PARTITIONING OF SOLUBLE CALCIUM IN THE WATER HYACINTH *(EICHHORNIA CRASSIPES* (MARTIUS) SOLMS, IN LAKE VICTORIA, UGANDA.

by
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DECLARATION

I John Robert Stephen Tabuti, declare that this dissertation has never been submitted for a degree in this or any other University or Institution of higher learning. All information presented in this dissertation is the result of my personal work unless otherwise stated.

....

TABUTI JOHN ROBERT STEPHEN Date

We are satisfied that this dissertation is now ready for examination.

....

MR. JUSTUS T. KASHAMBUZI Date

....

DR. GERLARD MAJELA MUTUMBA Date

DEDICATION

To my beloved mother Florence Nakagwa; my darling Veronica Baraza; sister Gorret Nassiwa; brother Sam Mpiira; friends: Emmanuel Magayane Tumuhaise, Kenneth Mulamba and Robert Ottala.

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ABSTRACT

An investigation of soluble calcium partitioning in organs of the water hyacinth was carried out from April 1996 to September 1996 along the shores of L. Victoria bordering Jinja town. Sampling of the water hyacinth was carried out during the wet and dry seasons. The complexometric method was used to determine the concentration of Ca in the water hyacinth. Calcium oxalate was determined from the acid extracts of the water hyacinth. The physico-chemical characteristics of the lake water were also studied. An Atomic Absorption Spectrophotometer was used to determine the concentrations of the principal cations such as Na^{+}, K^{+}, Mg^{2+} and Ca^{2+}. The pH and electrical conductivity of lake water were also determined.

The order of partitioning of Ca in decreasing magnitude in the different organs of the water hyacinth was leaf followed by rhizome, root, petiole and stolon in that order. In both young and mature plants the concentration of oxalate was highest in the leaves, followed by rhizome and lowest in the stolon. The concentration of oxalate in various organs of the water hyacinth were more than twice the soluble Ca in both the young and mature stages of growth.

Soluble Ca decreased with age in all organs of the water hyacinth except in the leaf, while oxalate increased with age in all organs of the water hyacinth, except the rhizome. There were site variations in the partitioning of both Ca and oxalate in the water hyacinth.

LIST OF ACRONYMS

µS cm^{-1}	Micro-Seimens per cm (Units for electrical conductivity)
FM	Fresh Matter of water hyacinth plant material
LSM	Least Squares Means
S.E	Standard Error of the mean

CHAPTER ONE

1.0 INTRODUCTION

The water hyacinth *(Eichhornia crassipes* (Martius) Solms) is a floating aquatic macrophyte belonging to the family Pontederiaceae, order Liliales. It originated from the northern neotropics, from where it spread throughout the tropical and subtropical fresh water regions of the world (Holm *et al*, 1977; Harley, 1990). It was largely spread around the world by man because of its aesthetically pleasing appearance (Holm *et al*, 1977; Harley, 1990). Once in its introduced range, it spread either vegetatively or by seed (Holm *et al*, 1977; Gopal, 1987; Harley, 1990; Cook, 1993).

Temperature has limited its distribution to the tropics and sub tropics (Holm *et al*, 1977; Spencer and Bowes, 1993). Optimum temperature range for water hyacinth growth is 28-30°C. Its growth is inhibited at temperatures lower than 12°C (Denny, 1985).

In the Ugandan part of L. Victoria, South westerly winds blow it from River Kagera to Ugandan waters (Twongo and Balirwa, 1995). The Ugandan side of Lake Victoria which lies between 0° 28'N and 1°S; 31°E and 34°E is especially suitable for the growth of the water hyacinth because of its sheltered shallow bays. It is a very rapid coloniser,

with rapid vegetative growth (Westlake, 1981; Cook, 1993), and spreads very fast in all its introduced ranges (Harley, 1990; Pieterse and Murphy, 1993; Twongo and Balirwa, 1995), forming dense impenetrable mats. Because of this, it causes serious social economic problems in natural and man made water bodies (Holm *et al.* 1977; Musil and Breen 1977b). It obstructs navigation, fouls water by its decomposing products, kills fish by starving them of oxygen, obstructs drainage and flow in canals, interferes with water recreation sports. These problems outweigh the potential benefits like biogas production, raw material for paper and others (Gopal, 1987; Harley, 1990; Twongo *et al*, 1992; Piertese and Murphy, 1993; Twongo and Balirwa, 1995).

The fast growth of the water hyacinth is promoted by many factors. Musil and Breen (1977b) reported that, under optimal growth conditions of light, water, and nutrients the water hyacinth shows rapid vegetative growth. Floating aquatic weeds require more nutrients than submerged weeds, and therefore, show a greater response to eutrophication conditions (Chadwick and Obeid, 1966; Boyd and Vickers, 1971; Rogers and Davis 1972; Reddy, *et al*, 1983; Spencer and Bowes 1993). Water hyacinth grows over a wide range of nutrient levels (Boyd and Vickers, 1971; Desougi, 1984). Deficiency of any macroelement leads to inhibition of growth of water hyacinth (Desougi, 1984). Calcium is one of the macroelements essential to the growth of water hyacinth (Desougi, 1984). Calcium deficiency affects

growth of water hyacinth more than nitrogen or phosphorous (Desougi, 1984). In the absence of Ca the water hyacinth will neither grow nor will it reproduce vegetatively (Desougi, 1984) and even death may occur (Talatala, 1974). Singh *et al* (1984) reported that the optimum Ca concentration for the growth of water hyacinth was 30 mg l^{-1} and that at higher concentrations it promoted biomass increase and multiplication. Oki *et al* (1978) reported that the threshold concentration of Ca for growth of water hyacinth as 5 mg l^{-1}.

Calcium requirement in plants is influenced by the concentration of other cations in the external medium (Wyn Jones and Lunt, 1967). pH also influences the uptake of Ca^{2+}. Okali (1977) reported that low pH makes Ca less available in lake water. At low pH the Ca^{2+} concentration has to be several times higher in order to counteract the adverse effects of high H^{+} concentration on root elongation (Marschner, 1986).

In contrast to other ions, Ca^{2+} to an appreciable extent diffuses into plants passively with water in the transpiratory stream. Calcium is taken up primarily in the youngest root zone where the endodermis is not yet established, to enter the apoplast (Kinzel, 1989). An increase in the concentration of Ca^{2+} in the external solution leads to increase in calcium levels in the leaves but not in organs with low respiratory rates such as fleshy

fruits (Marschner, 1986). Calcium is generally immobile in the phloem and as such it is not transported out of plant leaves, resulting in accumulation with age.

In the cell, Ca outside the cytoplasm is found in the vacuoles or in cell walls. In the cell walls it may be present as either anionic constituents (pectins) or as $CaCO_3$ (Kinzel, 1989). Calcium influences many biochemical and developmental process in plants (Zindler-Frank, 1995). It functions mainly outside the cytoplasm in the apoplast. It is a building block for the cell walls, where it holds together the basic lattice work of pectin in the middle lamella and is a stabiliser in cytoplasmic membranes (Kinzel, 1989). It may act as an enzyme component or as an enzyme effector, a regulator for active substances such as calmodulin, behave as an osmotic component of cell sap. Calcium acts as a protecting agent in the plant against harmful influences of other elements and compounds. (Marschner, 1986; Kinzel, 1989; Fink, 1991). It can protect plants from fungal infections, is involved in cell division and pollen tube growth (Marschner, 1986). Calcium is essential for flowering in the water hyacinth (Talatala, 1974). A general typical symptom of Ca^{2+} deficiency is the disintegration of cell walls and the collapse of the affected tissues, such as petioles and upper parts of stems (Marschner, 1986). Sutcliffe and Baker (1974) related damage of meristematic tissues to Ca deficiency. However, Ca^{2+} may also cause adverse effects in plants. It

precipitates inorganic phosphate in the cells and thus inhibits phosphate based energy metabolism (Fink, 1991). Therefore cytoplasmic concentration of Ca has to be kept very low (<1 µM), the excess Ca^{2+} has to be removed. This is done by actively pumping Ca^{2+} out of the cytoplasm into the vacuole and in some cases precipitating it as Ca-oxalate. Because Ca^{2+} are not mobile in the phloem they are therefore not transported out of the leaves and accumulate with age increasing the need for continuous removal out of the cytoplasm (Fink, 1991). The oxalate ion which binds Ca is widely distributed in the plant world (Kinzel, 1989). It is synthesised inter alia for charge compensation in nitrate reduction in some plants, while others synthesise malate for the same reason (Marschner, 1986).

Calcium influences formation of calcium-oxalate crystals. The number of Ca-oxalate crystals formed depends on calcium supply (Zindler-Frank *et al*, 1988). Work on *Phaseolus vulgaris* leaves by Zindler-Frank (1995) showed that these crystals control the formation of bundle sheath extensions. Low Ca concentration resulted in more palisade parenchyma and less bundle sheath extensions were formed at the adaxial side of minor veins of *P. vulgaris* leaves. Bundle sheath extensions serve as transporting tissues, directing the flow of solutes, including calcium ions, from the xylem predominantly towards the epidermes (Zindler-Frank *et al*, 1988). Another role played by oxalic acid is that by precipitating Ca it makes Ca osmotically neutral

(Marschner, 1986). Ca-oxalate crystals have specific shapes and locations and are, therefore, of taxonomic importance (Fink, 1991). In the water hyacinth palisade and mesophyll tissues of leaves posses raphides needle -like calcium oxalate crystals (Gopal, 1987).

Determining only a fraction of a mineral nutrient of plant tissue contents - for example, the fraction that is soluble in water (water soluble Ca) or in dilute acids (Ca-oxalate) - sometimes gives a better indication of the physiological status of a plant (Marschner, 1986; Kinzel, 1989). On the other hand, total Ca determination portrays the general nutrient status of a plant (Kinzel, 1989). For example, susceptibility of tobacco cultivars B 21 and Ky 10 to Ca deficiency were not related to the total Ca content but to the soluble fraction in the buds (Brumagen and Hiatt, 1966). These differences were caused by differences in the rate of oxalic acid synthesis and thus in the precipitation of little soluble Ca-oxalate. In this case determination of only the soluble fraction would be a more appropriate method for assessing the Ca nutritional status of these cultivars.

There is little literature on the behaviour of Ca in the water hyacinth, yet, Ca^{2+} plays a very central role in the growth and reproduction of this plant (Desougi, 1984). The present work was designed, therefore, to investigate the behaviour of Ca in the water hyacinth growing in the fresh

waters of L. Victoria. The work attempted to find out whether concentration of the physiologically active Ca i.e. water soluble Ca and Ca-oxalate varied in the different organs of the water hyacinth, whether the concentration of water soluble Ca and Ca-oxalate varied in different growth stages of water hyacinth, or whether the concentration of water soluble Ca and Ca-oxalate varied in the tissues of water hyacinth in the dry and wet seasons. This knowledge, it is hoped, will add to the available knowledge of water hyacinth and that it would be of interest to Uganda where our experience of the water hyacinth is limited. The knowledge could also add to the knowledge of the behaviour of Ca in plants.

CHAPTER TWO

2.0 MATERIALS AND METHODS.

2.1 STUDY AREA.

The study area is located in Jinja and lies between 0° 24'N to 0° 30'N and 33° E to 33° 12'E (Atlas of Uganda, 1967). The altitude of Jinja is 1175 m above sea level. Jinja area is receives an annual rainfall ranging between 104.2-183.4 mm (Dept. of Meteorology, 1997). The rains are of the bimodal type, with one rainy season from March to May and another one from September to November.

The soils are derived from gneiss and granite. The soils are of the clay loamy type. The dominant soil type is deep red clay, sometimes laterised. The soil is well drained with a high moisture retaining capacity. It has high phosphate concentrations and base content. It is acidic with a pH of 5-6 Ollier and Harrop (1959).

The vegetation of Jinja area was classified by Langdale-Brown (1960) as Pseudo savanna of mixed savanna woodland climax with moist semi-deciduous forest climax, fire climax tree savanna and fire climax pseudo savanna, consisting mainly of deciduous trees and perennial grasses. The present vegetation at Masese and Wanyange comprises of *Cyperus papyrus* L. *Vossia* spp, *Polygonum* spp, *Setaria* spp, *Cymbopogon* spp, *Chlorophora excelsa* (Welw.) Benth. & Hook,

Combretum spp, *Acacia* spp. Common species in the Dam area are *Pennisetum purpureum* Schumach, *Cymbopogon* spp. *Hyparrhenia dissoluta* (Nees ex Steud) Hubbard, *Lasiurus maitlandii* Stapf. & Hubbard, *Setaria sphacelata* (Schumach.) Stapf. & Hubbard ex Moss, *Themeda triandra* Forsk. Banana plantations and other agricultural crops are common in all sites.

Water hyacinth was sampled from three sites located, at the Owen Falls Dam, Masese and Wanyange fish landings (Figure 1). On the map, the Owen Falls Dam is marked as the Dam site.

Fig 1.Map of study area, showing Owen Falls Dam (1), Masese Fish landing (2) and Wanyange fish landing (3). Inset is a map of Uganda showing Jinja Town.

At the Dam site unlike the other two sites, the water was flowing. On the western side of the Dam three factories, namely Nytil, Nile breweries and Vita Foam industries are located. Masese fish landing has a busy market. It is located on the lower slopes of Masese hill. Its upper slopes are densely populated. There are few toilets in Masese village. In times of run off the beach waters could possibly get polluted. Wanyange is a fish landing that stopped operating when it got clogged up with the water hyacinth. Of the three sites it is the one least likely to be polluted. The study sites are made up of muddy, sheltered and shallow coastline favourable for the growth of the water hyacinth.

2.2 SAMPLING OF THE WATER HYACINTH AND LAKE WATER.

Sampling of the water hyacinth and lake water was done from April 1996 to September 1996. The sampling therefore straddled the wet season from March to May and dry season from June to July, of 1996. Sampling at each site was done once every month. The method of sampling used was the Completely Randomised Design. The sampling area within each site was approximately 5m **x** 100m.

Water samples were collected on the 14th of May and 30th September of 1996. Therefore one collection was made per season.

All sites were reached by a hired motor boat. In every case an experienced fisherman was hired to assist with the piloting of the boat and collection of the water hyacinth. The water hyacinth plants at the three sites were all healthy, showing vigorous growth and were about 1 m in height. They formed a continuous mat on the water surface in all places (Plate 1).

Plate 1.Water hyacinth plants at Masese study site.

They were always collected early in the morning. At each site, three replicates each of both young and mature vegetative stages were picked randomly. The young stage consisted of those plants exhibiting two pale green tender leaves and forward pointing roots (Penfound and Earle, 1948; Musil and Breen, 1977b). The mature vegetative stage was any plant with five or more leaves and one or more mature buds. The sampling areas were selected randomly by throwing a stone as far as it would go. Then three or more plants of either mature vegetative or young growth stages were picked from that area. Three or more plants were picked to compensate for possible damages of water hyacinth specimen on transit. But in all cases, one plant of either stage was picked for analysis. The collected specimens, were placed in polythene bags to reduce transpiration. After picking from one area a stone was thrown to select the second and third sampling areas respectively. The same procedure of collection was used at all sites. After collecting from one whole site, all the specimens were packed in a polythene sack and transported immediately to the laboratory at Makerere University.

2.3 MEASUREMENT OF pH AND CONDUCTIVITY OF LAKE WATER SAMPLES.

Samples of lake water were drawn from all study sites, for physico-chemical analysis. The principal cations and the heavy metals Cu^{2+}, Zn^{2+}, Fe^{2+}, and Mn^{2+} of the lake water were determined in the Soil Science Department of Makerere

University. The Atomic absorption spectrophotometer (Perkin-Elmer 2280) was used to determine the concentration of Ca^{2+}, Mg^{2+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, Mn^{2+} while the Flame photometer (Jenway PFP7) was used to determine the concentration of K^{+} and Na^{+}. The pH of the water at each sampling site was also determined using a pH meter (Aqualytica, model pH 17). The pH was determined because it influences the availability of nutrients in the external medium. The conductivity was determined using a conductivity meter (Hanna Instruments, H9033). Determination of conductivity was important because it gives an indication of the abundance of minerals at a given site of interest.

2.4 PREPARATION OF PLANT EXTRACTS.

Each plant specimen either of the young or mature vegetative stage was divided into leaf, petiole, rhizome, root and stolon components. Each component part of water hyacinth was carefully washed in distilled water. Because of the large number of specimens prepared from any given sampling, it was not possible to analyse all specimens at the same time. Some were therefore kept in clean polythene bags in a refrigerator. Each of the cleaned component part was divided into two portions. The weight of each portion was then recorded. One portion was then used to prepare the water extract and the other, the acid extract.

To prepare the water extracts, one clean and weighed portion from each of the component parts of the water

hyacinth was cut into small pieces using stainless scissors. Stainless steel scissors were used because iron would contaminate the extracts. The cut plant material was then put in boiling distilled water in a ratio of 1g fresh matter: 10ml of water and boiled for a further 3-5 minutes. After cooling down, it was homogenised using a blender and made up to a volume of 250 ml by addition of distilled water in a volumetric flask.

For the preparation of the acid extract, the other portion taken from each organ was treated as for the water extract. However, instead of making up the prepared extract to a volume of 250 ml, concentrated HCl (35.4 %) in a ratio of 1:10 acid HCl to the water extract was added after blending, so as to have a final concentration of 1M HCl. The extracts were then ready for analysis.

In all cases three different extracts from three different plant specimens were prepared. Because all the prepared extracts could not be analysed on the same day, some were kept in thick glass bottles in a refrigerator.

2.4.1 ANALYSIS OF EXTRACTS.

2.4.2 QUALITATIVE TEST FOR CALCIUM.

This test was performed on water extract from each organ of the water hyacinth. Five (5) ml of water extract was poured into each of two clean test tubes. To one, 3ml saturated ammonium oxalate was added, and to the other 3ml

of 10% calcium acetate was added. These were intended to test for the presence of soluble calcium and soluble oxalate, respectively. Formation of a Ca-oxalate precipitate in the first mixture, would indicate presence of much dissolved Ca, and in the second mixture an abundance of soluble oxalate. No precipitate would form when Ca or oxalate are present in equivalent amounts such that all soluble Ca is precipitated (Kinzel, 1989).

2.4.3 DETERMINATION OF CALCIUM AND MAGNESIUM CONTENT IN PLANT EXTRACTS.

To determine the content of both calcium and magnesium in the water and acid extracts of the water hyacinth, the complexometric method as described by Jeffrey *et al* (1989) was used. A volume of 20 ml of water extract was pipetted into a clean beaker. Then 2ml of a buffer of pH 10 made of a mixture of ammonium chloride in ammonia solution was added to the extract in order to bring the pH of the extract to 10, this being the right pH for the complexing of Ca by EDTA. Approximately 1g Mg-EDTA was added to improve the colour change. Eriochrome black-T indicator was then added. The colour changed to pink. This was followed by complexometric titration of 0.005M EDTA against the plant extract using an automatic burette. The end point was detected as a clear blue colour. The same procedure was used for the acid extract, but in this case 4ml of the buffer solution was added in order to attain the desired pH of 10. Three replicate titrations were done on

each extract from each plant organ. Extracts kept in the refrigerator were allowed to stand for about one hour in order to attain a temperature of 20°C.

2.4.4 DETERMINATION OF SOLUBLE Ca AND Ca-OXALATE CONTENT IN EXTRACTS OF THE WATER HYACINTH.

Soluble Ca alone was determined from the extract by precipitating the soluble Ca out of the extract using saturated ammonium oxalate (NH_4-oxalate) solution. For a proper precipitation of soluble Ca from the extract, a concentration of saturated ammonium oxalate more than double the content of both Ca and Mg calculated from above was added. A millilitre of saturated ammonium oxalate solution contains approximately 350 µM. To 20 ml of water extract, 2 ml of saturated ammonium oxalate was added. The mixture was stirred and kept in a refrigerator overnight to complete the precipitation. The extract was then centrifuged at 4,000 revolutions per minute for 15 minutes to separate the precipitate of Ca from the supernatant that contains Mg. The supernatant fluid was carefully pipetted off, after which 2 ml of 1M HCl was added to the precipitate. The mixture of the precipitate and 1M HCl was warmed in a hot water bath to dissolve the precipitate. The dissolved precipitate in the centrifuge tube was diluted with 10 ml of distilled water and poured carefully into a beaker with constant rinsing to remove all the Ca from the centrifuge tube. Then 2 ml of pH 10 buffer (NH_4Cl/NH_3) solution was added for neutralisation to pH 10,

followed by addition of 2 mg of Mg-EDTA to improve colour change. Eriochrome black-T indicator was added and the colour changed to pink. A complexometric titration of 0.005M EDTA solution was done against the Ca. The end point was detected as a clear blue colour.

Acid extracts were treated similarly. However, five (5) ml of saturated calcium acetate was added to the acid extract prior to the addition of saturated ammonium oxalate in order to neutralise the acid extract. This neutralised the extract to a pH of 6, this being the proper pH for the precipitation of Ca species. The precipitation resulting from the addition of saturated ammonium oxalate to the acid extract contained a sum of Ca-oxalate and soluble Ca. The concentration of Ca-oxalate was therefore determined as the difference between soluble Ca determined from the sum of ca-oxalate and soluble Ca. Three replicate samples of both water and acid extracts of all organs of the water hyacinth were used throughout the period of study.

The following methods were used to calculate the concentration of Ca and Mg or Ca alone in the extracts.

i) **x** grammes of fresh matter (FM) of water hyacinth were contained in 250 ml of extract. This meant that each ml of extract contained **x**/250 g FM of water hyacinth.

ii) 20 ml of extract was pipetted off for titration. The 20 ml contained **x**/(250 × 20) or **x** × 0.08 g of FM of water hyacinth.

iii) The molar amount of Ca or Ca and Mg in µmole in 20 ml of extract was given by the product of the titrated volume of 0.005M EDTA multiplied by 5 µmole. Five being the concentration of EDTA. This was because each mole of EDTA binds one mole of Ca and Mg or Ca alone.

iv) The molar amount of Ca or Ca and Mg in 20 ml of extract (iii. above) was divided by the amount of fresh matter (g) of water hyacinth in 20 ml of extract (ii. above) to determine the concentration of Ca or Ca and Mg in µmole/g FM, water hyacinth.

2.4.5 ANALYSIS OF RESULTS

Statistical data analysis was carried out using the computer software SAS/STAT. The General Linear Models (GLM) Procedure was used for ANOVA analysis, following the SAS/STAT® User's guide (1988). Means were separated by the Least Squares Means method.

CHAPTER THREE

3.0 RESULTS

3.1 PHYSICO-CHEMICAL CHARACTERISTICS OF THE LAKE WATER.

The pH at the three study sites ranged from a mean of 7.1 ± 0 to 8.5 ± 0.03 for Masese and the Dam, respectively for both the wet and dry seasons (Table 1). There was no seasonal variation in the pH of the water (P>0.05, LSM). On the other hand, the pH was highest at the Dam site and lowest at Masese (P<0.05, LSM).

Table 1. Mean pH, conductivity (µS cm^{-1}), and concentration of Ca^{2+}, K^{+}, Na^{+} and Mg^{2+} in µmole l^{-1} in the lake water for the three study sites, for the wet and dry seasons, presented as a mean of three readings ± S.E.

SEASON	WET			DRY		
SITE	DAM	WANYANGE	MASESE	DAM	WANYANGE	MASESE
pH	8.5 ± 0.12	8.3 ± 0.06	7.1 ± 0.01	8.5 ± 0.03	8.3 ± 0.17	7.1 ± 0.06
Conductivity (µS/cm)	92 ± 0.58	96 ± 1.00	94.3 ± 0.33	82 ± 1.00	83 ± 0.67	84 ± 1.00
Ca^{2+}	112.7 ± 1.45	110.3 ± 1.45	107.7 ± 1.45	103.3 ± 1.67	108.3 ± 1.67	103.3 ± 1.67
K^{+}	89.74 ± 1.48	88.89 ± 1.71	90.6 ± 0.86	87.18 ± 0.01	90.6 ± 3.42	88.89 ± 1.71
Na^{+}	360.9 ± 2.51	356.5 ± 2.51	359.4 ± 1.47	353.6 ± 1.43	357.97 ± 1.47	360.9 ± 0.01
Mg^{2+}	62.5 ± 2.41	58.33 ± 2.40	58.33 ± 0.01	62.5 ± 2.41	58.33 ± 2.40	59.7 ± 2.78

The conductivity at the three study sites ranged from the lowest value of 92 ± 0.58 to the highest value of 96 ± 1.00

micro Siemens per centimetre (µS cm^{-1}) for the Dam and Wanyange, respectively, in the wet season (Table 1). Likewise, in the dry season, the Dam site had the lowest conductivity of 82 ± 1 µS cm^{-1} while Masese had the highest conductivity of 84 ± 1 µS cm^{-1}. The Dam site had a higher conductivity than the other two sites ($P<0.05$, LSM). Conductivity was significantly higher during the wet season for all sites ($P<0.05$, LSM).

During the wet season, Na^{+} with a concentration ranging from 356.94 ± 2.51 to 360.9 ± 2.51 µmole l^{-1} was the most abundant ion, followed by Ca^{2+} with values from 107.7 ± 1.45 to 112.7 ± 1.45 µmole l^{-1}, K^{+} with values ranging from 88.89 ± 1.71 to 90.6 ± 0.86 and Mg^{2+} with 58.33 ± 2.4 to 62.5 ± 2.41 µmole l^{-1} in that order (Table 1). Similarly in the dry season, Na^{+} ion had the highest concentration with values ranging from 353.6 ± 1.43 to 360.9 ± 0.01 µmole l^{-1}, followed by Ca^{2+} with values from 103.3 ± 1.67 to 108.3 ± 1.67 µmole l^{-1}, K^{+} with 87.18 ± 0.01 to 90.6 ± 3.42 µmole l^{-1} and Mg^{2+} with 58.33 ± 2.4 to 62.5 ± 2.41 µmole l^{-1} in that order. The concentrations of Ca^{2+} and Na^{+} ions were significantly higher in the wet season ($P<0.05$, LSM). The concentrations of the principal cations were not significantly different between sites ($P>0.05$, LSM).

The method used to test for the heavy metals Cu^{2+}, Zn^{2+}, Fe^{2+}, and Mn^{2+} was not sensitive enough to detect them in the lake water.

3.2 QUALITATIVE TEST FOR Ca AND OXALATE

Extracts from all organs of water hyacinth for both stages of growth did not precipitate with either Ca-acetate or saturated ammonium oxalate solution.

3.3 THE EFFECT OF SEASON ON THE DISTRIBUTION OF Ca AND Ca-OXALATE IN DIFFERENT ORGANS OF THE WATER HYACINTH.

In the wet season the concentration of Ca in organs of the water hyacinth ranged from a mean of 2.6 ± 0.84 to 15 ± 0.72 µmole g^{-1} FM in the stolon and leaf, respectively (Figure 2). The petiole, root and rhizome had values falling between these two extremes in ascending order.

In the dry season the concentration of Ca in organs of the water hyacinth ranged from 3.3 ± 0.7 to 14.6 ± 0.72 µmole/g FM for the stolon and leaf, respectively. The concentration of Ca in the rhizome was second to that in the leaf, followed by the root and petiole in that order. There was no seasonal variation for all organs in their Ca concentration ($P>0.05$, LSM).

In the wet season the oxalate concentration in organs of the water hyacinth ranged from a mean of 3.6 ± 2.38 to 44.9 ± 1.95 µmole g^{-1} FM in the stolon and leaf, respectively.

The root, petiole and rhizome had values falling between these two extremes in ascending order.

Fig 2.Ca and oxalate concentration in different organs of the water hyacinth in the wet and dry seasons.

In the dry season the concentration of oxalate in organs of the water hyacinth ranged from 4.3 ± 1.95 to 34.3 ± 1.95 µmole/g FM water hyacinth for the stolon and leaf respectively. The concentration of oxalate in the rhizome was second to that in the leaf, the rhizome was followed by the petiole and root in that order.

The oxalate concentration in the leaf was higher in the wet season than in the dry season ($P<0.05$, LSM). There was no significant seasonal variations in the partitioning of oxalate in the other organs ($P>0.05$, LSM).

3.4 THE EFFECT OF SITES ON THE DISTRIBUTION OF Ca AND OXALATE IN DIFFERENT ORGANS OF THE WATER HYACINTH.

The concentration of Ca in organs of the water hyacinth plants from the Dam ranged from a mean of 2.6 ± 1.01 to 16.8 ± 0.85 µmole g^{-1} FM in the stolon and leaf, respectively (Figure 3). The root, petiole and rhizome had values falling between these two extremes in ascending order. At Masese the Ca concentration ranged from a mean of 3.3 ± 0.85 to 11.7 ± 0.89 µmole g^{-1} FM in the stolon and leaf respectively, while at Wanyange the range was from a mean of 2.91 ± 0.94 to 15.9 ± 0.89 µmole g^{-1} FM in the stolon and leaf respectively. At Masese and Wanyange the

petiole, root and rhizome had values falling between these two extremes in ascending order.

Fig 3.The Ca concentration in different organs of the water hyacinth at different sites.

The Ca concentration in the leaf, petiole and rhizome was higher at the Dam site than at the other two sites ($P<0.05$, LSM). However, the concentration of Ca in the root and stolon was not significantly different between sites ($P>0.05$, LSM).

The oxalate concentration in organs of the water hyacinth plants from the Dam ranged from a mean of 5.73 ± 2.78 to 51.0 ± 2.36 µmole g^{-1} FM in the stolon and leaf, respectively(Figure 4). At Masese the oxalate concentration ranged from a mean of 3.3 ± 2.31 to 30.8 ± 2.42 µmole g^{-1} FM in the stolon and leaf respectively. At the Dam and Masese the root, petiole and rhizome had values falling between these two extremes in ascending order.

Fig 4.The oxalate concentration in different organs of the water hyacinth at different sites.

At Wanyange the range was from a mean of 2.8 ± 2.88 to 37.8 ± 2.42 µmole g^{-1} FM in the stolon and leaf, respectively. The root, rhizome and petiole had values falling between these two extremes in ascending order.

Oxalate concentration in the leaf, petiole, rhizome and root was higher at the Dam than at the other two sites ($P<0.05$, LSM). However, the concentration of oxalate in the stolon was not significantly different between sites ($P>0.05$, LSM).

3.5 THE EFFECT OF GROWTH STAGE ON THE DISTRIBUTION OF Ca AND OXALATE IN DIFFERENT ORGANS OF THE WATER HYACINTH.

At the young growth stage, Ca concentration in tissues of water hyacinth ranged from a mean of 4.2 ± 0.72 to 12.4 ± 0.72 µmole g^{-1} FM in the stolon and leaf respectively (Figure 5). The petiole, root and rhizome had values falling between these two extremes in ascending order. The Ca concentration in young leaves and rhizomes was not significantly different ($P>0.05$, LSM) though, both these organs contained more Ca than the other organs ($P<0.05$, LSM).

In older plants of water hyacinth the trend was similar to that of the young plants. Ca concentration ranged from 1.7 ± 0.82 to 17.2 ± 0.72 µmole/g FM water hyacinth for the stolon and leaf respectively. Concentration of Ca in old leaves were significantly higher than for the other organs ($P<0.05$, LSM). Older leaves contained significantly more Ca than young ones ($P<0.05$, LSM). In the rhizome and stolon the Ca concentration declined significantly with age of the water hyacinth ($P<0.05$, LSM), while the reduction was non significant in the petiole and root with age ($P>0.05$, LSM).

Fig 5.Ca and oxalate concentration in different organs of the water hyacinth of different ages.

The oxalate concentration at the young stage varied from 3.2 ± 2.12 to 36.5 ± 1.95 µmole g^{-1} FM in the stolon and leaf, respectively. The oxalate concentration in the rhizome was second to that of the leaf, followed by the petiole and root in that order. The leaf at the young growth stage contained significantly more oxalate than the other organs ($P<0.05$, LSM). The concentration of oxalate was not significantly different in the petiole and rhizome ($P>0.05$, LSM), but was more than that of the other organs ($P<0.05$, LSM). The root and stolon were not significantly different at the young growth stage in their oxalate concentration ($P>0.05$, LSM).

In older plants the oxalate concentration ranged from 4.7 ± 2.24 to 42.7 ± 1.95 µmole g^{-1} FM water hyacinth for the stolon and leaf, respectively. The rhizome, petiole and root fell between these two extremes in ascending order. Leaves of older plants contained significantly more oxalate than the other organs ($P<0.05$, LSM). The petiole and rhizome were not significantly different ($P>0.05$, LSM), but contained more than for the other organs ($P<0.05$, LSM).

The root and stolon were not significantly different at the mature growth stage ($P>0.05$, LSM).

Older leaves contained more oxalate than young ones ($P<0.05$, LSM). But in the petiole, root and stolon there was no significant increase in the oxalate concentration with age ($P>0.05$, LSM). In the rhizome there was a nonsignificant decrease in oxalate concentration with age of the water hyacinth ($P>0.05$, LSM).

The oxalate concentration in leaves of the water hyacinth of both growth stages was approximately three times that of Ca. In the young petiole the oxalate concentration was twice that of Ca, while older petioles had three times as much. For the young rhizome and stolon the oxalate concentration was approximately equal to that of Ca, but twice that of Ca at the mature stage of growth. In the root, the concentration of oxalic acid was about equal to that of Ca for both growth stages.

CHAPTER FOUR

4.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 PHYSICO-CHEMICAL FACTORS OF THE LAKE WATER

4.1.1 pH

The measured pH range of 7.1 to 8.5 of the water of lake Victoria, agrees well with that observed by Talling and Talling (1965). According to Chadwick and Obeid (1966) a pH greater than 8.2 inhibits the growth of water hyacinth. However, in this study, the water hyacinth plant showed vigorous growth in all the study sites where the pH ranged from 7.1 to 8.5. This probably meant that pH within the range measured and the prevailing conditions of the shallow and sheltered bays of L. Victoria had little effect on the growth of water hyacinth

4.1.2 CONDUCTIVITY, MINERAL NUTRIENTS AND THEIR EFFECTS ON GROWTH OF THE WATER HYACINTH

The measured conductivity in L. Victoria waters was lower than that reported by Denny (1985) of 105 µS cm^{-1}. According to Denny (1985), this conductivity characterises a lake poor in mineral nutrients. Talling and Talling (1965) also reported that lake Victoria has a low ionic concentration. It would therefore seem that in L. Victoria the water hyacinth would show poor vegetative growth which was not the case. The reason why it grew well under the prevailing conditions was probably because it has a capacity to grow within a wide range of nutrient

concentrations. This idea seems to gain credence from Singh *et al* (1984). Singh *et al* (1984) reported that the water hyacinth could grow well in nutrient concentrations of conductances ranging from 87 to 8522 µS cm^{-1}. The observed trend of the principal cations of sodium being more abundant followed by Ca^{2+}, K^{+} and Mg^{2+} ions in that order agrees with that reported by Talling and Talling (1965). A trend such as this is thought to be representative of waters enriched by biogeochemical activities (Musil and Breen, 1977a). This means that surface runoffs probably contributed only a minimal effect to the mineral status of the lake.

It was observed that there was no significant variation in mineral nutrients between seasons except for Ca^{2+}. The lake possessed more Ca^{2+} in the wet season than the dry season. As such L. Victoria would not be expected to be influenced by seasonal cycles of wet and dry seasons. Talling and Talling (1965) also observed no seasonal changes in the ionic composition of Lake Victoria. They attributed this to the large volume of the lake which buffers it against any short period inflow of principal ions. This lack of variation in concentrations of major ionic composition and pH with season may explain the lack of significant seasonal variation in the Ca concentration in organs of the water hyacinth.

The concentration of Ca^{2+} measured in the lake water was lower than that reported by Singh *et al* (1984) for optimum growth of the water hyacinth. Singh *et al* (1984) reported the optimum concentration of Ca for the growth of water hyacinth to be 30 mg l^{-1} or 750 µmole l^{-1}. This would therefore imply that the observed concentration of Ca at the study sites would not have been ideal for the growth of the water hyacinth. However, water hyacinth showed vigorous growth in L. Victoria. The reason for the good growth of the water hyacinth could have been because this work was carried out in a natural environment as opposed to work by Singh *et al* (1984) done under laboratory conditions. Under natural conditions there is bound to be constant replenishment of nutrients through a constant mixing of the lake water and inflow of surface runoff.

4.2 CALCIUM AND OXALATE PARTITIONING IN DIFFERENT ORGANS OF THE WATER HYACINTH IN THE WET AND DRY SEASONS

Results showed that there were no seasonal variation in the partitioning of soluble Ca and oxalate in different organs of the water hyacinth. This was probably because the lake water quality and quantity did not vary much between the wet and dry season. Accordingly, Ca absorption and assimilation by water hyacinth was not affected by seasonal cycles.

4.3 CALCIUM ABSORPTION AND DISTRIBUTION OF OXALATE IN THE WATER HYACINTH FROM DIFFERENT SITES

The concentration of Ca^{2+} ions and other alkaline earth metals was similar over all the sites studied. Despite this, organs of plants sampled from the Dam site contained significantly more soluble Ca and oxalate than those sampled from Wanyange and Masese study sites. This may have been because of two reasons. One; the Dam unlike the other two sites had flowing water. Boyd and Vickers (1971) and Denny (1985) stated that flowing waters provide a continuous replacement of nutrients. Two; the Dam site unlike the other two sites did not have a surrounding swamp. Swamps are known to remove nutrients from runoff waters (Omagor, 1997). Organs of the water hyacinth from both Wanyange and Masese sites which had surrounding swamps had similar concentrations of soluble Ca and oxalate in their tissues but, lower than those from the Dam.

4.4 CONCENTRATION OF Ca AND OXALATE IN THE WATER HYACINTH

Extracts from all organs of water hyacinth for both stages of growth did not precipitate with either Ca-acetate or saturated ammonium oxalate. This meant that they contained very little amounts of both soluble Ca and oxalate, not detectable by the method used.

4.5 THE EFFECT OF GROWTH STAGES ON SOLUBLE Ca AND OXALATE PARTITIONING IN ORGANS OF THE WATER HYACINTH

Old leaves contained more Ca than all the other organs, while the concentration of Ca in young leaves was similar to that in the rhizome. The Ca concentration in leaves was higher probably because it primarily transported with the water flow of transpiration. On the other hand, its movement is severely restricted in the phloem interfering with subsequent redistribution to other organs in plants (Mengel and Kirkby, 1982).

The concentration of Ca in the old rhizome was second to that in the leaf. This was possibly because the rhizome required a lot of Ca to support the production of other organs. The rhizome is known to produce all the roots, leaves, offshoots and inflorescence of the plant (Penfound and Earle, 1948). Therefore Ca could have been transported and stored preferentially in this organ. Growing points preferentially accumulate Ca even though the rate of transpiration at these points is lower than in older leaves (Mengel and Kirkby, 1982).

Older leaves contained more Ca than young ones. The same trend has been reported by Mengel and Kirkby (1982) and Kinzel (1989). These workers explained that Ca is primarily transported to the leaves in the transpiratory stream, while being relatively immobile in the phloem. Therefore over time it accumulates in the leaf. In the

rhizome and stolon the Ca concentration decreased with age of the water hyacinth. This may have come about as a result of the biomass of the plant increasing relatively faster than the Ca uptake. In this case the Ca concentration would seem to fall with increasing age of the plant whereas this may not be necessarily true.

Oxalate increased with age in all organs of the water hyacinth except the rhizome. This was possibly because higher plants cannot dissolve oxalate, which would then accumulate with time (Kinzel, 1997 *Pers. comm*).

Generally for the leaf, petiole and rhizome the oxalate concentration was more than twice that of Ca. This would imply that these organs of the water hyacinth were stimulated to synthesise oxalic acid by the presence of Ca in excess of their needs. Kinzel (1989) and Fink (1991) have reported that some species of plants taking up Ca in excess of their needs are stimulated to synthesise oxalic acid.

4.6 CONCLUSIONS

The water hyacinth grew very well under the conditions prevailing in the shallow shores of L. Victoria. There was differential accumulation of soluble Ca in the various organs of the water hyacinth. Ca in organs of the water hyacinth varied between sites, but not between seasons. Soluble Ca concentration increased in the leaf while it

decreased in the rhizome and stolon with age of water hyacinth. Oxalate concentration in all organs, apart from the rhizome increased with increasing age of the water hyacinth.

4.7 RECOMMENDATIONS

It was observed that the water hyacinth grew in conditions which according to other workers are not favourable to its growth. For instance, L. Victoria which is low in mineral nutrients would not have favoured the observed vigorous growth of water hyacinth, on the contrary the water hyacinth grew very well. This implies that other factors may have been responsible. Future work could therefore, investigate what other factors contributed to this vigourous growth. Future research could also focus on population and nutrient dynamics of the water hyacinth. In this regard the effect of agricultural, industrial and sewage treatment activities could be investigated.

REFERENCES

ATLAS OF UGANDA, 1967. Department of Lands and Surveys, Uganda. 2nd ed.

BOYD, C.E. and VICKERS, D.H. 1971. Variation in the elemental content of *Eichhornia crassipes*. *Hydrobiologia,* **vol 38 3-4**: pp 409-414.

BRUMAGEN, D.M. and HIATT, A.J., 1966. The relationship of oxalic acid to the translocation and utilisation of calcium in *Nicotiana tabacum. Plant Soil* **24:** 239-249.

CHADWICK, M.J. and OBEID, M. 1966. A comparative study of the growth of *Eichhornia crassipes* Solms. and *Pistia stratiotes* L. in water culture. *Journal of Ecology* **54**: 563-575.

COOK, C.D.K. 1993. Origin, autecology, and spread of some of the world's most troublesome aquatic weeds. In *Aquatic weeds: the ecology and management of nuisance aquatic vegetation*. Pieterse A.H. and Murphy K.J. (ed) Oxford University Press, p31-38.

DENNY, P. 1985. Submerged and floating-leaved macrophytes (euhydrophytes). In *The ecology and management of African wetland vegetation*. Denny, P. (ed). Dr. W. Junk, 19-42.

DEPARTMENT OF METEOROLOGY, 1997. Unpublished data.

DESOUGI, L.A. 1984. Mineral nutrient demands of the water hyacinth (*Eichhornia crassipes* (Mart.) Solms) in the white Nile. *Hydrobiologia* **110:** 99-108.

FINK, S. 1991. Comparative microscopical studies on the patterns of calcium oxalate distribution in the needles of various conifer species. *Bot. Acta* **104:** 306-315.

GOPAL, B. 1987. *Water hyacinth. Aquatic Plant Studies 1.* Elsevier, Amsterdam.

HALLER, W.T. and SUTTON, D.L. 1973. Effect of pH and high phosphorous concentrations on growth of water hyacinth. *Hyacinth Control Journal,* **11:** 59-61.

HARLEY, K.L.S. 1990. The role of biological control in the management of water hyacinth, *Eichhornia crassipes. Biological News and Information* **Vol.11 (1)**. pp11-22.

HOLM, L.G., PLUCKNETT, D.L., PANCHO, J.V.,AND HERBERGER, J.P. 1977. *The world's worst weeds: Distribution and biology.* University Press of Hawaii, Honolulu.

JEFFREY, G.H., BASSETT, J., MENDHAM, J. and DENNEY, R.C. 1989. *Vogel's Textbook of quantitative chemical analysis.* 5th ed. Longman Scientific and Technical.

KINZEL, H. 1989. Calcium in the vacuoles and cell walls of plant tissue. Forms of deposition and their physiological and ecological significance. *Flora* **182:** 99-125.

KINZEL, H. 1997. *Pers. comm.*

MARSCHNER, H. 1986. *Mineral nutrition in higher plants.* Academic Press Inc., London.

LANGDALE-BROWN, I., 1960. *The vegetation of Uganda (excluding Karamoja).* Memoirs of the research division, series 2, vegetation. Number 6.

MENGEL, K. and KIRKBY, E.A. 1982. *Principles of Plant Nutrition.* 3rd ed. International Potash Institute, Bern, Switzerland.

MUSIL, C.F. and BREEN, C.M. 1977a. The influence of site and position in the plant community on the nutrient distribution in and content of *Eichhornia crassipes* (Mart.) Solms. *Hydrobiologia* **53(1):** 67-72.

MUSIL, C.F. and BREEN, C.M. 1977b. The application of growth kinetics to the control of *Eichhornia crassipes* (Mart) Solms. through nutrient removal by mechanical harvesting. *Hydrobiologia vol*. **53(2):** 165-171.

OKALI, D.U.U. and ATTIONU, R.H. 1974. The quantities of some nutrient elements in *Pistia stratiotes L.* from the Volta lake. *Ghana Jnl Agric. Sci.* **7:** 203-208.

Oki, Y.,Ito, M. and Ueki, K. 1978. Studies on the growth and reproduction of water hyacinth, *Eichhornia crassipes* (Mart.) Solms. 1. Effect of nutrients on the growth and reproduction. *Weed res., Tokyo* **23:** 115-120.

OLLIER, C.D. and HARROP, J.F., 1959. *The soils of the Eastern Province of Uganda. A reconnaissance Survey.* Memoirs of the research Division. Series 1 - Soils, No 2. Kawanda Research Station.

OMAGOR, N. 1997. Wetlands and the people. Paper presented during the celebrations marking World Wetlands day at Makerere University on 2nd February, 1997.

PENFOUND, W.T. and EARLE, T.T. 1948. The biology of the water hyacinth. *Ecol. Monogr. 18: 447-472.*

PIETERSE, A.H. and MURPHY, K.J. 1993.(ed). *Aquatic weeds: The ecology and management of nuisance aquatic vegetation*. Oxford University Press.

REDDY, K.R., SUTTON, D.L., and BOWES, B. 1983. Fresh water aquatic plant biomass production in Florida. *Soil Crop Science Florida Proceedings* **42:** 28-40.

ROGERS, H.H. and DAVIES, D.E. 1972. Nutrient removal by water hyacinth. *Weed Science* **20:** 423-8.

SAS INSTISTUTE INC. 1988. *SAS/STAT® User's Guide, Release 6.03 Edition.* Cary, NC: SAS Institute Inc., 1988.

SINGH, H.D., NAG, B.,SARMA, A.K., and BARUAH, J.N. 1984. Nutrient control of water hyacinth growth and productivity. In G. Thyagarajan (Ed) Proc. Int. Conf. Water Hyacinth. UNEP, Nairobi p243-263.

SPENCER, W. and BOWES, G. 1993. Ecophysiology of the world's most troublesome aquatic weeds. In *Aquatic weeds, the ecology and management of nuisance aquatic vegetation*. Pieterse H. A and Murphy J. Kevin, (ed). Oxford University Press p39-73.

SUTCLIFFE, J.E. and BAKER, D.A., 1974. *Plants and Mineral salts.* Edward and Arnold, London.

TALATALA, R.L. 1974. Some aspects of the growth and reproduction of water hyacinth *(Eichhornia crassipes* (Mart.) Solms. Southeast Asian Workshop on aquatic Weeds, Malang, June 1974. mss. 27pp.

TALLING, J.F. and TALLING, I.B., 1965. The chemical composition of African Lake waters. *Int. Revue ges. Hydrobiol.* **50**(3):421-463.

TWONGO, T., BUGENYI, F.W.B., and WANDA, F. 1992. The potential for further proliferation of water hyacinth in lake Victoria and Kioga and some urgent aspects for research. In proceedings of the CIFA sub-committee for management and development of the fisheries of lake Victoria, 6th session, Jinja Uganda.

TWONGO, T. and BALIRWA, S.J. 1995. The water hyacinth problem and the biological control option in the highland lake basin, Uganda,s experience. In proceedings of "Comprehensive water resources development of the Nile basin, taking off."

WADE, P.M. 1993. General biology and ecology of aquatic weeds. In *Aquatic Weeds, The Ecology and Management of Nuisance Aquatic Vegetation*. Pieterse, H.A. and Murphy, J. (Ed). Oxford University Press p17-30.

WESTLAKE D.F. 1963. Comparisons of plant productivity. *Biological reviews,* **38:** 385-425.

WYN JONES, R.G. and LUNT, O.R. 1967. The function of calcium in plants. *Bot. Rev.* **33:** 407-426.

ZINDLER-FRANK, E., WICHMANN, E., and KORNELI, M. 1988. Cells with crystals of Calcium Oxalate in the leaves of *Phaseolus vulgaris*-a comparison with those in *Canavalia ensiformis*. *Botanica Acta* **101:** 246-253.

ZINDLER-FRANK, E. 1995. Calcium, Calcium oxalate crystals, and leaf differentiation in the common bean (*Phaseolus vulgaris* L.) *Bot. Acta* **108:** 144-148.

APPENDICES

APPENDIX I. VOLUME (ML) OF EDTA TITRATED AGAINST PRECIPITATES OF ACID EXTRACTS AND AMMONIUM OXALATE OF COMPONENTS PARTS OF WATER HYACINTH.

DATE AND SITE			Replicate 1		Replicate 2		Replicate 3	
	STAGE	ORGAN	FM	Vol.	FM	Vol.	FM	Vol.
		Leaf	5.01	5.35	1.4	2	2.59	3
Dam		**Petiole**	8.78	4.85	6.61	2	4.91	3
	Young	**Rhizome**	2.54	2.35	2.06	1.1	2.6	1.5
14th/4/96		**Root**	0.19	0.3	2.16	0.6	0.74	0.2
		Stolon	18.68	3.3	7.42	1	8.7	1.8
		Leaf	5.02	5.75	5.96	5.53	4.05	4.5
	Mature	**Petiole**	15.46	10.08	17.38	7	11.21	5
		Rhizome	20.52	12.93	24.64	11.83	18.96	5
		Root	34.14	-	11.45	1.7	20.18	-
		Stolon	7.88	2	-	-	-	-
Masese		**Leaf**	5	2.02	6.63	4.9	4.09	2.85
		Petiole	11.4	2.25	17.07	3.58	18.92	4.08
28th/4/96	**Young**	**Rhizome**	2.08	0.75	4.76	1.55	2.44	0.92
		Root	1.36	0.18	1.98	0.18	1.01	0.1
		Stolon	9.28	0.68	14.91	1.78	9.31	0.77

		Leaf	9.97	10.25	7	4.02	4.71	3.03
	Mature	**Petiole**	27.7	8.73	12.75	2.58	10.61	3.52
		Rhizome	18.84	6.4	6.82	1.43	3.46	1.07
		Root	33.84	7.22	15.36	0.93	9.59	0.78
		Stolon	13.49	1.75	29.5	2.45	14.67	1.25
Wanyange		**Leaf**	1.53	0.82	6.05	3.63	3.69	2.52
		Petiole	4.3	0.88	12.68	3.65	8.92	2.33
14th/5/96	**Young**	**Rhizome**	2.12	0.55	2.86	1.1	2.08	0.52
		Root	1.78	0.18	1.05	0.18	2.3	0.15
		Stolon	13.22	0.4	13.2	1.4	17.89	0.65
		Leaf	4	7.1	7.03	5.45	5.33	8.83
		Petiole	20.55	4.1	25.23	6.6	24.32	5.25
	Mature	**Rhizome**	12.29	4.45	9.28	2	17.01	6.25
		Root	8.73	1.13	9.51	0.73	23.3	2.7
		Stolon	10.9	0.7	20.03	0.38	11.87	0.98
Masese		**Leaf**	3	2	3.38	1.7	3.6	2.63
		Petiole	11.53	2.5	9.66	2	9.6	1.9
14th/6/96	**Young**	**Rhizome**	1.37	0.9	1.69	0.6	1.95	0.7
		Root	0.75	0.1	1	0.08	1.4	0.1
		Stolon	5.27	0.7	5.22	0.5	6.45	1
		Leaf	2.96	2.08	2.62	2	3.21	1.8

	Mature	**Petiole**	17.83	4.4	23.49	5.5	15.58	3
		Rhizome	6.32	2.1	7.52	3	4.1	1.1
		Root	13.13	1.75	9.66	2.43	6.6	2.2
		Stolon	25.3	2.92	13.64	1.5	18.62	1.4
		Leaf	1.67	0.47	2.09	1.68	1.34	1.12
Wanyange		**Petiole**	7.51	1.03	3.1	1	2.01	0.88
	Young	**Rhizome**	2.79	1	1.96	1.15	3.55	2
28th/6/96		**Root**	2.69	0.28	1.69	0.15	4.43	0.5
		Stolon	7.88	0.75	5.13	-	4.74	0.75
		Leaf	6.14	4.55	2.94	2.03	4.6	3.1
		Petiole	19.84	5.95	17.25	5.53	10.18	2.48
	Mature	**Rhizome**	9.95	2.38	10.47	4.7	9.93	3.33
		Root	16.87	1.65	18.97	3.67	10.99	1.28
		Stolon	17.48	1.6	20.08	2.77	16.75	1.77
Dam		**Leaf**	2.52	2.37	1.58	1.68	3.67	3.4
		Petiole	4.74	1.47	4.72	1.42	6.25	2.08
17th/7/96	**Young**	**Rhizome**	2.24	1.32	2.7	1.52	2.59	1.6
		Root	0.88	0.18	0.28	0.07	0.38	0.1
		Stolon	9.62	1.03	4.85	0.57	5.61	0.62
		Leaf	6.47	6.5	7.45	8.77	5.81	6.07
	Mature	**Petiole**	12.3	5.07	11.4	5.07	15.25	6.05

Rhizome	19.77	9.05	15.45	9.7	14.2	8.82
Root	28.8	4.62	24.42	4.85	24.64	4.72
Stolon	14.7	1.97	19.8	2.83	10.76	1.42

APPENDIX II. VOLUME (ML) OF EDTA TITRATED AGAINST PRECIPITATES OF WATER EXTRACTS AND AMMONIUM OXALATE OF COMPONENT PARTS OF WATER HYACINTH.

DATE AND SITE			**Replicate 1**		**Replicate 2**		**Replicate 3**	
	STAGE	**ORGAN**	**FM**	**Vol.**	**FM**	**Vol.**	**FM**	**Vol.**
Dam		**Leaf**	4.51	1.35	1.47	0.33	2.86	0.37
		Petiole	6.34	1.08	5.2	0.68	6.51	1.23
14th/4/96	**Young**	**Rhizome**	3.11	1.13	2.26	0.6	3.4	0.9
		Root	0.99	0.2	3.15	0.33	0.98	0.33
		Stolon	13.27	0.78	11.5	0.35	9.87	1.23
		Leaf	6.75	2.7	7.9	2.1	4.89	0.77
	Mature	**Petiole**	16.82	2.63	20.68	1	13.71	1.43
		Rhizome	19.15	3.8	27.86	2.1	16.58	1.7
		Root	37.88	6.65	14.07	0.6	22.29	1.17
		Stolon	9.98	0.7	-	-	-	-

		Leaf	4.74	0.6	6.04	0.9	3.98	0.48
Masese		**Petiole**	13.84	0.53	19.41	0.65	18.39	0.7
	Young	**Rhizome**	2.17	0.2	5.45	0.55	2.64	0.5
28th/4/96		**Root**	1.58	0.15	2.24	0.2	1.28	0.1
		Stolon	6.31	0.4	16.28	0.77	10.25	0.7
		Leaf	9.19	2.4	6.71	1.25	4.55	0.85
	Mature	**Petiole**	24.67	1.97	18.86	0.95	8.06	0.75
		Rhizome	17.86	1.55	5.09	0.68	2.56	0.37
		Root	22.01	1.63	9.25	0.43	9.09	0.48
		Stolon	10.19	0.45	26.61	0.93	13.64	0.5
Wanyange		**Leaf**	1.49	0.45	6.17	1.15	3.6	0.77
		Petiole	10.79	0.75	11.25	0.82	9.48	0.43
14th/5/96	**Young**	**Rhizome**	1.84	0.6	1.97	0.33	2.1	0.32
		Root	1.3	0.15	0.84	-	3.06	0.3
		Stolon	10	0.47	12.78	-	17.6	0.45
		Leaf	3.89	1.6	5.16	0.6	4.84	1.93
		Petiole	15.55	0.8	24.36	0.98	22.56	1.01
	Mature	**Rhizome**	11.16	0.67	11.75	0.6	13.81	0.83
		Root	10.92	0.77	9.06	0.55	28.57	1.05
		Stolon	19.72	0.38	21.32	0.4	7.47	-
		Leaf	3.21	0.65	2.98	0.42	1.54	0.31

Masese		**Petiole**	12.03	0.78	9.88	0.53	6.68	0.35
	Young	**Rhizome**	1.4	0.23	1.13	0.1	1.67	0.15
14th/6/96		**Root**	-	-	1.91	0.1	0.39	0.05
		Stolon	5.02	0.4	5.53	0.3	2.85	0.25
		Leaf	2.68	0.62	4.98	1.23	3.46	0.67
	Mature	**Petiole**	19.17	0.97	22.55	1.13	12.56	0.8
		Rhizome	5.7	0.8	8.8	0.6	5.63	0.6
		Root	14.46	0.8	13.22	1.6	6.61	1
		Stolon	23.36	0.55	16.16	0.45	17.62	0.8
Wanyange		**Leaf**	1.56	0.22	2.04	0.3	1.33	0.23
		Petiole	7.63	0.52	4.08	0.43	3.2	0.5
28th/6/96	**Young**	**Rhizome**	1.52	0.33	1.63	0.37	1.62	0.77
		Root	1.7	0.13	1.15	0.1	0.59	0.05
		Stolon	7.07	0.48	6.75	0.78	5.01	0.57
		Leaf	7.13	2.03	3.06	0.53	4.43	0.9
		Petiole	16.12	0.58	15.16	0.45	20.45	1.4
	Mature	**Rhizome**	12.83	1.55	9.78	0.6	9.84	1.1
		Root	16	1.03	15.78	0.78	16.6	1.03
		Stolon	21.49	0.15	16.15	0.35	16.01	0.6
		Leaf	2.86	0.73	2.03	0.53	2.47	0.7
Dam		**Petiole**	6.72	0.62	7.5	0.78	7.57	0.78

	Young	Rhizome	5.06	1.37	5.96	1.55	7.99	2.12
17th/7/96		Root	0.98	0.07	0.2	0.02	0.25	0.02
		Stolon	9.87	0.45	5.7	0.28	7.02	0.35
		Leaf	7.57	2.27	4.69	1.47	5.89	1.97
	Mature	Petiole	8.85	0.83	6.94	0.75	9.81	1.05
		Rhizome	9.86	1.95	19.92	3.58	14.76	2.95
		Root	32.6	1.97	16.58	0.78	19.4	1.03
		Stolon	9.87	0.32	9.82	0.27	9.78	0.33

APPENDIX III. VOLUME (ML) OF EDTA TITRATED AGAINST ACID EXTRACTS OF COMPONENT PARTS OF WATER HYACINTH.

DATE AND SITE			Replicate 1		Replicate 2		Replicate 3	
	STAGE	ORGAN	FM	Vol	FM	Vol	FM	Vol
		Leaf	5.01	7.3	1.4	3.1	2.59	5.25
Dam		Petiole	8.78	7.17	6.61	4.15	4.91	5.95
	Young	Rhizome	2.54	3.32	2.06	2.03	2.6	2.7
14th/4/96		Root	0.19	0.68	2.16	1.65	0.74	0.5
		Stolon	18.68	6.32	7.42	1.92	8.7	3.3
		Leaf	5.02	8.65	5.96	16	4.05	7.15

	Mature	**Petiole**	15.46	15	17.38	11.97	11.21	9.3
		Rhizome	20.52	23.67	24.64	18.5	18.96	9.87
		Root	34.14	-	11.45	2.8	20.18	-
		Stolon	7.88	3.18	-	-	-	-
		Leaf	5	4.15	6.63	7.38	4.09	4.85
		Petiole	11.4	4.23	17.07	5.77	18.92	8.23
Masese	**Young**	**Rhizome**	2.08	1.73	4.76	3.2	2.44	1.53
		Root	1.36	0.47	1.98	0.63	1.01	0.3
28th/4/96		**Stolon**	9.28	1.65	14.91	3.22	9.31	2.12
		Leaf	9.97	13.65	7	7.03	4.71	5.47
	Mature	**Petiole**	27.7	14.73	12.75	4.6	10.61	5.4
		Rhizome	18.84	9.47	6.82	3.95	3.46	2.2
		Root	33.84	-	15.36	3.75	9.59	2.03
		Stolon	13.49	3.62	29.5	5.55	14.67	2.35
		Leaf	1.53	2.15	6.05	7.17	3.69	4.67
Wanyange		**Petiole**	4.3	2.23	12.68	7.03	8.92	4.42
	Young	**Rhizome**	2.12	1.92	2.86	2.85	2.08	1.6
14/5/96		**Root**	1.78	0.5	1.05	0.52	2.3	0.78
		Stolon	13.22	2.32	13.2	3.83	17.89	3.1
		Leaf	4	11.4	7.03	9.15	5.33	14.17
		Petiole	20.55	11.25	25.23	12.35	24.32	12.3

	Mature	**Rhizome**	12.29	9.2	9.28	6	17.01	10.83
		Root	8.73	4.55	9.51	-	23.3	-
		Stolon	10.9	2.52	20.03	2.55	11.87	2.15
		Leaf	3	3.1	3.38	2.65	3.6	4
Masese		**Petiole**	11.53	4.3	9.66	3.35	9.6	3.07
	Young	**Rhizome**	1.37	1.28	1.69	1.08	1.95	1.57
14th/6/96		**Root**	0.75	0.2	1	0.3	1.4	0.33
		Stolon	5.27	1.25	5.22	1	6.45	2.03
Masese		**Leaf**	2.96	3.25	2.62	3.13	3.21	2.78
	Mature	**Petiole**	17.83	7.62	23.49	9.45	15.58	5.25
14th/6/96		**Rhizome**	6.32	3.95	7.52	5.28	4.1	2.9
		Root	13.13	3.48	9.66	2.87	6.6	1.03
		Stolon	25.3	3.38	13.64	2.88	18.62	2.58
		Leaf	1.67	1.65	2.09	3.25	1.34	2.05
		Petiole	7.51	2.53	3.1	-	2.01	1.43
Wanyange	**Young**	**Rhizome**	2.79	2.18	1.96	2.45	-	-
		Root	2.69	-	1.69	0.5	-	-
28th/6/96		**Stolon**	7.88	-	5.13	-	4.74	1.35
		Leaf	6.14	7.95	2.94	3.55	4.6	5.4
		Petiole	19.84	10.78	17.25	10.05	10.18	5.05
	Mature	**Rhizome**	9.95	8.2	10.47	8.7	9.93	6.03

		Root	16.87	-	18.97	-	10.99	-
		Stolon	17.48	4.53	20.08	5.25	16.75	3.3
		Leaf	2.52	4	1.58	2.78	3.67	6.47
		Petiole	4.74	3.72	4.72	3.4	6.25	5.8
Dam	**Young**	**Rhizome**	2.24	2.55	2.7	2.4	2.59	2.67
		Root	0.88	0.35	0.28	0.07	0.38	0.12
17th/7/96		**Stolon**	9.62	2.92	4.85	1.05	5.61	0.9
		Leaf	6.47	12.47	7.45	15.75	5.81	10.75
	Mature	**Petiole**	12.3	10.23	11.4	8.2	15.25	11.73
		Rhizome	19.77	20.8	15.45	14.57	14.2	15.77
		Root	28.8	4.62	24.42	6.4	24.64	6.7
		Stolon	14.7	1.93	19.8	2.85	10.76	1.58

APPENDIX IV. VOLUME (ML) EDTA TITRATED AGAINST WATER EXTRACTS OF COMPONENT PARTS OF WATER HYACINTH.

DATE AND SITE			**Replicate 1**		**Replicate 2**		**Replicate 3**	
	STAGE	**ORGAN**	**FM**	**Vol**	**FM**	**Vol**	**FM**	**Vol**
		Leaf	4.51	2.45	1.47	0.97	2.86	0.97
Dam								

14th/4/96								
		Petiole	6.34	1.4	5.2	1.43	6.51	1.8
	Young	**Rhizome**	3.11	1.53	2.26	1.33	3.4	1.22
		Root	0.99	0.25	3.15	0.48	0.98	0.23
		Stolon	13.27	1.68	11.5	1.32	9.87	1.87
		Leaf	6.75	4.47	7.9	5.28	4.89	3.1
	Mature	**Petiole**	16.82	4.55	20.68	3.9	13.71	3
		Rhizome	19.15	9.2	27.86	7.2	16.58	2.87
		Root	37.88	10.7	14.07	1	22.29	1.5
		Stolon	9.98	1.4	-	-	-	-
		Leaf	4.74	1	6.04	1.68	3.98	1.3
Masese		**Petiole**	13.84	1.55	19.41	2	18.39	2.25
	Young	**Rhizome**	2.17	0.2	5.45	0.75	2.64	0.58
28th/4/96		**Root**	1.58	0.2	2.24	0.25	1.28	0.08
		Stolon	6.31	0.52	16.28	1.28	10.25	0.87
		Leaf	9.19	4.89	6.71	2	4.55	1.7
	Mature	**Petiole**	24.67	4.87	18.86	1.62	8.06	1.32
		Rhizome	17.86	1.9	5.09	0.93	2.56	0.37
		Root	22.01	2.7	9.25	1.5	9.09	0.9
		Stolon	10.19	0.48	26.61	1.65	13.64	0.75
		Leaf	1.49	0.75	6.17	2.4	3.6	1.75

Wanyange		**Petiole**	10.79	2.05	11.25	2.18	9.48	1.5
	Young	**Rhizome**	1.84	0.58	1.97	0.65	2.1	0.48
14th/5/96		**Root**	1.3	0.15	0.84	0.1	3.06	0.33
		Stolon	10	0.78	12.78	1.4	17.6	0.95
		Leaf	3.89	4.4	5.16	1.75	4.84	4.58
		Petiole	15.55	2.68	24.36	2.5	22.56	3.23
	Mature	**Rhizome**	11.16	2.68	11.75	2.5	13.81	2.75
		Root	10.92	2.5	9.06	1.27	28.57	2.98
		Stolon	19.72	0.83	21.32	0.9	7.47	0.33
		Leaf	3.21	1.07	2.98	0.73	1.54	0.55
Masese		**Petiole**	12.03	1.85	9.88	1.35	6.68	0.83
	Young	**Rhizome**	1.4	0.28	1.13	0.18	1.67	0.33
14th/6/96		**Root**	-	-	1.91	0.1	0.39	0.1
		Stolon	5.02	0.62	5.53	0.5	2.85	0.42
		Leaf	2.68	1.1	4.98	1.5	3.46	1.2
	Mature	**Petiole**	19.17	2.4	22.55	3.25	12.56	1.98
		Rhizome	5.7	1.9	8.8	2.7	5.63	1.38
		Root	14.46	1.85	13.22	2.45	6.61	1.53
		Stolon	23.36	1	16.16	1	17.62	1.32
		Leaf	1.56	0.4	2.04	1.2	1.33	0.78
Wanyange		**Petiole**	7.63	0.95	4.08	1.05	3.2	-

	Young	**Rhizome**	1.52	0.48	1.63	0.62	1.62	0.75
28th/6/96		**Root**	1.7	0.3	1.15	0.23	0.59	-
		Stolon	7.07	0.52	6.75	0.7	5.01	0.85
		Leaf	7.13	2.6	3.06	1.17	4.43	1.68
		Petiole	16.12	2.28	15.16	2	20.45	3.3
	Mature	**Rhizome**	12.83	4.23	9.78	3.3	9.84	1.85
		Root	16	3.35	15.78	3.83	16.6	3.88
		Stolon	21.49	1.33	16.15	0.85	16.01	0.6
		Leaf	2.86	1.33	2.03	1.1	2.47	1.17
Dam		**Petiole**	6.72	1.42	7.5	2.23	7.57	1.65
	Young	**Rhizome**	5.06	2.03	5.96	2.27	7.99	2.03
17th/7/96		**Root**	0.98	0.18	0.2	0.05	0.25	0.05
		Stolon	9.87	1.5	5.7	0.7	7.02	0.73
		Leaf	7.57	4.33	4.69	2.92	5.89	2.32
	Mature	**Petiole**	8.85	1.48	6.94	1.62	9.81	1.37
		Rhizome	9.86	3.43	19.92	7.15	14.76	4.25
		Root	32.6	3.87	16.58	1.45	19.4	1.97
		Stolon	9.87	0.55	9.82	0.52	9.78	0.7

APPENDIX V. RESULTS OF ADDING CA-ACETATE AND AMMONIUM OXALATE TO WATER EXTRACTS OF WATER HYACINTH.

ORGAN	Ca-acetate	Ammonium chloride
Leaf	No reaction	No reaction
Petiole	"	"
Rhizome	"	"
Root	"	"
Stolon	"	"

APPENDIX VI. ANALYSIS OF VARIANCE (ANOVA) AND TABLE OF MEANS FOR Ca.

A) ANOVA TABLE

Source	DF	F Value	P
ORGAN × STAGE	5	10.46	0.0001
ORGAN × SITE	10	7.16	0.0001
ORGAN × SEASON	5	0.70	0.6273

B) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND STAGE ± S.E.

ORGAN	STAGE	LS MEAN	S.E
Leaf	Young	12.4**a**	0.72
Leaf	Old	17.2**b**	0.72
Petiole	Young	5.5**c**	0.70
Petiole	Old	4.7**cd**	0.72
Rhizome	Young	11.8**a**	0.77
Rhizome	Old	7.5**c**	0.72
Root	Young	6.8**c**	0.74

Root	Old	4.2**cd**	0.74
Stolon	Young	4.2**cd**	0.72
Stolon	Old	1.7**e**	0.82

Means followed by a common letter are not significantly different at the 5% level of significance.

C) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND SITE ± S.E.

ORGAN	SITE	LS MEAN	S.E
Leaf	Dam	16.8**a**	0.85
Leaf	Masese	11.7**b**	0.89
Leaf	Wanyange	15.9**ac**	0.89
Petiole	Dam	7.7**d**	0.89
Petiole	Masese	3.5**e**	0.85
Petiole	Wanyange	4.1**ef**	0.85
Rhizome	Dam	13.8**bcg**	0.85
Rhizome	Masese	6.6**dh**	0.89
Rhizome	Wanyange	8.4**dhi**	0.98
Root	Dam	6.6**dfhi**	0.93
Root	Masese	5.2**efhjk**	0.89
Root	Wanyange	4.8**efhjkl**	0.89
Stolon	Dam	2.6**efkl**	1.01
Stolon	Masese	3.3**efkl**	0.85
Stolon	Wanyange	2.9**efkl**	0.93

Means followed by a common letter are not significantly different at the 5% level of significance.

D) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND SEASON ± S.E.

ORGAN	SEASON	LS MEAN	S.E
Leaf	Wet	15.0**a**	0.72
Leaf	Dry	14.6**a**	0.72
Petiole	Wet	5.3**b**	0.72
Petiole	Dry	4.9**bd**	0.69
Rhizome	Wet	9.1**c**	0.74

Rhizome	Dry	10.2**c**	0.74
Root	Wet	6.2**d**	0.77
Root	Dry	4.8**de**	0.72
Stolon	Wet	2.6**e**	0.84
Stolon	Dry	3.3**de**	0.69

Means followed by a common letter are not significantly different at the 5% level of significance.

APPENDIX VII. ANALYSIS OF VARIANCE (ANOVA) AND TABLE OF MEANS FOR OXALATE.

A) ANOVA TABLE

Source	**DF**	**F Value**	**P**
ORGAN×STAGE	5	1.16	0.3303
ORGAN×SITE	10	6.54	0.0001
ORGAN×SEASON	5	3.10	0.0113

B) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND STAGE ± S.E.

ORGAN	**STAGE**	**LS MEAN**	**S.E**
Leaf	Young	36.5**a**	1.95
Leaf	Old	42.7**b**	1.95
Petiole	Young	13.8**c**	2.01
Petiole	Old	15.6**cd**	1.89
Rhizome	Young	16.7**cd**	2.16
Rhizome	Old	15.6**cd**	2.04
Root	Young	5.0**e**	2.58
Root	Old	5.5**ef**	2.24

Stolon	Young	3.2**ef**	2.12
Stolon	Old	4.7**ef**	2.24

Means followed by a common letter are not significantly different at P<0.05 level of significance.

C) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND SITE ± S.E.

ORGAN	SITE	MEAN	S.E
Leaf	Dam	51.0**a**	2.32
Leaf	Masese	30.0**b**	2.43
Leaf	Wanyange	37.8**c**	2.43
Petiole	Dam	19.9**d**	2.43
Petiole	Masese	10.9**e**	2.32
Petiole	Wanyange	13.3**de**	2.43
Rhizome	Dam	23.5**bd**	2.32
Rhizome	Masese	13.0**de**	2.55
Rhizome	Wanyange	12.0**e**	2.86
Root	Dam	9.7**f**	3.14
Root	Masese	3.8**f**	2.87
Root	Wanyange	2.2**f**	2.91
Stolon	Dam	5.7**ef**	2.78
Stolon	Masese	3.3**f**	2.32
Stolon	Wanyange	2.8**f**	2.88

Means followed by a common letter are not significantly different at the 5% level of significance.

D) TABLE OF MEANS FOR THE INTERACTION OF ORGAN AND SEASON ± S.E.

ORGAN	SEASON	MEAN	S.E
Leaf	Wet	44.9**a**	1.95
Leaf	Dry	34.3**b**	1.95
Petiole	Wet	15.7**c**	1.95

Petiole	Dry	13.8**c**	1.95
Rhizome	Wet	16.9**c**	2.01
Rhizome	Dry	15.4**c**	2.18
Root	Wet	4.8**d**	2.65
Root	Dry	5.6**d**	2.25
Stolon	Wet	3.6**d**	2.38
Stolon	Dry	4.3**d**	1.95

Means followed by a common letter are not significantly different at 5% level of significance.

APPENDIX VIII. ANALYSIS OF VARIANCE TABLES WITH THEIR CORRESPONDING TABLES OF MEANS ± S.E. FOR THE INVESTIGATED LAKE WATER PHYSICO-CHEMICAL FACTORS; PH, CONDUCTIVITY, CONCENTRATIONS OF Ca^{2+}, K^{+}, Na^{+} AND Mg^{2+}.

A) ANOVA TABLE FOR pH.

Source	DF	F Value	P
SITE	2	139.98	0.0001
SEASON	1	0.00	1.0000
SITE × SEASON	2	0.07	0.9344

B) TABLE OF MEANS FOR pH.

SITE	SEASON	MEAN	S.E.
Dam	Wet	8.5**a**	0.12
Dam	Dam	8.5**a**	0.06
Masese	Wet	7.1**c**	0.01
Masese	Dam	7.1**c**	0.03
Wanyange	Wet	8.3**a**	0.17
Wanyange	Dam	8.3**a**	0.06

Means followed by a common letter are not significantly different at 5% level of significance.

C) ANOVA TABLE FOR S.E.

Source	DF	F Value	P
SITE	2	6.20	0.0141
SEASON	1	280.03	0.0001
SITE × SEASON	2	1.63	0.2367

D) TABLE OF MEANS FOR S.E.

SITE	SEASON	MEAN	S.E
Dam	Wet	92.0**a**	0.58
Dam	Dry	82.0**b**	1.00
Masese	Wet	94.3**ac**	0.33
Masese	Dry	84.0**b**	1.00
Wanyange	Wet	96.0**c**	1.00
Wanyange	Dry	83.3**b**	0.67

Means followed by a common letter are not significantly different at 5% level of significance.

E) ANOVA TABLE FOR Ca^{2+}.

Source	DF	F Value	P
SITE	2	3.10	0.0822
SEASON	1	16.73	0.0015
SITE × SEASON	2	2.87	0.0957

F) TABLE OF MEANS FOR Ca^{2+}.

SITE	SEASON	MEAN	S.E.
Dam	Wet	112.7**a**	1.45
Dam	Dry	103.3**b**	1.67
Masese	Wet	107.7**b**	1.45
Masese	Dry	103.3**b**	1.67
Wanyange	Wet	110.3**a**	1.45

Wanyange	Dry	108.3**a**	1.67

Means followed by a common letter are not significantly different at 5% level of significance.

G) ANOVA TABLE FOR K^+.

Source	DF	F Value	P
SITE	2	0.32	0.7312
SEASON	1	0.32	0.5820
SITE × SEASON	2	0.75	0.4937

H) TABLE OF MEANS FOR K^+.

SITE	**SEASON**	**MEAN**	**S.E.**
Dam	Wet	89.7**a**	1.48
Dam	Dry	87.2**a**	0.01
Masese	Wet	90.6**a**	0.86
Masese	Dry	88.9**a**	1.71
Wanyange	Wet	88.9**a**	1.71
Wanyange	Dry	90.6**a**	3.42

Means followed by a common letter are not significantly different at 5% level of significance.

I) ANOVA TABLE FOR Na^+.

Source	DF	F Value	P
SITE	2	1.79	0.2082
SEASON	1	0.99	0.3394
SITE×SEASON	2	3.97	0.0474

J) TABLE OF MEANS FOR Na^+.

SITE	**SEASON**	**MEAN**	**S.E**

Dam	Wet	360.8**a**	2.51
Dam	Dry	353.6**a**	1.43
Masese	Wet	359.4**a**	1.47
Masese	Dry	360.9**a**	0.01
Wanyange	Wet	356.5**a**	2.51
Wanyange	Dry	358.0**a**	1.47

Means followed by a common letter are not significantly different at 5% level of significance.

K) ANOVA TABLE FOR Mg^{2+}.

Source	DF	F Value	P
SITE	2	1.94	0.1865
SEASON	1	0.06	0.8062
SITE × SEASON	2	0.06	0.9394

J) TABLE OF MEANS FOR Mg^{2+}.

SITE	**SEASON**	**MEAN**	**S.E**
Dam	Wet	62.5**a**	2.41
Dam	Dry	62.5**a**	2.41
Masese	Wet	58.3**a**	2.40
Masese	Dry	59.7**a**	2.40
Wanyange	Wet	58.3**a**	0.01
Wanyange	Dry	58.3**a**	2.78

Means followed by a common letter are not significantly different at 5% level of significance.