somewhat as the palms become older and higher. This may not reduce the value of the places to any great extent as the fall of palms is due to weak root anchorage and not soil deficiency, hence, replanting should prove practical, if any considerable areas are affected in the future. The re-plant palms would

FALLEN COCO-NUT PALM, WITU ISLAND.
Trunk, showing growing point, with length and development otherwise normal.

need to be planted away from the original holes, and then they should continue to grow and yield again for many years. The experiences of re-planting lightning-struck areas, where the soil is rich, would confirm this opinion, as they were seen to come away well indeed in similar areas to those under consideration. It would be almost a waste of time to re-plant such misses if the soil were poor.

Dynamiting or Explosives.

This is, apparently, a case where the use of explosives in the original planting holes was indicated and, in fact, it was said that dynamite was used on a small scale in some of the original plantings. After these operations, plenty of top soil shou'd then be drawn into the enlarged holes. There is no danger of compacting the surrounding soil by explosives where such a hard-pan exists, and the hardened formation should give good results from such treatment.

Origin of the Hard Pan Layers.

This is really a question for the geologist and soil chemist and soil samples were taken for submission to Institutes dealing with such problems. It might be pointed out that the areas, where this fall of palms has occurred, are composed of geologically new soil, comparable with the whole of Witu Island. These islands are certainly volcanic in origin and, according to observers, John Albert (Johann Albrecht) and Peterhaven are practically breached craters filled by the sea. The predominant rock is stated by Stanley* to be "Augite Andesite," covered with a thick deposit of scoriaceous material, tuff and pumice, which, apparently, makes a fine soil for the growth of cacao, coco-nuts and rubber. The fact of its recent origin is also shown by no large virgin forest trees being present. There is a large proportion of *Albizzias*, Breadfruits (*Artocarpus* spp.), *Eugenias*, Galips (*Canarium* spp.) and other fruits present, a large proportion of which were, apparently, planted by natives in the first instance.

The John Albert Harbour still has hot springs near the entrance and this is one of the best examples of a submarine crater one could find. The areas where the falling palms are found are situated on what appears to be the slope of the raised lips of this crater. When this large rim was built up further volcanic activity occurred on the raised land and thus a newer land crater is found, facing these slopes. The chances are very probable that the top layer of good soil was derived from weathered rock of lava flows from this land crater, as the country rock here appeared to be a fine grained basic basalt. There are hard lava belts present, which are so young that they have not weathered sufficiently to support other than short vegetation, and coco-nuts, not at all. The rich, red, chocolate soil at the surface is derived from weathered basalts or Andesites. The hard pan layers appear to be derived from submarine volcanic disturbances. They are greyish in colour, and very fine grained and compacted, sometimes with contained small fragments of rock. In texture and appearance, it is very like the fine grained compacted mud thrown out of Matupi Crater during the recent volcanic eruptions in Rabaul.

The incidence of the mud-stone layer appears to be confined to comparatively limited areas of the island, and lies approximately in one direction. This again is comparable with what occurred at Matupi, where only an isolated, locular-shaped area was covered with mud. Saturated fine volcanic ash does not appear to be thrown very far out from the original focus, which is apparently due to its relative weight or high specific gravity. The lower layer of similar type apparently represents the results of earlier submarine eruptions. The central layers of scoria appear to be derived from a more explosive volcanic activity acting over a fairly wide range of time. It is also feasible to believe that the gradual sifting action of rainfall would assist in compacting such layers. A chemical and physical examination of these soils is intended and should provide interesting data concerning the profile described and its origin.

Fall of Mature Palms at Manus, Admiralty Islands.

During a recent visit to Manus, it was noticed that some patches of mature palms, growing on the coralline fringes of certain plantations, had fallen over, although the palms were otherwise healthy. These fallen palms were situated on

* Stanley, Evan Rd. "Report on the Salient Geological Features and Natural Resources of the New Guinea Territory." Reprinted from Report on the Territory of New Guinea, 1921–22 (Commonwealth Parliamentary Paper, No. 18 of 1923).

areas possessing a very loose soil at the surface, but with hard coral coming in at a shallow depth. This led to restriction of root growth at the base of the palms, while the loose root-hold in the surface layers led to their eventually falling over, particularly after heavy rains accompanied by strong winds.

On one plantation at Namatanai, New Ireland, it was noted recently by Mr. F. O. Moody, Departmental Inspector and Instructor, that a number of palms had fallen down in some areas. He ascribed this fall of palms, aged about thirteen years, to shallow planting where a loose top-soil was present overlying coralline rock, which in some areas came near to the surface. Furthermore, in these areas the secondary growth had been left to grow almost as high as the palms, or in some cases higher, and this undergrowth acted as an effective wind-break before being cut down. Once this tall undergrowth was removed any winds occurring gained increased velocity, and blew the shallow planted, shallow rooted palms over.

Ninigo Group of Coral Atolls, Western Islands.

The centres of the majority of these coral islands are low and swampy, and here the palms flourish best on the higher ground between these central lagoons and the sea. The proportion of dry ground present in a particular island greatly influences its value for growing strong coco-nut palms. Although a great deal of low-lying land is planted, the palms do not flourish so well, and they tend to become stunted, poor yielders with a tendency to fall over.

It was seen that most of these small islands taper towards their longest extremities and because the soil is newer and shallower there, the palms do not grow so well as in the deeper soil, found in the raised dry areas, present on the more central margins.

Underneath the whole of the Ninigo Islands, free, underground water is present at a relatively constant depth. The differences in depth from the ground surface to the water in the various places is more dependent on the slight irregularities of ground elevation present on these low-lying islands. On the higher ground in the central margins of the island, it may be 5 ft. 6 in. to the water surface, while it rises to ground level in the lagoons.

Owing to the existence of a very porous, gritty, sand layer at almost the sea-level, the underground water here is influenced by the tidal rise and fall with a time lag, dependent on the size of the island and the distance from the shore. Owing to the various salts being absorbed and filtered in the sand layers, the water is only slightly brackish and, hence, is used by the natives for drinking purposes, without any ill effects.

In between this underground water and the surface, there is, in all of these islands, a semi-hard pan of lime-impregnated sand, which, in most areas, restricts the access of the coco-nuts to the free water.

The holding up of the surface water by the lime-impregnated layer would tend to cause waterlogging in very wet seasons, as is periodically experienced. It is also a curious fact that despite the presence of free, underground water, the palms on these islands do feel the effects of prolonged drought, when the surface layers above the hardened lime layer are dried out.

In the low-lying lagoons or swampy depressions, it is the excess of free, brackish, rather stagnant water which restricts the root-growth and makes these areas unfavorable for the growth of the coco-nut palms.

The distance from the ground surface to the free water (practically at sea-level) determines the depth of rooting in such cases. In the swamps and semi-waterlogged areas, where the palms become dwarfed, lean over, and either partially or completely fall out of the ground, root-restriction due to waterlogging, is indicated.

Where the roots of such fallen palms are not entirely severed, the crowns commence to grow again, vertically at their growing point, but in such cases, they usually flower sparsely and give poor production.

The fall of mature palms on some areas in the Ninigo Group was definitely associated with the compacted layer already mentioned, especially where it was underlying the loose, sandy soil at a shallow depth.

In an examination of different soil profiles here, it was seen that at varying distances below the surface (never much greater than a couple of feet), this stiff, puggy layer of compacted sand was to be found and its consistency was comparable with mortar.

The origin and formation of this layer is explained by the fact that the calcareous or limey sand has great facility to become agglutinated into a clay-like layer of calcareous mud. The deposition of the layer is due to the leaching action of water taking the lime into solution, and depositing it into distinct layers at limited depth. Here it has a mortarizing effect and firmly cements the fragments of sand together, making the whole mass difficult to dig out. This layer is not altogether impervious to the coco-nut roots, but it badly restricts their spread and growth into the deeper layers. It also causes the roots to become thin, spindly and weak, thus providing a distinct break in the root system at the zone, where the restriction occurs. It is in patches where this layer is found close to the surface, such as where surface irregularities are present and the palms are growing in the low-lying patches, or where surface erosion has occurred, that the palms are most liable to fall over.

In all of the profiles examined in these islands, the depth of rooting, though variable, ranged from shallow to moderate depths only. The depth of rooting, apparently, was influenced by several main factors, such as, depth and age of the soil, presence of hardened sub-soil layers, distance to water table, and whether the palms were growing on the rim of islands, in, or near, the central lagoons, or at the extremities of the islands.

An attempt is made to describe, from a typical dry land profile on which the palms are growing well, what may be taken as approximating the prevailing coco-nut-root distribution in the Ninigo Islands. This description does not fit those areas where the palms are so shallow rooting as to have fallen over, as there the compacted layers are nearer the surface.

In the first 4 inches to 9 inches of soil, comprising the humus layers, the fibrous coco-nut roots are densely scattered as feeder roots.

At about 4 inches to 6 inches depth, it is usual to find that a compacted layer of larger main roots comes in which are mixed with the fibrous roots for a depth of a few inches.

These main lateral roots extend throughout the soil and sub-soil until the plaster-like layer is met, usually at about 2 feet to 2 ft. 6 in. After passing through this compacted layer, the larger, main water-feeding roots come to a looser layer of semi-saturated, gritty sand, and extend right to the free water

surface. As mentioned before, the lime infiltrated zone has a constricting effect on the root system. The roots in the looser, sandy layers, below the lime layer, are generally evenly distributed, but are often constricted, gnarled and discoloured, and do not appear so healthy, or well developed as in the upper layers. This is not always the case, because in several instances, what appeared to be perfectly healthy roots were seen in the water saturated zone.

Most of the native trees present in the Ninigo Islands are not deep-rooted, especially in the shallow lagoons where shallow, prop-rooted trees, such as Mangroves and species of Ficus are usually present.

Decided evidence of the influence of the underground compacted layer, mentioned, on the rooting system of the original bush trees was seen as Pelleluhn.

At the end of one small island, some large Casuarina trees, several feet in circumference, were observed growing on a comparatively shallow sand-spit. Two of these Casuarina trees had fallen over, and it was noted that despite the size of these trees, their roots had not extended much more than one foot into the ground.

The whole root system was completely flattened at the base, showing that the roots were living on the surface humic layer only. Owing to the shallow root-hold, the trees had fallen over when undermining and heavy winds had taken effect. The dense flattened mass of interlaced roots present, was closely comparable with what had previously been seen on certain coco-nut palms, which had fallen down.

Some of the roots present in this mass were as large as the limbs of a man, and these were intertwined with thousands of smaller roots, mainly feeding, fibrous roots.

Specific Instances of Fall of Mature Palms, Ninigo Group.

On the main areas of Ahettin and Paleotola Islands (Pelleluhn Plantation), also at Mal Island, shallow rooting was so apparent that many of the palms had actually fallen over on the relatively dry land. Restricted and shallow rooting was also observed on palms growing on the poorer areas of the islands, comprising Longan Plantation.

On one fairly extensive area on Mal Island, a little distance away from some areas of unfallen bush, it was seen that about 50 per centum of the palms growing under semi-swampy conditions had fallen over. In most instances, large rounded-shaped plates or balls of soil were left firmly attached to their bases. A large percentage of the palms, however, still continued to grow vertically from their crowns. In this instance, the surface soil was loose and sandy, while the palms, being shallow rooted with a weak hold, were liable to fall over in heavy winds.

In Ahettin and Paleotola Islands, it was observed, in some areas, that coco-nut palms had fallen completely over, and that many of these fallen palms had flat plates of hardened mortar-like ground attached to their bases. The depth of the rooting system was often only 18 inches in such instances. It was seen that, although some of the palms may have struck outliers of original coral, the hardened plates were usually derived from the hardened lime layer mentioned.

On the north end of Paleotola Island at 80 yards from the beach, the water-table was only 1 ft. 9 in. to 2 feet below the surface and here, in most cases, the palms were short and shallow rooted.

After heavy rains these areas become boggy and the water lies on the surface, though in the dry season, the same ground is relatively dry.

In such places, exposed masses of broken off prop-roots are seen to be covering the trunk for upwards of 3 feet above ground level. This is either due to the trunks being pushed upwards as the basal roots press against the hardened sub-soil layers or due to the ground sinking and leading to the same effect. One such palm examined was at least 50 feet high with a large, well-developed trunk, and a very heavy bunch of exposed and broken off prop-roots at the base. This palm which had recently fallen, showed very healthy fronds and had been forced over because of the restricted root-growth not being able to anchor the palm, when it had grown sufficiently tall and heavy.

At Sakalin Island, palms undermined by sea-shore erosion appeared very shallow-rooted, being flattened at the base, with the fibrous roots curled, matted and pressed closely to the lime-infiltrated, hardened, sand layer.

It might be pointed out that, at times (e.g., in 1932), some heavy gales are experienced accompanying sudden squalls in the Western Islands, and such occurrences in the areas described, assisted in blowing the palms over.

Relation of Restricted Root Development to Nutrient Intake.

It comes within another province to discuss the effects of root restriction, such as is described, on the nutrient intake and the yield of coco-nuts, nevertheless, a brief mention of the problem is thought desirable.

It the Witu Island Group, as already indicated, palms are found to be flourishing despite the fact that their roots could not penetrate more than 18 inches at the most, owing to the presence of hardened rock-layer underneath. In these islands, it was indicated that the surface soil was of volcanic origin, and chemically rich and friable. It is thus evident that shallow and restricted rooting of coco-nuts may not be detrimental to their healthy growth and heavy bearing propensities, providing that the soils are rich and that there are plenty of nutrients available in the soils to which the roots have access.

Where nutrients are not so plentiful, any restriction of the rooting system will most certainly have a more adverse effect on the life of the palms. This is most likely the case on those particular Western Islands, where it is believed that the soils, being sandy and shallow, are relatively poor in total nutrients, though these were readily available.

In this regard, chemical analyses are to be made.

The experiences in these islands, however, tend to bear this contention out, as, usually, the palms, though coming into bearing and producing excellently for some years have a relatively short period of maximum production.

It is found also that there is a very close relationship between the times of planting and the times at which the production tends to retrogress. There are other factors involved, such as original derivation of the soil, its nature, i.e. physical and chemical qualities, type of ground cover, original planting methods &c., which cannot be discussed here.

This physical adaptability of the root system of a coco-nut palm to its environment, as for instance, where the palms can flourish, although the roots do not penetrate deeper than 1 foot, providing the soil is good and sufficient water is present, provides a very good explanation why they do so well under such a wide diversity of conditions.

Erosion of Foreshore Areas.

Erosion of foreshore areas, accompanied by loss of coco-nut palms, is of common and regular occurrence in many parts of New Guinea, but more particularly on the island properties. Small islands have a large proportion of foreshore in proportion to total area, and are thus particularly susceptible to foreshore erosion, and loss of palms. Such loss of palms is very difficult to check on the foreshore fringes of the larger plantations situated so that the presence of bays and swirling currents, assisted by storms and heavy breakers, lead to the undermining and loss of old palms.

In some places, planting of *Ficus elastica*, *Casuarina* spp., &c., has been tried to lessen the effect, while in other areas, the original beach-loving trees, such as *Calophyllum inophyllum* and "Kwila", *Afzelia* (*Intsia*) *bijuga*, have been left in an attempt to remedy the position.

Erosion of foreshore areas is usually difficult to avert and attempts at prevention must depend upon the circumstances under which the erosion is occurring.

Heavy Floods and Shifting River Mouths.

In many parts of New Guinea, many hundreds of coco-nuts have been washed away. One plantation on the mainland has been greatly reduced in value, owing to a shifting river cutting right through the plantation.

Where short and rapid rivers are present, as in many of the islands here, losses from this cause are always likely to occur.

Washaways and Fall of Mature Palms following on the Recent Eruption—Rabaul.

Serious washaways consequent on the heavy storms following the eruption, caused widespread loss of palms and permanent damage in five plantations on the north coast of the Gazelle Peninsula. The compacting and sealing of the volcanic dust did not allow of the heavy rains penetrating to the porous soils underneath and, hence, surface run off became serious. The effects were particularly serious, where many ravines and low-lying gullies were present, such as at Kurakakaul Plantation, where several thousands of palms (estimated at 5,000 palms) were carried away. In some of the larger ravines, the coco-nuts were washed out by the roots and carried out to sea. The extent of these washaways can be judged by the immense deposition of new land which occurred at the sea shore.

Very serious damage was also caused, particularly in the native groves, by the breaking over of the palms due to the extremely heavy winds following the eruption. Palms which were suffering badly from soil deficiency and tapering stem, were most affected. In the zones of greatest deposition, the heads of the palms were full of pumice dust and mud, and the heavy winds caused the heads

to fall over under great pressure and, in almost every case, left a large split or gash on that side facing away from the wind. In some instances, the palms were so affected by the heavy winds as to have their fronds turn inside out, like an inverted umbrella.

As this damage due to the volcanic eruption is caused by unusual circumstances, it is not proposed to discuss it in detail in this article.

Summary.

Some occurrences of the falling of healthy, mature coco-nut palms in New Guinea plantations associated with particular physical soil and sub-soil conditions, are described. The appearances of such fallen palms and their compacted root system are also given.

In some areas of Buka Island, swampy conditions are associated with the fall of mature coco-nut palms.

In Bougainville Island, the presence of loose, sandy soil with an underlying retentive, stiff, clay sub-soil, which led to water-logging and root restriction, was the apparent cause.

At Witu Island, the fall of palms is found where the underlying country rock is geologically recent and only weathered to a shallow depth. Here the loose, friable, volcanic loam, which is rarely much more than 15 inches in depth, leads to shallow rooting.

At Manus, palms fall over where loose, sandy soil overlies the original raised coralline rock. A similar occurrence is recorded from New Ireland.

In the islands of the Ninigo Group of coral atolls, there are at least two causes, which may be inter-related, leading to the fall of mature palms. In some places, the presence of a raised water-table in the central swamps and lagoons leads to root restriction and fall of palms. Elsewhere, the fall of palms was often associated with the presence of a compacted lime layer formed by deposition and underlying a loose, sandy soil.

This compacted, mortarised layer is found in most coral atolls, and leads to root restriction, where water-logging occurs.

The explanation as to why palms fall only when they are fully grown and have reached a particular height, appears to be related to increased leverage, due to greater weight and height, causing the palms to fall during heavy winds.

Coco-nuts can flourish and produce normally with a very restricted rooting system, providing the surface soil is physically and chemically rich. Where the soils are poor or compacted, root restriction and water-logging will finally lead to deficiency symptoms and soil exhaustion becoming apparent.

It is clear from these observations that from a practical stand point, the study of soil profiles, yields much information concerning suitability of particular areas to coco-nut cultivation, even where chemical data is not available.

The planter or intending planter should be cognisant of the presence of hard-pans in his coco-nut areas, whether due to the natural country rock coming to the surface, or to deposition of lime, iron or other minerals.

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