NUTRIENT DYNAMICS OF DECOMPOSING WATER HYACINTH IN DESERT SOILS

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DEDICATION

To my father
To my mother
To my sisters, brothers and their families
To my dear friends and colleagues
With love and respect

Fatoma
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From the very beginning to the end I thank Allah who provides me with health and strength and through whom a number of relatives and friends and many more thank I can mention helped me throughout this study.

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ABSTRACT

Increasing organic matter content of arid soils using low quality material like water hyacinth may decrease the vulnerability of the soil to degradation. Studying the fate of organic input in soil is important before any attempts of application. Therefore, a field experiment (for 16 weeks) was carried out, to monitor decomposition and nutrient dynamics from water hyacinth (*Eichhornia crassipes*) in desert soil. Fresh residue samples (40g) were placed inside decomposition litter bags and were buried in the 0-top 30cm soil depth or left on soil surface. The site selected for this study is located in western Omdorman, Khartoum State, Sudan. Samples were drawn at intervals of 2, 4, 6, 8, 10, 12, 14 and 16 weeks, and analyzed for remaining dry matter weight, carbon (C), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) contents. Results showed that residues incorporated in the top 0-30cm soil depth significantly (P≤0.01) increased dry matter weight loss compared to surface application. Decomposition rate constants of surface application and incorporation were 0.028% week\(^{-1}\) and 0.041% week\(^{-1}\), respectively. Potassium was the fastest nutrient released with 50% loss attained after the 2\(^{nd}\) and 6\(^{th}\) week from incorporation and surface application, respectively. Nitrogen, P, Ca, and Mg releases from water hyacinth incorporated in the topsoil were significantly (P≤ range from 0.0001 to 0.008) higher compared to surface application. Their loss was in the order of K =Mg > P >N > Ca. The study concluded that slow decomposition of water hyacinth in surface application may provide a cheap alternative for erosion control through mulch application.
 koji, (yields 6) and increased K content
.40
to increase the yield of t. 2

(Dz30 - 0) 5 ml OSPKSp@ 

K + 5% Mg+ P+ N+ Ca

0.028

0.0001

K > Mg > P > N > Ca

K= Mg> P> N> Ca : OSPK Sp@, 16. OSPK Sp@, OSPK Sp@, OSPK Sp@,

0.028

0.0001
Arid-region soils are concentrated between 10° and 50°N, 15° and
50°S. Near the equator significant areas are confined to the coastal plains
of porn, north eastern Brazil, Kenya, Ethiopia and Somalia in east Africa.
In Sudan, the desert soils generally occupy the area north of Khartoum,
the desert soils are generally classified as arid sols and entisols. The
major continuous land of such soils begins on the west coast of Africa
and runs across the share and the Arabian Peninsula to eastern Mongolia,
a distance of more than 1300 km. Arid region soils possess many unique
characteristics that distinguish them from their more well-known counter
parts in the humid regions. They commonly have a low level of organic
matter less than 2%, soluble salts may be present in quantities sufficient
to influence plant growth. A base saturation of 90% or more, have
calcareous horizon within the top 2m of soil, the average annual
precipitation in both hot and cold arid regions is less than 250mm and
high temperature, usually average between 21-27°C. Infiltration rate was
rapid and Lack of water was the limiting factor (Dregne, 1976).

The limited availability and high cost of mineral fertilizers mean
that many tropical small holder farming system have to rely on plant
residues as plant nutrient source. Incorporation of crop residues in
agricultural systems is an important factor in the control of soil fertility
and nutrient cycling, and may contribute significant amounts of nitrogen
and other nutrients to the succeeding crop (Mubarak et al., 1999).
Disposal of water hyacinth during cleaning of river may have direct
efforts of it's use as an amendment. This plant was used on vermicompost
for growth and flowering of *Crassandra undulaefolia* (Gajalakshmi and
Abbasi, 2002). Similarly, it was used in phytoremediation experiments (Macek et al.; Susarla et al., 2002; Huilong Xia and Xiang Juan Ma, 2006). In Sudan, water hyacinth is mainly found along the White Nile causing navigation problems. Some local study used this plant in the reclamation of sodic sols. However, attempts to study their decomposition and nutrient release at the natural level is greatly lacking

**Objectives of the study:**

1- The major objective of this study was to determine decomposition and nutrient dynamics of water hyacinth (*Eichhornia crassipes*) in desert soils.

2- The minor objectives:

(a) Dynamics of dry matter loss from water hyacinth in desert soils an influenced by placement

(b) Determination of decomposition rates constants.

(c) Monitoring nutrients (N, P, K, Ca and Mg) changes during decomposition.

**CHAPTER TWO**

**LITERATURE REVIEW**

2.1 Environmental effects of water hyacinth:
Water loss as a result of evapotranspiration, of the plant is very high and under Sudan conditions evapotranspiration rates were found to be up to 3-fold compared to that from weed free open water surface (Desougi and Obeid 1978). The annual water loss due to the plant is some $750 \times 10^6 \text{m}^{-3}$. This amount is enough to cultivate 150,000 feddans (Obeid, 1975). Besides clogging canals and suction pumps in the White Nile schemes; the water hyacinth causes tremendous problems to the steamer traffic along the White Nile. Fish is not only an important diet for the river side dwellers but also for the inhabitants of many village and towns. The presence of the hyacinth has made fishing difficult for both the individuals and organized fishing camps. The plant often floating in huge mats tangle and tear a part fishing nets. This problem is even greater in khors and small channels which are completely clogged by the plant. These areas which are perfect fish breeding sites no longer are available to allow fish to hatch and spawn possibly as result of low oxygen content (Bishai, 1961) in the irrigation canals in the Northern part of the White Nile. The water hyacinths provide suitable breeding sites for mosquito and the fresh water snails *Bulinus* and *Biomphalaria*, the intermediate hosts for bilharzias, which have been found on water hyacinth roots (Desougi, 1974). In addition to the above mentioned hazards, the water hyacinth can be named an antagonist to all other aquatic plant life. Through its surface cover and shading, light penetration is drastically
curtailed and water turbulence is reduced. This in turn retards re-aeration
and hinders thermal water currents, prevents mixing and accelerates local
stratification. The oxygen resulting deficiency will influence the aquatic
fauna. The above problems are perhaps best appreciated by the financial
burden to the Sudan which amounts to about one million Sudanese
pounds spent annually on control operations alone. In addition, the river
of about another half a million from damages and higher operating cost.

Crop residue recycling is becoming an important aspect of
environmentally sound agriculture. This reduces NO₃ leaching by
inducing N immobilization (Darwis et al., 1994; Mary et al., 1996),
favors sustainable crop production by significant nutrient contribution to
the main crop (Jensen, 1994; Nicolarlo, et al., 1995), my improve soil
physical condition (Sidhu and Sur, 1993). The use of poultry manure as
an organic fertilizer for cotton has been reported in recent years
(Nyakatawa et al., 2000) and it can be an available alternative to
conventional fertilizers, provide that it is applied at an appropriate rate
and timescale. Plant litter and fine roots are important in maintaining soil
organic carbon levels as well as for nutrient cycling (Jabota; Dalal and
Harms 2006). Crop residue recycling has been reported to enhance crop
yields (Wicks et al., 1994; Adetunji, 1997). Also, plant residues could
reduce soil exposure to erosive processes, promote a greater nutrient
cycling and improve the synchrony of nutrient release with crop demand (Cobo et al., 2002).

2.2 Agricultural use of water hyacinth:

2.2.1 Water hyacinth as fertilizer:

Mineral fertilizers are expensive in Sudan, and therefore, use of an alternative source of nutrient is important. The possibility to use water hyacinth as a fertilizer was evaluated before. This included the use of water hyacinth as green manure, compost and ash applied to different crops and soil types. Its can be used as green manure when they are incorporated in to the top 20cm of soil depth. Ash from water hyacinth can also be used as fertilizer. In this respect, earlier Basher and Koch (1979) found an increase of about 17.3% and 10.9% in the yield of groundnut when ash was applied at rates of 2.5 and 5 tan/ha, respectively.

2.2.2 Water hyacinth as mulch:

Lutfi (1974) reported the benefits of using water hyacinth as mulch for young trees and stated this mulch slows down the rate of evaporation from the soil. It also keeps the soil surface permeable and reduces the run-off of the rain water and consequently reduces amount of soil the water can carry away, increases the proportion of the rain or irrigation water that percolates into soil.

2.2.3 Phytoremediation:
Phytoremediation is an emerging technology that is rapidly gaining interested promises effective and in extensive clean up of hazard on waste sites contaminated with metals, hydrocarbon, production and chlorinated solvents (Macek et al., 2001; Surarla et al., 2002; Xia et al., 2003; Xia and Ma, 2006). This phytoremediation has four mechanisms direct uptake, accumulation of contaminants, and subsequent metabolism in plant tissue. Water hyacinth, due to fast growth and large biomass production (Sirghal and Rai, 2003) has potential to clean up various wastes. *Eichhornia sp* was found to be a possible new raw material for mushroom cultivation became of it is ideal C/N ratio 24.3 and low lignin content (9%) (Murugesan, et al., 1995). Vermicost from the process of vermicomposting of water hyacinth is very popular as soil conditioner among the farmers especially in the third world (Gajalakshmi et al., 2002). Compost from water hyacinth was found to increase biomass, shoot root ratio of some herbs like *Crossandra sp* (Gajalakshmi and Abbasi, 2002).

**2.3 Decomposition of plant litter:**

The nutrients contained in plant litter are held as organic molecules, when the litter decomposes, these nutrients are released to the soil solution. They become available for uptake by plants. Decomposition requires decomposer action and takes place when soil microorganisms increase. The success of an agroforestry system is related to a mount and quality of the purring (Mendon and Stott, 2003). For plant materials,
decay occurs through initial fragmentation by soil macrofauna (earthworms, millipedes, and termites) with further transformations being accomplished by microbial activity via enzyme production Mendon and Stott (2003) found that litter quality was the main determinant of decomposition in the studied forests. They found that several litter quality parameters correlated with leaf disappearance varying according to stages of decomposition.

2.4 Factors affecting decomposition:

Decomposition is a complex microfauna's mediated process that is accelerated by environmental conditions that enhance faunal and microbial activity. The main factors affecting organic matter (O.M) decomposition are:

2.4.1 Chemical composition (C/N ratio, N content, polyphenols and lignin):

2.4.1.1 General:

The constituents of organic residues have been found to decompose at different rates. Most residues show two phases of decomposition, the first is rapid where constituents are released due to leaching of soluble materials. In this phase, the decay rate constant is usually faster as compared to the second phase. In the latter phase, decomposition slow and in governed by chemical composition (mainly). However, the second phase usually is characterized by lower rate of loss compared to the first
one. Simple sugars, amino acids, most proteins and cellulose decompose rapidly (mainly by bacterial action), while lignin and some microbial melanin decay slowly, mostly through the action of mycetes and fungi (Paulw. Unger, Mendonda and Stottt, 2003). Studies by Heal et al, (1997); Swift et al. (1997) and Cobo et al. (2003) have considered substrate quality as critical factor in determining the decay rate. Chemical indices of substrate quality include element concentrations and concentration of various classes of organic compounds. These include species and cultivars type, N concentration, C/N ratio, lignin, tannin and polyphenols. A number of recent studies supported that leaf chemistry factors have been reported to affect decomposition and nutrient release patterns, Nitrogen release, is influenced by factors such as N content (Constantinides and Fownes, 1994), C and C- to N ratio (Frankenberger and Abdelmagid, 1985) lignin and lignin to N ratio ( Melillo et al., 1982; Tain et al., 1992), soluble polyphenols and poly phenol-to- N ratio (Palm and Sanchez 1990; Oglesby and Fownes,1992) and lignin +poly phenol-to N ratio (Fox et al., 1990; Handayanto et al., 1994; Cobo et al., 2002). More recent studies also showed similar correlations between the (lignin+polyphenol / nitrogen) ratios and decomposition and N release for several agro forestry species (Mafongoya et al., 1998; Cobo et al., 2002).
2.4.1.2 N content and C/N ratio:

Direct relationship is known to exist between N content of the decomposing plant material and rate of decomposition. High initial N were, low C/N ratio, favor high rates of decomposition of plant residue (Cobo et al., 2002). Precott et al. (1993) stated that, the concentration of N and P in the litter influenced the rate of their uptake of them during the three first years, but was not consistently related to nutrient availability in the soil. Soil structure disturbance increases mineral N release from active and physically protected N pools (Kristensen et al., 2000). This is because organic matter under physical protection becomes were accessible to microbes. In fact, the C/N ratio was found to be an important index such as determinant of N release for wide range of N concentrations. Seneviralne (2000) reported that the lower C/N ratio, the easier OM decomposition. In addition, the C/N ratio helps to indicate the pathway of OM decomposition process, either towards mineralization (low C/N) or humification and immobilization (high C/N) low decomposition process. Generally, in decomposition there are three levels of C/N ratio (Duchaufour, 1984).

(a) Low C/N (±10) material mineralizes readily and releases high N amounts e.g. as in dry blood

(b) Medium C/N (±20) e.g. as in legumes, grass and herbs, both mineralization and humification can take place at similar rates.
(c) High C/N (>35) e.g. as in the coniferous litter, peak and sawdust, in this case the mineralization process almost and humification rate is strongly lowered.

2.4.1.3 Lignin and polyphenols:

Lignin and polyphenols contents of OM are known to influence the pattern and rate of its decomposition, especially during later phases (Palm and Sanchez 1991; Jama and Nain, 1995). Total polyphenols content was not a useful predictor of N release, but the reactivity of the polyphenols as measured by their protein-binding capacity can be a useful predictor (Mafongoya et al., 1998). These authors, also found that (lignin + polyphenols)/N ratio could be used to screen leguminous tree leaves for their potential to release N in short-term experiments. Material with lower quality (high C/N ratio, high lignin and polyphenols levels) decreased yield and N utilization efficiency. The lignin content exerted a much greater influence on N mineralization than polyphenol (Browaldh, 1997). The latter author also concluded that the best predictor of N utilization efficiency was the (lignin + polyphenols)/ N ratio. Cellulose and lignin and their ratios with other nutrients were key factors influencing litter decomposition and nutrient release (Guo and Sims, 2002).

2.4.2 Environmental factors:

Despite the rare researches in studies that are concerned with decomposition of water hyacinth especially in Sudan, much research has
already been conducted to develop proper management strategies for agricultural residues. These required knowledge of their decomposition pattern and the effect of edaphic and environmental factors influencing their breakdown rate of decomposition is essentially biological processes but, it is affected by a biotic factors through their effects on soil organisms (Mesquite et al, 1998).

2.4.2.1 Climatological factors:

These include mainly temperature, water availability (dry or humid climates).

2.4.2.1.1 Temperature:

It is generally accepted that, high temperature leads to reduction of soil organic matter content, but it is maintained under cold condition (5°C) since it was observed that physiological activity and substrate demand decline. High temperature enhances decomposition because it increases microbial activity responsible for the decomposition of soil OM. Very high temperature leads to oxidation of OM. It was found that high rates of microbial activity at warm soil temperature (25°C) are limited by the diffusion of substrate to metabolically active cells (Mubarak, 2001). It is evident that N-mineralization from slowly decomposable \((k=3.38\%, N=3.4)\) plant residues are enhanced by a rise in temperature than N–mineralization from highly decomposable
materials \((k = 5.36, \ 5N = 1.9)\). This indicates that, there is a strong interaction between temperature and resistance to degradation.

In regions with annual mean temperature of 5°C it was found that increase in temperature of 1°C could ultimately lead to loss of over 10% of soil organic carbon, but in the regions with annual mean temperature of 30°C, the same increase in temperature leads to loss of only 3% of soil organic carbon. This showed that, the sensitivity of organic matter decomposition increases with temperature in temperate regions (Kirschbaum, 1995). Similarly, observations by Homann and Grigal (1996) revealed that decomposition of below ground organic materials increased with temperature on cool forest slopes than in warm fields.

**2.4.2.1.2: water availability**

It leads to the existence of good plant cover and that in turn leads to increase of OM in the soil. Losses of OM, N and P were generally greater and more rapid during the wet than the dry and cool season (Somda and Powell, 1998). Kwabiah *et al* (1999) found that leaching in subhumid tropical conditions accelerated the release of P to meet the needs of decomposer organisms.

**2.4.2.2 Soil condition:**

Richard *et al*. (2002) found that the decomposition rate for fresh root litter was approximately 50% slower at 1m depth than it was at 10 cm. After 33 months, 55% of the roots mass buried at 10 cm remained,
while 72% of the root mass buried at 1m was still present. They also found higher decomposition rates between 15 and 30 cm than above or below this depth, because found alternative explanations include the leaching of soil carbon from shallow to deep soil layers or the vertical mixing of residues by soil organisms, soil fauna in the lower soil profile may modify lignin into more recalcitrant forms of humus than the fauna in shallow soil profiles.

2.4.2.2.1 Soil texture:

The roles of soil texture (clay and sand) on decomposition of OM incorporated into the soil seem to be inconsistent. Generally the OM in soil is thought to be reduced in the presence of clay. Fine soil particles and organic material interact very strongly to form complexes and micro-aggregates that render organic substances less susceptible to biodegradation (Skjemstal et al., 1993). Decomposition in light texture soil is faster compared to heavy texture soil. This is thought to be due to the fact that, OM more protected against microbial uptake in the presence of high content of clay particles, whereas more sand tend to decrease physical protection of organic matter (Hassink, 1994).

2.4.2.2.2 Soil structure:

This is important in affecting OM decomposition by controlling aeration. Structure may also be considered to determine the type and structure of decomposer communities. On the other hand, organic matter
increases soil aeration also moisture levels particularly in clay soil. Micro-morphological and processed-based studies have demonstrated the mechanistic role of organic matter in the formation and stabilization of soil aggregates (Elliott, 1986). This stability, in turn, is related to soil erodibility (Lal and Elliott, 1994) infiltration characteristics (Eldridge, 1993) and soil compact ability (Soane, 1990).

2.4.2.2.3 Soil moisture content:

Moisture content is an important factor in controlling decomposition (Linn and Doran, 1984). In most soils, net N mineralization was linearly related to moisture content in the available range (-0.03 to -4.0 MPa). Linn and Doran (1984) stated that decomposition of organic residues was carried out at 60% water filled porosity (0.24 g kg\(^{-1}\) soil). This is considered to be optimum for microbial growth. Similarly, Myers et al. (1982) reported that optimum moisture content for net N mineralization corresponded to a soil pore water potential between -0.01 and -0.03 MPa, while that at which no net N mineralization occurred was close to -4.0 MPa. However, K was the only nutrient affected by water regime and appeared to increase with wetting due to leaching, as it is not associated with the structural components of plant cell (Marschner, 1995).
2.4.2.3 Soil reaction:

Most studies showed an increase in soil pH after application of organic materials. The variability in the results of effect of organic matter application on soil PH probably resulted from the differences in characteristics of organic materials and soils, and the experimental conditions between studies. There was a number of incubation experiments using widely different types of organic materials and soils under various experimental conditions showed that addition of plant material increased, decreased or did not affect soil pH (Pochnee and Summer, 1997; Tang and Yu, 1999). The direction and extent of soil pH change depends on the concentration of excess cations/organic anions and Nitrogen in plant materials and initial pH of the soil. Soil pH affects decomposition by limiting the enzyme activities of microbial decomposers. Low pH decreases microbial activities and decomposition of OM (Motavlli et al., 1995). Recently, Seneviratne, (2000) found that critical levels of C and plant nutrients, which limit the enzyme activities of microbial decomposers are important for determining nutrient release. It is important to mention that, initially after application of organic matter, PH decrease was attributed to nitrification as result of microbial activities and also to release of organic acid (Zaman et al., 1998).

2.4.2.4 Microbial and fauna population:
Decomposer organisms consist of a complex community of soil biota including microflora and soil fauna (Tian et al., 1997). Accordingly the biodegradation and humification of, bacteria and fungi are ultimately responsible for the biochemical processes in the decomposition of organic residues. Soil fauna enhance the biodegradation and humification of organic residues in several ways (i) fragmentation and increasing the surface area for microbial activities (ii) by producing enzymes, which break down complex biomolecules to simple compounds and polymermerier compounds to from hums (iii) by improving the environment for microbial growth and interactions. In this context, earthworms incorporate organic materials in soil and termites are known to be efficient in digesting cellulose and lignified substances (Tian et al., 1995). Increase in organic matter increases C/N ratio of the microbial biomass probably due to increase in water soluble C and nutrients that stimulate the soil microbial growth. The decomposition rates of leaf litter were related to water soluble organic carbon and nitrogen content (Huang and Schoenau, 1997) In fact these organisms are function of the other conditions, they do not proliferate in dry conditions (Sahara for example), while they are numerous and abundant in warm humid conditions. A recent study showed that differences in soil characteristics and fauna did not seem to be enough to affect decomposition (Loranger et al., 2002).
Mubarak et al. (1999) showed that the significantly higher decomposition observed in presence of chicken manure could be attributed to the higher microbial activity contributed by higher pH and available N.

2.5 Effect of litter on crop-soil system:

Application of plant residues to the soil surface has been widely used in the semi-arid tropical agriculture and agroforestry. The benefits include the reduction of erosion hazards, better infiltration of rain water and less evaporation, lower soil temperature, better root growth also less run off and improvement of soil structure (Paulw. Unger; Cobo et al., 2002). The limited availability and high cost of mineral fertilizers mean that many tropical small holder farming system have to rely on plant residues as plant nutrient source. Trees in agroforestry systems are also an important source of such plant residues. Proper management of residues is necessary to maximize their benefit in different crop-soil systems this depends on knowledge of residue decomposition and nutrient release rates. Management options include, in addition, the selection of plant material with different chemical composition (i.e. quality) (Palm, 1995; Palm et al., 2001). Generally, most studies aimed at the best synchrony between nutrient release pattern and period of maximum supply, and demand of the crop and thus synchronization between N mineralization and its uptake as well (Luna-Orea et al., 1996; Ranells and Wagger,
2.5.1 Effect of plant residue on crop:

Browaldh (1997) in his study on the effect of mulching by different tree species found that mixing of low and high quality residues could increase yield and at the same time enhance organic matter build up. This is clearly related to the quality of the material added to the soil. In this respect, leucaena mulch and cattle manure agroforestry may was considerable as a source of N and K for crop growth in ally cropping system (Lupwayi and Haque, 1998). Study carried out in tropical hillside agroecosystem in which soils suffer from erosion and low availability of nutrients showed the potential of some plant materials as sources of nutrients (Gobo et al., 2002). They evaluated 12 plant material and found significant correlation ($P \leq 0.05$) between the initial quality parameters and nutrient release. Another study carried out in central high lands of Mexico by Reys-Reys et al. (2003) concluded that in ally cropping system the soil under canopy of mesquite and huisache effectively accumulated organic materials, microorganism and valuable nutrients. Although the mineralization of their leaves may only add small amount of inorganic N, it’s contribution to nutrient cycling in deteriorated soils and crop yields would be substantial.

2.5.2 Effect of plant residue on soil:
Use of plant residue can reduce soil exposure to erosive processes, promote a greater nutrient cycling and improve the synchrony of nutrient release with crop demand (Myers, *et al.*, 1994). In humid low land, *gliricidia* fallow was preferred to *imperata* fallow though its leaf litter contains litter N but keeps the soil moist (Hartzmink and O’Sullivan, 2001). O’Connell *et al.* (2003) suggested that legumes used as mulch in *Eucalyputs* plantations are a readily available source of N for trees and hence retention of harvested residues with better management practices will maintain soil N fertility in the long-term.

2.6 Nutrients release:

2.6.1 Nitrogen release:

Nitrogen lost only by mineralization Rutigliano *et al.* (1998) found that in his study. Seneviratne (2000) found N concentrations and polyphenol/N ratios are determinants of the N release of plant residues with limited N concentrations, i.e. of <2% and <1%, respectively. Lignin levels and lignin / N ratios were not observed to be good predictors of N release. The C/N ratio was found to be the best determinant of N release for a wide range of residue N concentrations. Lupwayi and Haque (1999) they found fertilizer N increased DM decomposition and N mineralization. Adding material with
Lower quality (high C/N ratio, lignin and phenol level) (Tian et al., 1993) will decrease yield and N mineralization. Nitrogen release from pruning of legume hedgerow trees in the tropics have been found to correlate more strongly with the phenols/ N and the (lignin+phenol)/ N ratios than with lignin, initial nitrogen or the lignin/N ratio (Fox et al., 1990; Palm and Sanchez, 1991; Oglesby and Fownen, 1992; Handayanto et al., 1994).

2.6.2 Potassium release:

Rutigliano et al. (1998) so that all litters lost K very quickly, mainly by leaching. K release appears not to be affected by leaf anatomy or chemical composition because this cat ion is not incorporated in the organic compounds tissue in the plant so it easily leached from residues (Berg, 1984; Sami, 1989; Reddy and Venkataiah, 1989; Mubarak et al., 1999, Pual, 2000).

2.6.3 Phosphors release:

Phosphor is lost initially by leaching, although at a lower rate than K, and later by mineralization (Rutigliano et al., 1998). Kwabiah et al. (1999) found that leaching in subhumid tropical conditions accelerated the release of P to meet the needs of decomposer organisms.

2.6.4 Calcium and Magnesium release:
Magnesium losses by leaching occurred only in litters with high initial Mg content, in litters with low initial Mg content, Mg losses occurred by mineralization. Ca is lost only by mineralization, (Rutigliano et al. 1998). Ca and Mg are known to be constituents of the cell wall (Hashimoto and Okamoto, 1953; Attimwell, 1968) as characterized by slow release.

A mobility series K > P>Mg > Ca = N is suggested (Rutigliano et al., 1998) in the anther study Muarak et al (1998) sow that nutrient release was in the order of (fast to slow) K > N = P> Mg > Ca.
CHAPTER THREE
MATERIALS AND METHODS

3.1 Study site:

This experiment was carried in farm wasted 35 km west Omdorman (lat-15°73' N, long-32°13'E). This study was set up between 21 November 2005 to 21 marches 2006 (i.e. four months). The area is characterized by lack of rain fall, desert encroachment, high wind erosion, low relative humidity, high temperature especially in summer and low temperature at early morning hours in winter. Normally at this climate the potential Evatranspiration exceeds the precipitation throughout the year at the start of the project. The soil of the site was classified as order: Aridisols, Hyperthermic, sandy clay loam, mixed, gypsic cambi orthid (National Centre Research, 1994).

Table (1) shows some properties of soil and irrigation water in the study site.

Table (1) shows some properties of soil and irrigation water in the study site.

This farm was established in 1995 and the area is about 7.56 ha. The irrigation system in this farm is drip irrigation and the area is divided into an area for forest plantation and nursery, wild life area, and

Table (1): Soil and water properties of study site.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Water</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1</td>
<td>Site 2</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>E.C. dSm⁻¹</td>
<td>1.10</td>
<td>0.60</td>
</tr>
<tr>
<td>pH</td>
<td>7.08</td>
<td>8.10</td>
</tr>
<tr>
<td>Na (Meq/L)</td>
<td>2.08</td>
<td>1.14</td>
</tr>
<tr>
<td>Ca+Mg (Meq/L)</td>
<td>4.50</td>
<td>2.50</td>
</tr>
<tr>
<td>K (Meq/L)</td>
<td>0.11</td>
<td>0.57</td>
</tr>
<tr>
<td>HCO₃ (Meq/L)</td>
<td>1.00</td>
<td>12.50</td>
</tr>
<tr>
<td>CL (Meq/L)</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Sand (%)</td>
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<td>72.00</td>
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<tr>
<td>Silt (%)</td>
<td>-</td>
<td>9.70</td>
</tr>
<tr>
<td>Clay</td>
<td>-</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Area for fruit trees. The vegetation of the site is composted of local trees and native range weeds found mainly on the valleys depressions during the rain fall.

3.2 **Plant material:**
Water hyacinth (*Eichhornia crassipes*) was collected from the White Nile in the Town of Gezira Aba, White Nile province (about 300 km south Khartoum). The whole plant material (roots, seudo- stem and leaves) were removed from the water, air-dried on mats beside the Nile, saved and transported to the study site. Immediately after received, a sub sample was taken, oven-dried (60-70°C) for 48 hrs, curried (0.5 mm) and stored dry for characterization. Analysis of C, N, K, Ca and Mg was done in the Institute of Plant Nutrition University of Gessen, Germany. Chemical analysis of the plant materials showed that, TN was 1.07%, total C was 258% (C/N: 24.1), total P was 0.199%, K was 1.9%, Ca was 1.69% and Mg was 0.77%.

**3.3 Field decomposition:**

The effect of placement on decomposition (mass loss) of the water hyacinth and nutrient release were monitored using the litter bags method (Anderson and Ingram, 1993). Nylon bags of 15 X 20 cm

<table>
<thead>
<tr>
<th>Local range weeds</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aristida funiculate</em></td>
<td>Elgaw um Asabie</td>
</tr>
<tr>
<td><em>Solanum dubium</em></td>
<td>Gubbein</td>
</tr>
<tr>
<td><em>Triabulys terrestries L</em></td>
<td>Derisa</td>
</tr>
<tr>
<td><em>Cymbopogan proximus</em></td>
<td>Nal</td>
</tr>
</tbody>
</table>
Dimensions with mesh size of the 2mm were used. One side of the bag was left open for faunal activity. About 30.8 g air dried weight from water hyacinth was placed into each the bag. About 24 bags were buried in the top 30 cm depth and a similar number (i.e. 24 bags) were placed on the soil surface in the same site with a label inserted inside the bag. Water was sprayed on the field and soil moisture content during decomposition was determined. At each sampling date 2, 4, 6, 8, 10, 12, 14, and 16 weeks, three bags were retrieved (i.e. 3 replicates), and soil attached was
carefully removed then after, each bag placed inside a paper envelope and transferred to the laboratory for analysis. The remaining residues were oven dried at 65-75°C until constant weight. The soil attached to the dried material was carefully brushed out and the weight of the remaining residue was recorded, ground to pass 0.5 mm sieve and analyzed for remaining C, N, K, P, Ca and Mg contents.

3.4 Chemical analysis:

3.4.1 Total nitrogen was determined by a semi-macro Kjeldanhi apparatus (Bremmer and Mulranzy, 1982): after wet digestion of 0.2 gram of sample by concentrated H₂SO₄ and gentle heating. It was distillated and titrated against HCL (0.1 N).

3.4.2 Organic carbon was measured by using the modified Walkley black methods (Walkley and Black, 1934): 10 ml of K₂Cr₂O₇ (1N) and 20 ml of conc. H₂SO₄ were added to 0.05g of the plant sample completed to 100 ml with distilled water, after awhile 10 ml of conc.H₃P₂O₅ (Orthophosphoric acid) and two or three drops of Orthophenatrole were added to 10 ml of the pure solution, then titrated up on ferrous sulphate (0.5 N).

3.5 Macro- nutrients by dry Ashing:

1- The samples were ashed at 150°C first, then at 550°C and dissolved in HCL (5N) to extract the samples and determine K, P, Mg and Ca.
and P were reading by flame photometer and spectrophotometer, respectively.

2- Ca and Mg were determined by titration against EDTA.

3.6 Statistical analysis:

The rates of mass loss and nutrient release of residues (expressed as percent remaining of initial contents) were calculated using the single exponential model \( W_t = W_0e^{kt} \) proposed by Alson (1963). \( W_t \) is the mass loss at time \( t \) in weeks, \( W_0 \) is the initial dry matter or nutrient pool and \( K \) is the rate constant. Statistical differences between surface application and incorporation were determined by subjecting the data to the analysis of variance (ANOVA) using the SAS program. Means separations were conducted using T-test.
CHAPTER FOUR
RESULTS

Table (3): Concentration of remaining nutrient during decomposition (g/kg)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Cg/kg</th>
<th>Ng/kg</th>
<th>Pg/kg</th>
<th>Kg/kg</th>
<th>Ca g/kg</th>
<th>Mg g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>257</td>
<td>10.9</td>
<td>1.9</td>
<td>18.7</td>
<td>16.8</td>
<td>7.8</td>
</tr>
<tr>
<td>2</td>
<td>253</td>
<td>10.7</td>
<td>1.9</td>
<td>14.6</td>
<td>16.8</td>
<td>7.6</td>
</tr>
<tr>
<td>4</td>
<td>240</td>
<td>10.1</td>
<td>1.6</td>
<td>14.3</td>
<td>14.8</td>
<td>5.4</td>
</tr>
<tr>
<td>6</td>
<td>232</td>
<td>9.6</td>
<td>1.4</td>
<td>14.1</td>
<td>14.3</td>
<td>5.2</td>
</tr>
<tr>
<td>8</td>
<td>225</td>
<td>9.4</td>
<td>1.3</td>
<td>13.7</td>
<td>14.1</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>211</td>
<td>9.1</td>
<td>1.1</td>
<td>13.4</td>
<td>13.8</td>
<td>4.6</td>
</tr>
<tr>
<td>12</td>
<td>201</td>
<td>8.8</td>
<td>0.8</td>
<td>13.2</td>
<td>13.6</td>
<td>4.3</td>
</tr>
<tr>
<td>14</td>
<td>197</td>
<td>8.4</td>
<td>0.6</td>
<td>12.5</td>
<td>13.3</td>
<td>3.8</td>
</tr>
<tr>
<td>16</td>
<td>182</td>
<td>7.8</td>
<td>0.4</td>
<td>11.7</td>
<td>13.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Subsurface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>257</td>
<td>10.9</td>
<td>1.9</td>
<td>18.7</td>
<td>16.8</td>
<td>7.8</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>10.5</td>
<td>1.8</td>
<td>13.5</td>
<td>16.5</td>
<td>7.3</td>
</tr>
<tr>
<td>4</td>
<td>223</td>
<td>9.9</td>
<td>1.4</td>
<td>13.3</td>
<td>12.1</td>
<td>4.9</td>
</tr>
<tr>
<td>6</td>
<td>214</td>
<td>9.3</td>
<td>1.1</td>
<td>13.0</td>
<td>11.9</td>
<td>4.6</td>
</tr>
<tr>
<td>8</td>
<td>199</td>
<td>8.9</td>
<td>0.9</td>
<td>12.7</td>
<td>11.7</td>
<td>4.2</td>
</tr>
<tr>
<td>10</td>
<td>187</td>
<td>8.4</td>
<td>0.9</td>
<td>12.4</td>
<td>11.5</td>
<td>3.6</td>
</tr>
<tr>
<td>12</td>
<td>179</td>
<td>7.7</td>
<td>0.5</td>
<td>12.1</td>
<td>11.3</td>
<td>3.4</td>
</tr>
</tbody>
</table>
Dry matter weight (DMW):

Dry matter weight loss during the 16 weeks of incubation period is shown in Fig. (1a). Generally, there was rapid DMW loss from both surface and sub-surface placements entire during the all period of the incubation (16 week). Statistical analysis showed that during all samplings, loss from sub-surface application was significantly ($P \leq 0.01-0.0005$) greater than from surface application. After the end of the second week, the DMW that remained in sub-surface application (81.2%) was significantly ($P \leq 0.007$) lower than that in surface application (87.4%) by about 7%. After the end of the fourth week, DMW that remained in sub-surface application (71.9%) was also significantly ($P \leq 0.04$) lower than that in surface application (83.07%) by about 14%. After the end of the sixth week, DMW that remained in residues incorporated in the sub-surface application (66.3%) was significantly ($P \leq 0.005$) lower than that determined in surface application (79.2%) by about 16%. After the end of the eighth week, DMW that remained in sub-surface placement (63.9%) was also significantly ($P \leq 0.03$) lower than that determined in surface placement (75.3%) by about 15%. After the end of the 10th week, DMW that remained in sub-surface application (61.1%) was still significantly ($P \leq 0.01$) lower than that determined surface application (73.1%) by
After the end of the 12\textsuperscript{th} week, DMW that remained in sub-surface application (55.7\%) was significantly (P ≤ 0.008) lower than that determined in surface application (67.9\%) by about 17\%. After the end of the 14\textsuperscript{th} week, DMW that remained in sub-surface placement (51.3\%) was still significantly (P ≤ 0.0003\%) lower than that determined in surface placement (63.9\%) by about 19\%. After the end of the incubation (16\textsuperscript{th} week) DMW that remained in sub-surface application (47.2\%) was significantly (P ≤ 0.0005) lower than that determined in surface application (60.9\%) by about 22\%. The Non-linear regressions showed that, decomposition of water hyacinth in both incorporation and surface application are best described using the single exponential model $W_0 = W_t e^{-kt}$ where $W_0$ is the original amount of material applied, $W_t$ is the proportion of the initial dry mater remaining after a period of time (t) in weeks, and K is the rate constant (Olson, 1963). Accordingly, DMW loss rate constant (K) for sub-surface application (0. 041\% week\textsuperscript{-1}) was higher than that of surface application (0. 028\% week\textsuperscript{-1}) by about 46.4\% (Fig. 1b). This indicates that of decomposition when organic residues are incorporated in a degraded soil.
About one and half folding that when left on the surface application. The degree of fitness was to be 0.96 (average value). Both management practices seemed to be looked in to one phase stage.
Figure (1a): Actual changes of percent dry matter weight remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
4.2 Nutrient release:

4.2.1 Remaining C:
Carbon release during the incubation period is shown in Fig. (2a). Generally, loss of C from sub-surface application was significantly ($P \leq 0.03-0.0006$) higher compared to the surface application. This was found in the whole sampling period. After the end of the second week, C that remained in sub-surface application (78.9%) was significantly ($P \leq 0.006$) lower than that determined in surface application (85.9%) by about 8%. After the end of the fourth week, C that remained in sub-surface application (62.5%) was also significantly ($P \leq 0.03$) lower than that determined in surface application (78.3%) by about 7%. After the end of the sixth week, C that remained in sub-surface application (55.3%) was significantly ($P \leq 0.005$) lower than that determined in surface application (71.45) by about 22%. After the end of the eighth week, C that remained in sub-surface application (49.6%) was significantly ($P \leq 0.01$) lower than that determined in surface application (66%) by about 24%. After the end of the 10th week, C that remained in sub-surface application (44.4% was significantly ($P \leq 0.007$) lower than that determined surface application (60.1%) by about 26%. After the end of the 12th week, C that remained in sub-surface placement (38.7%) was still significantly ($P \leq 0.004$) lower than that determined in surface placement (53.1%) by about 27% significantly ($P \leq 0.002$) lower than that determined in surface (49.1%) by about 33%. After the end of the incubation period (16th week) C that remained in residues incorporated in
sub-surface application (28.9%) was significantly (P ≤ 0.0006) lower than that determined in surface application (43.2%) by about 33%. Fifty percent release in C was attained after sixth and 12th week for sub-surface and surface applications, respectively. The pattern of C release was best fitted to the same exponential model for decomposition DMW. The model showed that carbon release rate constant (k) of sub-surface application (0.073% week⁻¹) was higher than that of surface application (0.049% week⁻¹) by about 48.9% (Fig. 2b). This indicates that the rate of C release when organic residues are incorporated in degraded soils is about one and half fold that when left on the surface application. The degree of fitness was to be 0.98 (average value).
Figure (2a): Actual changes of percent Carbon remaining of surface (S) and sub-surface (SS) applications during the period 16 weeks of incubation.
\[ y = 97.248e^{-0.0499x} \quad R^2 = 0.9956 \]

\[ y = 90.969e^{-0.0731x} \quad R^2 = 0.9839 \]

**Figure (2b):** Non-linear Carbon decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.

**4.2.2 Remaining N:**

Nitrogen release during the incubation period (16 weeks) is shown in Fig.3a. Generally, there was rapid N loss from both sub-surfaces in all period of incubation. Statistical analysis showed that during all samplings periods, loss of N from sub-surface application was significantly \((P \leq 0.08-0.0001)\) greater than that from surface application. After the end of the second week, N that remained in sub-surface application (78.4%) was
significantly ($P \leq 0.003$) lower than that determined in surface application (85.45) by about 8%. After the end of the fourth week, N that remained in sub-surface application (70.5%) was significantly ($P \leq 0.08$) lower than that determined in surface application (77.7) by about 9%. After the end of the sixth week, N that remained in sub-surface application (56.4%) was significantly ($P \leq 0.002$) lower than that determined surface application (70%) by about 19%. After the end of the eighth week, N that remained in sub-surface application (52.4%) was significantly ($P \leq 0.02$) lower than that determined in surface application (64.9%) by about 19%. The following weeks continued with the same pattern, where the remaining N in sub-surface application (46.9%) was also significantly ($P \leq 0.003$) lower than that determined for surface application (61.2%) by about 23%. After the end of the 10th week. After the end of the 12th week, N that remained in sub-surface application (39.5%) was also significantly ($P \leq 0.004$) lower than that determined surface application (54.6%) by about 27%. After the end of the 14th week, N that remained in sub-surface application (34%) was also significantly ($P \leq 0.0002$) lower than that determined surface application (49.1%) by about 30%. After the end of incubation (16th week) N that remained in residues incorporated in sub-surface application (28.7%) was still significantly ($P \leq 0.0001$) lower than that determined for surface application (43.7%) by about 34%. Fifty
percent release in N was attained after the end of the eighth and 12th weeks for sub-surface and surface applications, respectively. N loss rate constant (K) for sub-surface application (0.073% week⁻¹) was higher than that of surface application (0.048% week⁻¹) by about 52% per week (Fig. 3b.). This indicates that rate of decomposition when organic residues are incorporated in degraded soils is about half that when left on the surface. Degree of fitness was to be 0.99 (average value).
**Figure (3a):** Actual changes of percent Nitrogen remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.

\[ y = 96.214e^{-0.0484x} \]
\[ R^2 = 0.9918 \]

\[ y = 94.392e^{-0.0737x} \]
\[ R^2 = 0.9909 \]

**Figure (3b):** Non-linear Nitrogen decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
4.2.3 Remaining P:

P release during the incubation period is shown in Fig. (4a). Generally, there was rapid P loss from both surface and sub-surface applications during the period of incubation. Statistical analysis showed that during all samplings, loss of P from sub-surface application was significantly \( (P \leq 0.01-0.008) \) higher than that from surface application. After the second week, P that remained in sub-surface placement (75.5\%) was significantly \( (P \leq 0.03) \) lower than that determined in surface placement (86.1\%) by about 12\%. After the end of the fourth week, P that remained in sub-surface placement (51.7\%) was significantly lower than that determined in surface placement (69\%) by about 12\%. After the end of the sixth week, P that remained in sub-surface application (39.5\%) was significantly \( (P \leq 0.01) \) lower than that determined in surface application (59.7\%) by about 33\%. After the end of the eighth week, P that remained in sub-surface application (31.4\%) was also significantly \( (P \leq 0.01) \) lower than that determined in surface application (51.5\%) by about 39\%. The following weeks continued with the same pattern, after the end of the 10th week, P that remained in sub-surface application (24.5\%) was also significantly
(P ≤ 0.008) lower than that determined in surface application (40.9%) by about 39%. After the end of the 12th week, P that remained in sub-surface application (15.7%) was significantly (P ≤ 0.01) lower than that determined in surface application (29.7%) by about 47%. After the end of the 14th week, P that remained in sub-surface application (9.9%) was significantly (P ≤ 0.008) lower than that determined in surface application (21.3%) by about 51%. After the end of the incubation (16th week) P that remained in residues incorporated in sub-surface application (4.9%) was still significantly (P ≤ 0.01) lower than that determined in surface application (13.8%) by about 64%. Fifty percent release in P was attained after fourth and eighth week for sub-surface and surface applications, respectively. From this trend line it seems that sub-surface P rate constant (k) was (0.175% week⁻¹) was higher than that for surface (0.118% week⁻¹) by about 48.3% per week. Degree of fitness 0.96 (average value), (Fig. 4b).
Figure (4a): Actual changes of percent Phosphorus remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
Figure (4b): Non-linear Phosphorus decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.

4.2.4 Remaining K:
Potassium release followed a two stage pattern. The first stage started with immediate loss of K from both placements entire that happened with after the end of the second week. In the second stage, there was a steady slow release period from fourth to 16th week (Fig. 5a). Generally, statistical analysis showed that during all samplings, loss of K from sub- surface application was significantly ($P \leq 0.01-0.0002$) greater than that from surface application. After the end of the second week, K that remained in sub-surface application (52.1%) was significantly ($P \leq 0.01$) lower than that determined in surface application (65.5%) by about 20%. After the end of the fourth week, K that remained in sub-surface application (47.3%) was significantly ($P \leq 0.002$) lower than that determined in surface application (60.8%) by about 22%. After the end of the sixth week, K that remained in sub-surface application (44.5%) was significantly ($P \leq 0.01$) lower than that determined in surface application (56.6%) by about 21%. After the end of the eighth week, K that remained in sub-surface application (41.8%) was also significantly ($P \leq 0.006$) lower than that determined in surface application (53.7%) by about 21%. After the end of the 10th week, K that remained in sub-surface application (37.1%) was also significantly ($P \leq 0.004$) lower than that determined in surface application (48.8%) by about 23%. The following weeks continued with the same pattern, after the end of the 12th week, K
that remained in sub-surface application (33.4%) was also significantly (P ≤ 0.0002) lower than that determined in surface application (45.3%) by about 26%. After the end of the 14th week, K that remained in sub-surface application (29.8%) was also significantly (P ≤ 0.001) lower than that determined in surface application (40.9%) by about 27%. After the end of incubation (16th week) K that remained in residues incorporated in sub-surface application (25.8%) was still significantly (P ≤ 0.0001) lower than that determined in surface application (38.2%) by about 32%. Fifty percent release in K was attained after the end of second and eighth week for sub-surface and surface applications, respectively. The exponential model revealed that K release rate constant (k) form sub-surface application (0.066% week⁻¹) was higher than that for surface application (0.05% week⁻¹) by about 32% per week. (Fig. 5b). The degree of fitness 0.87 (average value).
Figure (5a): Actual changes of percent Potassium remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
Figure (5b): Non-linear Potassium decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation

4.2.5 Remaining Ca:

Ca release during the incubation is shown in Fig.6a. Generally, there was rapid Ca loss from both surface and sub-surface placements entire during the period of incubation (16 week). Statistical analysis
showed that during all samplings, loss from sub-surface application was significantly ($P \leq 0.009-0.0006$) greater than that from surface application. After the end of the second week, Ca that remained sub-surface application (79.9%) was significantly ($P \leq 0.009$) lower than that determined in surface application (87.3%) by about 8%. After the end of the fourth week, Ca that remained in sub-surface application (51.9%) was also significantly ($P \leq 0.007$) lower than that determined in surface application (73.9%) by about 29%. After the end of the sixth week, Ca that remained in sub-surface application (47.1%) was significantly ($P \leq 0.002$) lower than that determined in surface application (67.5%) by about 30%. After the end of the eighth week, Ca that remained in sub-surface application (44.7%) was also significantly ($P \leq 0.007$) lower than that determined in surface application (63.4%) by about 25%. After the end of the 10th week, Ca that remained in sub-surface application (41.9%) was significantly ($P \leq 0.003$) lower than that determined in surface application (60.1%) by about 31%. After the end of the 12th week, Ca that remained in sub-surface application (37.5%) was also significantly ($P \leq 0.001$) lower than that determined in surface application (54.9%) by about 31%. After the end of the 14th week, Ca that remained in sub-surface application (33.8%) was significantly ($P \leq 0.0006$) lower than that determined in surface application (50.8%) by about 33%. After the end of
the incubation (16th week) Ca that remained in residues incorporated in
sub-surface application (29.8%) was still significantly (P ≤ 0.0003) lower
than that determined in surface application (47.4%) by about 37%. These
results showed that more than half of the initial content of Ca was loss
after fourth and 16th week for sub-surface and surface applications,
respectively. The exponential model revealed that Ca release rate constant
(k) for sub-surface application (0.068% week⁻¹) was higher than that for
surface application (0.044% week⁻¹) by about 54.5% per week, degree of
fitness 0.93 (average value), (Fig. 6b).
Figure (6a): Actual changes of percent Calcium remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.

Figure (6b): Non-linear Calcium decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
4.2.6 Remaining Mg:

Mg release during the incubation period is shown in Fig. (7a). Generally, there was rapid Mg loss from both surface and sub-surface applications during period of incubation (16 weeks). Statistical analysis showed that during all samplings, loss from sub-surface application was significantly \( (P \leq 0.01-0.0001) \) greater than that for surface application. After the end of the second week, Mg that remained in sub-surface application (76.3\%) was significantly \( (P \leq 0.003) \) lower than that determined in surface application (85.6\%) by about 10\%. After the end of the fourth week, Mg that remained in sub-surface application (44.9\%) was significantly \( (P \leq 0.01) \) lower than determined in surface application (57.6\%) by about 22\%. After the end of the sixth week, Mg that remained in sub-surface application (39.1\%) was also significantly \( (P \leq 0.001) \) lower than that determined in surface application (52.8\%) by about 25\%. After the end of the eighth week, Mg that remained in sub-surface
application (34.7%) was significantly ($P \leq 0.01$) lower than determined in surface application (48.6%) by about 28%. After the end of the 10th week, Mg that remained in sub-surface application (28.5%) was also significantly ($P \leq 0.002$) lower than determined in surface application (43.4%) by about 34%. After the end of the 12th week, Mg that remained in sub-surface application (24.1%) was also significantly ($P \leq 0.006$) lower than determined in surface application (37.2%) by about 35%. After the end of the 14th week, Mg that remained in sub-surface application (20.2%) was also significantly ($P \leq 0.003$) lower than determined in surface application (31.4%) by about 35%. After end of incubation (16th week) Mg that remained residues incorporated in sub-surface application (16.5%) was still significantly ($P \leq 0.0001$) lower than determined in surface application (26.8%) by about 38%. These results showed that more than half of the initial content of Mg was lost after fourth and eighth week for sub-surface and surface applications, respectively. The exponential model revealed that Mg release rate constant (K) for sub-surface application (0.1 week$^{-1}$) was higher than that of surface application (0.07 week$^{-1}$) by about 42.8% per week, degree of fitness 0.96 (Fig. 7b).
**Figure (7a):** Actual changes of percent Magnesium remaining of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation.
**Figure (7b):** Non-linear Magnesium decomposition rate curves of surface (S) and sub-surface (SS) applications during the period of 16 weeks of incubation

**CHAPTER FIVE**

**DISCUSSION**

5.1 Dry matter weight (DMW):
Significantly higher loss of DMW from sub-surface application as compared to surface application. Their was observed in the study is similar to that observed by Richard et al., 2002 who found higher decomposition rates when Bouteloua gracilis roots was incorporated in the 15-30cm soil depth. Because found leaching of soil carbon from shallow to deep soil layers, the vertical mixing of residues by soil organisms and soil fauna in the lower soil profile may modify lignin in to more recalcitrant forms of hums than the fauna in shallow soil profiles. Richard et al. (2002) also found that the cooler, environment in the lower soil profile or surface, relative to the sub-surface soil, may promote bacteria or fungi that degrade residues compounds. Fifty percent loss of DMW was attained after 120 days compared to the study of Paul et al. (2000) on biological management of water hyacinth in Uganda fifty percent loss of DMW was attained after 20 days. This difference may be attributed to the dry period in our study and moist period in the other study. A similar pattern of dry matter weight loss was observed in study of Ahlam (2004) on assessment of rate of decomposition and nutrient release from leaf residue of some tree species. The rapid initial mass loss could be attributed to the removal of water-soluble material by rain fall; this was supported earlier by Parsons et al. (1990). Mass loss in the early stages involved both physical leaching and microbial (Berg and Saaf, 1981; Berg and Wessen, 1984). Abest to fit the decaying period of three
species (R² ranged between 0.99 and 0.95), in our study (R² ranged between 0.95 and 0.97)

5.2 Nitrogen:

Nitrogen release was higher when litters were incorporated than surface application. This was happens consistently during all the period of incubation. The increase in N release when litters were incorporated may have been due to:

1- More contact with soil which gives more chances for accessibility to microbes

2- Higher microbial activity in sub-surface application. Jubia et al. (1997) found the significantly higher decomposition observed in the presence of chicken manure could be attributed to higher pH and available N. The higher microbial activities in sub-surface than surface application could be attributed to temperature and soil moisture variability through soil profile. (Richard et al. 2002).

Fifty percent loss of N was found after 84 days as compared to it studies of Paul et al. (2002) when fifty percent loss of N occurred after 13 days. This difference attribute to variation in environmental conditions between it two studies and possibly difference microbial activity. Generally, N was found to be the lower nutrient released in this study compared to P, K, Ca and Mg. This may be due to factors that determined like C/N and %N which
were found to be 24.5 and 1.07%N, respectively. Nitrogen content and C/N were earlier used as indicators of litter quality (Reys-Reys et al., 2003; Cobo et al., 2002). Plant material with high C/N (i.e., >20) and low N (i.e., >1.7) immobilize N during decomposition, (Duchaufour, 1984). Some studies found that N release was slower compared to other nutrients (e.g. P, K, Ca & Mg) (Rutigliano et al. 1998).

5.3 Phosphorus:

The rapid loss of P observed in sub-surface incorporation compared to the surface application, could also be attributed to higher microbial activity in the farmer first application (Julia et al., 1997). Richard et al. (2002) so that soil fauna in the lower soil profile may modify lignin into more recalcitrant forms of hums than fauna in shallow soil profiles. Many workers have reported leaching in the early stages of decomposition (Tripathi and Singh, 1992). The variability in leaching of P had been attributed to the differences in solubility of P compounds in the vestigated litter type, (Babbar and Ewel 1989). Also, it could be attributed to the differences in residue mineralization.

5.4 Potassium:

Generally, K is the fastest nutrient released in this study. Release of K was also faster from sub-surface application compared to the surface application. The rapid release of K in this study could be attributed to its
high mobility. This has also been observed by many studies in decomposition of organic materials (Berg, 1984; Saini, 1989; Reddy and Venkataiah, 1989; Mubarak et al., 1999; Paul et al., 2000). These authors reported that K release was not affected by leaf anatomy or chemical composition since this is not bows to the structure of the organic compounds tissue and occupy the free solution. Consequently, it is easily leached from residues. The slower release rate in the later phase may be attributed to the environmental conditions (dry months) during the period of study and also to the little change in soil exchangeable cation contents, this was also supported by the study of Lupwayi and Haque (1998).

5.5 Calcium and Magnesium:

Release of Ca and Mg was faster in sub-surface compared to the surface. This is probably attributed to the higher microbial activities in the first one (Richard, 2002). Ca and Mg are known to be constituents of the cell wall (Mubarak et al., 1999; Attiwel, 1968) as characterized by their slow release. However, Mg release was more rapid than Ca; more than 50% of the initial Ca remained after 16 weeks after residue application while 50% of the initial Mg remained after 6 weeks after residue application. This is similar to that studied by Mubarak et al., 1999 and Paul et al., 2000. The presence of a mobile cation in the cell fluid subjects Mg to rapid loss upon cell membrane disintegration. Edmonds (1979) and
Budelman (1988) reported release of Mg from a needle litter and leaf mulch of *Gliricidia sepium* to be as fast as K.

CHAPTER SIX
CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS
FOR FURTHER STUDIES

6.1 Conclusion:

1- Decomposition (weight loss) of water hyacinth was found to be slow when the material was applied on top of the soil surface as compared to incorporation where about 60.9% and 47.2% remained after 16 weeks in surface and sub-surface applications, respectively.

2- Nitrogen release from water hyacinth was to be slow when the material was applied on top of soil surface as compared to incorporation where about 43.7% and 28.7% remained after 16 weeks in surface and sub-surface applications, respectively.

3- Phosphorus release from water hyacinth was to be slow when the material was applied on top of soil surface as compared to
incorporation where about 13.8% and 4.9% remained after 16 weeks in surface and sub-surface applications, respectively.

4- Potassium release from water hyacinth was to be slow when the material was applied on top of soil surface as compared to incorporation where about 40.9% and 29.8% remained after 16 weeks in surface and sub-surface applications, respectively.

5- Calcium and Magnesium release from water hyacinth was to be slow when the material was applied on top of soil surface as compared to incorporation where about 47.4%, 26.8% and 29.8%, 16.5% remained after 16 weeks in surface and sub-surface applications, respectively.

6.2 Recommendations:

1- Spreading water hyacinth at the surface of degraded soil may help to create good mulch for protection of soil particles from being removed.

2- Water hyacinth could be used for building up organic matter in degraded soil.

- Since the study did not find a period of N immobilization it could be used as a source of N release despite it is high C/N ratio

- Water hyacinth provides degraded soil (especially sandy soil) with K, P, Ca and Mg.

6.3 Suggestion for further study:
1- Determination of potential mineralization N.
2- Correlations of decomposition of water hyacinth with chemical properties.
3- Contribution of water hyacinth to microbial biomass Ca and N.

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