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EFFECT OF WATER HYACINTH AND INORGANIC FERTILIZER ON MAIZE FODDER PRODUCTION

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ABSTRACT

Fodder yield must be improved for sustainable livestock production despite the poor quality of soils found in the tropics. A one-year field experiment was carried out on poorly aerated, low-fertility soil at Nsukka in south-eastern Nigeria. The study's objective was to examine the potential of chopped water hyacinth (WH) and NPK as soil conditioners in maize fodder production. Treatments were factorial combinations of four WH rates (0, 10, 20, and 40 t/ha) and inorganic fertilizer (NPK) at 0 and 0.15 t/ha, giving a total of eight treatment combinations with three replications in a randomised complete block design. The results revealed that nutrient management practices using organic manure (water hyacinth) and inorganic fertilizer (NPK) influence maize performance. Conclusively, the sole application of WH40 or the treatment combination of WH40+NPK0.15 proved more effective in maize performance with respect to vegetative growth, while WH20 effectively produced fodder yield and is therefore recommended for optimum fodder yield for pasture farmers.

INTRODUCTION

The insufficient concentration of crucial nutrients in the soil for crop growth and development is one of the challenges facing tropical crop production. According to Okalebo et al. (2009), most Nigerian soils are deficient in organic matter and macro- and micronutrients. Due to continuous cultivation without proper soil management practices, these soils are also delicate in nature and highly erodible (Oguike & Mbagwu, 2009). Application of manure as a soil management technique improves soil productivity, soil organic carbon content, soil microorganisms, soil crumb structure, soil nutrient status, crop growth and yield (Yang *et al*., 2021). In an agrarian society like Nigeria, there is currently a need to increase soil productivity and subsequently crop production, which will lead to the use of less expensive organic fertilizers like those made from water hyacinth (*Eichhornia crassipes* (Mart.) Solms).

A perennial hydrophyte that floats freely, water hyacinth is a member of the *Pontederiaceae* family. The ovate, broad, glossy, and thick leaves float above the water. The plant spreads quickly on stagnant water bodies like lakes, streams, ponds, waterways, and ditches as a dense green mat (Sahana &Sowmyalatha, 2022). The environmental risks of water hyacinth include impediments to water transportation, and canal and river blockages, which result in flooding. Chemical, physical, and biological methods haven't been very effective at controlling the weed (Abdelsabour, 2010). According to Ayesha and Padmaja (2010), fresh water hyacinth has a high moisture content (92.8%), a pH of 8.1, 417 g kg-1 of ash, 338 g kg-1 of total organic carbon, 9.5 g kg-1 of total nitrogen, a C:N ratio of 36:1, 5.4 g kg-1 of total phosphorous, and 9.7 g kg-1 of potassium. The plant's value as manure is increased during drying because it tends to keep the majority of its nutrients (Gunnarsson & Petersen, 2007). Heuzé *et al*. (2015) also highlighted the possibility of using composted or dried water hyacinth material as high-quality manure to enhance soil fertility and, consequently, crop yields generally. Dried water hyacinth contains a lot of organic material and may be a good source of nutrients for cereals such as wheat, sorghum, and maize.

As one of the most produced and consumed cereal crops in Nigeria, maize (Zea mays L.) is ranked third behind rice and wheat (Agbogidi & Okonmah, 2012). In terms of producing biomass, maize is a superior crop. Since ancient times, maize straw has been used as animal feed. Its fodder is prominent among the non-legume-cultivated fodders as it yields more biomass and has better nutritional quality. When 30% of the plant material is dried, maize can be ensiled with ease. Wet weather is not a problem when using the plant material to make hay because there is no need to attempt to further dry it out. Despite having economic and nutritional value for both humans and the livestock industry, maize production has been hampered by low yields brought on by a variety of issues, the most prominent being low soil fertility. Although the crop yield potential of Nigerian soil is high, farmers typically only achieve modest yields because of ineffective soil management and conservation techniques. The use of either inorganic or organic fertilizer can address this low soil fertility. However, due to inorganic fertilizers' scarcity, high price, and unpredictable availability, its use by resource-poor farmers is limited (Almaz, 2021; Purseglove, 1998).

Although inorganic fertilizer has been shown to increase maize production in intensive crop farming, it has not been beneficial because it is linked to soil acidity, nutrient imbalances, and a decrease in crop yield (FAO, 2022). However, by using other nutrient-enriching techniques, such as using water hyacinth as organic manure in addition to inorganic fertilizer, this issue can be resolved. Achieving a satisfactory fodder yield using water hyacinth will not only reduce dependence on inorganic fertilizer but also improve environmental well-being. Therefore, the objective of this study was to investigate the proper application of water hyacinth and inorganic fertilizer levels.

MATERIAL AND METHODS

The research was carried out at the Teaching and Research Farm of the University of Nigeria, Nsukka (06° 51 N; 07° 25 E) in southeastern Nigeria. A land area of 1,280 m^2 was slashed manually using a cutlass and weeded using a hoe. The experiment employed two factors: water hyacinth (WH) at four levels (0, 10, 20, and 40 t/ha) and inorganic fertilizer (NPK 15-15-15) at two levels (0 and 150 kg/ha), with WH and NPK serving as organic and inorganic soil amendments, respectively. These amendments and their levels were laid out as a 4 x 2 factorial in Randomized Complete Block Design (RCBD). Hence, eight treatment combinations were achieved and replicated three times.

Water hyacinth was harvested from River Niger; then dried, chopped and applied two weeks before planting, whereas NPK was applied by side placement method two weeks after planting. Each treatment plot was 2 m by 3m in dimension.Maize (Oba super variety) was the fodder crop. The maize was sourced from Enugu State Agricultural Development Project (ENADEP). All other cultural practices for area maintenance were adopted uniformly.

Analyses of the Amendments Used for the Study

The chopped water hyacinth (WH) was sieved, processed and analyzed for chemical constituents. WH was analyzed for pH, organic carbon, organic matter, N, P, and K. Soil pH was determined using a combined glass electrode pH meter in 1:2.5 soil water suspension as described by McLean (1982). Available phosphorus was determined using Bray-2 method of Bray and Kurtz as described by (Olson & Sommers, 1982), available phosphorus in the extract was determined by blue colour method (Murphy & Riley, 1962). Total nitrogen was measured by Kjeldahl method according to the procedures described by (Bremmer & Mulvaney (1982). Soil organic carbon was determined using the modified Walkely and Black wet digestion method as described by Nelson and Sommer (1996). An empirical factor of 1.724 was used to multiply the organic carbon to convert it to organic matter. The NPK contained 15% nitrogen, 15% phosphorus and 15% potassium

Soil Analysis

A composite sample was obtained for the soil physiochemical properties of the site by taking soil samples from 16 different points in the site to a depth of 15-20 cm (corresponding to the rooting depth of maize). Nelson and Sommer's (1982) Walkley and Black dichromate method was used for calculating organic carbon. By multiplying by a correction factor of 1.724, soil organic matter was adjusted for, as described by Nelson and Sommers (1996). The Kjeldhal method, as described by Bremner and Madison (1996), was used to calculate total nitrogen, and soil pH was calculated using a hand pH metre with a soil solution ratio of 1:2.5.

Data Collection

Up until the eighth week, measurements of the height, number, and area of the leaves on the maize plant were taken every other week. Data on the yield of fodder was gathered at harvest. The length and width of the leaf were measured, and the leaf area was then calculated as length × width × 0.75 (Stewart & Dwyer, 1999). The biomass was dried at the screen house to obtain the fodder yield, and then the dried biomass' weight was measured using a weighing balance.

RESULTS AND DISCUSSION

Table 1 shows that the soil's textural class was sandy loam. On average, coarse sand made up 39% of the soil used in the experiment, while fine sand made up 27%. The soil's chemical components revealed that it had a low fertility potential, as evidenced by low levels of soil organic matter (2.24 g/kg), total nitrogen (0.90 g/kg), available phosphorous (8.39 mg/kg), and acidity with a pH (H20) value of 5.1.

Table 2 shows that water hyacinth application had no significant influence on the leaf area at 4 and 5 weeks after planting (WAP). A similar observation was made regarding the number of leaves in 4 WAP. Comparing WH40 to other water hyacinth treatment levels at week 9, it was found that WH_{40} had the most leaves and the largest leaf area. The significant (P 0.05) effects of water hyacinth application on leaf area in this study revealed that incorporating water hyacinth into soil crop systems improved maize plant performance. In agreement with this, Osoro et al. (2014) reported that the growth characteristics of maize were significantly influenced by the application of water hyacinth compost. Furthermore, the highest values for the number of leaves and leaf area associated with WH40 can be attributed to the availability of sufficient nutrients (N, P, and K) for maize. According to Amoding et al. (1999), water hyacinth can absorb N, P, and K; this property could be used to increase crop production. Accordingly, nitrogen is important for photosynthesis and protein synthesis, leading to fast growth in terms of leaf number and area expansion, whereas phosphorous is important for root growth and development and consequently nutrient uptake (Hawkesford et al., 2012). However, the number of leaves or the area of the leaves at weeks 4 and 5, respectively, were unaffected by the application of water hyacinth at various rates ($P > 0.05$).

This may be explained by the fact that water hyacinth green manure contains nitrogen in the form of ammonium (Jamal et al., 2000), which may take two to three weeks to break down and release. The rate at which this happens is influenced by the soil's temperature, moisture content, population of soil microbes, and efficiency of incorporation.

The amount of leaf area did not change significantly (P 0.05) after a single application of NPK fertilizer. Despite the fact that NPK0.15 had the highest leaf area value at 9 WAP when compared to the control, this may be because the nutritional value of NPK fertilizer encouraged vigorous vegetative growth at an early stage.

Table 1: Physical and chemicalproperties of soilbefore amendment and chemical properties water hyacinth used as amendments

Parameters	**Soil**	**Water hyacinth**
Textural class	Sandy loam	
Coarse sand (g/kg)	39%	
Fine sand (g/kg)	27%	
Silt (g/kg)	9%	
Clay (g/kg)	25%	
pH- H_2O	5.1	8.20
pH- KCl	4.00	7.70
Organic carbon (%)	1.30	26.07
Organic matter (%)	2.24	44.94
Total nitrogen (%)	0.9	1.54
Available phosphorous (mg/kg)	8.39	0.33
Potassium (%)	0.04	0.14
Calcium (%)	1.40	2.00
Magnesium (%)	0.60	1.92
Sodium (%)	0.06	0.12

Table2: Main effects of treatments on leaf area (LA) and number of leaves (NL) of maize plants

Water Hyacinth	Week4		Week 5		Week6		Week 7		Week 8		Week 9	
	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL
WH_0	66	5.85	165	8.39	260	8.26	332	9.34	409	10.51	443	10.96
WH_{10}	63	5.58	162	8.72	279	8.41	365	9.31	447	10.28	501	11.18
WH_{20}	80	6.40	201	9.32	334	9.01	414	9.69	512	10.92	528	11.29
WH_{40}	91	6.20	225	9.51	360	9.54	438	9.99	527	10.63	571	11.28
$LSD_{(p<0.05)}$	Ns	Ns	Ns	Ns	75	0.98	ns	Ns	94	ns	86	Ns
NPK Fertilizer												
NPK_0	68	5.91	178	8.92	288	8.62	370	9.50	469	10.47	508	11.35
$NPK_{0.15}$	82	6.11	198	9.05	329	8.99	404	9.67	479	10.70	514	11.02
$LSD_{(p<0.05)}$	Ns	Ns	Ns	Ns	ns	ns	ns	Ns	ns	ns	ns	0.24

LA−leaf area, NL−number of leaves, WH_0−water hyacinth at 0 t/ha, WH_{10}−water hyacinth at 10 t/ha, WH_{20}−water hyacinth at 20 t/ha, WH_{40}−water hyacinth at 40 t/ha, NPK_0−nitrogen, phosphorous and potassium at 0 kg/ha, $NPK_{0.15}$−nitrogen, phosphorous and potassium at 150 kg /ha

Interaction Effects of Water Hyacinth and NPK Fertilizer on Leaf Area and Number of Leaves of Maize Plants

The combined application of NPK fertiliser and water hyacinth (WH) on the amended plot had no significant (P 0.05) impact on the number of leaves or leaf area from 4 to 8 weeks after planting. Only in the ninth week, though, were the interactions significant for the number of leaves and leaf area. In comparison to other treatment combinations, WH_{40}+$NPK_{0.15}$ produced the greatest number of leaves in the ninth week. This might be explained by an increase in the nitrogen and phosphorous released by water hyacinth and NPK fertilisers. According to Fashino et al. (2002) and Obi et al. (2005), the availability of adequate growth nutrients led to enhanced cell activities, multiplication, expansion, and flourishing growth, as well as high dry matter accumulation.

The highest value for leaf area was provided by WH_{40}+NPK_0 at 9 WAP. This could be a result of the water hyacinth's incorporation, which provides an adequate supply of nitrogen. These were consistent with Olaniyi and Adelasoye's (2008) report that celosia plants grew more as nitrogen fertiliser rates were increased. They observed that nitrogen increases stem girth, the number of leaves, and other vegetative parts of the plants by increasing the size and number of cells produced by cell division and expansion. On the amended plot, however, the simultaneous application of water hyacinth and NPK fertiliser had no significant (P 0.05) impact on the number of leaves and leaf area from weeks 4 to 8 after planting. The values for the number of leaves and leaf area at weeks 4, 5, 6, 7, and 8 are therefore considered to be statistically similar (P 0.05). This may be caused by the slow release of nitrogen into the soil and incomplete decomposition. The amount of soil moisture, soil temperature, the number of soil microbes present, and the effectiveness of incorporation all affect how quickly the nitrogen in water hyacinth manure is degraded to release it as ammonium (Gamal et al., 2000). The nitrogen content of the NPK fertiliser applied may have been lost as a result of leaching or denitrification processes because the experimental site had little organic matter. The low nutrient status of tropical soils, particularly nitrogen, phosphorus, and potassium, as a result of the practice of slash and burn farming systems associated with bush fallow and excessive leaching of soil nutrients, has been attributed to yield differences between temperate and tropical areas (Kolawole et al., 2009).

Table 3: Interaction effects of water hyacinth and NPK fertilizer on leaf area and number of leaves of maize plants

Water Hyacinth	NPK Fertilizer	Week 4		Week 5		Week 6		Week 7		Week 8		Week 9	
		LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL	LA (cm^2)	NL
WH_0	NPK_0	52	5.67	158	8.22	254	8.19	336	9.43	418	10.40	457	11.45
WH_{10}		48	5.17	137	8.56	217	7.87	291	9.07	372	10.08	428	11.25
WH_{20}		82	6.53	194	9.31	305	8.75	399	9.61	525	10.86	515	11.39
WH_{40}		88	6.28	224	9.61	376	9.68	456	9.88	559	10.54	630	11.30
WH_0	$NPK_{0.15}$	80	6.04	171	8.55	266	8.33	328	9.25	401	10.61	430	10.47
WH_{10}		78	6.00	187	8.89	342	8.95	438	9.55	522	10.48	573	11.11
WH_{20}		78	6.28	208	9.33	362	9.28	430	9.78	498	10.98	541	11.20
WH_{40}		93	6.12	225	9.41	345	9.41	419	10.09	494	10.73	513	11.27
$LSD_{(p<0.05)}$		Ns	ns	Ns	Ns	Ns	Ns	Ns	ns	ns	ns	122	0.48

LA−leaf area, NL−number of leaves, WH_0−water hyacinth at 0 t/ha, WH_{10}−water hyacinth at 10 t/ha, WH_{20}−water hyacinth at 20 t/ha, WH_{40}−water hyacinth at 40 t/ha, NPK_0−nitrogen, phosphorous and potassium at 0 kg/ha, $NPK_{0.15}$−nitrogen, phosphorous and potassium at 150 kg/ha levels

Main Effects of Treatments on Plant Height and Fodder Yield

Application of water hyacinth significantly (*P*<0.05) influenced plant height at 6−9 week after planting (Table 4). At week 9, the trend was as follows: $WH_{40}>WH_{20}>WH_{10}>WH_0$. The tallest plant height was observed in plots amended with WH_{40} because it had the highest nitrogen and phosphorus concentrations.Phosphorus is important in root growth and developmentand therefore nutrient uptake; while nitrogen is importantin photosynthesis and protein formation hence fastgrowth in terms of height and leaf expansion (Hawkesford, *et al.*, 2012).This is also in harmony with the reports of Gunarsson and Mattsson (1997) who work with water hyacinth found that the maize plants were higher in plants treated with water hyacinth than in those which had not been fertilized. In contrast, application of water hyacinth at different rates on amended plots had no significantly (P< 0.05) effects plant height from week 4−5 and also on folder yield. However, plots amended with WH_{20} had the highest fodder yield when compared with other treatments. This is in consistent with several reports on soiltreated with green manure prepared from water hyacinth has been successfully utilized to improved cropyield in maize(Chukwuka & Omotayo, 2008) and tomato (Kayum,*et al*., 2008). Furthermore, NPK fertilizer did not significantly (P<0.05) improve fodder yield of maize. As weight obtained from untreated plot was observed to be higher than treated plot. This could be as a result of leaching and the inability of inorganic fertilizer in improving soil physical and biological properties, as supported with the report of Altuhaish and Hamim (2014) that sole application of inorganic fertilizer causes damage on physical, chemical and biological properties of soils, so that the soil fertility will be more decreased.

Table 4: Main effects of treatments on plant height and fodder yield

Water Hyacinth	Plant height (cm)						Fodder yield
	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	
WH_0	13.47	24.10	36.00	45.30	51.10	57.40	0.27
WH_{10}	13.48	24.80	39.50	47.80	54.00	58.70	0.41
WH_{20}	15.86	29.70	44.40	56.30	62.50	69.40	0.58
WH_{40}	16.20	30.90	49.10	61.00	67.80	72.70	0.52
$LSD_{(p<0.05)}$	Ns	Ns	8.82	11.69	11.40	10.82	Ns
NPK Fertilizer							
NPK_0	14.15	27.10	41.10	50.30	56.80	62.50	0.46
$NPK_{0.15}$	15.36	27.70	43.30	54.90	60.90	66.50	0.43
$LSD_{(p<0.05)}$	Ns	Ns	Ns	Ns	Ns	Ns	Ns

WH_0−water hyacinth at 0 t/ha, WH_{10}−water hyacinth at 10 t/ha, WH_{20}− water hyacinth at 20 t/ha, WH_{40}−water hyacinth at 40 t/ha, NPK_0−nitrogen, phosphorous and potassium at 0 kg/ha, $NPK_{0.15}$−nitrogen, phosphorous and potassium at 150 kg/ha

Interaction Effects of Water Hyacinthand NPK Fertilizer on Plant Height and Fodder Yield of Maize Plants

At 6 WAP, WH and NPK fertiliser interactions significantly (P 0.05) increase plant height, while at 9 WAP, the tallest plant was WH20+ NPK0.15 (Table 5). This increase in maize growth at 6 WAP could be a result of providing ample amounts of necessary nutrients (N, P, and K) as well as enhancing the physical and chemical characteristics of the soil. This is consistent with the findings of Abera et al. (2019), who noted that the use of organic manure along with inorganic fertiliser could significantly reduce the negative nutrient balance in many cropping systems. The combined use of organic manure and inorganic fertiliser is preferred to the sole use of either one alone, particularly in intensive agricultural systems. Combining organic manure and mineral fertiliser improves nutrient use efficiency (Nweke et al., 2013; Nweke and Nsoanya, 2013b; Nweke and Nsoanya, 2015). In contrast to this assertion, the interaction had no significant (P 0.05) impact on plant height at 4, 5, 7, and 8 WAP in this study. The non-significant difference (P < 0.05) in maize height between WH20+NPK0.15 and WH40+NPK0.15 implies that the plant had absorbed enough of the nutrients it required at WH20+NPK0.15. There was no significant difference (P 0.05) in growth parameters like plant height from 7 to 9 WAP because the majority of nutrients that were absorbed above WH20+NPK0.15 were not utilized in the plant growth and development processes.

Table 5: Interaction effects of water hyacinth NPK fertilizer on plant height and dry matter yield on maize plants

Water Hyacinth	NPK Fertilizer	Plant height (cm) (Week 4)	Plant height (cm) (Week 5)	Plant height (cm) (Week 6)	Plant height (cm) (Week 7)	Plant height (cm) (Week 8)	Plant height (cm) (Week 9)	Fodder Yield
WH_0	NPK_0	8.81	15.20	21.80	28.10	33.40	41.40	0.06
	$NPK_{0.15}$	8.19	13.00	21.30	31.10	36.40	41.90	0.10
WH_0	NPK_0	16.56	34.10	50.40	59.40	66.20	73.20	0.77
	$NPK_{0.15}$	20.33	33.90	50.50	62.40	68.40	73.30	0.17
WH_{10}	NPK_0	8.28	16.10	25.30	30.80	36.40	42.10	0.07
	$NPK_{0.15}$	14.51	29.50	44.40	51.30	57.80	63.20	0.41
WH_{10}	NPK_0	15.59	27.60	43.40	55.70	62.90	65.50	0.72
	$NPK_{0.15}$	15.55	26.20	44.80	53.60	58.90	63.90	0.44
WH_{20}	NPK_0	14.25	27.10	40.30	47.20	52.40	59.40	0.12
	$NPK_{0.15}$	12.78	22.80	31.80	47.70	53.60	59.60	0.72
WH_{20}	NPK_0	16.97	30.20	44.70	58.80	65.70	71.30	0.72
	$NPK_{0.15}$	19.45	38.90	60.70	71.60	78.30	87.20	0.74
WH_{40}	NPK_0	16.03	32.10	46.10	57.90	66.70	71.10	0.74
	$NPK_{0.15}$	20.69	36.10	57.10	69.70	76.50	81.30	0.75
WH_{40}	NPK_0	16.72	34.40	57.10	64.70	71.40	76.40	0.77
	$NPK_{0.15}$	11.37	21.10	36.00	51.70	57.20	62.00	0.14
$LSD_{(p<0.05)}$		Ns	Ns	17.64	Ns	ns	Ns	Ns

WH_0−water hyacinth at 0 t/ha, WH_{10}−water hyacinth at 10 t/ha, WH_{20}−water hyacinth at 20 t/ha, WH_{40}−water hyacinth at 40 t/ha, NPK_0−nitrogen, phosphorous and potassium at 0 kg/ha, $NPK_{0.15}$−nitrogen, phosphorous and potassium at 150 kg/ha

In a similar vein, interactions between WH and NPK fertilizer had no significant (P 0.05) impact on the maize fodder yield. As might be expected at this level, an increase in vegetative parameters as a result of interactions between WH and NPK fertilizer for plant height over the period did not result in an increase in fodder yield. This could be attributed to treatments applied to amended plots that released insufficient phosphorous and leached potassium, which could be the cause of low dry matter or fodder yield. This supports the findings of Hani et al. (2006), who found that P deficiency frequently causes multiple reductions in maize yield. Insufficient P supply, according to HUE (1995), will lead to reduced synthesis of RNA, the protein maker, causing stunted growth.

CONCLUSION

The study showed that nutrient management practices using organic manure (Water hyacinth) and inorganic fertilizer (NPK) influence maize performance. It was concluded that sole application of WH_{40} or treatment combination of WH40+$NPK_{0.15}$proved more effective in maize performance with respect to vegetative growth while WH_{20} effectively produced fodder yield and therefore recommended for optimum fodder yield for pasture farmers.

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