Introductory paper on coconut soils

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INTRODUCTION

THE coconut is essentially a palm of the tropics and its cultivation in the world on a commercial scale is limited to the area bordered by the latitudes represented by the tropic of Cancer and the tropic of Capricorn. Beyond these limits, the palm is only very rarely seen and that too in a condition of impaired production. The palm likes a climate characterised by warm and humid conditions. The limit to altitudes up to which coconut can be grown successfully is set by the latitudes also. Generally speaking it may be possible to grow the crop successfully up to an elevation of 600 m. to 900 m. near the equator. An annual rainfall of 100 to 225 cm. evenly distributed throughout the year appears necessary. When rainfall is low or badly distributed the crop may be able to grow satisfactorily only under irrigation. Regarding temperature requirements, the optimum mean annual temperature for satisfactory growth and yields is round about 27°C with limited diurnal variations. Other factors like humidity, sunshine and wind also appear of some importance, but in view of the fact that the various climatic factors act and interact in various ways, it is not possible to indicate the individual effects of them with any degree of confidence.

Within the limits set by the climate coconut is being grown under a variety of soil conditions. Though the crop is thus highly adaptable, it prefers a deep and well drained soil possessing good retentive capacity for moisture and nutrients and free from any toxic conditions.

SOIL TYPES ON WHICH COCONUT IS BEING GROWN IN DIFFERENT COCONUT GROWING COUNTRIES

In India the main soils in which coconut is being grown at present may be broadly classified into four groups, viz., alluvial soils, red

soils, laterite soils and coastal sandy soils. The extensive black soil areas account for only a very small proportion of the coconut acreage in India.

Alluvial soils. These are formed by the deposits of silt from the rivers along their course both on their banks and estuaries. The depth of soil is variable and the profiles may show layers of sand, silt and fine clay. Being transported soils they are not related to the rocks underlying them. The important deltas noted for coconut cultivation are those formed by the rivers Godavary, Krishna and Cauvery.

The soils reflect the nature of the regions drained by the rivers. The alluvium formed by Godavary and Krishna rivers is largely black in colour as these rivers drain black soil areas. The soils are clayey and fertile. The catchment area of the Cauvery river consists mostly of red soils of the mixed type and the river alluvium is of lighter colour, loamy and of lesser fertility.

In alluvial soils the fertility status is being maintained, through annual deposits of silts brought by the rivers.

Red soils. These are derived mainly from granites, gneisses and allied rocks of the micaceous type. The soils are red in colour of varying shades due to the presence of iron oxides in a free state. The soils are light with the texture varying from gravelly and sandy type to loams. The depth of soils varies from shallow depth to very great depths as observed in some parts of the State of Kerala. These soils are generally poor in organic matter content, plant nutrients and base exchange capacity, but absorb water easily, permit easy movement of water and respond very well to fertiliser application and irrigation.

Laterite soils. In Kerala State coconut is being grown to a large extent in this soil type. The soil is red in colour and of varying depths with a layer of kaolin below, resting on parent granite and gneiss rock formations. Under the heavy rainfall conditions of the region, bases and silica have been leached out to a large extent and sesquioxides are found to predominate. They are poor in all plant nutrients, particularly calcium and potassium and have a low base exchange capacity. Phosphorus is present in combination with iron and aluminium and is not readily available to the plants. The laterite soils are generally heavy and well drained and belong to the textural classes of clayey loam and clayey soils with the laterite rocks showing as outcrops in many places. Where gravels or pebbles are present in plenty the soils are called laterite gravelly soils. The pH ranges from 6.0 to 6.5.

Coastal sandy soils. These are found along the sea coast as a narrow belt and may be sedentary soils or coastal alluvium formed by rivers and overlaid with sand blown from the sea beaches. In this category, soils ranging from sandy loam to fine sand are met with. With plenty of manure and irrigation good crops can be raised especially where watertable is high.

Other soil types met with to a limited extent and in particular locations include peaty soils and soils of disintegrated coral rocks of Laccadive and Nicobar Islands. The depth of the latter soil type is reported to vary from 0.9 m. to 3.7 m.

In Philippines the soils on which coconuts are raised are reported to vary from sand to clay. The best soil is thought to be light alluvium, lime stone soils of river valleys and along the shores. Volcanic soils are also reported to be highly suitable for coconuts. All the soils are on the alkaline side in reaction.

In Indonesia the soils are mainly of volcanic origin.

In Ceylon coconuts are reported to be raised on river alluviums, estuarine deposits, limestone derived soils, laterite rocks, laterite gravel, cinnamon sands and estuarine clays. The laterite soils are reported to be deficient in phosphoric acid and potash, and moisture conservation is indicated in laterite gravel. Cinnamon sands require fertiliser application, conservation of organic matter and improvement of drainage facilities. The estuarine clays require manuring and deep ploughing. Recently attempts have been made to study nutrient status of coconut soils of Ceylon in "soil pot" cultures using indicator plants, but how far these results give an indication for the real requirements of a deep rooted crop like the coconut palm remains to be appraised.

In Malaya, on the west coast and in the inland areas, the crop is usually grown on alluvial clays, clay loams and silts of deltaic or marine origin. On the east coast cultivation is on sandy soils. Clayey soils contain plant nutrients, but the growth of the crop is determined by the physical conditions and drainage facilities of the soil.

The main soil types of Pacific Islands are reported to be of marine and coralline origin. Soils of larval origin are also common.

In Seychelles Island largest acreage is reported under sedentary laterite soils which lack proper physical conditions for proper growth. Coral sands of marine origin is another common soil. This is reported to be very light and extremely friable and to allow free percolation. Though inherently poor, this soil type is reported to offer optimum conditions for the coconut palm because of high watertable and the

presence of natural deposits of sea bird guano. In Trinidad coconuts are found grown on sandy fringes of the beach and the heavy inland clays.

In East Africa the coconut soils are mostly sandy or sandy loam low in organic matter, phosphoric acid and potash.

FACTORS AFFECTING SOIL MANAGEMENT

Proper understanding of the soil is a very necessary prerequisite for using it effectively for crop production. A good soil management programme should have as its aim keeping the soil in good condition where the physical, chemical and biological properties of the soil are optimum for crop growth. The physical conditions of the soil should be such that it should be able to store sufficient water for the use of the palm, provide at the same time enough aeration for the healthy growth of the roots and for the efficient working of the micro organisms. From the chemical point of view the soil should be able to provide the crop with macro and micro nutrients in sufficient quantities and in proper balance in accordance with its special requirements. Good soil management will also have to deal with factors harmful to the growth of the crop such as bad drainage, waterlogging, excessive dryness, soi erosion, toxic conditions, etc.

How soil management practices will be affected by the differen factors are discussed hereunder.

Texture. Texture refers to the size of the particles of which a soil is composed. Depending upon the proportion by weight in which the four soil separates, viz., coarse sand, fine sand, silt and clay are present in a soil, international textural classification recognises three main groups, viz., clays, loams and sands and 13 kinds of soils falling within these groups.

Texture affects tree growth possibly by influencing the available water and nitrogen supply in the soil and the development of the roo systems. Considering the requirements of the palm and its growth characteristics and special affinities, loams appear to be the mos suitable type for its growth. These soils can be managed easily, and respond to treatments very well. Because of its free permeability, water soaks in readily and gets safely stored in the subsoil layers for the use of the palms in times of drought. Excellent plantations are met with on loamy soils.

The clayey soils are rich but require considerable skill in management. The experience in Malaya has, however, proved that even

such soils can be made to sustain excellent plantations under proper drainage and irrigation control. The sandy soils suffer from poor retentive capacity for water and nutrients but can produce satisfactory crops if the defects are remedied. A remarkable instance of such a transformation was seen at the Coconut Research Station, Nileshwar III of the Kerala State. In a deep sandy soil of poor fertility which did not respond to many cultural and fertilizer treatments tried, provision of irrigation stepped up the annual yield from an insignificant figure of 5 nuts per tree to as much as 30 nuts within a period of three years.

The texture of a given soil is constant within limits and cannot be modified. But by the addition of large quantities of suitable soil fractions brought from outside it may be possible to improve in course of time the texture in the desired direction. The practice of applying in coconut gardens of silt and clay to sandy soils and silt and sand to clayey soils is widely prevalent in parts of Kerala and Mysore States. The added material, particularly silts and clays, helps not only to improve the physical texture of the soil but also its fertility status because of the polymanurial value of silts.

In loamy soils the root system shows its maximum development. In clays and sands some restrictions are seen.

Soil structure. The term structure as applied to soil refers to the arrangement of the soil particles in the soil. While the texture of a soil cannot be easily changed. the structure of the soil is amenable to changes by management. Soils which are crumby and granular have a good structure. In a crumby soil, lumps of soil disintegrate and crumble on being gently pressed with the finger and the thumb. On cultivation it breaks into small lumps and granules instead of forming clods or powdery material. Clay, humus and lime in the soil promote the formation of crumbs and this is greatly assisted by the cultivation of the soil at the proper moisture content.

The structure of soils can be adversely affected by indiscriminate cultivation or by trampling of the soil by cattle or human beings in a wet condition. Frequent cultivation of the land in the tropics promotes quicker oxidation of organic matter affecting soil structure. Injudicious application of fertilisers may also destroy soil structure.

A soil in proper structure will provide simultaneously optimum conditions for the coconut palm. Thus it will be well drained, while retaining sufficient water for the use of the crop, provide enough aeration for the healthy growth of the root system and for the efficient working of the beneficial micro-organisms. Good aeration will prevent

the formation of deleterious reduction products such as sulphides, ferrous compounds, etc.

Minerological composition. The chemical and physical properties of a soil depend upon the minerological composition of the parent rock, the extent and intensity of weathering undergone by it, climate, topography and the type of clay minerals present. If the clay mineral is of the sesquioxide type containing aluminium and iron hydroxides, the soil will have a low base exchange capacity and will be of poor fertility. The physical properties will, however, be favourable in that the soil may not possess plasticity and cohesion permitting cultivation in a wet state without damaging soil structure. If the clay mineral is of the silicate type those containing montmorillonite and illite types may be of value as a source of potassium and magnesium while those containing kaolinite type are not of much value.

In India bulk of the acreage under coconuts is in soils derived from granite or gneiss rocks.

In view of the fact that the coconut palm requires well drained soils and that its potash requirement is heavy it is only to be expected that the minerological composition of soil will have a decisive influence on the performance of the palms, particularly under neglected conditions where native soil fertility will largely influence the productivity of the palms.

Soil reaction. Soil reaction denoted by the conventional notation of pH of the soil solution is a very important characteristic of the soil. It influences the availability of the nutrients and the development of toxic conditions. In the region of neutrality all the major nutrients are in a readily available condition. On the acidic side their availability gets reduced and iron and aluminium occur in a soluble form which ties up the phosphorus present in the soil and that applied in fertilisers in an unavailable form. In high concentrations they are also toxic to plants. Beneficial micro organisms also fail to function properly under acidic conditions. Under alkaline conditions, the availability of phosphorus, boron and manganese gets reduced.

The coconut palm is highly tolerant of a wide range of soil reaction, from extreme alkaline conditions of coral soils to extreme acidic conditions of peaty soils. The palms are found to thrive well so long as the soil is deep and well drained and nutrients are available in required amounts. Therefore, the exact part played by soil reaction directly or indirectly on the coconut palm is not fully known. The application of lime to coconut palms is a common practice in many coconut growing countries of the world but definite experimental

evidence regarding its practical utility is lacking. It was only from Malaya that some beneficial effects from liming have been reported. These have been attributed to its counteracting effect against aluminium toxicity. A detailed investigation in progress at the Central Coconut Research Station, Kasaragod has not so far revealed any substantial response to liming.

Soil depth. Effective soil depth is the depth of the soil which is readily accessible to the roots and may indicate depth to bed rock, compacted hard pan or water table.

Depth of soil is an important factor as it determines the availability of moisture and nutrient supply for the crop. In the coconut, an extensive and deep root system will enable the palm to mobilise moisture and nutrients from a larger volume of soil and will provide a strong anchorage enabling it to withstand severe storms. Palms growing in shallow soils are likely to get uprooted easily and may also have only a short productive life. The fall of large number of mature palms growing in shallow soils has been reported from New Guinea.

A few instances of palms performing excellently in spite of shallow soil conditions have been reported. Pagden (quoted by Jacks) has made mention of an estate on very hard shelly limestone covered by only a few centimetres of soil in Solomon Islands yielding as high as a ton of copra per acre. In Viti Levu Island in Fiji also coconuts have been reported to thrive well in shallow soils. It will be very interesting and informative if a detailed study of these palms is taken up as it may throw light on the powers of adaptation of the palm to unusual environments.

Subsoil conditions. In the case of shallow rooted annual crops where the root system is confined mainly to the surface layers, the subsoil conditions may not be of major importance but in the case of crops like the coconut which has an extensive and deeper root system the subsoil conditions have a great deal to do with the performance of the crops.

A well developed soil profile is composed of a ploughed horizon, then a leached horizon followed by an accumulative horizon and then a layer which is practically unaffected by soil changes. In some coconut soils, however, such clear-cut horizons are not seen. The surface soil to ploughed depth may contain all the organic matter, available phosphorus and part of available manganese and potash. The leached horizon is generally devoid of plant nutrients other than iron and manganese but supplies considerable quantities of moisture. The accumulative horizon receives the fine soil particles and soluble salts

leached from the soil. This layer has a tremendous water holding capacity and also has much of magnesium, potash and secondary elements such as manganese and iron.

Not infrequently the production of a soil is considerably influenced by an unfavourable subsoil. Subsoils that are impervious to the free movement of water affect the proper development of root system and also promote conditions of water stagnation in times of heavy rainfall. Similarly subsoils of a very sandy or gravelly character drain too rapidly and the crops suffer in dry season. A loamy subsoil is most desirable.

Soils are often underlaid within small depths by rock concretions of different kinds and sometimes by a particularly objectionable condition called hard pans. Hard pans may be formed by the cementing together of the soil grains into a hard stone-like mass. Hard pans considerably affect the drainage and development of root system.

In ill drained areas the subsoil sometimes contains reduction compounds of iron which are poisonous to the root system. In a peaty soil area in Thottappalli (Kerala State) the sudden wilting of large numbers of healthy coconut palms was seen when the subsoil was dredged and dumped into the gardens. On investigation, wilting was traced to a combination of factors including the presence of toxic substances such as sulphides, ferrous iron compounds and soluble aluminium. The possibility of the occurrence of harmful organic acids under waterlogged conditions has also been reported.

The depth of ploughing is to be regulated with reference to the nature of the subsoil. When the subsoil is poor, deep ploughing would bring the poor soil to the top and affect crop productivity.

Subsoil conditions affecting the performance of the coconut crop have been observed and recorded. The good performance of the palms growing in sandy soils in some cases has been traced to the occurrence of a moisture retentive subsoil. On coral islands which are built upon reefs, it has been found necessary to break through the reef and plant coconut seedlings in the soil below for ensuring better growth.

Subsoil conditions are also found to influence the presence and ease of utilisation of subsoil water resources for irrigating coconut palms. For the proper installation and functioning of filter point tube wells certain forms of subsoil conditions are found desirable.

Depth of water table. Another important factor which affects the depth of soil in certain areas and under certain conditions is the water

table. Usually coconut roots do not grow to any extent in water or into a layer of soil where water stagnates. Stagnant water conditions ultimately kill the roots. Therefore, where such conditions prevail, the root system gets confined to a narrow layer and root-bound conditions develop within a short period of time. The life of coconut palms under such conditions is relatively short even when soil conditions are good. The situation is, however, quite different if water-table shows a fluctuating movement. Here the palms get optimum conditions because roots can develop satisfactorily, and toxic conditions do not develop. In areas adjoining river banks where these conditions do prevail, excellent plantations are found to exist. If the water-table were to go down considerably below as is the case on the West Coast during summer, the root system is not able to utilise this source and therefore palms are liable to suffer from drought effects.

Replenishment of soil moisture from ground water takes place through capillary rise. This rise is influenced by the texture and structure of the soil. It is reported to be maximum in medium textured soils such as loams and silts. In clayey soils though the maximum height to which water can rise is great, the rate of rise is so very slow that it often fails to meet the needs of crops in times of stress. In coarse textured soils such as sand, water rises relatively rapidly but the distance covered is little. It has been stated that the rise of water by capillarity does not exceed 2 to 2.5 metres from the ground water level. These conditions necessitate that in clayey and sandy soils water-table should be relatively high and can be below in loams for the coconut palms to be benefitted. In areas adjoining the sea coast where water-table is high and where it is subject to movement according to the ebb and flow tides, moisture and aeration conditions in the soil are very satisfactory and this should explain the satisfactory performance of the palms under such conditions.

Organic matter content. Organic matter in the soil is composed largely of material of vegetable origin. It exerts considerable influence on the physical and chemical constituents of the soil. It is very effective in moisture conservation as it can absorb and retain several times its weight of water for the use of the crop. In heavy soils its incorporation has the effect of loosening the physical structure and improving aeration thus making the soil easier to work. In light soils it tends to bind the soil particles together and improve water holding capacity. The organic matter is also a store house for plant nutrients as on decomposition large quantities of nutrients become available to the crop in a readily assimilable form. The development and activity of the soil micro organisms get stimulated. It also enables soil to resist rapid changes in its reaction and prevent the development of toxic and deficient conditions.

In tropical soils because of intense microbial activity it is possible to maintain organic matter content at a satisfactory level only by repeated small applications of organic matter.

Soil erosion. In sloping lands under high rainfall conditions soil erosion is a great hazard and care has to be taken to prevent it by proper terracing, contour bunding or by maintaining suitable cover crops, etc. Erodibility depends upon the soil type and location.

Chemical properties. Plants absorb their nutrients from the soil, and hence their growth and productivity will depend upon the form and extent to which they are present in the soil. The nutrients that are essential for the growth of the coconut crop and whose deficiencies have often been observed are nitrogen, phosphoric acid and potash. The quantities in which they are present, the form of occurrence and the relative amounts in which they occur are all of importance. A deficiency of an element may arise by its presence in too small a quantity or in a form which cannot be made use of by plants. Imbalance in the presence of nutrients may bring in antagonism, affecting nutrient absorption.

Information on the quantities of certain other elements such as iron, aluminium, manganese and sodium is also valuable as they are concerned in reaction of changes that take place when particular fertilisers are applied. For instance, in soils with a high percentage of iron and aluminium oxides, phosphate manuring will have to be carefully studied in respect of the kind of phosphate, method of application and the quantities to be applied. The need for liming may also arise in such cases. Not much information is available regarding the trace element contents of soils and their influence on the palm performance. From the nutrient point of view soil fertility management should concern itself with building up the nutrient level to that required for efficient crop production and then maintain it at that level by making good the nutrient loss arising through cropping and otherwise.

Inherently fertile soils are found to sustain high yields even without manuring. In fact such soils seldom show any response. The fertile clayey soils of Malaya, deltaic alluvium and rich volcanic soils are examples of soils on which coconut palms have been found to grow luxuriantly even in the absence of manuring.

AGRONOMIC PRACTICES OF THE COCONUT CROP IN RELATION TO SOIL FACTORS

It is well known that agronomic practices are considerably influenced by the physical and chemical properties of the soil. How these are of importance to the coconut crop are briefly indicated below.

Selection of site: Considering the preferences of the crop and its reaction to soil environment sites with shallow soils underlying hard rock, lowlying areas subject to water stagnation and sandy soils with deep water-table and stiff clayey soils are better avoided as it will be difficult to raise successful coconut plantations under such conditions. Steep lands subject to soil erosion are also not to be planted up with coconuts.

Planting: Planting aspects such as spacing, mode of planting, etc., are found to be influenced by the nature of the soil. In loamy soils with low water-table, planting in 0.9 m. deep pits is recommended. When the water-table is high planting on the surface or even on mounds formed with soil may be necessary. In laterite soils with rocky stratum underneath, pits have to be taken deep, say some 1.2 m. to reach soft parts of the rock where roots can penetrate more easily. Where hard pan lies below, these have to be broken up and the pits taken below that layer for ensuring satisfactory growth.

Spacing of palms is also to be done with reference to the nature of soil but there is no unanimity of opinion as to what is to be done. There is one school of thought that rich soils can carry more number of palms in a unit area than poor soils. Others argue that in a rich soil where the palms can grow to a larger size, wider spacing has to be adopted and that in a soil subject to drought conditions, closer planting may be preferable as the overlapping of leaves will provide shade and prevent over-heating of the soil and slow down moisture loss. Under the latter conditions, however, the possibility of more moisture getting transpired from the leaves of the additional number of palms resulting in ultimate depletion of soil moisture cannot be ruled out.

Care of young plantations: In loose soils irrigation and proper manuring are extremely necessary for ensuring establishment and satisfactory growth. In heavy soils with good moisture retaining capacity more attention may have to be paid for preventing water stagnation in the pits for long periods at a time as wilting of seedlings is seen under such conditions.

Intercultivation and manuring: The need for intensity of and the method of intercultivation of adult bearing coconut gardens are considerably affected by soil conditions. In sandy soils which are generally of low fertility and do not support much of weed growth, the need for regular intercultivation is not great but in other soil types which permit rank growth of weeds, intercultivation is very necessary to keep the weeds under control and create soil mulch. While intercultivation can be done in sandy soils under a wide range of soil moisture conditions,

in clayey soils the operation has to be done at the optimum moisture content. Otherwise the soil structure will be spoilt. Again, while ploughing can be done easily in loose soils, in heavy soils digging with spade or even more stronger implements such as crow bar has to be done. For conservation of moisture, more number of intercultivations are indicated for sandy soils than for heavier soils.

The need and method of manuring will also be affected by soil types. In poor sandy soils a higher dose of nutrients may have to be applied than for palms growing in more fertile soils. Again, in soils not having proper nutrient retaining capacity, fertilisers may well be applied in two or three split doses in order to prevent loss by leaching. In other soils where there is no fear of such loss, fertilisers can be applied in one dose. Again, in soils where fixation of applied phosphoric acid and potash are likely, placement method of application such as in basins may have to be adopted. Soil differences also influence the types of green manure crops grown and their methods of incorporation.

Irrigation: Though the major portion of the coconut acreage is raised under rainfed conditions, irrigation is being given in certain areas during summer months to prevent drought effects. In clayey soils with high water holding capacity irrigation at longer intervals will be sufficient while in less retentive sandy soils irrigation may have to be given more frequently.

RESULTS OF RESEARCH ON PLANTATION MANAGEMENT

Research on soil management problems does not appear to have received as much attention as it deserves. The soil management in plantations having seedlings or young palms has received only very little attention though it is recognised that the critical time for the palm is during the early stages of its life and that it is only by giving careful attention during this period that the palm can be made to bear early and well. Work done in Ceylon has shown that in the case of underplanted seedlings adequate manuring is very essential. In fact it has been stated that underplanting without manuring is a sheer waste of money.

The management of adult plantations has received some attention both in Ceylon and in this country. Schedules of manuring for bearing coconut palms on different types of soil have been drawn up. Manurial experiments have shown that the palm responds in general to nitrogen and potash. Response to phosphoric acid has been obtained only from certain localised areas in Ceylon.

In India yield response to nitrogen was observed early but it is not seen to be maintained. Nitrogen has a very adverse effect on quality. With increase in dosage the copra content per nut has shown a decline of 10 per cent when compared to the control. Potash on the other hand benefitted copra content. During the same period there was an increase in copra content by about 8 per cent. On working out the copra out-turn per tree the improvement was as high as 20 per cent. The results are in general agreement with the findings in Ceylon. Remarkable response to potash application has been reported from Ivory Coast. Over a period of five years application of potassium chloride at 1 5 kg. per tree is reported to have increased the production of copra by about a ton per hectare.

In regard to intercultivation of coconut gardens spectacular responses have been received in the red loam soils of the Central Coconut Research Station, Kasaragod. Over a 25-year period, the increase in yield due to intercultivation alone was as high as 32.9 nuts per year. Among the intercultivation practices piling up of mounds was in general better than the others. This particular aspect does not appear to have been investigated to any great extent in other coconut growing countries, though reports about the beneficial effects of cultivation have been reported.

The growing of green manure crops and cover crops for increasing the organic matter content of the soils as well as to control weed growth and soil erosion has received some attention. In India, *Crotalaria striata* and sunnhemp have been found suitable for growing in the plantation depending upon the soil type and climatic conditions. For growing along the borders of the gardens, the quick growing green manure bush, *Gliricidia maculata* has been found quite promising. As cover crops, *Calopogonium mucunoides* and *Pueraria phaseoloides* have been found satisfactory, but their proper management appears to need investigation specially in regard to their effects during drought periods and over a long period. Bad effects of growing cover crops have been reported from Ceylon and Malaya.

The coconut palm is affected considerably by drought conditions particularly in loose soils where rainfall distribution and subsoil water conditions are unfavourable. In these circumstances moisture conservation is a very important matter deserving attention. Not much work appears to have been done in this direction.

Irrigation has been found to be very useful in stepping up yields and even sea water has been found suitable for the purpose in sandy soils along the sea coast. This aspect has, however, not received much

attention. Frequency, intensity, etc., of irrigation have to be decided for the proper and profitable utilisation of irrigation water.

Experiments conducted in Ceylon and India have shown that in gardens under rainfed conditions burial of coconut husks is a very desirable agronomic practice. This has given definite and profitable increase in yield even in the absence of fertiliser application. The effect of one operation was found to last for about six years. This practice is not recommended in soils subject to water stagnation.

SOIL PLANT RELATIONSHIP

The plants take nutrients from the soil, and to that extent the soil should directly influence plant growth. If a soil does not contain a a nutrient or contains it only in limited quantities or in an unavailable form, the plant growing on that soil will exhibit a deficiency. On the other hand, the plant may take an element which is not useful or required by it or may take another in excess of its requirements leading to the well-known phenomenon of luxury consumption.

Absorption of nutrients from the soil by a plant is a very complicated process and is considerably influenced by soil properties; climatic conditions and the capacity of the crop itself and a full picture can only be obtained by a simultaneous study of all these factors. In the soil the nutrients should be available in sufficient quantities and in proper balance as otherwise antagonism among nutrients may affect absorption.

Chemical analyses of soils estimate the concentration of soil nutrients available in the soil for plant growth and furnish information of great value for estimating the fertiliser requirements of crops, but considering the multitude of factors that affect crop growth, it cannot give more than a general picture of the situation. Tissue tests which have of late come to the fore, on the other hand, give an integrated picture of all the factors that have influenced the crop because the nutrient concentration found in the tissue directly reflects the ability of the plant to acquire nutrients from the soil in the environment in which the plant grows.

The inability to correlate satisfactorily the soil analytical results with the performance of coconut palms growing on such soils has been experienced by many workers. Dr. Salgado of Ceylon in his attempts to devise better methods found that the potash content of nut water afforded a relatively simple method of assessing its availability in the soil in relation to the needs of the coconut palm. He claims superiority

or this method over the conventional method of soil analysis on the plea that the former measures the capacity factor whereas the latter measures only the intensity factor. While soil analysis attempts to measure the nutrient supply of a limited strata of soil, capacity factor takes into account not only the nutrient status of the soil but also the volume of soil available for the roots of the palm to grow in search of plant food. This opens up an interesting field of investigation and will prove of considerable help if its general applicability could be established and the method properly standardised. Dr. Salgado has also shown that phosphorus content of nut water may also show the phosphorus status of the soil in relation to the phosphorus needs of the palm

Foliar analyses method as a tool for estimating the nutrient requirements of the coconut palm has received the attention of workers of Dahomey and Togo. They have tentatively proposed for the major nutrients, critical level values for the first leaf completely developed and showing a hardly visible inflorescence sampled at the end of the dry season.

N_c	—	1.70 per cent
P_c	—	0.10 ,,
K_c	—	0.45 ,,
Ca_c	—	0.50 ,,
Mg_c	—	0.35 ,,

The critical level is defined as the percentage of the element in a leaf below which the application of that element in mineral manure forms is very likely to increase yields. Here also it would be extremely useful if work on similar lines is carried out by other coconut growing countries. Of course, to determine these critical levels a considerable number of field experiments of fertilisers should be available, where the response to manures and the manurial element contents of leaf can be followed at the same time.

A difficulty that may be expected in working out correlations is the high genetic variability of the palm population and the differential response to fertiliser application exhibited by palms of different yield capacities.

POSSIBLE SOURCES OF NUTRIENT ENRICHMENT OF SOILS IN COCONUT PLANTATIONS

Often coconuts have been found growing well under conditions which might appear to be not congenial for the crop. It has, therefore,

been suggested that the usual forms of soil fertility cannot be applied to the coconut crop and that separate standards have to be laid down for assessing the fertility status of coconut soil in the different soil climatic regions. In this connection some possible sources of natural nutrient enrichment of coconut soils appear to need consideration.

In tropics where there are distinct rainy and non-rainy seasons, the soil is subject to alternate wetting and drying. This process of drying and aeration has been reported to affect a number of soil constituents, particularly nitrogen. A soil subjected to drying for 9 weeks is reported to have produced on subsequent moistening extra nitrogen equivalent to over a ton of sulphate of ammonia per acre. 15 m. depth. The effect of soil drying on potash absorption by plants has been reported to be equivalent to 60 to 120 lb. of potash per acre. These are really very substantial amounts and it is not known whether this particular phenomenon plays any part in the productive capacity of soils of coconut plantations.

Nutrient enrichment of the soil through rainfall is another aspect which is worth studying in relation to soil fertility. That rainfall received in tropics contains nutrients required by the plant has been recorded by many workers. Work in progress at the Central Coconut Research Station, Kasaragod seems to show that substantial quantities of nitrogen, mostly of the organic form and sodium are being received by the soil through rainfall. To what extent palms are benefitted by these appears worth investigation in different soil climatic regions.

The good performance of palms on apparently poor soils is sometimes sought to be explained by saying that they are able to utilise nutrients brought by the subsoil water moving towards the sea from high ground in the interior. How far this is a true statement of fact is not known.

SOIL CLIMATIC COMPLEX

Though soils have been dealt with as a separate entity here, it is well to remember that soil factors cannot be considered in isolation of climatic factors in judging the suitability or otherwise of the soil for a particular crop. Atmospheric climate affects the soil climate and through it the crops grown on it. Though fundamental knowledge on how the atmospheric climate affects the soil climate under different situations with particular reference to the coconut palm is lacking, practical observations show that it can have decided influence. Thus in a poor soil such as sandy soil, the palms may grow well if the rainfall distribution is even in all the months of the year. On the other hand if the rainfall is low or ill distributed, a moisture retentive soil will be

seen to advantage. This aspect has been recognised, and in India the coconut growing regions have been divided into eight soil climatic zones for intensive work on problems of regional importance. Large scale fertiliser demonstration trials carried out by the Potascheme within Kerala State itself did provide enough evidence of differential responses of palms under different soil and climatic conditions.

RESUME

An attempt has been made to present in a general way the available information on coconut soils. It may be mentioned here that except for the coconut soils of Ceylon and India not much detailed information is found in published literature. In such circumstances it is quite possible that this paper might not have covered the subject more fully. Experts from other countries present here would be able to supplement or provide new information.

The following is a list of important items of research on coconut soils which appear to merit detailed investigation.

1. The information on coconut soils is at present very sketchy and is quite inadequate to permit a comparative study of them in relation to palm performance. Detailed classification of coconut soils based on internationally accepted criteria, accompanied by soil analytical data according to standardised procedures will be extremely useful.

2. Information as to how the texture and structure of soils affect root development and disposition of coconut palms will prove helpful in deciding upon the proper methods of plantation management with particular reference to aspects such as intercultivation fertiliser application, etc.

3. The important limiting factor for satisfactory growth of the coconut palm in many areas appears to be soil moisture deficiency. The various methods of overcoming the limiting factors need detailed investigation.

4. Regular intercultivation of coconut gardens has been seen, under certain conditions, to be highly beneficial. This aspect has to be gone into in more detail to trace the changes that take place in the soils in different soil-climatic zones.

5. The possible role of rainfall and wetting and drying of soils in tropics on nutrient enrichment of soils needs investigation.

6. Studies on the phosphate and potash fixing and releasing powers of soils will throw light on fertiliser needs of the palm in different soil climatic zones.

7. The phosphate status of the soils in relation to the phosphate requirements of the palm is not clearly understood. The absence of response to even large doses of applied phosphate has led some workers to suspect that the methods now being used for extracting phosphoric acid cannot estimate the readily available fraction which the palm is able to utilise. It thus remains to decide which is the method giving the best correlation between crop results and the fertility of the soil.

8. Information on the micro nutrient status of coconut soils is very meagre. Their importance in the nutrition of the coconut palm needs to be properly assessed.

9. Liming and application of common salt are widely prevalent in coconut producing areas but many trials carried out so far have failed to show any beneficial effects. It is necessary that the investigation is carried out in relation to different soil types so as to pin-point the particular situations wherein they might prove beneficial.

For obtaining definite information on many perplexing factors relating to soils and the coconut crop, radio isotope technique will be extremely useful. In fact there appears to be no other method of studying the rooting pattern in different soil types, the best method of application of fertilisers, contribution of different sources to the nutrient uptake from the soil, comparative effects of different fertilisers, etc. Such a research project, however, requires specialised equipment and the services of highly qualified personnel involving heavy outlay. Therefore, the establishment of an Institute under international auspices for radio isotope work on the coconut crop may be considered.

DISCUSSION

The introductory paper on coconut soils, presented by Mr. M. M. Krishna Marar, deals with the various types of soil on which coconut is being grown in different coconut growing countries of the world. The soils are broadly grouped into alluvial soils, red soils, laterite soils and coastal sandy soils. The factors affecting soil management such as texture and structure of soils, mineralogical composition, soil reaction, soil depth, subsoil condition, depth of water-table, organic matter content, soil erosion, chemical properties etc. are also dealt with in detail. The nutritional needs of coconut plantation are also discussed.