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FORMS AND SPATIAL DISTRIBUTION**

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United Nations Educational Scientific and Cultural Organization  
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FORMS AND SPATIAL DISTRIBUTION**

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## Abstract

Potassium forms the third most important plant nutrient limiting plant growth and consequently reducing crop yields. This study was conducted on soil potassium availability, distribution and relationship with other soil properties. Seventeen top soil samples (0-15 cm) were collected from four agro-ecological zones of the Central and Western Regions of Ghana. Water soluble, exchangeable and non-exchangeable forms of K were determined. The exchangeable K was extracted with 1 N  $\text{NH}_4\text{OAc}$ , 0.1 N  $\text{HNO}_3$ , 0.01 M  $\text{CaCl}_2$ , Bray No. 1 and 1 N boiling  $\text{HNO}_3$ . The non-exchangeable K was extracted with 1 N boiling  $\text{HNO}_3$ . Potassium was determined using flame photometer.

The results showed that potassium is available in the soil in different forms and amounts. Soils from the forest-savanna transition and coastal savanna zones had relatively higher soil solution K concentration than soils from the moist rainforest and semi-deciduous forest zones. Also, soils of the semi-deciduous forest and forest savanna transition as well as the coastal savanna zones contained 2-3 times exchangeable K of the soils of the moist rainforest.

The results also showed that the pH, texture as well as the land use affected K availability in the soils.

## 1.0 Introduction

With the world's ever increasing population, it becomes expedient for agricultural researchers to consider factors that enhance food production more critically, such that a particular land would be able to support crop growth and maintain yields in a sustainable way. Plant nutrition is one most important factor that is worth considering. Soil potassium (K) directly affects crop yield since K is responsible for the maintenance of osmotic pressure and cell size, which in turn influences photosynthesis and the energy production along with stomatal opening and carbon dioxide supply. Except nitrogen, K is a mineral nutrient plants require in largest amounts (Marschner 1995). Potassium is assimilated in relatively large quantities by the growing crop as the yield and quality are closely related to soil K (Tisdale et al 1993; Marschner 1995). Plants require soil K for ATP production, translocation of sugars, starch production in grains, nitrogen fixation in legumes and protein synthesis.

The concentration and availability of K in the soil is primarily controlled by inorganic processes. Though K does not pose the potential environmental concerns that nitrogen and phosphorus do, an understanding of K cycling and availability is important for the management of profitable long-term cropping systems. Soil K has, however, not been given much attention by researchers as it deserves in the tropics. Forde (1966) in his research found this to be true. Possibly this neglect in K research could be due to the general assumption that most tropical soils contain adequate amounts of K to sustain crop growth. Whilst this assumption could be true, losses of K are basically incurred through leaching in drainage waters, crop removal, continuous cropping and utilization by living organisms (Jones 1982).

### 1.1 Forms of soil K

Based on availability to plants, K can be categorized into three major forms:

- i) Relatively unavailable K; this is contained within the crystalline structure of micas, feldspars and clay minerals. Plants cannot use the K in these insoluble forms and therefore mineral weathering must take place. Because feldspars and micas are resistant to weathering they release only small quantities of K during a single cropping season (Follet et al 1981).
- ii) Slowly available (fixed) K; this form of K is trapped between the layers or plates of certain kinds of clay minerals as illite, vermiculite and chlorite. Potassium held in this manner cannot be used much by plants during a single growing season. However, the supply of fixed K largely determines the soil's ability to supply K over extended periods of time.
- iii) Readily available K; is that which is dissolved in soil water or held on the surface of clay particles. Plants absorb dissolved K readily, and as soon as the concentration in the soil solution drops, more is released into the solution from the exchangeable forms. Potassium in the soil solution, which represents a very small fraction of total soil K, is an important indicator of K availability (Nye 1972).

Generally, 90 to 98 percent of the total K in soils is in the relatively unavailable form, 1 to 10 percent in the slowly available form and about 0.1 to 2 percent in the readily available form (Follet et al 1981). In Ghana, there is scanty information on the different forms of K and their relations with some soil properties which affect the availability of the element. The objectives of this study were, first, to assess the availability of K and its distribution in selected soils and second, to determine the effect of some soil properties on K availability.

## 1.2 Sources of K in soils

Clay minerals are the most important sources of soil K aside that from fertilizers. They hold the bulk of mobile K and release it when the concentration of the soil solution falls due to uptake by plants or to an increase in soil moisture. Olaitan and Lombin (1984) observed that over 95 percent of the K in tropical soils is contained in primary and secondary minerals. Potash feldspars, muscovite and biotite are generally considered the original sources of K in soils. At equal clay content, the K concentration of soil solution depends on the nature of the clay minerals.

- i) Kaolinitic clay minerals have no interlattice binding sites for K and a low cation exchange capacity. They do not hold non-exchangeable K and therefore behave similarly to sand and soil organic matter, as far as K dynamics are concerned.
- ii) Illitic clay minerals, vermiculite and chlorite adsorb K selectively. According to Olaitan and Lombin (1984) illites form the most important clay mineral that contains K.
- iii) The selectivity of montmorillonitic clay minerals (smectite) for K is lower than that of illitic but greater than that of kaolinitic clay minerals.
- iv) Allophanes contain very small amounts of K.

## 1.3 Potassium levels in tropical soils

Potassium occurs on the exchange complex of soils especially clayey soils. It is mobile and subject to considerable leaching particularly in sandy soils. The leaching, however, depends on the concentration of K in the soils solution, the amount of water moving through the soil and the ability of the soil to bind K. These reasons account for why the total K content in soils vary widely from less than 0.01% to about 4% and most commonly 1% (Black 1968).

Soil K content is related to the material from which the soil was formed and the degree of weathering. According to Salmon (1964) in highly weathered soils of the tropics, the K content is similar to that in the parent rock and primary materials in the sand and silt fractions. But after continued weathering and leaching the K content in all particle size fractions became low. The K content of soils would thus vary depending on the intensity of cropping as well as leaching. It is generally accepted that soils of temperate regions have higher K content than the more weathered acid soils of the humid tropics (Schroeder, 1978). Castro et al (1972) verified that higher total K content appears in less weathered soils and in soils subject to lower rainfall. Also, in an experiment to find out the effect of continuous cropping on K availability, Charter (1955) noted that the K level of a virgin forest dropped from 0.36 to 0.26 meq/100 g after 7 years of cropping. Similarly, the K content of a semi-deciduous forest in Nigeria decreased from 0.125 to 0.084 meq/100 g after 11 years of continuous cropping for the top 20 cm (Kowal and Tinker 1959). Fauck (1956) also reported exchangeable K value of 0.22 meq/100 g for the top 20 cm on a Savanna Coastal Thicket of Guinea. The value, however, dropped to 0.12 meq/100 g after 6 years of continuous cropping. Studying the K status in some soils of Eastern Colombia, Rodriguez (1975) found mean values of 0.07 meq/100 g K in the surface top soil. Acquaye (1973) also obtained a mean exchangeable K value of 0.19 meq/100 g in studying the K supplying power of some forest soils in Ghana under continuous cropping.

## 1.4 Factors affecting K availability in the soil

The type of clay mineral affects K availability. Potassium only takes one form-  $K^+$ , but there are tree basic soil clay types that hold or trap K and control its availability. Muscovite and mica-clay minerals are rich in K. However, the K contained in this clay is imprisoned between the clay layers, making it virtually unavailable to plant roots. Soils containing predominantly kaolinitic clay have less exchangeable K to release than soils that have higher percentage of illite and vermiculite clay (Black 1968). Illitic clay types

are the product of weathered muscovite and mica clays. The edges of these clays are frayed and wedged open, exposing the interior K that is deeper within the clay layers. Montmorillinitic clays lack all the interior K that normally binds the clay layers together. This allows these clay types to expand and contract during wetting and drying cycles. These clay types hold onto the K in a manner that makes the K readily available for plant roots.

The cation exchange capacity of the soil also affects K availability. Clay and organic matter are negatively charged and therefore have the ability to hold positively charged cations such as  $K^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Na^+$  and  $H^+$ . The ability to hold these positively charged cations is called the soil's cation exchange capacity. The availability of K increases as the percentage of the exchange sites occupied with K increases.

The amount of water in the soil affects the aeration of the soil which eventually decreases the K availability possibly due to the negative effects on K-mobility (Barber 1961).

### 1.5 Methods of evaluating K availability in the soil

A wide range of methods is available for use in determining the K status of soils, but of them give information which relates to only one form of K or to one of the mechanisms involved in the transfer of one form of K to another. The standard method is to shake the sample with a solution of neutral normal ammonium acetate. According to Russell (1973), ammonium and potassium ions are about the same size so that determinations by this method are not influenced by changes in size of the wedge-shaped exchange sites of the interlayer space of 2:1 clay minerals. When other cations are used, exchange proceeds more slowly and particularly in the case of sodium, eventually results in giving a higher reading than ammonium (Quémener 1978). It is, however, an incomplete measure of the amount of K which can pass into solution due to the dominance of  $Ca^{2+}$ , which tends to enlarge the interlayer space and hence releasing more K. Sobulo (1973) used various extractants and procedures and obtained good correlations between K extracted by dilute acids and salts while Ekpete (1970) obtained good correlations with various extractants which included 1 N boiling nitric acid for reserve K and 0.01 M  $CaCl_2$  for exchangeable K.

### 1.6 Relationships between K forms and other soil properties

Levy (1964) reported greater exchangeable K availability to plants in soils of coarse texture than on fine texture. Thus replacement of a given amount of exchangeable bases will cause release of more K ions from sandy soils than from clayey soils with equal exchangeable K content. Kaila (1965) found that K fixation by samples of many soils of Finland increased with clay content indicating that soils with higher clay content are likely to contain more non-exchangeable K. Sands are often made up of almost entirely of quartz and therefore contain very small amounts of K minerals.

According to Acquaye (1973) organic matter has no strong affinity for absorbing K. Van Diest (1978), however, argued that the CEC of organic matter increases with pH and that at higher pH levels organic matter may be able to serve better as a source of plant available K.

The effect of soil pH on the availability of soil K is still a debatable issue. York et al (1953) noted that the fixation of fertilizer K takes place more readily in neutral than in acid soils and liming an acid soil increases its ability to fix K. Geodert et al (1975) stated that though liming decreases K susceptibility to leaching, it might also reduce solution K to levels where plants suffer deficiencies.

Gonzalez (1976) observed that in soils with 4-5% aluminium saturation, the solution K dropped from 0.63 to 0.34 meq/litre. Also, calcium has been shown to compete with K for entrance into the plant despite plant roots selective absorption of nutrients (Barber 1968).

## 2.0 Materials and methods

### 2.1 Sample area covered

In all seventeen (17) soil samples of different tillage practices were taken from the Coastal Savanna (Central Region) and the Rain Forest (Western Region) zones of Ghana. Six (6) samples each were collected from Aiyinasi and Twifo Praso while two (2) samples were collected from the University of Cape Coast Experimental Farm. The remaining three (3) samples came from Edumfa and Ahomfi (Forest-Savanna Transition Zone) in the Southern part of the Central Region. Table 1 shows the location of the soils, their texture, soil management and land use systems. Apart from the Semi-Deciduous Rainforest zone which was cleared from a secondary regrowth in 1990, the other sites had been under continuous cultivation for periods ranging from 17 years in the Central Savanna to over 25 years in the moist Rainforest zones. The site at Aiyinasi has been sparingly fertilized occasionally while the site at Cape Coast has always received moderate amounts of N, P and K fertilizers. There has been no fertilization in the Semi-Deciduous Rainforest and the Forest-Savanna transitional zones.

### 2.2 Background of the different sample sites

#### 2.2.1 University of Cape Coast farm site

The parent materials are Sekondian deposits which are mainly sandstones, shales and conglomerates of Devonian age (Asamoah 1973). The soils are medium to fine textured due to the fair amount of weathered shales in the parent material. The relief is gently undulating to rolling in a hilly area. The height above sea level ranges from 15.2-30.5 m. the average annual rainfall and temperatures are 932 mm and 23.2 °C respectively. The high intensity of weathering coupled with leaching of bases has given rise to soils that are generally acidic, low in cation exchange capacity and dominated by kaolinite clays and sesquioxides (Asamoah 1973).

#### 2.2.2 Aiyinasi site

The soils have been developed from tertiary sands which overlie the Apollonian formations and small areas of adjacent lower Birrimian granitic rocks. The Aiyinasi Agricultural Research Station is flattish to gently undulating with an altitude of about 33-50 m above sea level. The mean annual rainfall of the area is approximately 2100-2200 mm (Dedzo 1988). Generally, the vegetation comprises broken forest, secondary forest and thickets of regrowth.

#### 2.2.3 Twifo Praso oil plantation site

The site is about 79 km North-West of Cape Coast. The soil is red to yellowish red clay loams developed in weathered biotite granite, biotite schists and phyllites. The mean annual rainfall is about 1700 mm, well distributed in two wet seasons separated by a pronounced dry season in August. Temperatures are uniformly high between 25 °C- 26 °C. The topography is undulating to rolling and the soil pH is on the acid side. The predominant tree species include Triplochiton scleroxylon and Celtis mildbreadii (Taylor 1952).

#### 2.2.4 Edumfa and Ahomfi sites

The area is about 18 km South West of Cape Coast. The soils are medium to fine texture and contain appreciable amounts of clay. This is justified by the red clay loams developed in deeply weathered biotite schists and phyllites. The height above sea level may range between 18 m - 35 m.



### 2.3 Sampling method

Soil sampling was done with a shovel at a depth of 0-23 cm of the top soil. Each composite sample consisted of ten random cores in an area ranging from 0.1-1.0 hectare (ha). The sampling was done between December 1993 and January 1994.

### 2.4 Laboratory analysis

The soil samples were air dried at a room temperature for three weeks, crashed in a mortar and sieved through a 2 mm mesh sieve prior to laboratory analysis. Particle size distribution was determined by the Bouyoucos hydrometer method using sodium hexametaphosphate as dispersing agent (Day 1965). Soil pH was determined in both water and 1 N KCl at soil-solution ratio of 1:1 using a Pye Unicam pH meter. The organic carbon content determination was accomplished by the Walkley-Black method (Walkley and Black 1934) using 1 N  $K_2Cr_2O_7$  and  $H_2SO_4$  and with diphenylamine as indicator. The exchangeable bases were extracted with neutral ammonium acetate solution. Calcium plus magnesium ions were determined by the complexometric titration with EDTA, using Eriochrome Black T indicator. Cal red indicator was used for only calcium. Exchangeable aluminium and hydrogen were extracted with

1 N KCl. Aluminium and hydrogen ions were then determined by titration with 0.02 N NaOH using phenolphthalein as indicator for both and sodium fluoride as indicator for aluminium (McLean 1965). Percentage potassium saturation was determined by calculation using the relation:

$$\% \text{ K-Saturation} = \frac{\text{exchangeable K}}{\text{cation exchange capacity}} \times 100$$

Forms of potassium in the soils were also determined. Water soluble K was extracted using distilled water. Exchangeable K was determined in five extractants; 1 N  $NH_4OAc$  at pH = 7, 0.1 N  $HNO_3$ , 0.01 M  $CaCl_2$ , 0.5 M  $NaHCO_3$  and Bray No. 1 (1 N  $NH_4F$  + 0.5 N  $HCl$ ). A soil-solution ratio of 1:10 was used (Sobulo 1969) and K concentration in each case was determined flame photometrically. The concentration of non-exchangeable K was also determined using flame photometer with 1 N boiling  $HNO_3$  as the extractant at soil-solution ratio of 1:10 (Haylock 1956).

### 2.5 Statistical analysis

Relationships between forms of K and other soil properties were established by simple correlation analysis (Mead and Curnow 1983).

## 3.0 Results

### 3.1 Physical properties of the soils

Table 2 presents the results of the particle size distribution determination of the soils. The sand, silt and clay contents varied from 44.8 – 77.4, 2 – 12 and 17.2 – 49.2 percent respectively. The silt content of the soils exhibited the highest variability (53%), followed by clay (13%) and the least by sand (9%).

### 3.2 Chemical properties of the soils

Some chemical properties of the samples investigated are shown in Table 3. Soil pH ( $H_2O$ ) ranged from 4.4 – 7.6. The soils of the moist rain forest zone (Aiyinasi) showed the highest acidity. They ranged from very strongly acidic to strongly acidic (4.5 to 5.5).

### 3.3 Forms of potassium in soils

Water soluble potassium of the soils ranged from 0.013 – 0.092 cmol<sub>c</sub> kg<sup>-1</sup> with a variability of 66%. The non-exchangeable K<sup>+</sup> constituted the greatest fraction while the water-soluble K was the lowest form extracted from all the soils. The non-exchangeable K extracted by 1 N boiling HNO<sub>3</sub> ranged from 0.026-0.996 cmol<sub>c</sub> kg<sup>-1</sup> with a mean of 0.371 cmol<sub>c</sub> kg<sup>-1</sup>. The mean exchangeable potassium extracted from the soils with the five different extractants followed in ascending order; 0.01 M CaCl<sub>2</sub> < Bray No. 1 < 0.5 N NaHCO<sub>3</sub> < 1 N NH<sub>4</sub>OAc < 0.1 N HNO<sub>3</sub>. High variability ranging from 58 – 66% was observed among the exchangeable K values in the soils.

The percentage K-saturation ranged from 0.50-8.02% with a mean of 3.31% (Table 3). This indicates that 59% of the soils studied are well supplied with available potassium. Webster and Wilson (1980) reported that K uptake from the soil is satisfactory if the K-saturation is 2% or more. Figure 1 shows a graphical representation of the various extractants used for the determination of the different forms of K. Figure 2 shows the forms and amounts of potassium in the different ecological zones. In all four agro-ecological zones, the moist rainforest showed the least amounts of K by the various extractants. The greatest amounts of K were extracted by 1 N boiling HNO<sub>3</sub>.

### 3.4 Relationship between forms of potassium and some soil properties

Results of simple correlation analysis between the different forms of K<sup>+</sup> and the various soil properties are given in Table 4.

pH significantly correlated with exchangeable K (0.1 N HNO<sub>3</sub>) and K-reserve extracted by 1 N boiling HNO<sub>3</sub> (P < 0.01) (Table 4). There was no correlation between organic carbon, silt, sand and exchangeable acidity with any of the K forms. Sand in most of the cases gave a negative correlation because it is made up of entirely of quartz and therefore contains very little amounts of K minerals. There was no significant correlation between the exchangeable cations (Ca<sup>2+</sup> and Mg<sup>2+</sup>) and K<sup>+</sup> determination from most of the extractions. This might be due to competing effects of these cations at the exchange sites.

The exchangeable acidity showed negative correlation with all the extractants. This is because as the soil becomes more acidic, exchangeable aluminium increases, thereby competing with K<sup>+</sup> at the exchange sites.

Table 5 presents correlation coefficients among the extractants. Potassium extracted by the various solutions significantly correlated with one another. The results indicated that all the extractants used were only slightly superior to one another, perhaps due to the fact that the clay fraction which is probably kaolinitic could not hold K strongly and it was therefore easily removed even by any weak extractant as remarked by Sobulo (1973).

## 4.0 Discussion

The major soil texture encountered was sandy clay loam which constituted 58.8 percent of the total soils investigated. Sandy loams formed 35.3 percent while sandy clay was only 5.9 percent of the total soils.

The soils of the coastal savanna zone (Cape Coast) are also very acidic. While the low pH of the soils of the moist rainforest zone is apparently due to excessive leaching of bases, that of the coastal savanna soils at the University of Cape Coast farm could be ascribed to continuous use of sulphate of ammonia. The soil reaction of the soils of the semi-deciduous forest zone ranged from slightly acidic to neutral, but those of

the forest savanna transition zone were all slightly acidic. The  $\Delta$  pH (pH (KCl) – pH (H<sub>2</sub>O)) values of the soils were negative, suggesting that the soils could exhibit cation exchange.

Basic cations and organic carbon generally increased with increasing pH of the soils, while exchange acidity was the reverse. Soils from the semi-deciduous forest zone had higher basic cations and organic carbon apparently because they have not been under intensive cultivation compared to soils from the other agro-ecological zones. Organic carbon, exchangeable bases and exchange acidity had very high variability (41%, 73% and 96% respectively. pH in water recorded low variability (17%).

Soils from the moist rainforest and the semi-deciduous forest zones had lower soil solution concentration while those from the forest savanna transition and the coastal savanna zones had relatively high values. Excessive leaching of K salts in the Aiyinasi and Twifo Praso soils might have accounted for the low water-soluble K concentrations (Table 4).

With the exception of the 0.01 M CaCl<sub>2</sub>, the other four electrolytes extracted essentially the same amount of exchangeable K from the soils of the moist rainforest, coastal savanna and the forest savanna transition zones. However, 1 N NH<sub>4</sub>OAC and 0.1 N HNO<sub>3</sub> extracted greater amounts of exchangeable K than the other three extractants in all the ecological zones. It was also observed that the weak electrolytes extracted 2-3 times the amount of K extracted by water. The soils of the Semi-deciduous forest and forest-savanna transition as well as the coastal savanna zones contained 2-3 times exchangeable potassium of the soils of the moist rainforest. This trend could be attributed to differences in K-bearing minerals, the extent of weathering and leaching. The values obtained were, however, in agreement with those reported by other workers (Acquaye 1973; Olaitan and Lombin 1984).

The soils of the moist rainforest and coastal savanna zones contained relatively low K reserves compared to those from the semi-deciduous and forest-savanna transition zones. This is a reflection of very poor reserves of the acid soils.

Generally, the amount of the various K forms extracted increased as the soil pH increased. The results indicated that the K status of the soils varies considerably. This variation apparently depends on differences in mineralogical composition of soils, parent material as well as the degree of weathering and the intensity of leaching of K-salts.

pH significantly correlated with exchangeable K (0.1 N HNO<sub>3</sub>) and K-reserve extracted by 1 N boiling HNO<sub>3</sub> (P < 0.01) (Table 4). Similar observation was made by Sobulo (1973) for some Nigeria soils. This probably indicates that acidification (pH < 2) of soils could mobilize K from the reserves. Also, the mean exchangeable K for soils with pH > 5 was higher than for soils with pH < 5. The lack of significant correlation of K with organic matter is probably due to its low affinity for absorbing K (Acquaye 1973).

Blakemore (1973) suggested that available K<sup>+</sup> in tropical soils is lost so rapidly through leaching or plant uptake that the development of significant relations with other more stable soil parameters is precluded. The same phenomenon would also explain why there was lack of significant correlation between K-reserve and most of the extractants used. With the exception of 0.1 N HNO<sub>3</sub> extractable K, clay did not significantly correlate with any of the other K forms extracted. This contradicts the findings of Kaila (1965) who found significant correlation between exchangeable K and clay content in Finland. These differences in the findings may be due to differences in mineralogical composition of the clay fraction of the tropical and temperate soils. The significant correlation between clay and 0.1 N HNO<sub>3</sub> extractable

potassium could similarly be attributed to the acidification of soils, thereby mobilizing appreciable amounts of K from the clay fraction at the exchange sites.

The percentage K-saturation was the only soil property which significantly correlated with both water soluble and exchangeable K. However, it did not correlate significantly with the non-exchangeable K. The highest correlation was with 0.01 M CaCl<sub>2</sub> ( $r = 0.735$ ). These results suggest that the percentage K-saturation may be the best index of K availability of the soils studied. Similar observation has been made by several investigators (Tinker and Bull 1957).

In conclusion, soils from the forest-savanna transition and coastal savanna zones had relatively higher soil solution K concentration than soils from the moist rainforest and semi-deciduous forest zones. Also, soils of the semi-deciduous forest and forest savanna transition as well as the coastal savanna zones contained 2-3 times exchangeable K of the soils of the moist rainforest. However, the same amount of exchangeable K was obtained from soils of the rainforest, the coastal savanna and the forest-savanna transition zones using

Bray No. 1, 0.5 N NaHCO<sub>3</sub>, 1 N NH<sub>4</sub>OAc, and 0.1 N HNO<sub>3</sub> extractants.

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### **References**

- Acquaye, D. K. (1973): Factors determining the Potassium Supplying Power of Soils in Ghana. 10<sup>th</sup> IPI-Colloquium.
- Asamoah, G. K. (1973): Soils of the proposed farm sites of the University of Cape Coast. Technical Report 88. Soil Research Institute. pp. 1-6.
- Barber, S. A. (1961): The influence of moisture and temperature on phosphorus and potassium availability. Trans. 7<sup>th</sup> Int. Congr. Soil Sci. 3, 435-442.
- Barber, S. A. (1968): Mechanism of potassium absorption by plants. *In* The role of potassium in agriculture. (V J Kilmer, S E Younts and N C Brady, eds.). Amer. Soc. Agron., Madison, WI. pp. 293-319.
- Black, C. A. (1968): Soil-plant relationships. John Wiley and sons, Inc., NY.
- Blakemore, L. C. (1973): Potassium status of Western Samoa soils. A note. N. Z. J. Exp. Agric. 1, 213-216.
- Castro, A. F., Anastcio, M. L. A., and Berreto, W. O. (1972): Potassio disponivel em horizontes superficiais de alguns solos brasileiros. *Pesqui: Agropecu Bras Ser Agron* 7, 25-80.
- Charter, C. F. (1955): The Mechanization of peasant agriculture and the maintenance of soil fertility with bush fallow. C.C.T.A. Conference on the Mechanization of Agriculture, Entebbe.

- Day, P. R. (1965): Particle fractionation and particle size analysis. *In* C A Black et al. (eds.). *Methods of analysis, Part 1. Agron. 9, 545-566.*
- Dedzo, C. D. (1988): Sulphur status of some soils in the rain forest and coastal thicket zones. B.Sc. Thesis. University of Cape Coast. 91 pp.
- Ekpete, D. M. (1970): Responses to potassium in Eastern Nigerian soils. *Proceedings of the Agricultural Society of Nigeria. 57 pp.*
- Fauck, R. (1956): Evolution of soils under Mechanized Cultivation in tropical areas. *Trans. 6<sup>th</sup> Int. Congr. Soil Sci. E, 593-596.*
- Follet, H. R., Murphy, L. S., and Donahue, R. L. (1981): *Fertilizers and Soil amendments. Prentice-Hall Inc., New Jersey, pp. 163-168.*
- Forde, C. M. (1966): Potassium Supplying Power of soils in South Eastern Nigeria. *Quarterly Progress Report Nigeria Inst. of oil palm Res. 57, 21-22.*
- Geodert, W. J., Corey, R. B., and Syers, J. K. (1975): The effect of potassium in soils of Rio Grande do Sul, Brazil. *Soil Sci. 120, 107-111.*
- Gonzalez, E. (1976): Effect of depth of lime incorporation on growth of corn in Oxisols of Central Brazil. Thesis for degree of Ph.D., N. Carolina State Univ., Raleigh 125 pp.
- Haylock, O. F. (1956): A method for estimating the availability of non-exchangeable potassium. *6<sup>th</sup> Int. Congr. Soil Sci. B, 403-408.*
- Jones, S. U. (1982): *Fertilizers and soil fertility. Reston Publishing Company, Inc., U.S.A, pp. 190-192.*
- Kaila, A. (1965): Fixation of potassium in Finnish soils. *Maat. Aikak. 37, 116-126.*
- Kowal, J. M. L., and Tinker, P. B. H. (1959). Soil changes under a plantation established from high secondary forest. *J. West Afric. Inst. Oil palm Res., 2, 376-389.*
- Levy, J. F. (1964): Exchangeable soil potassium, potassium uptake by plants and soil texture (Translated title) *potasse 38, 9-14. (Soils and Fertilizers 27, Abstr. 1315, 1964).*
- Marschner, H. (1995): *Mineral Nutrition of Higher Plants. Academic Press. London, p. 889.*
- Mead, R., and Curnow, R. N. (1983): *Statistical Methods In Agriculture and Experimental Biology. J. W Arrowsmith Ltd., Bristol. Repr., 1990. pp. 125-189.*
- McLean, E. O. (1965): Aluminium. *In: C A Black (ed.) Methods of Soil Analysis. Agron. No. 9 Part 2, Amer. Soc. Agr., Madison, Wisconsin. Pp. 978-988.*
- Nye, H. P. (1972) Localized movement of potassium ions in soils. *Proc. 9<sup>th</sup> Colloq. Int. Potash Inst., Bern, 147-155.*

Olaitan, S. O., and Lombin, G. (1984): Introduction to tropical soil science. Macmillan Publishers Ltd., Hong Kong, pp. 66-69.

Quémener, J. (1978): The measurement of soil potassium. IPI Research Topics No.4 48 pp.

Rodriguez, P. M. S. (1975): Calcium, magnesium and potassium status in some soils of the Eastern plains of Colombia. Thesis for degree of M. S., Cornell Univ., Ithaca, NY. 177 pp.

Russell, E. W. (1973): Soil conditions and plant growth. 11<sup>th</sup> ed. Alan Wild (ed.). Longman Group U.K. Ltd., 1988. pp. 743-760.

Salmon, R. C. (1964): Potassium in different fractions of some Rhodesian soils. Rhodesian J. Agric. Res. 2, 85-90.

Schroeder, D. (1978): Structure and weathering of potassium containing minerals. Proc. Congr. Int. Potash Inst. 11, 43-63.

Sobulo, R. A. (1969): Evaluation of methods of assessing available potassium in some typical soils of Western State of Nigeria. Niger. Agric. J. 6, 65-73.

Sobulo, R. A. (1973): Evaluation of analytical methods for determining potassium status of Nigerian soils. 10<sup>th</sup> IPI-Colloquium.

Taylor, C. J. (1952): Vegetation zones of the Gold Coast. Bulletin No.4, Gold Coast Forestry Department Accra. Government Printer.

Tinker, P. B. H., and Bull, R. A. (1957): Some aspects of variations in soil potassium and magnesium on yield responses and deficiency symptoms in oil pails. Proc. of the West African Soils and Plant Nutrition Conference. W.A.I.I.S., Accra. Mimeo pp 72-84.

Tisdale, S. L., Nelson, W. L., Beaton, J. D., and Havlin, J. (1993): Soil Fertility and Fertilizers; 5<sup>th</sup> ed. Macmillan Publishing Co. New York, pp. 230-265.

Van Diest, A. (1978): Factors affecting the availability of potassium in soils. Conference on the 25<sup>th</sup> Anniversary of the Scientific Board of IPI. Pp. 29-32.

Walkley, A., and Black, I. A. (1934): An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci. 37, 29-38.

Webster, C. C., and Wilson, P. N. (1980): Agriculture in the tropics. Longman Group Ltd., England. pp.73-74.

York, E. T. Jr., Bradfield, R., and Peech, M. (1953): Calcium-Potassium interactions in soils and plants: *In* Lime-induced potassium fixation in Mardin silt loam. Soil Sci. 76, 379.

Table 1: Location of soils, their texture, soil management and land use

Samplpe No.	Location	Textural class	Soil management	Land use
S1	Aiyinasi	SCL	Two years fallow, hand cleared	Cassava
S2	Aiyinasi	Sl	Hand cleared, lime experiment plot	Cowpea
S3	Aiyinasi	SCL	Hand cleared, tractor tillage	Rubber
S4	Aiyinasi	SCL	Bulldozer cleared, tractor tillage	Coconut
S5	Aiyinasi	SCL	Bulldozer cleared, tractor tillage	Groundnut Plantain
S6	Aiyinasi	SL	Bulldozer cleared, tractor tillage	Oil palm
S7	Twifo Praso	SCL	Bulldozer cleared, minimum tillage	Cassava
S8	Twifo Praso	SCL	Hand cleared, no burn, no tillage	Cassava
S9	Twifo Praso	SCL	Bulldozer cleared, tractor tillage	Cassava
S10	Twifo Praso	SCL	Bulldozer cleared, tractor tillage	Cassava
S11	Twifo Praso	SCL	Hand cleared, no burn, minimum tillage	Cassava
S12	Twifo Praso	SL	Bulldozer cleared no tillage	Cassava
S13	Edumfa	SL	Hand cleared with burning	Teak
S14	Ahomfi	SCL	Hand cleared with burning	Cassava
S15	Ahomfi	SC	Hand cleared with burning	Plantain/ Cocoa
S16	Cape Coast	SL	Hand cleared, tractor tillage	Maize
S17	Cape Coast	SL	Hand cleared, tractor tillage	Pasture

KEY: SCL      Sandy Clay Loam  
           SL        Sandy Loam  
           SC        Sandy Clay

Table 2: Particle size distribution of the soils

Agro-ecological Zone	Location	Land use	% Sand	% Silt	% Clay	Textural class
Moist Rainforest	Aiyinasi	Cassava	61.4	9.4	29.2	SCL
	Aiyinasi	Cowpea	77.4	3.7	18.9	SL
	Aiyinasi	Rubber	75.4	4.0	20.6	SCL
	Aiyinasi	Coconut	75.4	2.0	22.6	SCL
	Aiyinasi	Groundnut/ Plantain	68.8	6.0	25.2	SCL
	Aiyinasi	Oil palm	70.8	12.0	17.2	SL
Semi-deciduous	Twifo Praso	Cassava	70.8	6.0	23.2	SCL
	Twifo Praso	Cassava	66.8	4.0	29.2	SCL
	Twifo Praso	Cassava	71.4	5.7	22.9	SCL
	Twifo Praso	Cassava	70.8	6.0	23.2	SCL
	Twifo Praso	Cassava	77.4	4.0	20.6	SCL
	Twifo Praso	Cassava	66.8	2.0	18.6	SL
Forest-Savanna transition	Edumfa	Teak	71.4	10.0	18.6	SL
	Ahomfi	Cassava	66.8	6.0	27.2	SCL
	Ahomfi	Plantain/ Cocoa	44.8	2.0	49.2	SC
Coastal Savanna	Cape Coast	Maize	70.8	10.0	19.2	SL
	Cape Coast	Pasture	69.4	12.0	18.6	SL
		Mean	69.4	6.2	24.4	
		S.D.	6.5	3.3	7.5	
		CV (%)	9	53	31	

KEY: SCL                      Sandy Clay Loam  
 SL                              Sandy Loam  
 SC                              Sandy Clay



Table 3: Some chemical properties of the soils

Agro-Ecological Zone	Location	Land use	pH (H <sub>2</sub> O)	pH KCl	Basic cations (cmol <sub>c</sub> kg <sup>-1</sup> )			Sum of basic cations (cmol <sub>c</sub> kg <sup>-1</sup> )	Ex. Acidity (cmol <sub>c</sub> kg <sup>-1</sup> )	O.C (%)	% K-saturation
					Ca	Mg	K				
Moist Rainforest	Aiyinasi	Cassava	5.1	4.5	3.6	0.4	0.17	4.17	0.500	1.24	3.66
	Aiyinasi	Cowpea	4.6	4.1	5.4	0.6	0.04	6.04	1.200	1.19	0.50
	Aiyinasi	Rubber	4.4	4.0	1.2	0.8	0.07	2.07	0.910	1.14	2.24
	Aiyinasi	Coconut	4.7	4.1	0.8	0.2	0.05	1.05	0.560	1.04	3.17
	Aiyinasi	Groundnut/ Plantain	5.8	5.3	4.0	0.4	0.12	4.52	0.185	1.57	2.55
	Aiyinasi	Oil palm	5.0	4.3	1.4	0.4	0.06	1.86	0.955	1.27	2.17
Semi-Deciduous Rainforest	Twifo Praso	Cassava	7.1	6.7	8.0	2.0	0.13	10.13	-	1.94	1.25
	Twifo Praso	Cassava	7.6	7.1	14.8	3.4	0.25	18.45	-	2.56	1.35
	Twifo Praso	Cassava	6.5	6.0	5.4	2.0	0.12	7.52	-	2.01	1.57
	Twifo Praso	Cassava	6.9	6.4	11.8	3.0	0.16	14.96	-	1.87	1.07
	Twifo Praso	Cassava	6.4	5.9	2.0	2.0	0.13	4.13	-	1.64	3.08
	Twifo Praso	Cassava	6.8	6.4	7.5	2.4	0.21	10.11	-	3.14	2.05
Forest Savanna Transition	Edumfa	Teak	6.1	5.5	4.0	1.0	0.10	5.10	-	1.05	1.94
	Ahomfi	Cassava/ Plantain	6.6	6.0	3.2	0.8	0.39	4.39	-	1.17	8.02
	Ahomfi	Cocoa	6.6	5.9	7.0	4.8	0.24	12.04	-	1.36	1.97
Coastal Savanna	Cape Coast	Maize	5.2	4.8	2.0	0.8	0.31	3.11	0.790	0.69	7.85
	Cape Coast	Pasture	4.8	4.7	1.8	0.8	0.19	2.79	0.085	0.84	6.67
	Mean		5.89	5.39	4.85	1.52	0.16	6.53	0.38	1.51	3.31
	S.D.		0.98	0.97	3.81	1.25	0.09	4.84	0.37	0.61	3.12
	C.V (%)		17	18	78	82	57	73	96	41	92

Table 4: Correlation analysis between forms of K and some soil properties

Soil	Distilled	1 <u>N</u>	0.1 <u>N</u>	0.5 <u>N</u>	Bray	0.01 M	1 N boiling
Property	water	NH <sub>4</sub> OAc	HNO <sub>3</sub>	NaHCO <sub>3</sub>	No. 1	CaCl <sub>2</sub>	HNO <sub>3</sub>
pH(H <sub>2</sub> O)	0.402	0.460	0.607**	0.343	0.332	0.353	0.696**
% sand	-0.212	-0.515	-0.565	0.360	-0.242	-0.361	-0.295
% silt	0.109	0.049	-0.065	0.173	0.132	0.102	-0.039
% clay	0.137	0.429	0.522*	0.239	0.154	0.271	0.275
% O.C	0.203	0.083	0.249	-0.039	0.147	-0.105	0.374
Ca <sup>2+</sup>	0.284	0.174	0.374	0.108	0.144	0.133	0.496**
Mg <sup>2+</sup>	0.252	0.327	0.501*	0.189	0.187	0.207	0.451
Exch. Acidity	-0.325	-0.443	-0.541	-0.336	-0.282	-0.433	-0.613
% K Saturation	0.503*	0.719**	0.510*	0.716**	0.557*	0.735**	0.100

\* and \*\* denote significance at P < 0.05 and < 0.01 respectively

Table 5: Correlation coefficients for the pairs of the extractants

	Distilled water	1 <u>N</u> NH <sub>4</sub> OAc	0.1 <u>N</u> HNO <sub>3</sub>	0.5 <u>N</u> NaHCO <sub>3</sub>	Bray No. 1	0.01 <u>M</u> CaCl <sub>2</sub>
1 <u>N</u> boiling HNO <sub>3</sub>	0.531*	0.523*	0.726**	0.442	0.466	0.510*
0.01 <u>M</u> CaCl <sub>2</sub>	0.907**	0.962**	0.914**	0.967**	0.900**	
Bray No. 1	0.950**	0.827**	0.814**	0.853**		
0.5 <u>N</u> NaHCO <sub>3</sub>	0.846**	0.935	0.849**			
0.1 <u>N</u> HNO <sub>3</sub>	0.852**	0.938**				
1 <u>N</u> NH <sub>4</sub> OAc	0.836**					

\* and \*\* denote significance at P < 0.05 and < 0.01 respectively

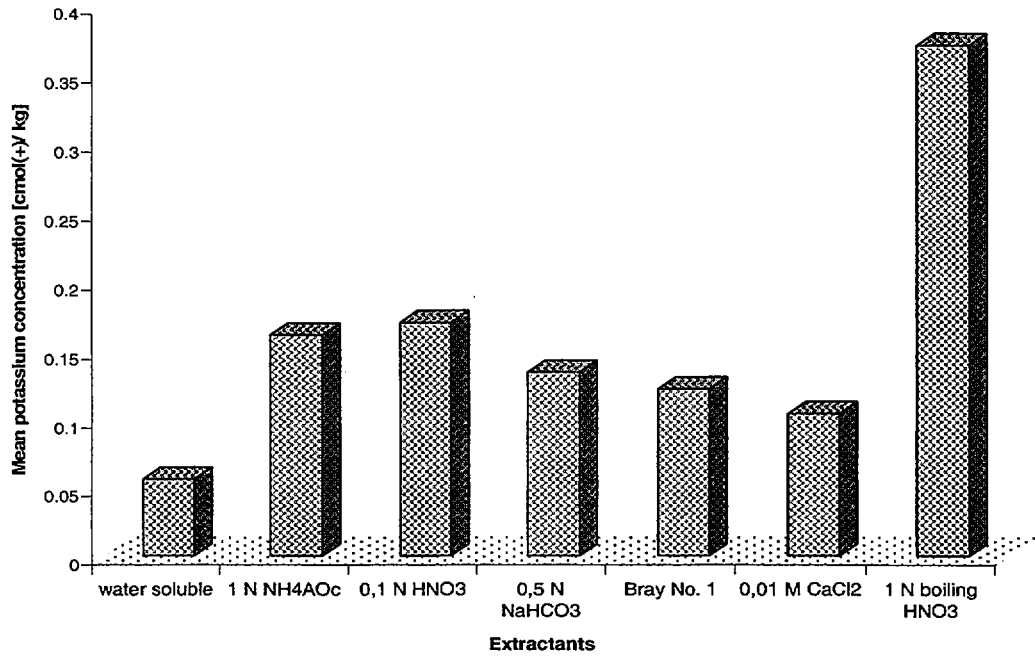


Figure 1: Forms of potassium in the soils

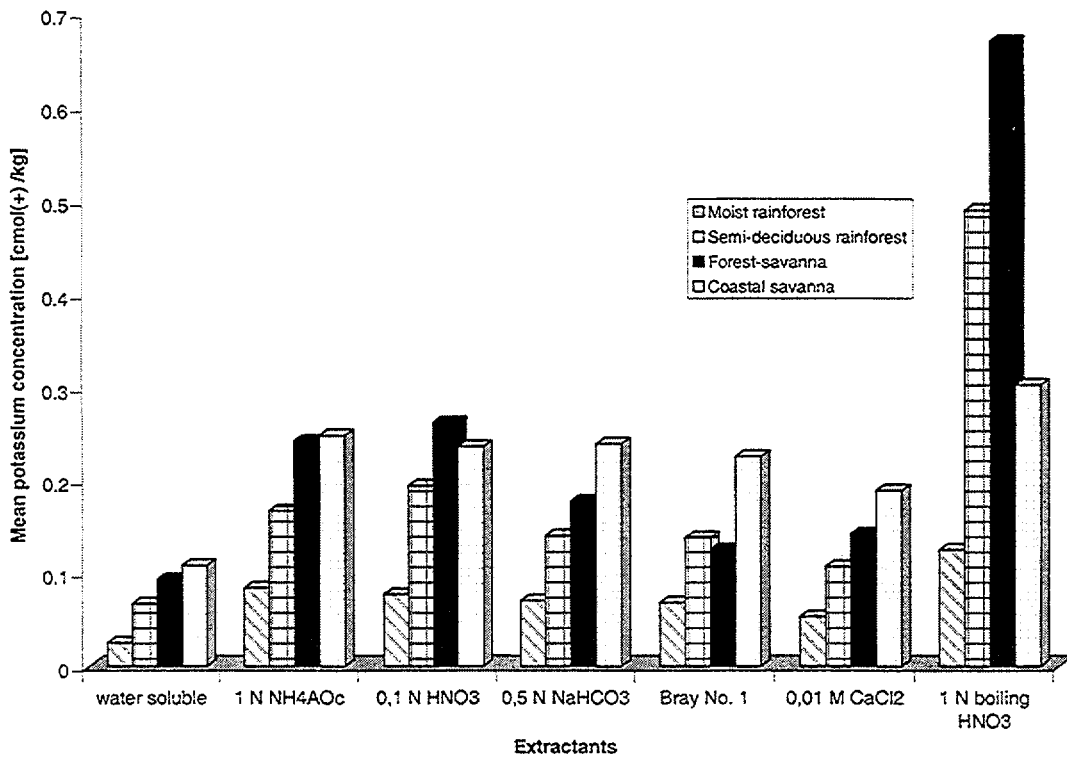


Figure 2: Forms and amount of K in the different ecological zones

