Soil Potash and its Availability in relation to Potash Manuring of Coconuts*

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THE coconut palm is a potash-loving crop. This view is based on the heavy uptake of potash compared to nitrogen and phosphoric acid by the palm and the predominance of potash in the composition of the various parts of the palm, *e.g.*, husks, water, leaflets, &c.

If the resources of " available " potash in the soil are low or inadequate, manuring with potassic manures should produce a response. On the other hand, if the supply of available potash is sufficiently high to produce a level of potash in the soil to meet the demands of high production, manuring with potash may not produce a response.

The chemistry and mineralogy of soil potash is a highly technical subject, on which there was no clear understanding until the subject was clarified by recent work during the last two decades by the study of clay minerals in the soil.

Our soils are derived from the weathering of gneissic rocks ; in this process the original primary minerals containing potassium such as feldspars and mica, which are present in the original rocks, break down and finally change chemically by the leaching action of water. The great bulk of the soil potassium usually exists in the difficulty available category as feldspar and mica.

Transformation of potassium thus held to more available forms is very slow. In this process the potash is retained in various forms in secondary minerals and finally in the clay fraction. Clay may be described as the salt of a complex weak acid of which the bases are calcium, magnesium, potassium and sodium.

CLAY MINERALS AND POTASH AVAILABILITY

The clay fraction is the seat of mineral fertility in the soil.—It is a colloid but at the same time crystalline. This colloidal material is not of uniform composition and varies for different soils depending on the degree and extent of weathering and the composition of the original rocks from which the clay is derived. The potassium supplying power of the soil for crops and its

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* Paper read at the December 1950 Sessions of the Ceylon Association of Science.

durability is essentially a story of colloid chemistry. This ability which is the essence of potassium fertility and its complementary phenomenon response to potash manuring, is dependent primarily on the more or less flexible equilibrium among the " forms " of potassium in the colloid clay.

According to recent work done during the last two decades particularly in America, by the application of X-ray analysis by Hendricks, Ross, Kelley *et al.*, the clay minerals chiefly concerned consist of an isomorphous series of three characteristic types:

(*a*) The Kaolinite Type (1 : 1 Lattice Type). In this type, owing to its molecular structure the colloidal character would seem to be associated rather with the external surfaces than with internal reactions. The typical members of this group are Kaolinite and Hallyosite.

In areas of deep and long continued weathering, especially in the tropics under conditions of high temperatures and high rainfall, and more especially where the parent rock is characterized by alkaline feldspars, kaolinite is formed. This may be the typical mineral in the soil of the low country wet zone.

(*b*) The Hydrated Mica Types (2 : 1 Lattice Type).

This is a less weathered mineral type, represented by illite : which consists of somewhat hydrated potash micas in which increase of hydration is accompanied by decrease of potassium. The dehydrated end member is therefore claimed to be Muscovite.

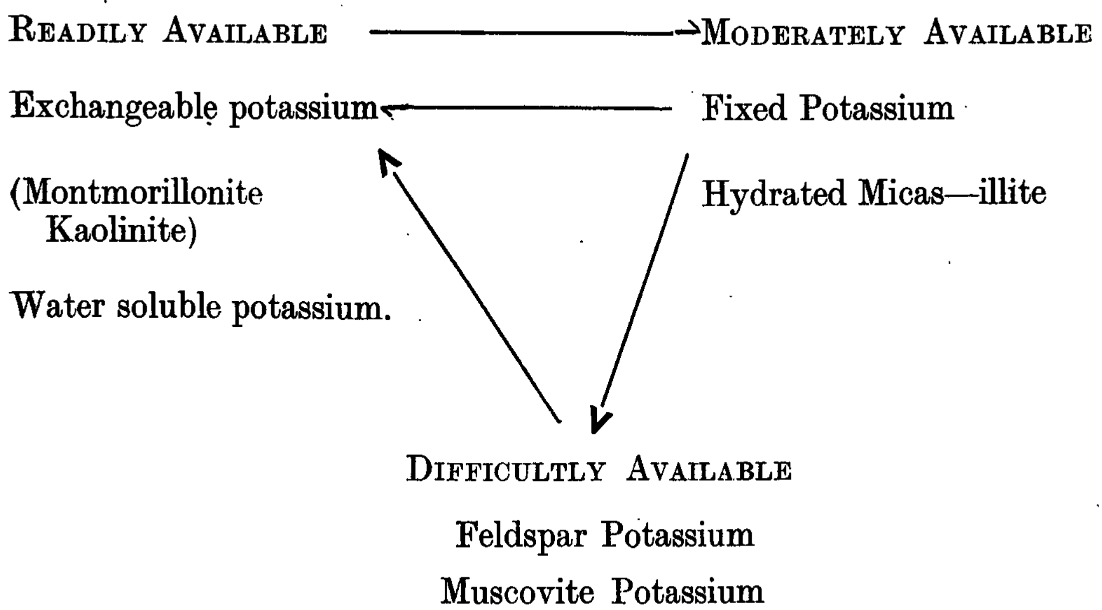
(*c*) The Montmorillonite or Expanding Lattice Group (2 : 1 Lattice Type). This group has been exhaustively studied by Marshall (1), important members of which are Montmorillonite and beidellite. These occurring in the fine clay fractions, have a high base exchange capacity, and is the typical clay mineral in soils of temperate regions and in many arid zones.

"FORMS OF AVAILABLE POTASH"

Potassium occupies a graded series of positions in these minerals resulting in a gradient in relative ease of removal.

At the more flexible end of this series potassium is attached to the clay mineral in a form which is well known as " exchangeable " or " replaceable " potassium. In this form potassium is bound up loose in the outer kernel of the clay minerals and can be easily taken up by plants by its conversion to water-soluble potash which forms the " soil solution ", feeding plant roots. If on the other hand potassium manures are added to the soil, the K-ion enters the clay by replacing " the exchangeable " calcium and replenishes the stocks of " exchangeable " potash to supply the potash in the soil solution as and when the plant needs. The water-soluble potash and the exchangeable potash are reversibly convertible and this relationship forms the key to potash availability and potash response. If the original reserves of the exchangeable potash are high, the plant may not respond to added potash.

At the less flexible extreme end the potassium--ion occupies a stable position, deeply buried in the colloid particle (*e.g.*, illite which is allied to the primary rock mineral muscovite or mica), and it is dislodged with great difficulty under field conditions. The following diagram illustrates the equilibria between different potash minerals :—



There are numerous gradations in the status of the potassium used up in relative ease of removal.

Ordinarily 90 per cent. or more of the readily available potassium in soils exists in exchangeable form. The potassium added in plant residues and commercial fertilizers exists almost entirely as water-soluble salts, and when these materials are added most of the potassium contained therein goes into the exchangeable form.

POTASH FIXATION

According to recent work, added potassium which reacts with the clay fraction and enters into the exchangeable form by chemical reaction may revert to non-exchangeable or " fixed " form. This is called " potash fixation " and is said to be brought about mainly by alternate drying and wetting such as occur during droughts and should be of significance under the conditions in which coconuts are grown in Ceylon.

Although the potassium involved in this fixation is much less available than that in the exchangeable form, it is considerably more available than that in the difficultly available form. It may therefore be considered as *moderately available.*

When the supply of exchangeable potassium is drawn upon by cropping, some of the fixed potassium changes over to the exchangeable form. The transformation of exchangeable potassium to the fixed form and back again is a balanced equilibrium reaction. In fact the phenomenon of fixation is of considerable value and provides a reservoir in which potassium is held against leaching but is yet available for crop needs.

POTASH STATUS OF CEYLON SOILS

Unfortunately in Ceylon there has been hardly any work done on these basic points regarding the potash status in Ceylon soils. We have commenced some work on these lines in a study of exchangeable potassium in relation to potash reserves of Ceylon coconut soils and the response to potash manures. At the same time with the co-operation of the Government Mineralogist, the primary minerals in different fractions of some soils we are studying will be determined as we do not have the necessary facilities.

Work on these lines is of fundamental importance and until further data are available on these lines, analytical figures for potash contents such as hydrochloric acid soluble potash and citric acid soluble potash are of little value.

It may be mentioned that in the well known and valuable series of papers by Joachim *et al.* in their studies of "Ceylon Soils", no values for exchangeable potassium are given, except in one isolated case. It is of course conceded that the analytical methods for its determination are time consuming.

This property of "fixation" by which normally exchangeable potassium is rendered non-exchangeable and therefore less readily available to plants was shown by recent work (page 129 Marshall) to be characteristic of clays of the Montmorillonite and Illite groups and is absent from that of the Kaolinite group. One can therefore assume that fixation of added potash would not normally be a problem associated with our low country wet zone coconut soils or the lateritic gravels.

Most coconut soils are not heavy clay soils and would be expected to be normally deficient in potash. This is particularly true of such extreme types as the cinnamon sands and the laterites and lateritic gravels, the former containing a very small amount of clay (the seat of potash fertility) and the latter the residual heavily leached type of soil where most of the bases including potash have been leached out.

The soils at Bandirippuwa Estate may be considered typical of the average coconut soils of the Chilaw District and our $3 \times 3 \times 3$ N.P.K. manurial experiment during a period of 14 years has shown that potash produces a marked response in yield of copra (2).

While in general coconut soils should be expected to respond to potash there may be soils in isolated areas such as the heavier alluvia in certain parts of the Kurunegala District and local formations that may have adequate supplies of available potash that may show no response to potash manuring.

On this point the $3 \times 2 \times 2$ manurial $\times$ cultivation experiment at Ratmalagara Estate, 6 miles north-east of Madampe, is of particular interest. Here, among others, 3 levels of potash (0, 1 lb. and 2 lb. K_2O per palm) are compared, but so far no significant response to potash has been obtained during the last 6 years.

Preliminary studies have shown that the Ratmalagara soil, on that area of the estate which comprise this experiment, is comparatively rich in exchangeable potash. It is a heavier red loam compared to the Bandirippuwa soil and in contrast to the latter which contains about 0·02 milligram equivalents exchangeable potash per 100 gms. soil, the Ratmalagara soil contains about 10 times this amount.

POTASH CONTENT OF COCONUT WATER IN RELATION TO AVAILABLE POTASH AND POTASH RESPONSE

The possibility exists of obtaining useful indications of " potassium-supplying power " of soils from analysis of samples of plant tissue taken at suitable stages of growth from crops growing in the field. The fundamental idea behind this method is that the amount of nutrient absorbed by the plant reflects the available amount in the soil. It is evident from the work of many investigators, particularly Hoagland at California and of Wallace at Bristol (both working on orchard crops comparable to a plantation crop like the coconut), that plant tissue content of potassium may be greatly influenced by the nutrient medium and that there is a high correlation between percentage of potassium in the vegetative tissues and the response of the plant to potash manuring.

This technique as applied to the potash content of coconut water is giving hopeful results. Coconut water studies have been carried out with the N.P.K. experiment at Bandirippuwa since 1946 up to the end of 1949 (24 picks) and since this year similar studies have been commenced with the Ratmalagara Experiment since January this year.

Some of you may recollect the preliminary work on this subject which was presented at the 1947 sessions of our section in a paper entitled " The potash content of coconut water as a guide to the manuring of coconut palms " (3). Further data have been accumulated since then and are of great interest. The results given below are revealing.

K_2O in nut water (gms. per litre)

	K_0	K_1	K_2
Ratmalagara	2·26 ..	2·29 ..	2·39
Bandirippuwa	1·00 ..	1·49 ..	2·09

The corresponding yield data (lb. copra/acre) are given below :

Ratmalagara	1,438 ..	1,466 ..	1,589
Bandirippuwa	891 ..	1,292 ..	1,437

It will be seen that there is a high correlation between the yield and the potash content of the coconut water.

At Bandirippuwa the potash content of the water rises *pari passu* with the potash content of the soil and provides an index (*a*) of the potash status of the soil and (*b*) of expected yields.

At Bandirippuwa the yield of copra increases significantly with potash manuring. From 891 lb. copra per acre per annum for the plots without potash (K_0) the yield increases to 1,292 lb. where the palms receive 0·75 lb. K_2O per palm (K_1) and 1,437 lb. where 1·50 lb. per plam are applied (K_2). There is a corresponding increase in the potash in the water from 1 gm. per litre to 1·49 gms. and 2·09 gms. an increase of about 0·5 gms. K_2O per litre for each addition of potash manure.

No such differences in yield or potash content of water are found at Ratmalagara in spite of the fact that the rates of application of potash are higher (1 lb. and 2 lb. K_2O per palm).

A possible explanation is that the reserves of available potash in the form of exchangeable potash are so high that added potash makes no effect on yield.

It is hoped that this " Biological " method (which is very quick and adaptable as a routine method) will be a reliable guidance for studying potash status of coconut soils in contrast to time consuming " soil analysis " or leaf analysis. While leaf analysis of bearing palms involves difficulties of sampling, the use of coconut water has advantages as a routine diagnostic method, particularly in view of the fact that the water does not need preliminary treatment to remove sugars for the determination of potash by the gravimetric method, as shown by critical studies carried out by us.

LUXURY CONSUMPTION OF POTASH

There is another aspect of potash manuring in relation to potash response that is of considerable scientific and economic value. It was shown by Hoagland that beyond a certain critical level, applied potash is absorbed by the plant and accumulates in the tissues and at this stage there is no corresponding increase in yield. This is designated " luxury consumption " by Hoagland (6). In our Bandirippuwa experiment at the upper levels of manuring used by us (K_2–1·5 lb., K_2O per palm) this does not seem to occur as the rising potash content of the water runs more or less parallel with yield curves. On the Ratmalagara soil the addition of K_2–2 lb. K_2O per palm even though it does not produce significant yield increase, does not produce any increase in potash content of the water compared to K_0. This can be easily explained by comparing the relative contributions of exchangeable potassium and added potash to the potash status of the soil.

There is evidence to show that the soil at Ratmalagara is exceptional, as it appears to be a very immature soil, and certain studies on its clay fraction as well as mineralogical analysis that have been proposed should confirm this.

Among other typical coconut soils where the potash response may be small the following are likely :

(*a*) The red soils of the Matale-Wahakotte, and Wahakotte-Kurunegala area (*e.g.*, Melsiripura) derived from dolomitic limestone).

(*b*) Heavy alluvial deposits of the Kurunegala-Mawatagama area.

(*c*) Chocolate loams of Marawila.

SUB-SOILS AND SOIL POTASH

These soils give high yields of 4,000 nuts/acre *without manuring* by cultivation alone if rainfall is favourable. However, except in (*a*) and (*b*) the potash content of the soil (as shown by Joachim's analysis published in the *Tropical Agriculturist* (4) (5) is comparatively low (on a per cent. basis); but as the soils are very deep, sometimes, up to 30 or 40 feet roots have an extensive area to scour for plant food, so that, although the percentage content of available potash is small, the nett quantity available is considerable. Coconut roots have been found at great depths on these soils.

We know that on these soils, unlike on shallow soils with impermeable subsoils such as laterites and lateritic gravels, coconut roots penetrate to great depths. It is unfortunate that Sampson (7) has classified coconut roots into " feeding roots " and " water roots ". Such a classification is obviously illogical on elementary physiological grounds. Is it likely that there is a mechanism in the subsoil roots which enables them to take up the needed water and to exclude the necessary plant nutrients ?

There arise difficulties when we adopt chemical procedures for estimating the fertility of soils when we confine our attention almost exclusively to efforts to measure the nutrient supply in terms of surface soils—the so-called 9 inches of " top soil ". We thereby measure merely the *Intensity Factor* of soil fertility and disregard the *Capacity Factor*. The actual capacity should be the product of the Intensity Factor, expressed say, as weight of nutrient available per unit weight of soil by a Capacity Factor, which will take into account the actual volume or weight of soil which the crop will be able to exploit.

There are almost unlimited reserves of practically all nutrients, major, minor and trace, except nitrogen, which lie beneath the surface soil which adequate cultivation, particularly drainage to provide the necessary aeration for root development, can help to exploit ; of these potash is of major importance to the coconut palm.

To study these problems satisfactorily several $3 \times 3 \times 3$ NPK experiments of the type laid down at Bandirippuwa are necessary, on which corresponding soil studies and complementary plant tissue analyses (*e.g.*, coconut water) can be made.

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