USE OF WATER HYACINTH (*Eichornia crassipes*) IN AMELIORATION OF A SANDY SOIL

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ABSTRACT

Soil fertility management is a key issue for sustaining agricultural production in dry lands. Organic resources are important for nutrient availability and maintenance of soil organic matter. Sustaining fertility of arid soils necessitates increasing inputs of organic residues. Two experiments with water hyacinth were carried out to monitor (in the first; field study with litter bags) decomposition and changes in N, P, K, Ca and Mg as influenced by method of application where, in the second (greenhouse study) short-term effect on some properties of a sandy soil and early establishment of fodder sorghum (*Sorghum bicolor*). Results of the first experiment showed that residues incorporated in the top 0-30cm soil depth had significantly (P≤0.01) increased loss of dry matter weight compared to surface application. Decomposition rate constants of surface and sub-surface application were 0.029% week^{-1} and 0.041% week^{-1}, respectively. Potassium was the fastest nutrient released with 50% loss attained after the 2nd and 6th week from incorporation and surface application, respectively. Nitrogen, P, Ca, and Mg releases from water hyacinth incorporated in the sub-soil were significantly (P≤ range from 0.0001 to 0.008) high compared to surface application. Nutrients loss was in the order of K =Mg > P > N > Ca. However, results of the second experiment showed that incorporation of water hyacinth residues significantly (P ≤ 0.001) decreased pH (by about 27%) and hydraulic conductivity (by 40-46%). Also, cation exchange capacity and organic C were significantly increased by about 23 and 100%, respectively. The study concluded that application of water hyacinth could be one of the good alternatives for improving quality of arid soils.

INTRODUCTION

Aquatic plants like water hyacinth have invaded rivers and lakes of many East African countries. Woomer (1997) estimated that it accumulated at power plants of approximately 900 Mg dry weight and mechanically removed every 14 to 20 weeks interval. Disposal of water hyacinth during cleaning of rivers may have direct change of attention to its use as a soil amendment. This plant was used on vermicomposting for growth and flowering of the angiosperm crossandra (*Crassandra undulaefolia*) (Gajalakshmi and Abbasi, 2002). Similarly, it was used in phytoremediation experiments such as removal of heavy metals from effluents (Macek *et al* 2000; Susarla *et al* 2002; Xia and Ma, 2006).

In Sudan. water hyacinth is mainly found along the White Nile causing navigation problems. counteracting with pumping water from the Nile and increasing water loss. A local study found that incorporation of water hyacinth improved the leaching capacity of salt-affected soils and it was attributed to better aggregation. (Ahmed, 1995). Since this plant contains more than 95% water. drying besides removing areas would benefits small farms with degraded lands (Bekunda and Woomer, 1996). Incorporation of any organic residues needs information on nutrient cycling in the specific ecosystem.

Researches on decomposition and mineraliza-
tion rates of added organic matter to the soils were
concentrated in humid ecosystems with high biotic
activities (e.g. **Cochran 1990; Taylor et al 1991;
Issac and Nair, 2005**). Studies on extreme dry
conditions of arid and semiarid were carried in
North America (e.g. **Whiteford et al 1988**) and
the Negeve Desert **(Hamadi et al 2000)**. Attempts
to study decomposition and nutrient release under
desert conditions of Africa are greatly lacking.
Therefore, the objectives of this study were (1) to
determine decomposition and nutrients dynamics
of a decomposing water hyacinth under arid condi-
tions and (2) to determine the effect of incorpora-
tion of dried water hyacinth on some selected
properties of a sandy loam soil.

MATERIALS AND METHODS

Experiment 1: Decomposition and Nutrient Release from Water Hyacinth

This experiment (21 November, 2005 to 21
March, 2006) was carried out in a farm located in
the peripheries of the capital (Khartoum, lat-
$15°73^-$ N, long-$32°13^-$E). According to **Soil Sur-
vey Staff (1996)**, the soil (pH 7.3, TN 0.1 g kg^{-1},
O.C. 0.3 g kg^{-1}, CEC cmole (+) kg^{-1}, ECe 1.6 dS
m^{-1}, hydraulic conductivity 10.2 cm hr $^{-1}$, soluble
Ca, Mg, Na and K are 3.4, 0.8, 0.9 and 0.12 meq
L^{-1}, respectively, Sand 72%, Silt 9.7%, clay
18.3%) of the site was classified as hyperthermic,
sandy loam, mixed, gypsic cambi orthid. The cli-
mate is semi-arid with total annual rainfall (July –
September) of about 155.5mm, average maximum
and minimum temperatures are 41.6 and 15 °C,
respectively **(Fig. 1)**.

Plant Materials

Water hyacinth (*Eichornia crassipes*) was col-
lected from the White Nile in the village of Gezira
Aba, White Nile province (about 300 km south
Khartoum). The whole plant material (roots,
seudo- stem and leaves) were removed from the
White Nile, air-dried on mats beside the Nile,
packed and transported to the study site. Immedi-
ately after they were received, a sub sample was
taken, oven-dried (60-70°C) for 48 hrs, crushed
(0.5 mm sieve) and stored dry for characterization.
Analysis of C, N, K, P, Ca and Mg were done by
the Institute of Plant Nutrition, University of Gies-
sen, Germany. Plant material contained 1.07%
TN, 25.8% total C (C/N: 24.1), 0.199% total P,

1.9% K, 1.69% Ca, 0.77% Mg, ash content 39.5%,
lignin of 7.5% and pH (1g in 10 ml distilled water)
of 6.0.

Field Decomposition

Decomposition (mass loss) of the water hya-
cinth and nutrient release were monitored between
21/11/2005 and 21/3/2006 using the litter bags
method **(Anderson and Ingram, 1993)**. Nylon
bags of 15 X 20 cm dimensions with mesh size of
the 2 mm were used. One side of the bag was left
open for faunal activity. Exactly 30.8 g air dried
weight from water hyacinth was placed into each
bag. A total number of bags were 24 and were
buried in the top 30 cm depth (sub-surface) 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 (gravimetric) during decom-
position was determined. Soil temperature of the
0-30 cm depth was measured every two weeks
using soil thermometers during the experiment and
it was recorded to vary from 22 to 30°C (average
of 25) whereas soil moisture content varied from 2
to 7% (average of 4%). At each sampling date 2,
4, 6, 8, 10, 12, 14, and 16 weeks, three bags were
retrieved, and the soil attached was carefully re-
moved then after, each bag was 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 resi-
due was recorded, ground to pass 0.5 mm sieve
and analyzed for remaining C, N, K, P, Ca and Mg
contents.

Experiment Two: Short-term effect of incorpora-
tion of water hyacinth on some properties of a
sandy soil and early establishment of fodder sor-
ghum *(Sorghum bicolor)*.

The hypothesis of this experiment was based
on the results of the first experiment. Accordingly,
it was decided to incubate the water hyacinth for
12 weeks before studying the establishment of the
crop.

Experimental Layout

This experiment was setup in the glasshouse of
the Faculty of Agriculture, University of Khar-
toum, Sudan. The soil (2 mm sieve) was obtained
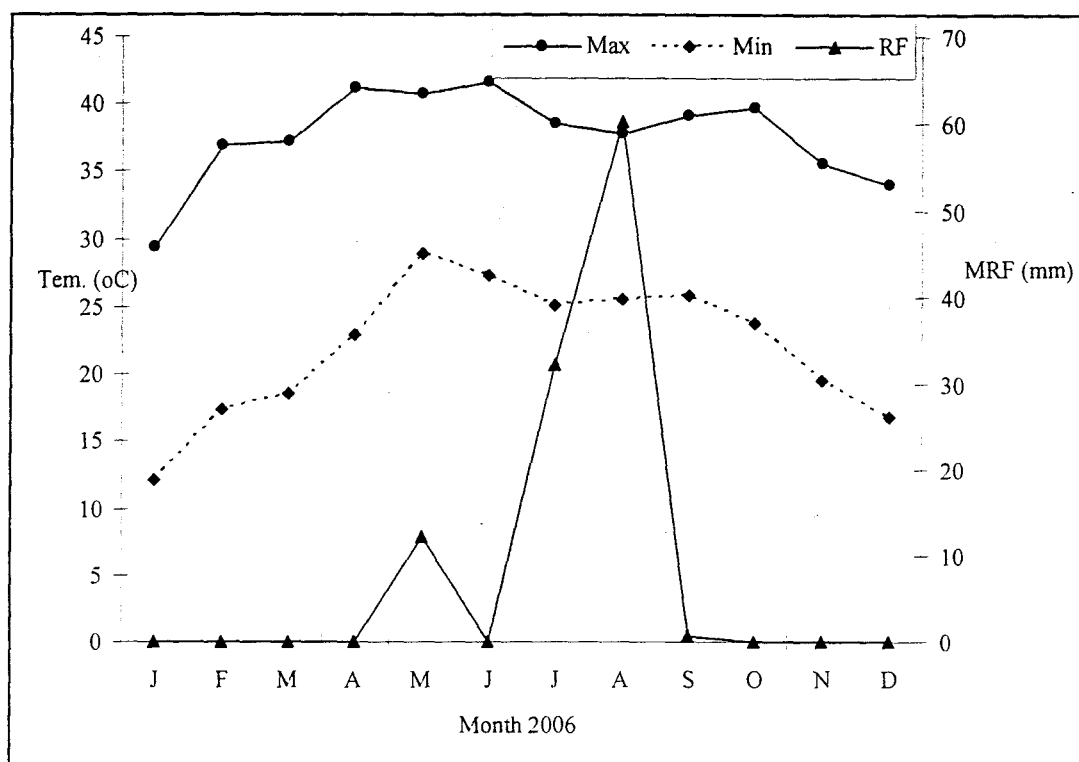from the surface (0-30 cm) of the same farm

Fig. 1. Mean monthly rainfall (mm), maximum and minimum temperatures (°C) during the decomposition period (experiment 1)

where experiment was done. Water hyacinth of experiment one was used in this study. Plant material was oven-dried (65-70°C for two days) and crushed (1 mm size) before evenly incorporation into the whole soil of polyethylene bag. Exactly 5 kg soil was added to a polyethylene bag (18 cm wide) with the following treatments:

1. Control (no fertilizer no water hyacinth)
2. Recommended inorganic fertilizer (87 kg N as urea, 45kg P_2O_5 as TSP / ha)
3. Water hyacinth (6.7 t DM ha^{-1}; equivalent amount of recommended N)

The experiment was arranged in Randomized Complete Blocks Design (RCBD) with 3 replications (18 experimental units). Bags were placed in the glasshouse (1 May 2006) and only those with plant materials were regularly irrigated (every 7 days) with amount of tap water that was equivalent to the field capacity of the soil (26.7%). After 12 weeks (1 August 2006), the recommended inorganic fertilizer dose was applied and all bags were sown with 3 seeds of fodder sorghum (Sorghum bicolor) and irrigation (every 3 days). After 4 weeks from sowing, plants were cut (2 cm above the soil surface) with a blade, placed inside an envelope and dry matter was recorded after drying

at 65-70°C for two days. The soil of each bag was air-dried, roots were removed and transferred to the laboratory for determination of pH, CEC, OC, TN, hydraulic conductivity, ECe and soluble cations (K, Ca, Mg and Na) as previously described. ANOVA analysis with Least Significant Difference (LSD) was performed for determination of statistical variations between treatments (Gomez and Gomez, 1984).

Plant and Soil analysis

Total N in the soil and plant was determined using the semi-macro Kjeldahl method described by Bremner and Mulvaney (1982). Soil and plant organic C was determined by the modified Walkley Black method (Walkley and Black, 1934). Plant samples were ashed at 150°C first, then at 550°C and dissolved in 5N HCL and analyzed for K (also soil soluble) by flame photometer, P by spectrophotometer and Ca, Mg and Na (also soil soluble) by titration against ethylene diamine tetra acetic acid (Chapman and Pratt, 1982) and lignin was determined by the acid detergent fiber method (Goering and Van Soest, 1970). Electrical conductivity of the saturation

extract (EC_e) was measured according to **Richard (1954)**, Soil pH (paste) was measured using knick digital pH-meter, and hydraulic conductivity was measured according to **Kirkham and Powers (1972)**.

Statistical Analysis

Rates of mass loss and nutrient release of residues (expressed as percent remaining of initial contents) were calculated using the single exponential model $W_t = W_0 e^{-kt}$ proposed by **Olson (1963)** where 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 (% week^{-1}). The time required for 50% ($T_{0.5}$) and 95% ($T_{0.95}$) were equal to 0.693/k and 3/k, respectively. Statistical differences between surface application and incorporation were determined by subjecting the data to the analysis of variance (ANOVA) and means separation was conducted using T-Test (**SAS, 1985**).

RESULTS AND DISCUSSION

Decay and nutrient release

Weight loss

Remaining dry matter weight (%) during 16 weeks of incubation period is shown in **Fig. (2)**. Statistical analysis showed that during all samplings, loss from sub-surface application was significantly ($P \leq$ 0.01-0.0005) greater than those of surface application. After the end of the incubation (16th week) DM that remained in sub-surface application (47.2%) was significantly ($P \leq$ 0.0005) lower than that determined in surface application (60.9%) by about 22%. Decomposition rate constant (k) and time to 50%, 95% weight loss were significantly higher when plant materials were buried than left on the surface (**Table 1**). Aerobic decay of fresh water hyacinth was very fast in the study carried out by **Woomer et al (2000)** in the semi-arid tropics of Kenya (total annual rain-fall during the study period of 214-373 mm) compared to 0 mm in this study. However, regular sprinkling of water raised soil moisture to 5-8% which was far below the optimum for biological activities. In the study of **Woomer et al (2000)**, time to 50% weight loss in mulch application found to be 3 weeks compared to 24 weeks in our's. This big difference shows that under arid conditions, soil moisture availability and organic matter content are important for biotic activity. Better soil-plant

contact would possibly justify fast decay in incorporated water hyacinth compared to surface application (**Jama and Nair, 1996**) or improved moisture content (**Hamadi et al 2000**). However, this slow decomposition especially at surface application would provide good opportunity for use in protecting surface soils against erosion. Sub-surface placement of bags resembles residue incorporation by tillage. The latter was earlier considered as a regulator or driving variable enhancing elemental cycling in agroecosystem (**Buchanan and King, 1993**).

Nutrients dynamics

Nitrogen remained during decomposition showed a consistent release in both placements (**Fig. 3a**). **Table (1)** shows that N release rate from sub-surface (0.074) was significantly ($P \leq$ 0.08-0.0001) higher than that from surface placement (0.049). By the end of the incubation period, about 29% and 44% remained in sub-surface and surface placements, respectively. Percent N remained during the incubation period did not exceeded 100% which indicates absence of immobilization. Moreover, N concentrations measured during all samplings were lower than the initial content (**Table 2**). Kinetic rate constants showed that after half of the material was finished expressed as $T_{(0.5)}$, loss of N from sub-surface placement was more pronounced compared to surface application. This is clear as when 50% depletion occurred in surface application, longer time was needed for apparent 95% fate of the material. **Goyal et al (2005)** showed that during 90 days composting of water hyacinth, N concentration was never higher than the initial. Other study found reported that non composted water hyacinth was found to be a viable substrate for mushroom cultivation despite the fact that their C/N ratio (24) was above the threshold (20) of N mineralization (**Murugesan et al 1995**). In this study, absence of N immobilization could possibly be due to the low lignin: N ratio. Lignin: N ratio was reported to be highly correlated with litter decay (**Cortez et al 1996 and Mafongoya et al 1998**). **Maithani et al (1998)** reported that due to low lignin and C/N ratio, N was found to be released from a decomposing tropical tree (*Schima khasiana*) leaves (%N of 1.09%). This pattern of N release reflects that recycling of such plant materials would not cause N starvation to growing plants and hence offers better alternative for amelioration of poor desert sandy soils. Both treatments showed that actual
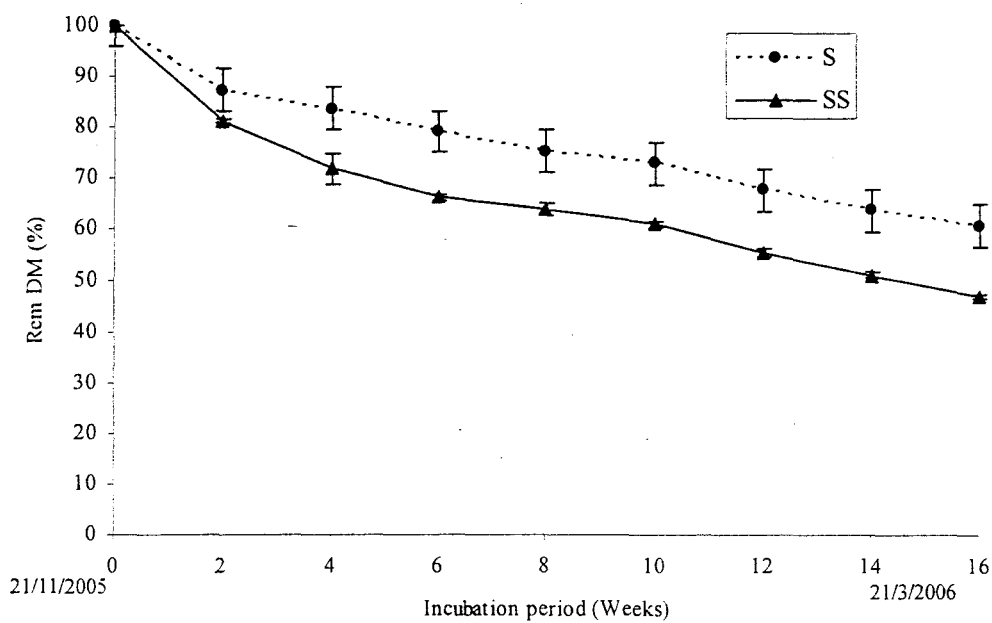
Fig. 2. Remaining dry matter weight (%) during decomposition of water hyacinth in surface (S) and sub-surface (SS) application. (Vertical bars are standard deviations)
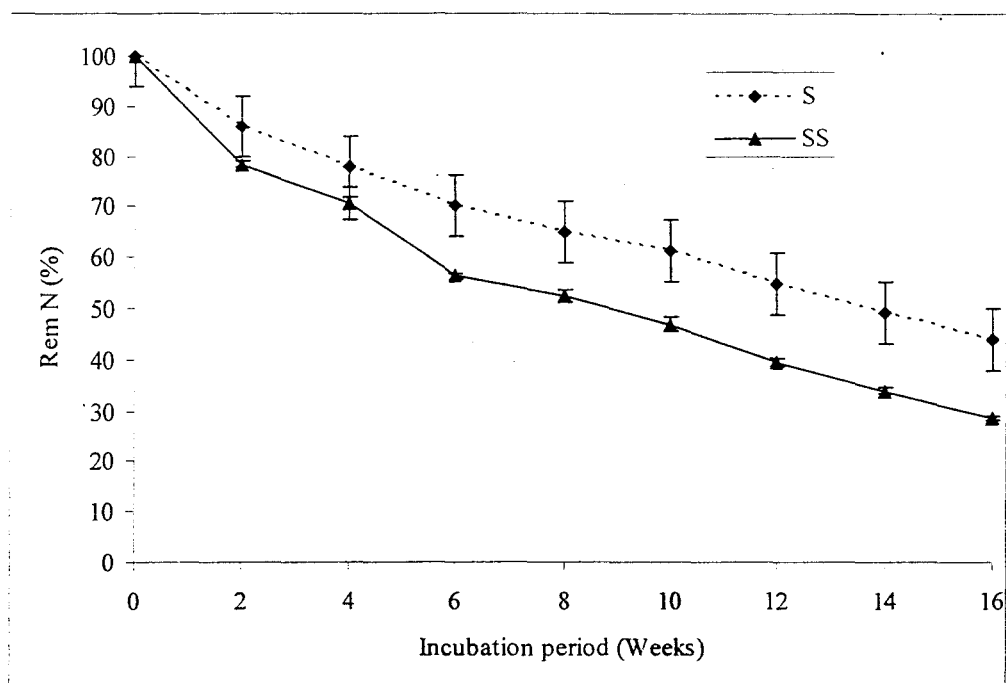

Fig. 3a. Changes in N during decomposition of water hyacinth in surface (S) and sub-surface (SS) application. (Vertical bars are standard deviations)

Table 1. Decomposition rate constant (k, week^{-1}), half-time (T $_{0.5}$) and time required for 95% (T$_{0.95}$) loss of dry matter and nutrients

Parameter	k				T$_{(0.5)}$		T$_{(0.95)}$	
	S	SS	Probability	r^2	S	SS	S	SS
DM	0.0285	0.0414	0.0007	0.96	24	17	105	72
N	0.0485	0.0737	0.0005	0.99	14	9	62	41
P	0.1179	0.1753	0.008	0.96	6	4	25	17
K	0.0580	0.0686	0.0002	0.89	12	10	52	44
Ca	0.0444	0.0679	0.0009	0.94	16	10	68	44
Mg	0.0779	0.1063	0.0001	0.96	9	6	39	28

K decomposition rate constant, DM dry matter, S surface application, SS sub-surface incorporation

P remained by the end on the period (5-15% was less than the corresponding amount of N (**Fig. 3b**). Also, P concentration did not show that P was limiting element during decomposition (**Table 2**). Nutrients changes showed that P is the most element released with quite higher rates (**Table 2**). Earlier **Woomer** *et al* (**2000**) calculated that 50% loss of P from whole plant of water hyacinth was attained after about 2 weeks compared to 4 to 6 weeks in this study. Although K is well known as a non structural element, its release from the decomposing water hyacinth was not very rapid as expected. However, initially (i.e. after 2 weeks), K was the only element determined to have higher mobility, i.e 35 - 48% loss (**Fig. 3c**). It is quite clear that K concentration in the remained material (**Table 2**) was abruptly decreased after 2 weeks while there was a steady release during later stages. It might possibly be that regular water spraying was not enough to leach K during later stages as occurred at the beginning of the experiment. We can not say that K release from water hyacinth is a function of its distribution among plant parties. However, it is important that mobility of nutrients from decomposing organic materials applied to sandy soils with low adsorption capacities should be slow to decrease chances of K leaching. Generally, in both placements, Ca was the least nutrient released. By the end of the incubation period, about 78% of the initial concentration remained (**Fig. 3d**). The order of nutrient release could be as follows: P > Mg > K > N = Ca (surface application) and P > Mg > N > K = Ca (sub-surface placement) **Fig. (3a, b, c, d and e)**. Quite similar release pattern was earlier found

elsewhere (**Luna-Orea** *et al* **1996; Rutigliano** *et al* **1998**).

Effects on soil properties

Short-term effects of incorporation of water hyacinth on soil properties are shown in **Table (3)**. Addition of water hyacinth residues decreased final soil pH (after 12 weeks) from 7.3 to 5.3 (i.e. 27% reduction). Previous researches on impact of residue application on soil pH shows different results (**Xu** *et al* **2006**). They varied from increase (**Marschner and Noble, 2000**) or decrease, increase or remained unchanged (**Xu** *et al* **2006**). It is well known that almost all results showed pH increase of acid soils. However, it seems that initial soil pH will greatly influence the direction of change. Within the acid range, **Xu** *et al* (**2006**) observed that pH of a sandy soil (initial pH 5.06) decreased by application of many residues. Similarly, **Tang and Yu** (**1999**) found pH decrease in soils with moderate acidity. Although, in this study excess cations of water hyacinth were not determined, we speculate that pH decrease could possibly be due to residue type of acidic nature (6.0) and initial soil pH. Since in our experiment, plants were sown in the bags, NH$_4$ uptake is associated with the excretion of H[1] (**Bolan** *et al* **1991**). Cation exchange capacity and organic C were significantly (P $\leq$ 0.0001) increased by about 23 and 100%, respectively. On the other hand, hydraulic conductivity was significantly (P $\leq$ 0.0001) decreased by 46%. It is clear that temporary incorporation of water hyacinth improved soil organic matter content which eventually increased water
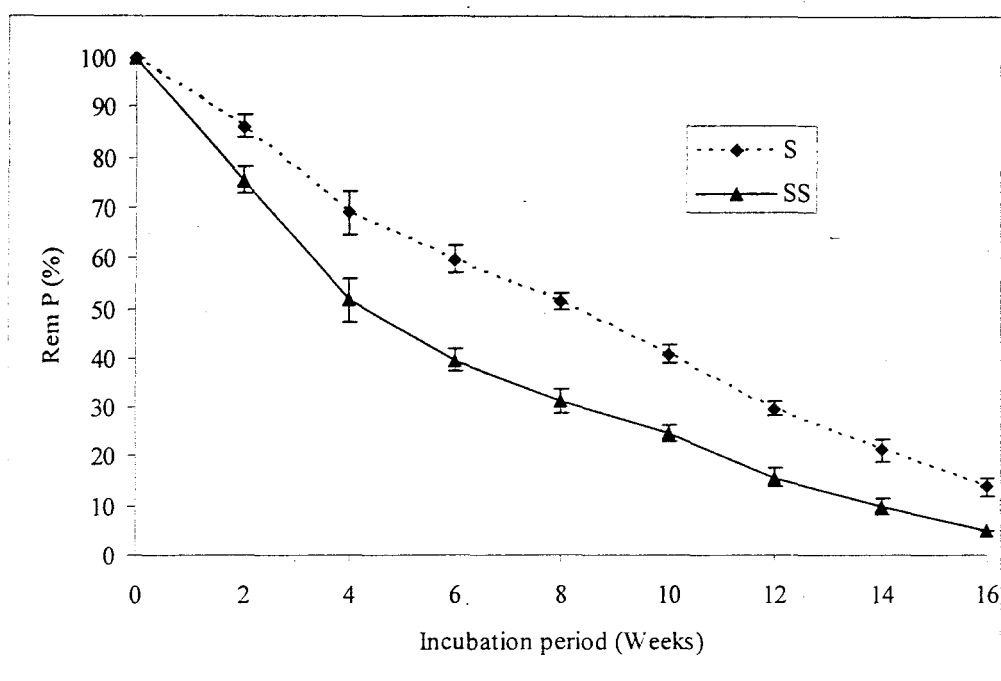
Fig. 3b. Changes in P during decomposition of water hyacinth in surface (S) and sub-surface (SS) application. (Vertical bars are standard deviations)

Fig. 3c. Changes in K during decomposition of water hyacinth in surface (S) and sub-surface (SS) application. (Vertical bars are standard deviations)

Fig. 3d. Changes in Ca during decomposition of water hyacinth in surface (S) and sub-
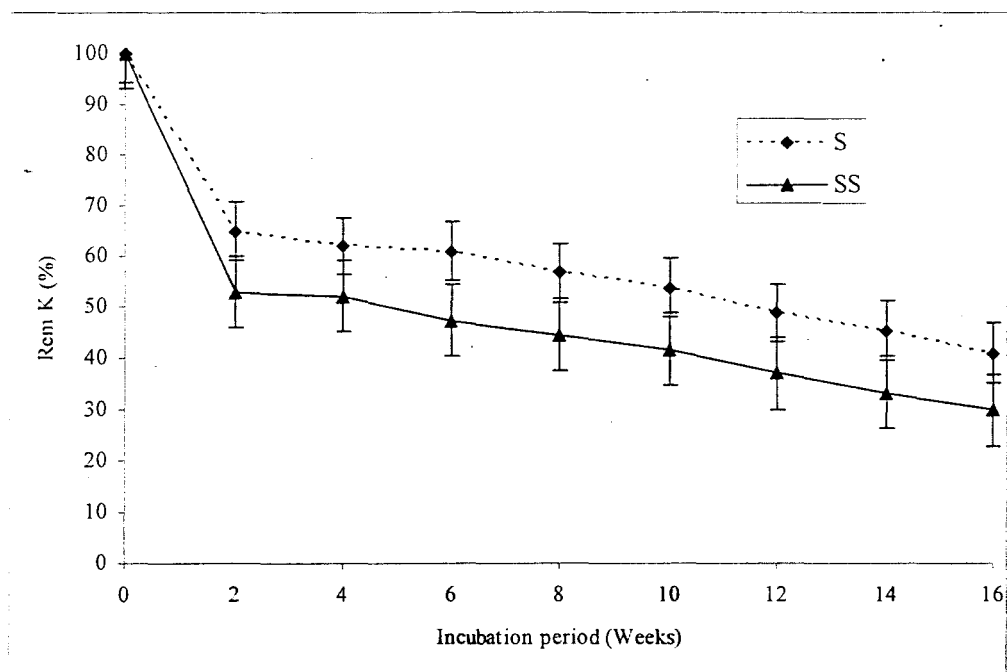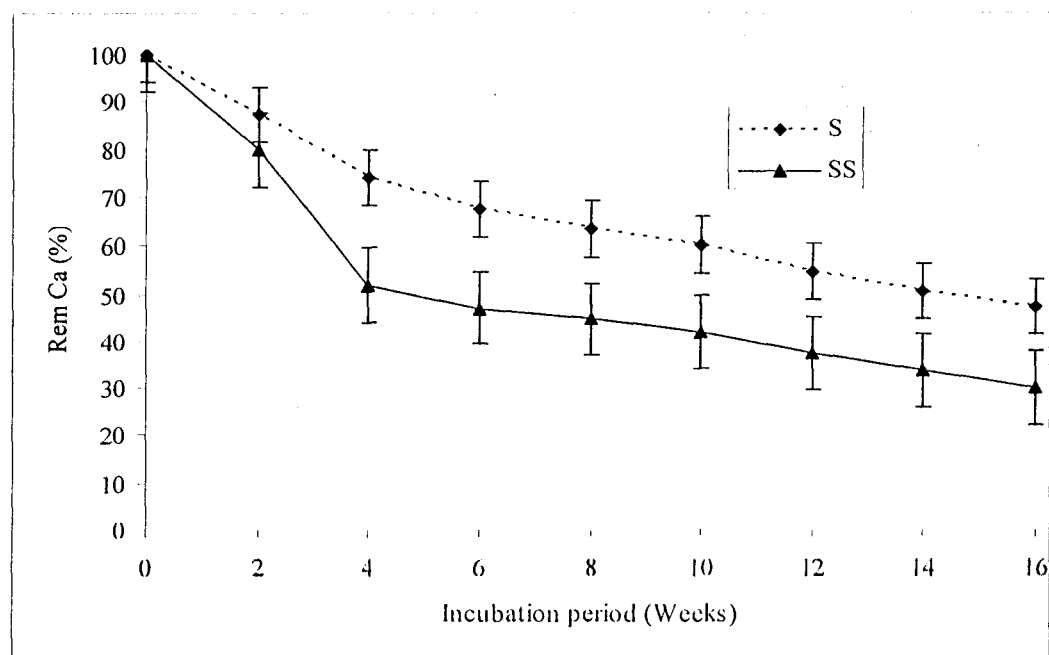surface (SS) application. (Vertical bars are standard deviations)
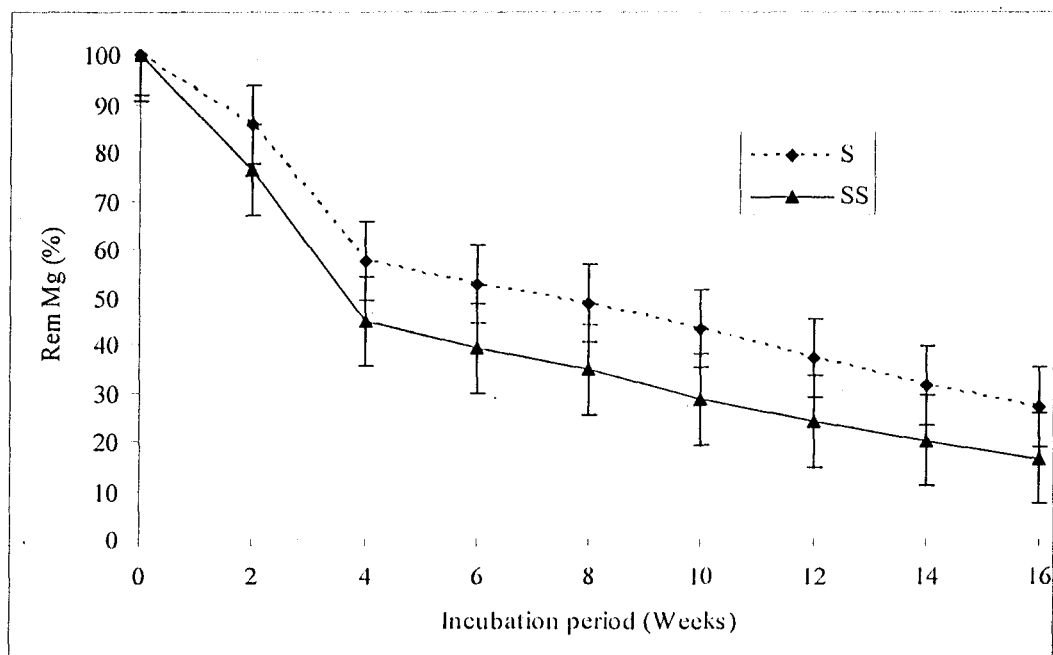

Fig. 3e. Changes in Mg during decomposition of water hyacinth in surface (S) and sub-
surface (SS) application. (Vertical bars are standard deviations)

Table 2. Concentration of remaining nutrients during decomposition (g kg^{-1})

Incubation period (Weeks)	Nutrients concentrations (g kg^{-1})				
	N	P	K	Ca	Mg
Surface application (S)					
0	10.9	1.9	18.7	16.8	7.8
2	10.7	1.9	14.6	16.8	7.6
4	10.1	1.6	14.3	14.8	5.4
6	9.6	1.4	14.1	14.3	5.2
8	9.4	1.3	13.7	14.1	5
10	9.1	1.1	13.4	13.8	4.6
12	8.8	0.8	13.2	13.6	4.3
14	8.4	0.6	12.5	13.3	3.8
16	7.4	0.4	11.7	13.1	3.4
Sub-surface application (SS)					
0	10.9	1.9	18.7	16.8	7.8
2	10.5	1.8	13.5	16.5	7.3
4	9.9	1.4	13.3	12.1	4.9
6	9.3	1.1	13.0	11.9	4.6
8	8.9	0.9	12.7	11.7	4.2
10	8.4	0.9	12.4	11.5	3.6
12	7.7	0.5	12.1	11.3	3.4
14	7.2	0.4	11.8	11.1	3.1
16	6.6	0.2	10.9	10.7	2.7

Table 3. Effect of Water hyacinth incorporation on some selected soil properties and dry matter accumulation (g plant^{-1}) of fodder sorghum (average ± sd)

Treatment	pH	CEC cmol (+) kg^{-1}	OC	TN	HC Cm hr^{-1}	ECe dSm^{-1}	K	Ca	Mg	Na	DM (g plant^{-1})
			g kg^{-1}				meq L^{-1}				
Control	7.3 ± 0.01	12.93± 0.06	0.3± 0.0	0.12± 0.01	9.73± 0.06	1.36± 0.06	0.08± 0.01	2.26± 0.06	0.63± 0.06	0.7± 0.03	1.2± 0.06
Water hyacinth	5.3± 0.01	15.90± 0.23	0.6± 0.06	0.12± 0.01	5.23± 0.06	1.33± 0.0	0.07± 0.01	2.23± 0.12	0.56± 0.06	0.7± 0.02	1.3± 0.10
Inorganic fertilizer	7.3± 0.01	12.96± 0.68	0.3± 0.01	0.15± 0.01	8.73± 0.15	1.43± 0.06	0.08± 0.01	2.33± 0.06	0.64± 0.06	0.7± 0.01	1.8± 0.06
C.V.	0.12	1	8.4	-	1.2	-	-	-	-	-	5.1
P	0.0001	0.0001	0.0001	-	0.0001	-	-	-	-	-	0.0001
LSD	0.0163	0.28	0.0067	NS	0.19	NS	NS	NS	NS	NS	0.1489

CEC: Cation exchange capacity, OC: Organic carbon, TN: Total N, HC: Hydraulic conductivity, ECe: Electrical conductivity of the saturation extract
C.V.: Coefficient of variability, P: Probability at 0.05 level, LSD: Lease Significant Difference

holding capacity and thereby reduced downwards movement of water. Application Organic materials were earlier found to improve soil water content through increase of negative charges (Khaleel *et al* 1981; Barzegar *et al* 2002). We speculate that absence of significant effects on soil soluble cations, CEC and dry matter accumulation could be due to sub-optimal amount added. However, most important that during removal of water hyacinth, incorporation of this plant waste to sandy soils away from the Nile will certainly reduce irrigation water needed. This study showed that during field decomposition of water hyacinth residues, N and P (most important nutrients), were not limiting the decomposition process.

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٢٢٤

استخدام ورد النيل فى استصلاح الاراضى الرملية

[١٦]

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المقدمـــــة

تعتبــر المعاملات المرتبطة بخصوبة التربة هى العمود الفقرى لاستدامة الانتاج الزراعى فى المناطق الجافة ، عليه فإن مصادر السمـاد العضـوى هامة لامـداد النبات بالعناصر الغذائيه على المدى القصير وكذلك للحفـاظ على المـادة العضويــه على المدى الطويل .

تم اجراء تجربتان بأستخدام ورد النيــل كاضافة للمـادة العضوية للاراضى رمليـة حيث كانت **الأولى**: تجربـــة حقلية لرصد تحلل وأنطلاق بعض العناصر الغذائيه (النيتروجين، الفوسفور، البوتاسيوم، الكانسيوم والمغنسيوم) تحت تأثير طريقــة الأضافه و**الثانية**: فى الصوبة (على المدى القصير) لدراسة تأثير أضافة ورد النيـل على بعض خواص التربة وعلى المراحل الاولى لنمو نبات سورجم العلف.

أوضحت نتائج التجربة الاولى، ان خلط المخلفات بعمق ٣٠سم (تحت سطحيه) من سطح التربة ادى الى زيادة معنويــة فى تحلل المـادة الجافة عن الاضافة السطحية. كـان معـدل ثابت التحلـل عند الأضافه السطحيـه وتحـت السطيــه ٠,٠٢٩ و٠,٠٤١/% الأسبوع ، على الترتيب. كما اوضحت الدراسه أيضا أن البوتاسيــوم كان أسرع العناصر أنطلاقا، وعموما يمكـن ترتيب تحـرر العناصر الغذائيـة كالتالـى K=Mg > P > N > Ca الا ان نتائج التجربة الثانيـة اوضحت ان الاضافـة أدت إلـى نقص الرقـم الهيدروجينـى لمستخلص التربــة والتوصيـل الهيدروليكى للماء بحوالى ٢٧% و ٤٠-٤٦%، على التوالى مع زيادة السعة التبادلية للكاتيونات.

وقد خلصت الدراسة الى ان اضافة نبات ورد النيل تعتبر من افضل البدائل فى تحسين خواص التربة الرملية بالمناطق الجافة.