Nutrient uptake of Archidium acanthophyllum and Cyanotis lanata from Savanna Microsites on Baasi Inselberg in Southwestern Nigeria

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ABSTRACT

Nutrient concentrations and their mobility between soil and two dominant plants, moss (*Archidium acanthophyllum* Snider. (Archidiaceae) and succulent monocot (*Cyanotis lanata* Benth. Commelinaceae) growing on Baasi -Inselberg was investigated over a period of 36 months. The surface of the inselberg was divided into four microsites (Ms). Ms-1, bare soil; Ms-2, *A. acanthophyllum* only; Ms-3, *C. lanata* only; Ms-4, both Ms-2 and Ms-3. Samples of soil and plants were taken from one quadrat (0.5 m x 0.5 m) in each microsite for analysis of their ion contents. Plant debris, dust and rain water formed the primary sources of nutrients on the inselberg. Early rainfall (in April) triggered the growth of *A. acanthophyllum* which peaked in May and sharply decreased in June. Thereafter growth rate increased gradually from June to December (early dry season) and remained constant between January and March. In the early rainy season and early dry season, nutrient concentrations were higher (Ca^{2+}, 1500 μgg^{-1}; K^{+}, 150 μg g^{-1};Mg^{2+}, 100 μg g^{-1};Na^{+}, 30 μg g^{-1}) than other months of the seasons. In Ms-4 there was a higher resultant sequestration of ions in the plant tissues (K^{+}, 800 μgg^{-1};Ca^{2+}, 600 μgg^{-1}; Mg^{2+}, 160 μgg^{-1};Na^{+}, 28 μgg^{-1}). The Ms-1 was the source of Na^{+} concentration in Ms-4, for K^{+}Ms-2 and Ms-3, for Mg^{2+} Ms-2 only and for Ca^{2+} Ms-1, 2 and 3.

Keywords: *Archidium*, *Cyanotis*, Inselberg, Nigeria, Microsite, Nutrients.

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INTRODUCTION

The mineral uptakes by tropical bryophytes have not been well addressed in Nigeria. Akande *et al.*, (1985) working in Nigeria, reported the accumulation of nutrients in six rainforest bryophyte species with progressive increase from dry to wet season and that the dust particles and bark constitute the major sources of nutrients in the stemflow. Other reports from tropical montane rainforest have shown that bryophytes contribute to the ionic balance of the forest by releasing salts stored in their cells during rainfall or gradual decomposition (Coxson 1992; Sastre–De Jesus 1992). There is virtually no such information available to the author on savanna bryophyte communities.

During an ecological survey of bryophytes in the Guinea savanna of southwestern Nigeria, several inselbergs had patches of sedges, grasses, succulent monocots, herbs, bryophytes (*Archidium acanthophyllum, Bryum* spp. and *Riccia* spp.), and lichens. It was not very clear why a moss like *A. acanthophyllum* and the succulent monocot *C. lanata* should dominate inselbergs. Could this be due to the topography of the low-lying inselberg? Owoseye and Sanford (1960), working on a large well-drained inselberg in the northern Guinea savanna in Nigeria, reported mutual association of *Calymperes leucomitrium* and the sedge *Velozia* spp. Besides, Hambler (1964) described mixed stands of *C. lanata* and sedges on granite outcrops in western Nigeria. The dominance of *Archidium* and *Cyanotis,* on the Baasi inselberg in southern Nigeria Guinea savanna further raised some questions.

i) What is the source of nutrients to these plants?
ii) How do they obtain these nutrients?
iii) What are the seasonal stored nutrients in the substrate soil? and
iv) How does this relate to the mixed stands of *Archidium* and *Cyanotis?*

The need to know the nutrient status of the moss and the succulent monocot was to ascertain the contribution of both plants to the nutrient budget on the inselberg. The present study therefore monitored the mineral nutrients cycle between the plants and the substrate soil and importance to the micro ecosystem.

Materials and Methods

Description of the study area

Baasi inselberg (c.3.500 m², 286 m. a.s.l) (Lat. N 08° 20 12 , Long. E003° 23 40) is located 40 km south of Saki (Lat. N 08° 40 30.51 , Long. E003° 23 16.92) in an open rock surrounded by scattered shrubs and grasses. The hard basalt black inselberg was dotted randomly by microsites (horseshoe depressions, c. 0.2 m to 1.0 m dia., c. 0.05 m to 0.15 m depth) (Oyesiku and Egunyomi 2004). Plant debris and dust were the main sources of the substrate on the inselberg. Incompletely burnt plants gave the substrate its blackish grey colour. The accessibility to the inselberg and availability of the target plant association (*A. acanthophyllum* and *C. lanata*) were criteria for selecting Baasi inselberg.

Two years of climatic raw data near the study area was supplied by the Federal Meteorological sub-station in Iseyin, Nigeria. Rainfall mainly from April to September with a monthly mean of 125.0 mm for two years. The annual mean maximum temperature was 31.2 °C and the minimum 21.0 °C, annual mean RH of 75%, and 6 h monthly mean of sunshine hours with a minimum of 3 h in August and maximum of 8 h in February.

On the study inselberg, four microsites (Ms) based on the composition of vegetation cover, were selected. Ms-1 (=bare soil), Ms-2 (=*A. acanthophyllum* only), Ms-3 (=*C. lanata* only) and Ms-4 (=mixture of *A. acanthophyllum* and *C. lanata*).

Description of Samples

Cyanotis lanata (Cya) an annual plant that formed extensive canopy over an acrocarpous moss *A. acanthophyllum* (Arc) in microsite (Ms) depressions on the inselberg. During the wet season, *C. lanata* leaves were bright green and open. However, during the dry season flowers were produced and the leaves were green purple tinged or brown. These leaves were brittle and rolled longitudinally enclosing the adaxial surface.

Archidium acanthophyllum (Arc) forms the cushion on which Cya was growing. This acrocarpous moss thrived on a well-drained part of the Ms which normally dries out for a large part of the year. Growth was characterized by terminal, apical or lateral sterile and fertile innovations. Production of numerous rhizoids in the leaf axils and along the stem where it contacted the substrate is followed by new, erect branches the following year.

Collection and analysis of samples

Data for vegetative growth measurement of Arc were collected for 36 months. Twenty unbranched shoots (n=20) were carefully teased out with the aid of fine forceps from four (r=4) wire quadrats (0.5 m x 0.5) from each of Ms-1, Ms-2, Ms-3 and Ms-4 each month. The unbranched shoots were selected on the assumption that they represented an active growth marker compared to the ones with terminal or subterminal innovations. The length (mm) of each unbranched shoot was measured from the stem base (from upper rhizoids end) to the tip of the stem under dissecting scope (10X). Innovations were observed frequently during the dry season.

Rainwater was collected in four polythene rain gauges (20 cm dia.) made of polyethene funnel fitted into a 2-liter black polythene bottle, secured by a rubber sleeve and a metal frame, Carlisle, Brown and White (1966). The four gauges were placed at random locations adjacent to the four Ms and left there for the whole period of sampling. Rainwater volumes for each month were collected and measured.

In each month, samples of soil (Ms-1), Arc (Ms-2), Cya (Ms-3) and mixture of Arc and Cya (Ms-4) were collected and the green portions of each plant were used for the analysis of their cation metal contents. This method was adopted since it would be difficult to wash off the contaminants without leaching the ions out of the moss tissue (Tamm 1983). The samples of soil, sieved through 2 mm mesh (5 g) and each of the plant (5 g) were dried to a constant weight at 60 °C in a ventilated oven. Dried soil of 0.5 g was weighed into a 100 ml volumetric flask. Twenty-milliliter of Ammonium acetate ($C_2H_7NO_2$), with pH adjusted to 7, was added to the

soil sample and shaken at 10-minute intervals for 1h. The mixture was left overnight and later filtered through Whatman (No. 42) ash-less filter paper. The first few drops of filtrate were discarded, a control solution was prepared with filtered C H_7NO_2 adjusted to pH 7 (Adepetu, *et al.,* 1984). The resultant filtrate was analysed for cations. Na and K were analysed by the Gallenkamp flame photometer. For Ca and Mg, Buck 2000 Atomic Absorption spectrophotometer was used. The values obtained were expressed in g g-1 dw.

Ground samples (0.5 g) of Arc unbranched stems, Cya and mixed Arc and Cya were weighed into separate conical flasks (100 ml) and wet digested with Analar grade Nitric : Perchloric acids (HNO_3: $HClO_4$, 4:1) at moderate heat in the fume chamber until a white fume appeared. The resultant solutions were heated for a few minutes to remove the Perchloric acid and allowed to cool down. The residue was redissolved by adding 20 ml of HNO_3 and evaporated down to 10 ml in a boiling water bath. The cooled solution was filtered through Whatman (No. 42) ash-less filter paper and stored in an HNO_3 prewashed vial. The control was prepared by filtering fresh HNO_3. The cation values were determined on the same instruments used for the soil.

Statistical Analysis

The relationship between rainfall and growth rate of *Archidium acanthophyllum* was analyzed by correlation analysis. Least significance difference (LSD0.05) was used to compare the significance of ion concentrations from the four microsites using SPSS version 14

Results

Table 1 shows the baseline ion (Ca^{2+}, Mg^{2+}, K^+ and Na^+) concentration present in the rainwater at the study site over a period of 24 months. Calcium ion concentration was higher than all other ions and Na^+ was lower than all other ions.

Figure 1 shows the correlation between growth rates of *A. acanthophyllum* gametophytes and rainfall distribution in months. Early rain in April triggered the growth of *A. acanthophyllum*, which peaked in May (14 mm) and sharply decreased in June (scanty population) and subsequently increased gradually throughout the rainy season into the dry season (July – December). From January to March the growth rate of *A. acanthophyllum* was constant.

Figure 2 a-d show monthly status of ions (Ca^{2+}, Mg^{2+}, K^+ and Na^+) sequestered in the soil of the microsites on Baasi inselberg. In the months of April, May and December the Ca^{2+} sequestered in the soil was higher than 1500 µg g^{-1} and lower than 300 µg g^{-1} in July, the peak of the rainfall. (Fig 2a). In the months of February (late dry season), April (early rainy season) and December (mid-dry season) the Mg^{2+} sequestered in the soil was higher than 100 µg g^{-1} and lower than 10 µg g^{-1} in July (Fig 2b). In the months of January and February (late dry season), April (early rainy season), September (late rainy season) and December (mid-dry season) the K^+ sequestered in the soil was higher than 150 µg g^{-1} and lower than 50 µg g^{-1} in dry August (Fig 2c). In the months of January, April, September and December the N^+ sequestered in the soil was higher than 30 µg g^{-1} and lower than 20 µg g^{-1} in March and November (Fig 2d).

The results in Fig 3 a-d show the status of ions (Ca^{2+}, Mg2+, K^+ and Na^+) sequestered in the soil, tissues of *A. acanthophyllum* (Arc) and *C. lanata* (Cya) in microsites on Baasi inselberg. In Ms-4 the resultant uptake of Ca^{2+} by both Arc and Cya was higher than 600 µg g^{-1} and lower than 350 µg g^{-1} in Ms-1 (Fig 3a). In Ms-2 and 4, the uptakes of Mg^{2+} were higher than 160 µg g^{-1} and lower than 20 µg g^{-1} in Ms-1 and 3 (Fig 3b). In Ms-4 the resultant uptakes of K^+ were higher than 800 µg g^{-1} and lower than 200 µg g^{-1} in Ms-1 (Fig 3c). In Ms-1, 2 and 4 the uptakes of Na^+ were higher than 28 µg g^{-1} and lower than 25 µg g^{-1} in Ms-2 (Fig 3d).

Discussion:

It was anticipated that the nutrient uptakes by the microsite soil would be higher during the rainy season than the dry season this was not so. Realizing that salts might be lost through the surface "run off" of water from the rock microsites, the vegetation on the rock absorbed most of the ions supplied by the rain. This observation is supported by the high concentrations of ions by Ms-4 during the dry season. The foregoing observation was further confirmed by the low concentration of nutrients in the Ms-1. Although the present observation contradicts the report of Akande *et al.,*

(1985) that corticolous mosses, accumulate stem flow nutrients more in the rainy season than in the dry season, the apparent contradiction could be due to differences in microhabitats and habits of the mosses.

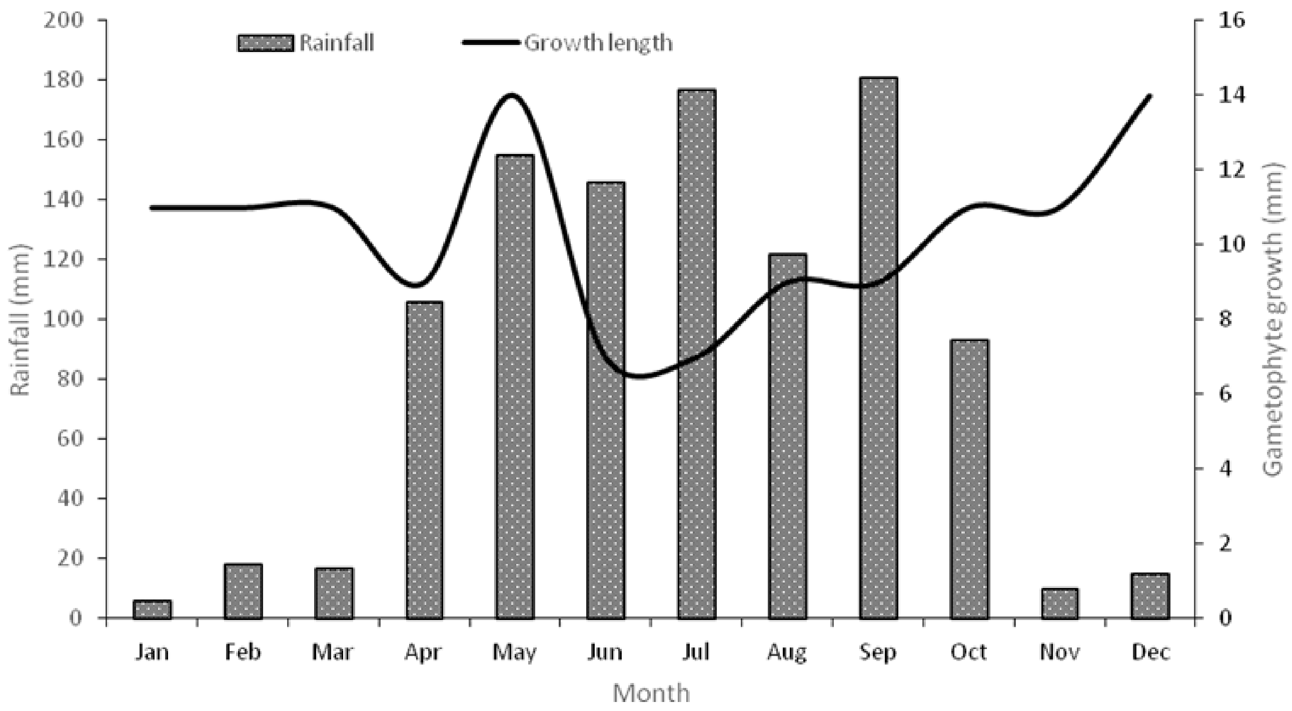
The high growth rate of Arc in the dry season was due to a capability to absorb more nutrients as accumulated during the early wet season than when the rains become were heavier and the growth rate was slower because the source hydration was night dew. The present observation does not agree with the two views of certain authors. Firstly, unlike some previous observations (Babb and Whitfield, 1977; Coxson, 1992; Longton, 1992) that bryophytes are capable of absorbing nutrients from dilute solutions as well as releasing them from their cell walls during heavy rainfall. Secondly, contrary to the findings of Allen *et al.* (1968) and Thornton (1965) that the heavier the precipitation, the more nutrients are found in bryophytes and vascular plants, *A. acanthophyllum* exhibited its highest nutrient concentrations during the dry season. The sequestrated K^+ and Mg^{2+} in Arc and Cya tissues most probably enhanced their growth rates. Relatively, Ms-4 sequestrated more K^+ and Ca^{2+} than individuals of Ms-2 and Ms-3. In addition, the K^+ and Mg^{2+}, (in particular K^+), function as natural activators of many growth enzymes, and regulates osmosis processes in plants (Sutcliffe, and Baker, 1981). Several authors (Coxson, 1992; Onianwa and Egunyomi, 1983; Onianwa *et al.*, 1986) have established that mosses have high ion-exchange capacities for storing essential cations. The mostly mobile cations (K^+ and Mg^{2+}) are absorbed directly into the plant cell walls while Ca^{2+}, which is least mobile, adsorbs more to exchange sites of the soil (Ms-1) than onto Arc (Ms-2) and Cya (Ms-3). Longton (1992); Brown and Bates (1990) reported that the divalent cations are generally, more strongly held at the cation exchange sites of the plant cell walls than monovalent ions. This statement was supported by Arc (Ms-2), but it was not the case with Cya (Ms-3). Instead, Cya showed a preference for monovalent ion (K^+).

The nutrient status of the microsite soil varies with time of the year. According to Sastre–De–Jesus (1992) sequestrated cations from the plant tissues into the soil are released by a dynamic process through leaching from plant debris and decomposing tissue into humus and soil.

In conclusion, the sources of nutrients to the vegetation on the inselberg include the plant debris, dust and rainfall. The nutrients (K^+, Mg^{2+} and Na^+) were obtained by the plant tissue through absorption processes while Ca^{2+} was by adsorption due to its low mobility. The seasonally stored ion in the soil was Na^+.The sequestration of Na^+ in both Ms-1 and Ms-4 were similar, an indication that Na^+ was majorly stored in the soil. Therefore, the mineral nutrients mobilization between the vegetation and the substrate soil enhanced the establishment of microsite ecology on the inselberg.

Table 1: Elemental ions content of the rainwater on Baasi-inselberg.

Element	Concentration (Kg/ha/month)
Ca^{2+}	7.6
K^+	6.3
Mg^{2+}	5.0
Na^+	2.1



[illegible] mean rainfall and mean shoot growth pattern of *A. acanthophyllum* on Baasi inselberg over 36 months. Rainfall (n=4), shoot growth (n=20)

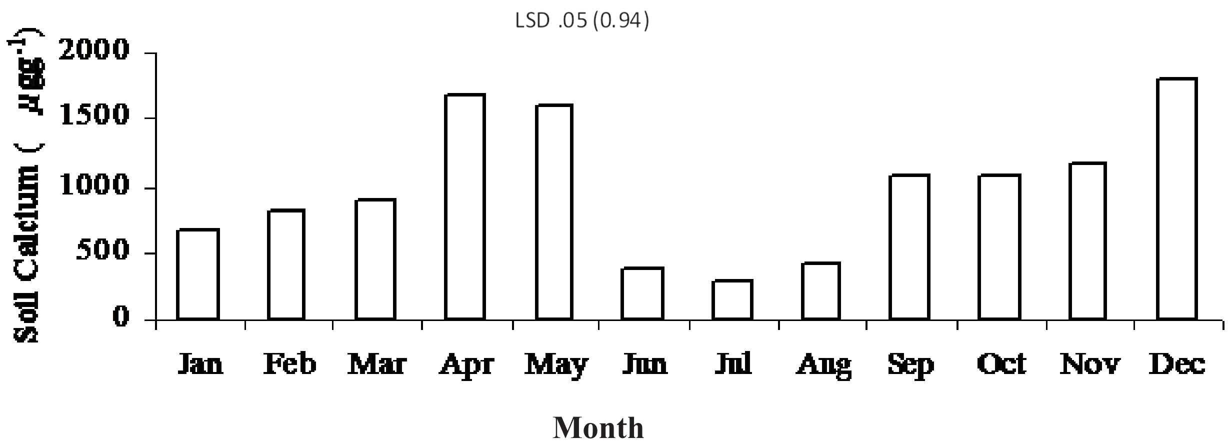


Figure 2a. Annual mean concentration of Ca^{2+} in studied microsite soil on Baasi-inselberg for period of three consecutive years (n=3)

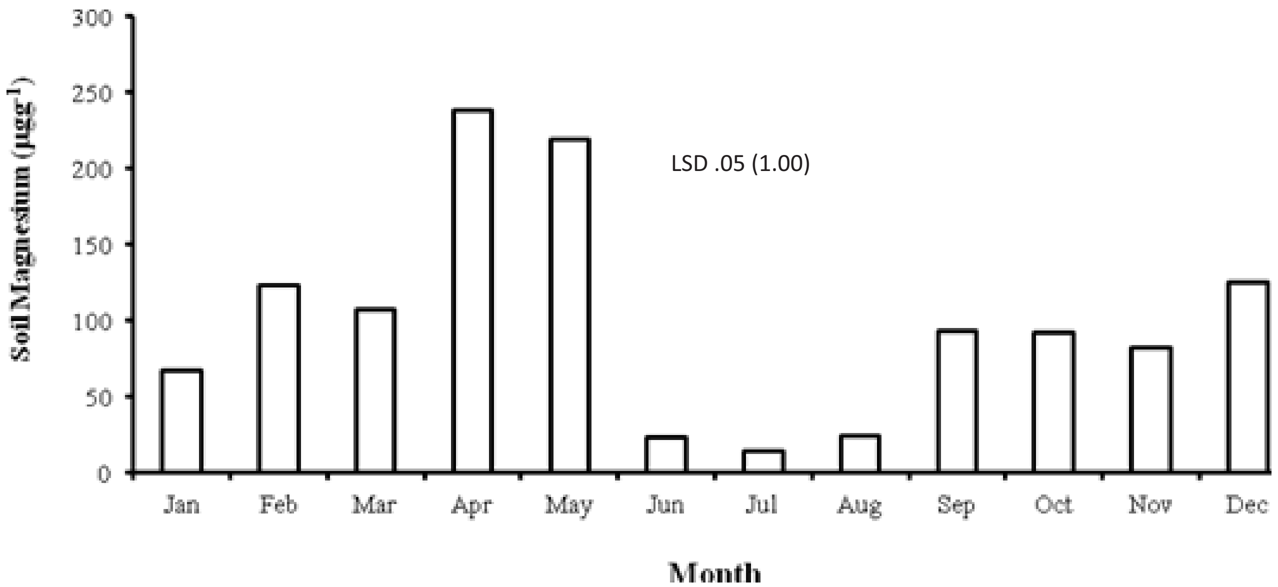


Figure 2b. Annual mean concentration of Mg^{6+} in studied microsite soil on Baasi-inselberg for period of three consecutive years (n=3)

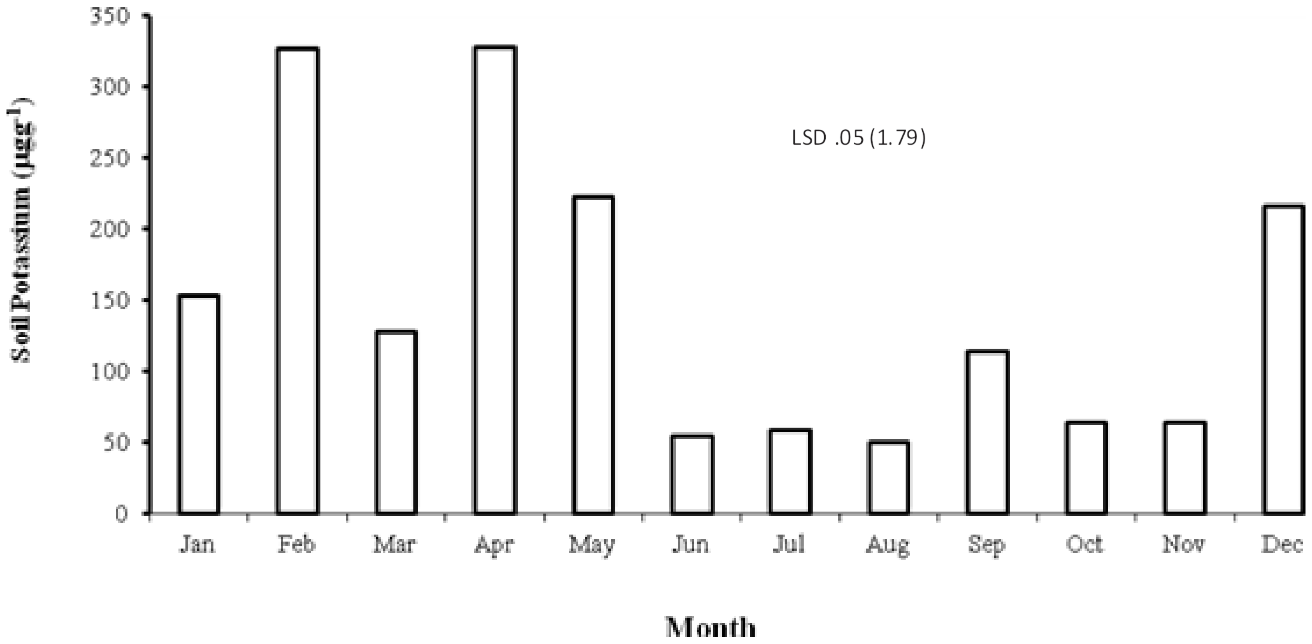


Figure 2c. Annual mean concentration of K^{+} in study microsite soil on Baasiinselberg for period of three consecutive years (n=3)

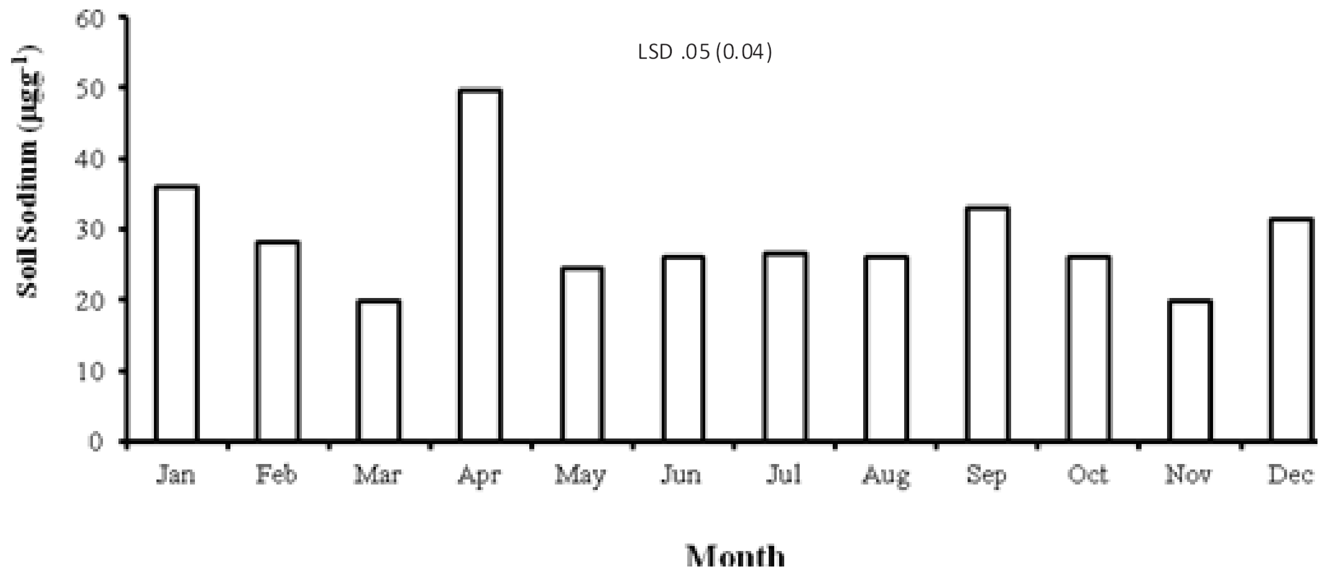


Figure2d. Annual mean concentration of Na^{+} in study microsite soil on Baasiinselberg for period of three consecutive years (n=3)

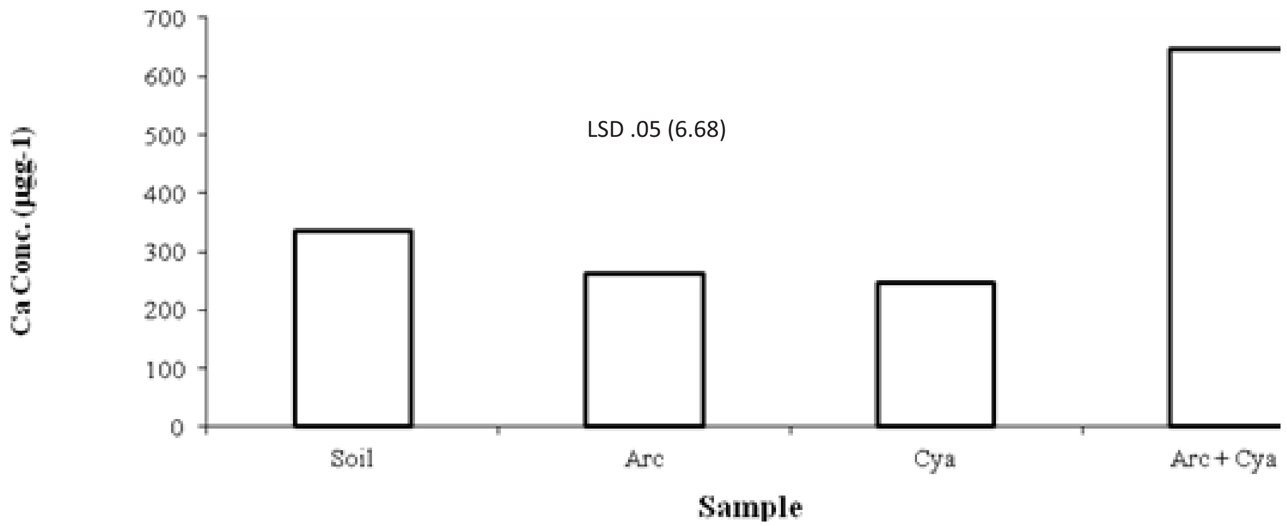


Figure 3a. Uptakes of Ca^{2+} in soil (Ms-1), *A. acanthophyllum* (Arc, Ms-2), *C. lanata* (Cya, Ms-3), Arc + Cya (Ms-4) and on Baasi-inselberg for period of three consecutive years, n=3, Ms=microsite

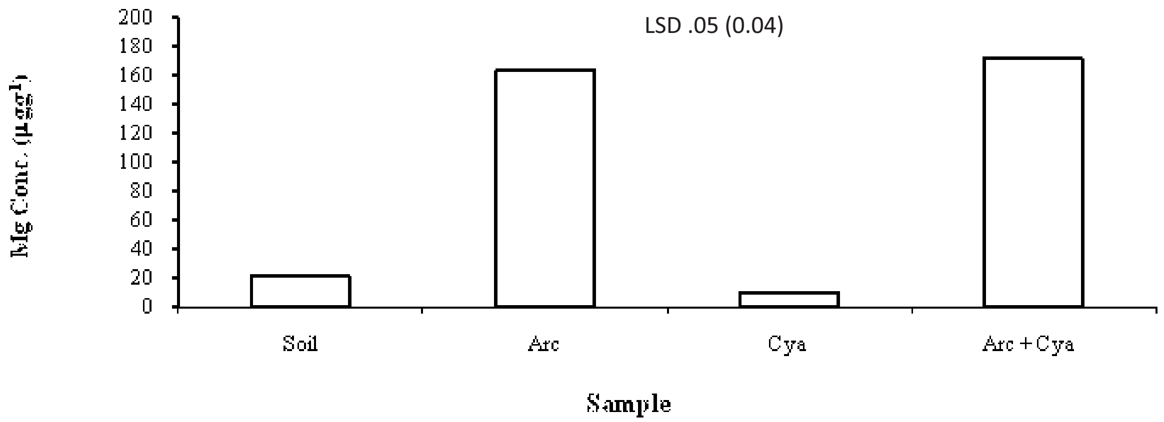


Figure 3b. Uptakes of Mg^{2+} in soil (Ms-1), *A. acanthophyllum* (Arc, Ms-2), *C. lanata* (Cya, Ms-3), Arc + Cya (Ms-4) and on Baasi-inselberg for period of three consecutive years, n=3, Ms=microsite

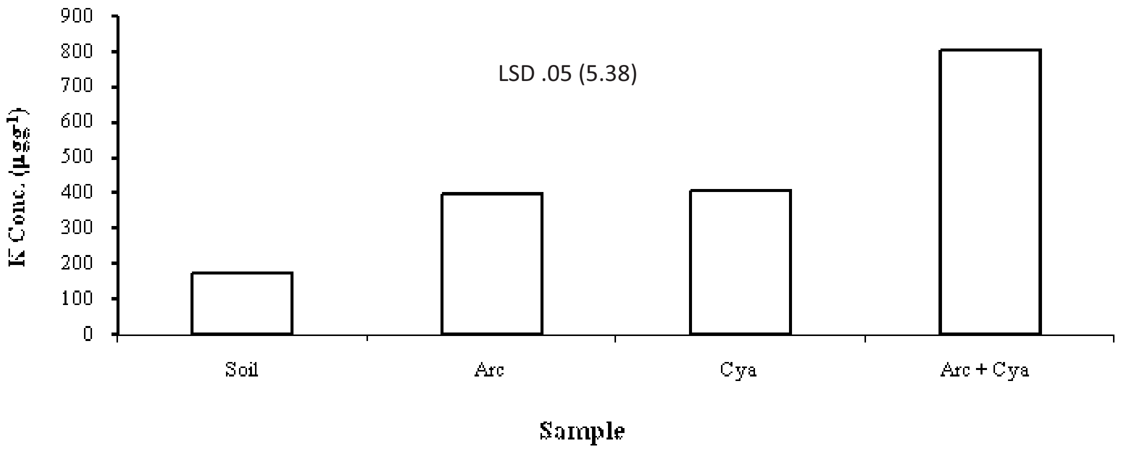


Figure 3c. Uptakes of K^{+} in soil (Ms-1), *A. acanthophyllum* (Arc, Ms-2), *C. lanata* (Cya, Ms-3), Arc + Cya (Ms-4) and on Baasi-inselberg for period of three consecutive years, n=3, Ms=microsite)

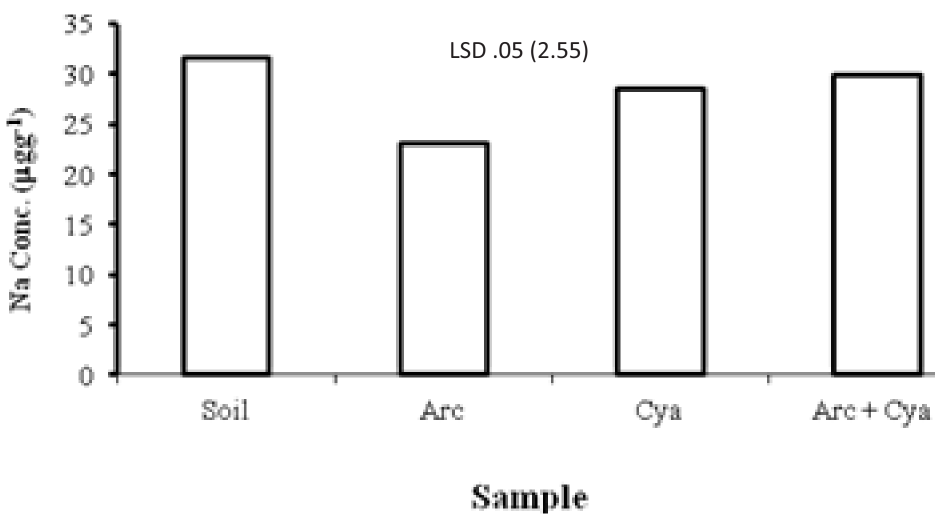


Figure 3d. Uptakes of Na^{+} in soil (Ms-1), *A. acanthophyllum* (Arc, Ms-2), *C. lanata* (Cya, Ms-3), Arc + Cya (Ms-4) and on Baasi-inselberg for period of three consecutive years, n=3, Ms=microsite

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