FISHERIES PRODUCTION

Journal of Applied Agricultural Research 2020, 9(1): 168 - 178
ISSN 2006-750X.

EVALUATION OF SOME AGRO WASTES SOURCES FOR SOIL MICROBIAL GROWTH AND PERFORMANCES OF COCOYAM (*COLOCASIAESCULENTA*) IN SOUTH EASTERN NIGERIA

Iwoh, E. F
National Root Crops Research Institute Umudike, P.M.B. 7006 Umuahia, Abia state, Nigeria
Corresponding author *Email: georgeiwoh1@gmail.com*

ABSTRACT

This study was conducted to evaluate the short-term effects of some agro organic waste sources of nutrients on soil microbial activity, growth and yield, using randomized complete block design in four replications with cocoyam (*colocasiaesculenta*) as the test plant. The trail involved four treatments: non-fertilized (control), cassava peel (CP), empty palm bunch (EPB), saw dust (SD) and rice husk (RH). Soil samples were collected from the surface (0-20 cm) soil for microbial analysis before and after treatments at monthly intervals for 4 months. The data were subjected to Duncan new multiple range test at $p \leq 0.05$. Cultural morphology and biochemical identification were carried out using standard microbiological techniques. Results obtained showed that bacterial population was higher than the fungal population in all the treatments. Saw dust (SD) induced the highest increase in microbial population of (126.66 $x10^6 \pm 2.88$ cfu/g), followed by cassava peel (CP) 112.43 $x10^6$cfu/g, rice husk (RH) 105.00$x10^6$cfu/g, empty palm bunch (EPB) 88.63$x10^6 \pm 2.51$cfu/g and control 14.33$x10^2 \pm 1.19$cfu/g, respectively. Similar effect was observed on fungal population which SD gave the highest (28.66$x10^2 \pm 1.73$cfu/g), followed by CP (26.33 $x10^2 \pm 1.25$cfu/g), RMW (20.53$x10^2 \pm 1.65$cfu/g) and EPB (19.00$x10^2 \pm 1.16$cfu/g) and control (14.33$x10^2 \pm 1.19$cfu/g). The Microbial isolates and percentage occurrence in the soil sample included bacteria such *as; Bacillus cereus (100%), Proteus mirabilis* (100%), *Escherichiacoli* (100%),*Micrococcusvarians* (80.0%) *Pseudomonasaeruginosa* (80.0%), *Staphylococcusaureus* (80.0%),*Lactococcuslactis* (60.0%), while the fungal isolates were *Aspergillusniger* (100%), *Rhizopus*spp(80.0%), *Penicillium*spp (80.0%), *Fusarium* (60.0%), *Mucor*spp(40.0%) and *Aureobasidium*spp(40.0%). Cocoyam yield showed that SD gave the highest yield of 8.6 t/ha, followed by cassava peel (CP) 7.8 t/ha, rice husk (RH) 7.8 t/ha, empty palm bunch (EPB) 5.5 t/ha and control, 3.6 t/ha. The effects of different amendments were observed, confirming that some effects of integrated fertilizer strategies may occur in the short term.

Keywords: Agro wastes, cocoyam, microbial activity, microorganisms, soil, yield

INTRODUCTION

Agro-waste is defined as waste which is produced from various agriculture activities. This includes manures, bedding, plant stalks, hulls, leaves, and vegetable matter. Agro-wastes contain essential nutrients needed for improvement of soil fertility, plant growth and yield (Oladipo *et al*., 2005). However, proper utilization of these organic wastes by farmers is still poor despite their high nutrient composition (Ayeni and Adeleye 2011), and improvement of physical, chemical and biological properties in the soil (Lui*et al*., 2007; Yu *et al*., 2015). Increasing the sustainability of cropping systems involves the reduction of agrochemical and fertilizer inputs through the reliance on soil ecosystem processes and biological interactions for the provision of plant nutrients (Drinkwater and Snapp 2007).

Management of soil fertility through organic fertilizers has always been a pivotal principle of sustainable agriculture. Fertilizer impacts on soil microbial community structure and function as well as on nutrient availability can vary widely, having extremely different impacts on crop productivity (Chivenge*et al*. 2011). There is need to consider soil microbial processes as they are crucial for plant nutrient supply given their central role in soil organic matter decomposition and nutrient dynamics (Paul, 2007). Better understanding of the microbial processes that take place in soil under organic fertilization could help identify the main drivers determining nutrient availability in order to improve crop growth.

Extensive use of chemical fertilizers in relation to organic fertilizers has led to decrease in soil organic carbon and soil quality (Kumar *et al*., 2018). Therefore, there is need to consider soil microbial processes as they are crucial for plant nutrient supply given their central role in soil organic matter decomposition and nutrient dynamics. Thus the need to utilize plant residues such as Cassava peel, Empty palmbunch, saw dust and Rice husk to maintain a satisfactory level of soil fertility, and this can be practicable and adopted by farmers. The objective of this study is therefore to investigate the effects of agro organic wastes sources of nutrient for soil microbial growth and performances of cocoyam (*colocasiaesculenta*) in an ultisol of south eastern Nigeria.

MATERIALS AND METHODS

Study Site

The study was carried out on a loamy soil at the agricultural experimental field of National Root Crops Research Institute Umudike, Nigeria (longitude 07^0 33'E, latitude 05^0 29'N and altitude 122 M). Umudike is in the low-land humid tropics of south eastern Nigeria. The research plots were established in April 2018, and the trial was set-up as a randomized complete block design (RCBD), with four replications. Each plot size measured 15 m^2 (3 m x 5 m); with 1m spacing between the plots. The test plant used in the experiment was cocoyam *(Colocasiaesculenta)*. Treatments comprised Control (without fertilization), cassava peel at 5 t/ha, Saw dust (SD) at 5 t/ha, empty palm bunch (EPB) at 5 t/ha and Rice husk (RH) at 5 t/ha; and were uniformly distributed on the experimental soil.The treatments were allowed to incubate for one week before planting the test crop with a depth of 5cm and spacing of 0.7 m between rows and 0.25 m within row, respectively.

Soil sampling was conducted in accordance with the method of Saeki and Toyota, (2004). Soil samples were collected from the study site before application of treatment and four times after application of treatments at monthly intervals beginning from May 2018 to August 2018. Soil auger was used to collect top soil sample from depth of 0-20 cm at four randomly selected locations in each of the plots. Composite samples were collected from each plot and stored in a sterile polypropylene bag and kept cool using coolers during field sampling. The composite samples were homogenized and sieved twice using meshes (2.0 and 0.2 mm) in order to remove stone and plant debris. Samples collected were subsequently processed within 24 - 48 hour.

Physicochemical Analysis of Soil Samples

Physicochemical properties of each soil sample were determined using the methods of Bremner (1996) and the Association of Official Analytical Chemists (AOAC, 1990). Parameters for consideration were pH, organic carbon, organic matter, total nitrogen (N), available phosphorus and exchangeable potassium (K).

Microbiological Analysis

One gram (1g) of each of the soil samples was weighed and agitated in 9 mL of distilled water, to dislodge the organisms from the soil particles. An aliquot of 1 mL was serially transferred from each sample into series of test tubes containing sterilized distilled water to obtain dilution of 10^{-1} and 10^{-10}.

For total heterotrophic bacteria aliquot (0.1mL) of 10^{-2}, 10^{-4}, 10^{-6} and 10^{-8} was inoculated into nutrient agar plated in triplicates (Anderson and Domasch, 1958). Total soil fungi were enumerated by inoculating aliquots (0.1mL) and determined using Sabouraud dextrose agar (SDA) supplemented with streptomycin (1 mg/100 mL) to suppress bacterial growth with the diluted soil samples of 10^{-3} (Scharlau Microbiology, 2000). The plates were all incubated aerobically at room temperature (30^{0} C) for 24hours (bacteria) and 96 hours (fungi). The resulting colonies were counted and recorded as colony forming units per gram (CFU/g) using colony counter. The counts were characterized based on cultural characteristics, staining reaction and biochemical tests.

Plant Height Measurement

Measurement was done after one month of planting, with 95% germination; three plants were randomly selected and tagged for monthly data collection. Plant height was measured using a meter rule from the surface of the soil to the tip of the tallest leaf (Nwafor*et al*., 2010)

Yield Determination

Cocoyam yield was determined through the weight of tubers collected from two middle rows of each plot (expressed in t/ha), and was done at the end of the growing season (4 MAP).

Statistical Analysis

The data were subjected to an analysis of variance (ANOVA Statistical SPSS 5), using a GENSTAT and the significant effects between individual-factor level and interaction means were separated using Duncan new multiple range test (DNMRT) at $P \leq 0.05$ level.

RESULTS AND DISCUSSION

Physicochemical Characteristics of the Soil Samples

The result in Table 1 shows the physicochemical properties of the experimented soil before treatment. This revealed that soil pH is moderately acidic, with a medium organic carbon, low in total nitrogen, low in Organic matter content, low in available phosphorus and low in exchangeable potassium. Soil particle size distribution indicated that the soil texture was clay loam and the sand fraction account for an average of 52.7%, while the silt was 14.7% and clay account for 32.6%.

Table 2 shows the physicochemical properties of experimental soil after treatments application. The soil is slightly acidic with a textural class of clay loam, this highest in soil pH (6.37±0.12) is recorded from a plot amended with empty palm bunch (EPB), compared to soil samples from CP, SD and RH. Application of saw dust (SD) also increases the value of organic carbon content (1.52±0.04%), organic matter content (1.61±0.06%) and total nitrogen content (0.87±0.01%), This is in line with Kang *et al.* (2005) the application of organic manures significantly increased the soil organic carbon content. The increase in soil organic carbon content can depend on both organic inputs as well as higher crop residue fall to soil. Whereas increase in available phosphorus (23.47±0.09 mg/kg) and exchangeable potassium (0.45±0.26Cmol/kg) recorded in plots amended with cassava peel (CP).

Microbial Analysis of the Soil Samples

The results revealed that soil microbiological characteristics, stem height and cocoyam yield were significantly affected by the amendments. Microbial population of the study soil before application of different treatments showed bacterial population of 78.33 x 10^6 CFU/g, while fungal population was 5.53 x 10^2 CFU/g (Table 3). These showed that the microbial population was low compared to treated plots. There is need to improve the fertility status of the soil for better microbial activity, growth and optimum crop yield.

Bacterial population recorded the highest in a plot amended with 5 t/ha saw dust (126.66x106±2.18 CFU/g) while the lowest in control plot (81.33x10^6±2.00 CFU/g), there was significant variation in bacterial population between treated plots and control $P \leq 0.05$; (Table 4). Saw dust (SD) provided organic substrates that proliferated bacterial population and their activities in the soil, as they breakdown soil organic matter and multiply in the soil, which accounted for the highest bacterial count in the 2nd month of sampling. The increased in bacterial population in saw dust (SD) amended plots might be as a result of suitable conditions which acted as a good substratum for microbial activity. Similar short-term increases in microbial biomass have been reported previously by (Aranconet *al*., 2006; Dinesh *et al*., 2010) and this was attributed to the supply of organic carbon substrates.

Other researchers have also shown that incorporation of organic amendments such as poultry manure increased soil microbial population, enzymatic and microbial diversity (Girvan, *et al*., 2004; Iwoh, *et al*., 2020). Saw dust promoted biological and microbial activities, which accelerated the breakdown of organic substances in the soil with evidence in relatively high carbon content and enzyme activities. Further increased in bacterial population was recorded with plot amended with cassava peel (CP), which also might be attributed to thesymbiotic and mycorrhizal relationships with soil microorganisms. Also, Mader*et al*., (2002) reported that soils under organic farming had enhanced microbial functional diversity in comparison with the soils of conventional farming. In general, the bacterial population was higher than the fungal population throughout the sampling period. Bacteria were the most sensitive microbial group recorded. Also, bacteria have much shorter turnover time than fungi and can react faster to the environmental changes in soil. Li *et al*., (2015) reported that addition of animal or green manures on organic farms provided a significantly greater input of organic carbon, which increased bacterial populations, while the use of excessive chemical fertilizers reduced microbial functional diversity and enzymatic activity in the soil.Bacterial growth is often limited by the lack of readily available

Carbon substrates, even in soils with a high Carbon/Nitrogen ratio, and comprised the first group of microorganisms to assimilate most of the readily available organic substrates after they are added to the soil (Demoling*et al*. 2007; Kuzyakov 2010). Both substrates promoted the growth of bacteria showing that the organic substrates added were used by the soil microorganisms not only for maintenance, but also for production of new biomass, which therefore reinforces the hypothesis of the Carbon limitation on the soil (Demoling*et al*. 2007).

Total heterotrophic fungal population recorded was maximum in plot amended with 5 t/ha cassava peel (28.33 x10^2±1.25 CFU/g), followed by 5 t/ha saw dust (26.66x10^2±1.73CFU/g), 5 t/ha rice husk (20.53x10^2±1.65 CFU/g), 5 t/ha empty palm bunch (19.00 x10^2±1.16 CFU/g) and minimum population recorded in control (13.33x10^2±1.19 CFU/g). Total heterotrophic fungal populations during the four months of sampling under different treatments showed that fungal count was highest at 1st month (May) and gradually reduced at 2nd, 3rd and 4th months. Cassava peel (CP) promoted fungal growth in the soil with a significant variation between the treated plot as well as control plot at $P \leq 0.05$ (Table 5). The increased in fungal population noticed in the cassava peel plot might be as a result of adequate nutrient supply which acted as a good substratum for in for fungal growth and utilization. Lowest values of fungal count were recorded on control plot across the 4 sampling periods.Studies showed that increased soil pH in the acidic range caused a shift towards dominance of the bacterial community, while fungal communities were unaffected (Pennanen, 2001).Fungal population in soil at harvest was low as compared to bacterial population. Decreased fungal population is typical of intensively cultivated agricultural soils and it has been attributed to different factors such as physical disturbance, altered amount and complexity of the nutrient inputs and decrease in soil organic matter as compared to undisturbed soils.

Table 1: Initial soil physicochemical properties of the experimented soil

Soil parameters	Values
pH	5.83±0.05
Organic Carbon (%)	0.45±0.03
Organic Matter (%)	0.50±0.05
Total Nitrogen N (%)	0.27±0.01
Available Phosphorus P(mg/kg)	15.7±0.22
Exchangeable Potassium K (Cmol/kg)	0.14±0.04
Sand (%)	52.7±0.40
Silt (%)	14.7±0.24
Clay (%)	32.6±0.61
Texture	Clay loam

Table 2: Soil physicochemical properties of the soil samples after treatments application during 2018 cropping season

Soil Parameters	Soil samples			
	CP	SD	EPB	RH
Ph	5.73±0.12^{e}	5.77±0.06^{d}	6.37±0.12^{a}	6.10±0.19^{c}
Organic. Carbon (%)	1.34±0.02^{c}	1.52±0.04^{a}	1.33±0.03^{cd}	1.40±0.02^{b}
Organic Matter (%)	1.31±0.04^{b}	1.61±0.06^{a}	1.29±0.03^{c}	1.40±0.03^{d}
Total Nitrogen (%)	0.51±0.02^{c}	0.87±0.01^{a}	0.30±0.01^{e}	0.73±0.01^{b}
Available Phosphorus (mg/kg)	23.47±0.09^{a}	18.80±0.13^{b}	15.59±0.09^{cd}	16.70±0.34^{d}
Exchangeable Potassium (Cmol/kg)	0.45±0.26^{a}	0.37±0.63^{c}	0.25±0.03^{e}	0.28±0.41^{b}

Values show means of triplicate analysis ± standard deviation figure with superscripts in the row show significantly different at P≤0.05, according to DNMRT.

CP =Cassava peel; EPB= Empty palm bunch; SD= saw dust; RH= Rice husk, DNMRT = Duncan New Multiple Range Test

Table 3: Initial soil sample for microbial population

Microbial soil sampling	Microbial counts (CFU/g)
Bacterial	81.33 x10^{6}
Fungi	18.73x10^{2}

Table 4: Effect of different treatment applications on total heterotrophic bacterial mean count (CFU/g) in 2018 cropping season

	Sampling period			
Treatments	May	June	July	August
Control	81.33x10^{6}±3.05^{a}	81.33x10^{6}±2.00^{a}	81.33x10^{6} ±2.51^{a}	81.33x10^{6}±1.62^{a}
CP	102.43x10^{6}±1.52^{d}	112.43x10^{6}±2.5^{d}	110.43x10^{6}±1.73^{d}	106.00x10^{6}±2.30^{e}
EPB	82.43x10^{6}±2.71^{b}	88.63x10^{6}±1.42^{b}	87.43x10^{6}±1.72^{b}	84.00x10^{6}±2.10^{b}
SD	99.33x10^{6}±1.15^{e}	126.66x10^{6}±2.18^{e}	122.66x10^{6}±1.20^{e}	103.66x10^{6}±2.20^{c}
RH	95.66x10^{6}±1.70^{c}	105.00x10^{6}±2.20^{c}	108.00x10^{6}±1.32^{c}	97.33x10^{6}±1.63^{d}

Values show mean of triplicates analysis ± standard deviation. Figure with different superscripts down the column were significantly different according to Duncan new multiple range test at P≤0.05.

CP =Cassava peel; EPB= Empty palm bunch; SD= saw dust; RH= Rice husk

Table 5: Effect of different treatment applications on total heterotrophic fungal mean count (CFU/g) in 2018 cropping season

	Sampling period			
Treatments	May	June	July	August
Control	$13.33x10^2±1.19^a$	$14.33\ x10^2±1.15^a$	$13.33x10^2±1.52^a$	$13.33x10^2±1.17^a$
CP	$28.33\ x10^2±1.25^d$	$25.66\ x10^2±1.25^d$	$24.16x10^2±1.25^d$	$22.61x10^2±1.19^{dc}$
EPB	$19.00\ x10^2±1.16^b$	$18.66\ x10^2±1.55^{cb}$	$16.26x10^2±1.35^c$	$14.28x10^2±1.45^b$
SD	$26.66x10^2±1.73^e$	$23.66x10^2±1.35^e$	$22.43x10^2±1.42^e$	$20.61x10^2±1.35^e$
RH	$20.53x10^2±1.65^c$	$18.00x10^2±1.17^{bc}$	$18.10x10^2±1.31^b$	$16.19x10^2±1.65^{cd}$

Values show mean of triplicates analysis ± standard deviation. Figure with different superscripts down the column were significantly different according to Duncan new multiple range test at P≤0.05.

Microbial diversity recorded indicates that different heterotrophic bacteria and fungi were isolated from the experimented soil (Table 6). The Microbial isolates and percentage occurrence in the soil sample include bacteria such as; *Bacillus cereus* (100%), *Proteus mirabilis* (100%), *Escherichia coli* (100%), *Micrococcus varians*(80.0%) *Pseudomonas aeruginosa*(80.0%), *Staphylococcus aureus* (80.0%), *Lactococcuslactis* (60.0%), while the fungal isolates include *Aspergillusniger*(100%), *Rhizopus*spp(80.0%), *Penicillium*spp (80.0%), *Fusarium* (60.0%), *Mucor*spp(40.0%), and *Aureobasidium*spp(40.0%). According to Iwoh*et al*., (2020) changes in nutrient composition have the potential to directly or indirectly affect the microbial community in the soil, thereby stimulating the development of certain group of microorganisms, and increased microbial count and diversity. Also, Kourtev*et al*., (2003) found that the ratio of gram-negative and gram-positive bacteria can be attributed to quality of organic matter and its content in the soil and this might reflect the loss of easily decomposable materials.

Table 6: Microorganisms isolated from the soil sample and their percentage occurrence (CFU/g)

Organisms isolated	Control	CP	EPB	SD	RH	% Occurrence
Bacterial						
Bacillus subtilis	+	+	+	+	+	100%
Proteus mirabilis	+	+	+	+	+	100%
Escherichia coli	+	+	+	+	+	100%
Micrococcus varians	-	+	+	+	+	80.0%
Pseudomonas aeruginosa	+	+	-	+	+	80.0%
Staphylococcus aureus	+	+	-	+	+	80.0%
Lactococcuslactis	-	-	+	+	+	60.0%
Fungal						
Aspergillusniger	+	+	+	+	+	100%
*Rhizopus*spp	-	+	+	+	+	80.0%
*Penicillum*spp	+	+	+	+	-	80.0%
*Fusarium*spp	-	+	+	-	+	60.0%
*Mucor*spp	-	+	-	+	-	40.0%
*Aureobasidium*spp	-	+	-	+	-	40.0%

(+) = present of microbes; (-) = absent of microbes; CP = Cassava peel; EPB= Empty palm bunch; SD= saw dust; RH= Rice husk

Effect of agro-wastes amendment on the growth and yield of cocoyam

Stem height of cocoyam recorded showed that the amendments significantly (P<0.05) increased the height of cocoyam starting from 5 weeks after planting (WAP) when compared to control (Table 7). At 12 WAP, plot amended with 5 t/hasaw dust (SD) recorded the highest stem height of 31.40 cm, followed by 5 t/ha cassava peel (28.52 cm), 5 t/ha rice husk (29.62 cm) and 5 t/ha empty palm bunch (27.47 cm), while the least was from control plot (10.62 cm) height. Yield of cocoyam recorded also showed significant increases (P<0.05). as plot amended with 5 t/hasaw dust waste recorded the highest yield of 3.8 t/ha, this was followed by the plot amended with 5 t/hacassava peel (3.6 t/h) and then the plots treated with 5 t/ha rice husk (3.3 t/ha), and 5 t/ha empty palm bunch (3.1 t/ha), while control recorded the lowest value of 2.6 t/ha (Table 8).

The effect of the treatment on yield is in line with results obtained by other authors who reported the importance of both their individual and combined use not only in terms of yield, but for improvement of soil production characteristics and preservation of soil ecological status (Cerny*et al*., 2010). Manqiang*et al*., (2009) also stressed the importance of substituting costly mineral fertilizers with manure and other organic substrates as part of the improvement of soil biological productivity and crop yield. Application of organic agro wastes did not result in the immobilization of plant available nutrients but increased nutrient turnover through both increased microbial biomass and activity. Altogether, the changes in microbial community function with organic fertilizers seemed to be enough to maintain and even increase the uptake of plant nutrients by the cocoyam crop as compared to control. Changes in the composition, and particularly the function, of soil microbial community due to agricultural management practices can have large impacts on crop health and productivity (Chaparro*et al*. 2012; Franco-Otero *et al*. 2012). Even though organic fertilizers have been traditionally used as sources of plant nutrients, the understanding of their role on plant growth and soil fertility has not always been well understood (Manlay*et al*. 2007). The present investigation showed that all the agro organic amendment applied had great impact on soil microbial community and its activity, and these would help provide a better understanding of the importance of these neglected agricultural wastes in promoting soil microbial activities, growth and cocoyam yield.

Table 7: Effect of treatments on plant height (cm) of cocoyam at 4 MAP in 2018 cropping season

Treatments	Stem height				
	May	June	July	August	Mean
Control	4.7	9.5	14.1	14.3	10.62
CP	10.9	29.7	36.8	36.7	28.52
EPB	8.6	26.5	37.3	37.5	27.47
SD	11.2	32.6	40.9	40.9	31.40
RH	10.8	30.4	38.6	38.7	29.62

Table 8: Effect of treatments on tuber yield (t/ha) of cocoyam at harvest in 2018

Treatments	Root yield (t/ha)
Control	2.6
CP	3.6
EPB	3.1
SD	3.8
RH	3.3

CP = Cassava peel; EPB= Empty palm bunch; SD= saw dust; RH= Rice husk

CONCLUSION

This study has shown that agro-wastes can improved soil fertility status, microbial activity and increase crop yield. Beneficial effects occurred even when the organic agro waste amendments were only a small portion of the total amounts supplied to the soil throughout the 4 months, suggesting that a shift to more sustainable production systems could significantly improve soil fertility while maintaining crop yield at all treatment levels. We therefore recommend application of 5 t/ha saw dust agro waste for successful integrated cocoyam production system in order to promote biological and microbial activities, soil fertility, growth and yield of cocoyam production in an ultisol of Southeastern Nigeria under the agro environmental conditions specified in this study.

REFERENCES

Adekayode, F.O. and Olojugba, M.R. 2010. The utilization of wood ash as manure to reduce the use of mineral fertilizer for improved performance of maize (*Zea mays* L.) as measured in the chlorophyll content and grain yield. *Journal of Soil Science and Environment* 1: 40-45.

Anderson, J. P. E. and Domasch, K. H. 1958.A physiological method for the quantitative measurement of microbial biomas in soil.*Journal of Soil Boil and Biochemistry*, 10: 215-221.

Arancon, N. Q., Edwards, C. A. and Bierman, P. 2006. Influences of vermicomposts on field strawberries: Part 2. Effects on soil microbiological and chemical properties.*BioresourTechnol*97:831–840

Association of Official Analytical Chemist (A.O.A.C).(1990), Official methods of Analysis.2nd Edition. Washington D.C.

Ayeni, L.S. and Adeleye, E.O. 2011.Soil nutrient status and nutrient interactions as influenced by agro wastes and mineral fertilizer in incubation study in the South West Nigeria. *Int. Journal of Soil Science* 6: 60-68.

Bremner, J. M. (1996). Methods of soil analysis part –chemical methods, Nitrogen-Total In: D.L Madison, USA. pp 1085-1122.

Cerny, J., Balik, J., Kulhanek, K., Casova, K. and Nedved, V. 2010.Mineral and organic fertilization efficiency in long-term stationary experiments.*Plant Soil Environ*. 56(1): 28-26.

Chaparro, J. M., Sheflin, A. M., Manter, D. K. and Vivanco, J. M. 2012.Manipulating the soil microbiome to increase soil health and plant fertility.BiolFertil Soils 48:489–499

Chivenge, P., Vanlauwe, B. and Six, J. 2011. Does the combined application of organic and mineral nutrient sources influence maize productivity? A meta-analysis. Plant Soil 342:1–30

Demoling, F., Figueroa, D. and Bååth, E. 2007.Comparison of factors limiting bacterial growth in different soils.*Journal of Soil Biology and Biochemistry* 39:2485–2495

Dinesh, R., Srinivasan, V., Hamza, S. and Manjusha, A. 2010. Short-term incorporation of organic manures and biofertilizers influences biochemical and microbial characteristics of soils under an annual crop [Turmeric (Curcuma longa)]. BioresourTechnol 101:4697–4702

Drinkwater, L.E. and Snapp, S. 2007. Understanding and managing the rhizosphere in agroecosystems. In: Cardon ZG, Whitbeck JL (Eds) the rhizosphere: an ecological perspective. Elsevier Academic Press, London, UK, pp 127–153

Franco-Otero, V.G., Soler-Rovira, P., Hernández, D., López-de-Sá, E. G. and Plaza, C. 2012. Short-term effects of organic municipal wastes on wheat yield, microbial biomass, microbial activity, and chemical properties of soil. BiolFertil Soils 48:205–216

Girvan, M.S., Bullimore, J., Ball, A.S., Pretty, J.N and Osborn, A.M. 2004. Response of active bacterial and fungal communities in soil under winter wheat to different fertilizer and pesticide regiments.*Journal of Applied Environental Microbiology* 70: 2692-2701.

Iwoh, E. F., Onyegbula, O. D., Ibok, I. U. and Peter U.U. 2020. Assessment of the Short-term effect of different fertilizers on soil Microbial population, Biomass Carbon and microbial diversity in Ginger (*Zingiberofficinale*) based soil. *International Journal of Research and Innovation in Applied Science*.5:5 pp. 55-59

Kang, G.S., V. Beri, O.P. Rupela and Sidhu, B.S. (2005).A new index to assess soil quality and sustainability of wheat based cropping systems. Biol. Fertil. Soils, 41: 389-398.

Karim, T.H., Qadir, K.S. and Aziz, S.A. 2013. Rate of soil aggregates disintegration as affected by type and rate of manure application and water quality. *International Journal of Plant and Animal*3: 94-102.

Kumar, U., Nayak, A.K., Shahid, M., Gupta, V.V.S.R., Panneerselvan, P., Mohanty, S., Kaviraj, M.,Kumar, A., Chatterjee, D., Lal, B., Gautam, P., Tripathi, R and Panda, B.B. 2018. Continuous application of inorganic and organic fertilizers over years in paddy soil alters the the bacterial community structure and its influence on rice production. Agricultural Ecosystem Environment. 22: pp 5-75.

Kuzyakov, Y. 2010. Priming effects: interactions between living and dead organic matter. Soil BiolBiochem 42:1363–1371

Li, J., Yang-ting, L., Xiang-dong, Y., Jian-jun, Z., Zhian, L and Zhao, B. Q. 2015. Microbial community structure and functional diversity are associated with organic carbon availiability in an agricultural soil. *International Journal of Agriculture*Pp 61229-61231

Liu, B., Gumpertz, M. L., Hu,S and Ristaino, J.B. 2007. Long term effects of organic and synthetic soil fertility amendments on soil microbial communities and development of southern blight. Soil Boilogy and Biochemistry 39: pp. 2302-2316.

Mader, P., Fliebbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. Science, 296: 1694-1697.

Manlay, R.J., Feller, C. and Swift, M. J. 2007.Historical evolution of soil organic matter concepts and their relationships with the fertility and sustainability of cropping system. Agricultural Ecosystem Environment 119:217–233

Manqiang, L., Feng, H., Xiaoyun, C., Qianru, H., Jiaguo, J., Bin, Z. and Huixin, L. 2009. Organic amendmenes with reduced chemical fertilizer promote soil microbial development and nutrient availability in a subtropical paddy field. The influence of quality, type and application time of organic amendments. Apply Soil Ecology 42: 166-175

Nannipieri, P., Ascher, J., Ceccherin, M.T., Landi, L., Pietramellara, G and Renella, G. 2003. Microbial diversity and soil functions.*European Journal of Soil Science* 54:655–670.

Nwafor, O.E., Adepoju, S.O., Mba, A.A., Okonkwo, M. Emefiene, C. M. and Aminu, K. (2010).The effect of manual weeding intervals on the yield of water melon (*Citrulluslanatus*) in Jos Metropolis, Nigeria. Proceedings of the 24th Annual National Conference of Farm Management Association of Nigeria, September 6-9, 2010, Adamawa State University, Mubi, Nigeria, pp: 35-38.

Oladipo, O.G., Olayinka, A. and E.A. Aduayi. 2005. Effects of organic amendments on microbial activity, N and P mineralization in an Alfisol. *Environment Manage Journal* 2: 30-40.

Parham, J. A., Deng, S. P., Da, H. N., Sun, H.Y and Raun, W.R. 2003. Long-term cattle manure application in soil. II. Effect on soil microbial populations and community structure. Biology Fertility Soils, 38: 209-215.

Paul, E. (2007). Soil microbiology, ecology, and biochemistry, 3rd ed.n Elsevier Academic Press

Pennanen, T. 2001. Microbial communities in boreal coniferous forest humus exposed to heavy metals and changes in soil pH- a summary of the use of phospholipid fatty acids biolog and ^{3}H-thymidine incorporation methods in field studies. Geoderma, 100: 91-126

Saeki, M and Toyota, K. 2004. Effect of bensulfuron-methyl on the soil bacterial community of a paddy soil microcosm, Biology Fertile soil (40) 110-118.

Scharlau Microbiology: Handbook of Microbiological Culture Media 2000. Ref. 1-051 (Czapek-Dox), p. 87, Sixt Int. Edition, Barcelona, Spain.

Yevdokimov, I., Gattinger, A., Buegger, F., Munch, J. C. and Schloter, M. 2008. Changes in microbial community structure in soil as a result of different amounts of nitrogen fertilization. Biology Fertility Soil 44:1103–1106

Yu, C., Hu, W., Deng, W.,Li, Y., Xiaong, C., Ye, C., Han, G. M and Li, X. 2015. Changes in soil microbial community structure and functional diversity in the rhizosphere surrounding mulberry subjected to long- term fertilization. Apply Soil Ecology 8: pp 30-40.

Zhong, W., Gu, T., Wang, W., Zhang, B., Lin, X., Huang, Q. and Shen, W. 2010. The effects of mineral fertilizer and organic manure on soil microbial community and diversity. Plant Soil 326:511–522

Journal of Applied Agricultural Research 2020, 9(1): 179 - 192
ISSN 2006-750X.

ASSESSMENT OF RELATIONSHIP BETWEEN SOIL PROPERTIES, OCCURRENCE AND DISTRIBUTION OF AQUATIC MACROPHYTES IN THE FLOODPLAINS OF RIVER BENUE AT MAKURDI

Jimin, A. A.[1]*, Anjembe, B. C.[2] and Ibrahim, A. J.[3]
[1]Department of Crop & Environmental Protection, University of Agriculture, Makurdi
[2]Department of Soil Science, University of Agriculture, Makurdi
[3]Department of Agronomy, Nasarawa State University, Keffi
*Corresponding Author: abdul@nsuk.edu.ng

ABSTRACT

Experiments were carried out in 11 locations during the rainy season of 2016 at River Benue and its floodplains to determine the effect of selected soil properties on the occurrence and distribution of aquatic macrophytes in the water bodies. All sample sites were selected on the basis of weed presence, density and diversity. The soil properties observed were soil pH, texture, exchangeable Calcium, Magnesium, Potassium and Sodium, available Phosphorus, Nitrogen, organic matter content and base saturation. The water quality parameters assessed were: pH, odour, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and total oxygen demand (TOD). Results indicated that pH of the soils, clay content, Soil texture,water pH, water turbidity TDS, DO, BOD, COD, TOD were varied in the different locations sampled. There was a negative but significant relationship between the occurrence and density of water hyacinth compared with the amount of sodium (Na) contained in the beds of the sampled areas. Similar trends were also observed between the occurrence and population density of *Cyperus difformis* and the content of potassium (K) in the bed soils, *Pteridium esculentum and percentage clay content and bed organic matter content;occurrence and density of Rorippanasturtum-aquaticum, Ludwigia abbysinica A.Rich, Scleriana umanniana Boek., Eleocharis calva, Limnocha risflava, Cyperush aspan, Salvinianym phellula Desv., Anredera cordifolia and Myriophyllum aquaticum,Cyperus erecta and the bed soil pH.A negative and significant relationship also existed between the observed weeds and percentage clay content and bed organic matter content;the occurrence and density of Pycreus lanceolatris, and potassium content in the soil, the occurrence and density of Ludwigia decurrens and the sodium content in the soil while there were positive and significant relationships between the occurrence and density of Ludwigia hyssopifolia, Sacciolepis Africana and Cardiospermum helicacabum and the percentage contents of Calcium (Ca) and Magnesium (Mg) and the water quality parameters at the study locations.*

Keywords: Aquatic macrophytes, bed soils & water

INTRODUCTION

Aquatic ecosystems are critical components of the global environment, as they are essential contributors to biodiversity and ecological productivity, through provision of a variety of services for human populations, including water for drinking and irrigation, recreational opportunities and habitat for economically important fisheries (Poff *et al.*, 2002).

Aloo *et al*. (2013) reported that aquatic weeds are higher plants that grow in water or in wet soils. They usually occur along the shores of water bodies like dams, lakes and along rivers and river mouths, and also, spread over some water bodies (Jimin *et al.*, 2014). According to Adesina *et al.*, (2011), aquatic weed infestation of water bodies is a worldwide problem. Aquatic plants develop explosively large populations only when the environment is altered either physically or through the introduction of pollutants (Okayi and Abe, 2001). They perpetuate their life cycle in still or moving water or inundated or non-inundated hydric soils (Donald, 1996). These groups of plants have their whole vegetative body adapted for a successful life cycle in water and mostly obtain their nutrients from the sediments on the bottom of the pond (Department of Environmental Protection (DEP), 2012).

Aquatic weed growths in any source of water create problems involved with practically all water uses (Joshi, 2012).There are numerous aquatic plants that grow in dams, streams and waterways (Masser *et al*. 2001, 2013), and are an important and integral component of the aquatic ecosystem and can be of ecological importance since they represent the major structural component of littoral habitats (Hudon *et al*., 2000).

Aquatic vegetation abundance is influenced by factors such as irradiance, temperature, water chemistry (nitrogenous and phosphorus nutrients), wave action, lake size, and catchment basin morphology (Gasith and Hoyer, 1998).In most subtropical and tropical rivers, the excessive growth of aquatic macrophytes may provoke some negative effects (Bini *et al.*, 2005), such as impairment or prevention of recreational activities (swimming, fishing, and boating), excessive densities and biomass can also result in stunted fish growth and overpopulation of small-bodied fishes because the production of too much vegetative cover prevents effective predation of small fish by larger fish, excessive aquatic plant growths decrease localized dissolved oxygen levels (Lembi,2003). Excessive growth during the summer results in large quantities of organic matter, that when decomposed via bacteria and microbes, results in high rates of microbial respiration and thus oxygen consumption. Similar processes can occur in the winter for lakes that freeze. Snow cover decreases light levels and reduces or prevents photosynthesis and oxygen production, but organic matter continues to be decomposed by bacteria, thus consuming oxygen (Lembi, 2003).

MATERIALS AND METHOD

Collection of Composite Soil Samples.

Composite soil samples were collected with a soil augar by drilling into the bed soils to a depth of 30 cm. Soils collected by the augar were then placed in sterile polythene bags and sealed using a tape. All sample sites were selected on the basis of weed presence, density and diversity.

The soil parameters assessed in this study were all measured using appropriate methods as outlined below.

Soil pH

Soil pH was measured using a Glass-electrode pH meter. About 20 g of air dried soil passed through a 2 mm sieve was poured into a 50 ml beaker containing 20 ml of distilled water and allowed to stand for 30 minutes. This was occasionally stirred with a glass rod. The electrodes of the pH meter were then inserted in the suspension and the pH reading was taken as the soil pH measured in water.

Determination of Soil Texture

Soil texture was determined using the Hydrometer method. About 50 g of each of the soil samples from the study area was collected and dispersed in 1 litre of water after which a hydrometer reading was taken at 40 seconds and 2 hours after suspension (dispersion) of the samples. The percentages of sand, silt and clay were then calculated using the textural triangle of the soil (USDA, 1938). The hydrometer reading at 40 seconds represented silt and clay in the suspension, calculated as:

$$\text{Sand (\%)} = \frac{\text{sample mass-40 seconds hydrometer reading}}{\text{Sample mass}} \times 100$$

$$\text{Clay (\%)} = \frac{\text{40 seconds hydrometer reading}}{\text{Sample mass}} \times 100$$

Silt (%) = 100-(sand % + clay %)

Determination of Exchangeable Ca, Mg, K, Na

About 5 g of the soil samples collected at the study locations added with 30 ml of 1 NH_4OAC were poured into a mechanical shaker and shaken for 2 hours after which this was centrifuged for 10 minutes in a centrifuge of 2000 rotations per minute (rpm). The clear supernatant was then carefully decanted into a volumetric flask of 100 ml. Another 30 ml of 1 NH_4OAC solution was added to the supernatant and shaken for another 30 minutes and centrifuged and poured into the same volumetric flask. This procedure was repeated for a second time. K, and Na were then determined on a flame photometer while Mg and Ca were determined on an atomic absorption spectrometer. Effective CEC was calculated by the sum of exchangeable bases (Ca, Mg, K and Na).

Available Phosphorus (P) in soils (using the Bray 1 P method)

About 1g of weighed air-dried soil samples collected from the study locations and passed through a 2mm sieve were poured into a 15ml centrifuge of 2000 rpm containing 7ml of an extracting solution (1. ON NH_4 and 25ml of 0.5N HCl added to 460ml of distilled water). About 2ml of the clear supernatant formed from the centrifuge was then pipetted into a 20ml test tube and 5ml of distilled water and 2ml of ammonium molybdate solution were then added into the test tube containing the supernatant and the content were properly mixed and again added with a diluted solution of 1 ml KH_2PO_4after 5 minutes of dilution, percentage transmittance was measured using a 660 mμ electro-photometer. A standard curve was then plotted within the range of 0-1 ppm P. The optical density of standard solution was then plotted against the ppm and the content of extractable P was calculated using the standard curve.

Determination of Nitrogen (N) using the Kjedahl method

About 10 g of air-dried soil samples collected at the study locations containing 10mg of N were ground and passed through a 0.5 mm sieve and poured into a dry 500 ml macro Kjedahl flask. Then 20 ml of distilled water was added to the flask and shaken for at least 2 minutes after which this flask was allowed to stand for 30 minutes. One tablet of 1g K_2SO_4 –HgO (mercury catalyst), 10 g of K_2SO_4 and 30 ml concentrated H_2SO_4 were subsequently added through a pippet. The flask was then heated at low heat on a digestion stand until frothing ceased. After this the heat was increased until the digest cleared. The mixture was again heated for 5 hours ensuring also that the heat was regulated to allow for the condensing of H_2SO_4 to half way up the neck of the flask. As the flask was allowed to cool, 100ml of water was also slowly added to the flask and transferred to a clean macro-Kjedahl flask of 750 ml. At this point, 50 ml of H_2SO_4 (an indicator fluid) was added to a 500 ml Erlenmeyer flask and placed under a condenser of the distillation apparatus which was attached to the 750 ml Kjedahl flask. NH_4-N was determined in the distillate by titrating with 0.01 N standard HCl using a 25 ml burette graduated at 0.1 ml intervals and the colour change determined at the end point from green to pink. The percentage (%) N content in the soils were then calculated by subtracting the excess of sulfuric acid from the total (original) amount of sulfuric acid from the trapping solution:

$$V_{react} = Vtot_{H2SO4} - V_{ExH2SO4.}$$

Determination of Soil Organic Matter Content (OM)

Soil Organic Matter (OM) was determined using the Colorimetric method. About 1 g of each of the soil samples collected at the study locations were scooped into a 50 ml Erlenmeyer flask. 10 ml of dichromate sulfuric acid digestion solution were then pipetted into the flask and covered with a glass marble to minimize the loss of the chromic acid. The flask was afterwards placed in the digestion oven and heated to about 90^0C for 90 minutes after which the samples were removed from the oven, the cover removed and cooled for 10 minutes during which 25 ml of water was also added. The suspension was then thoroughly mixed by airing via the 25 ml pipette and allowed to stand overnight. The supernatant formed overnight was carefully transferred into a colorimeter tube and the blue colour intensity of the supernatant was read on the colorimeter at 645 nm with the reagent blank set to give 100% transmittance (the instrument was calibrated to read % OM from a standard curve prepared from soils of known organic matter content).

Base Saturation

Percentage Base Saturation (%BS) was determined as $\frac{Ca+Mg+Na+K}{Ca+Mg+Na+K+H+AL} \times 100$

RESULTS AND DISCUSSION

Selected water quality parameters of the water bodies in which soils were sampled are as shown in Table 1.

Water pH was observed to be variable, ranging from 5.7 at River Benue, at the point at which effluents from BBL are discharged to 7.8 at River Benue. The occurrence or abundance of aquatic macrophytes (of mostly emergent and floating forms) found in the studied area at pH range of mostly acidic soils showed that the occurrence of these weeds, their distribution or density were either unaffected, or not limited by acidity of soils. Earlier reports by Haller and Sutton (1972 and Gettys *et al.* 2009) had indicated that water hyacinth especially, and several other aquatic plants grew over a range of pH of 4.0 to 10 and also, that maximum growth of aquatic plants occurred in acid to slightly alkaline conditions.

The occurrence or presence of *Cyperus erecta*, *Eleocharis calva*, *Limnocha risflava*, *Cyperus haspan* and *Anredera cordifolia* to only River Benue (compared to the other locations with acidic to slightly acidic water conditions) and the preponderance of *Pteridium esculentum*, *Rorippanasturtum-aquaticum*, *Ludwigia abbysinica*, *Myriophyllum aquaticum* and *Sclerianaum anniana* at the locations with acidic to slightly acidic water conditions showed the preference of these weeds to flourish under varying water conditions. Similarly, the abundance of these weeds in slightly acidic to alkaline water situations corroborates the findings of Ngodhe *et al.* (2013) that natural differences in pH and alkalinity may be important determinants of aquatic structure and low acidities reflect better buffering and higher productivity (Busulwa and Bailey, 2004). It implies therefore, that these weeds will most likely do well at high pH (alkaline) levels. Their relationship to dissolved oxygen at time of water collection indicated the sufficiency of oxygen in these water bodies and hence, the favorable conditions for these weeds to thrive under conditions of relatively high dissolved oxygen. Ngodhe*et al.* (2013) also reported that the structure and function of aquatic organisms reflect physical/chemical conditions and further, that the main physico-chemical factors that affect aquatic environments are temperature, discharge, DO, pH, nutrients and conductivity. Temperature generally usually fluctuates and regulates the amount of DO in water (Kalff, 2002), as increased temperatures lower the solubility of DO resulting in low values. Higher levels of DO at time of water collection were also, suspected to be responsible for the higher occurrence and distribution of these weeds.

High BOD may indicate faecal contamination or increases in particulate and dissolved organic carbon from non-human or animal sources. This is capable of restricting water use and development, necessitate expensive treatment and impair ecosystem health. *Polygonium lanigerum*, *Heliotropium indicum* and *Persicaria decipens* were found predominantly at the point of effluent disposal at BBL and River Benue close to the point of effluent disposals from BBL, Berbesa and Tyumugh. Their presence and preponderance at these places and their strong responses (or increases in density) in the presence of high levels of BOD, COD and TOD indicated their affinity (tolerance)and effective water utilization under highly contaminated water sources depleted of oxygen and replete with organic compounds. This further confirms why they were found only at these points.

Odour was also variable, ranging from objectionable at the point of effluent disposal at BBL, BBL 2, new bridge abattoir and Tyumugh 2 to unobjectionable odour at Adubu, AnamAdubu, Tyumugh 1, Berbesa 1 and 2, Agongul and River Benue. As odour increased, the occurrence of *Heliotropium indicum* also decreased. This trend is assumed to have occurred because odour will most likely create conditions of foams and scums that are capable of causing the inhibition of biological activities that would have facilitated respiration and therefore, availability of oxygen in the water for the sustenance of aquatic flora and fauna. The uninhibited occurrence and distribution of *Ludwigia hyssopifolia* and *Sacciolepis africana* at Berbesa 1 and 2 under turbid water conditions indicated that other than nutrients, turbidity did not limit the growth, distribution and perhaps photosynthetic ability of these plants. On the other hand, it is possible that some of the inputs arising from the sources of turbidity at this location (agriculture, rearing of animals along the shores of this water body, sediments from storm water, human defecations andsoil excavation activities), (Jimin *et al.* 2014) improved the fertility status of the water to levels that increased the ability of these weeds to survive even under turbid water conditions.

The relationships between soil properties, occurrence and population density of identified weed species is shown in Table 2. There was a negative but significant relationship (r=-0.640) between the occurrence and density of *Eicchornia crassipes* (water hyacinth) and the amount (or content) of sodium (Na) contained in the beds of the sampled areas. The implication of the negative relationship between amount of sodium and occurrence and density of *Eicchornia crassipes* was that as the amount of sodium increased, its distribution and density decreased. This implied that the presence of sodium (especially if the amounts found in water are high) is most likely to limit or reduce the occurrence (or infestation) of this weed. Reports by Patil *et al.* (2011) had indicated that application of NaOH aided the breakdown of the lignin and cell walls of *Eicchornia crassipes* in the presence of a range of pH thereby, causing its death. This may conversely, cause growth of other aquatic plants especially in acid to slightly alkaline conditions. Patil *et al.* (2011) further reported that with an improved pH, the methanogens gain access to nutrients trapped in *Eicchornia crassipes*. This, as observed in this study, has the likelihood to supply nutrients and promote growth of other surrounding or existing plants. This view is predicated on reports by United Nations Environmental Programme

(UNEP), (2012 and 2013), supporting water hyacinth as a plant that extracts and stores nutrients. Such nutrients under conditions of cell wall breakage will obviously disperse in water and may be absorbed by catchment plants (of water hyacinth) thereby supporting the flourishing of existing plants. The mere presence of aquatic macrophytes in a body of water often indicates that it is fertile (or nutrient rich). It means therefore, that sodium may be used to increase water salinity as a management tool to control water hyacinth infestation. Reports by Wu and Harivandi, (1988) also suggest that where salinity is high, grass roots wilt and plants may eventually die mainly due to nutritional imbalances and mineral toxicities and increased osmotic pressure of the soil solution thus making water less available to plants.

There was a negative and significant relationship (r=-0.607) between *Cyperus difformis* and the content of potassium (K) in the soil beds. The negative relationship between *Cyperus difformis* and potassium (K) indicated the inverse relationship between the two, suggesting that the occurrence, density or distribution of this weed can be limited or suppressed by enhanced amounts of K. Reports by Adkins *et al.* (2009) indicated that the presence of sodium in soils is capable of decreasing permeability, a situation which reduces the flow of water to plants. Sodium may also increase compactness of soils thereby limiting the soil's ability to supply plants with water and nutrients. The consequence is that height, germination success, number of leaves and biomass of the plants are reduced (Comparative Cost of Rock Salt and Magnesium Acetate, 1991).

The assumption is that a combination of factors were likely to have been responsible for the suppression of *Cyperus difformis* in this study. These factors were probably salinity of the beds, water and impairment of nutrient imbalances most of which are most likely determinant factors responsible for the enhanced growth of this weed. Their impairment therefore, suppressed growth of the weed.

Cyperus erecta,(r=-0.839) and *Pteridium esculentum* (r=-0.664) related negatively and highly significantly with the soil pH. A negative but highly significant (r=-0.839) relationship also existed between *Rorippana sturtum-aquaticum*, *Ludwigia abbysimia* A.Rich, *Sclerianaum anniana* Boek., *Eleocharis calva*, *Limnocha risflava*, *Cyperus haspan*, *Salvinianym phellula* Desv., *Anredera cordifolia* and *Myriophyllum aquaticum* and the soil pH.*Cyperus erecta* and these macrophytes also had a negative and significant relationship also existed between these weeds and percentage clay content (r=-0.637) and the organic matter content (r=0.664) ,respectively. Anegative but significant (r=-0.637) relationship also existed between *Cyperus erecta*, *Pteridium esculentum* and clay content. No other relationship was observed between these weeds and the other soil properties. *Ludwigia decurrens* showed a negative but significant (r=-0.712) relationship with the sodium content in the soil. No other relationship existed between this weed and the other soil properties.

Soil pH often influences plant growth by its effect on activity of beneficial microorganisms, depending on the pH. Microbial activity that enhances soil organic decomposition are hindered, (or inhibited) (Belinda, 2000),in strong acid soils (such as some of those in the study area), this usually prevents the breakdown of organic matter, resulting rather in accumulation and unavailability of nutrients that are held in the soil. Vossen (2001) reported that the ideal pH range for soils is from 6 to 6.5 since most plant nutrients are in their most available state within this range. Belinda, (2000) further reported that at low pH, beneficial elements such as molybdenum, phosphorus, magnesium and calcium become less available to aquatic plants, and aluminum and manganese maybe more available and reach levels that are toxic to plants. Also, the sparse occurrence, growth and density of *Cyperus erecta*, *Pteridium esculentum* and *Ludwigia decurrens* as observed in this study must have been limited by decreased soil permeability due to increased soil compaction of the clay soils, and most likely by the presence of sodium. This increased soil compaction, reduced water and nutrient availability (through poor intake) to this weeds and consequently, reduced its growth and population in the studied area. Also, Clay soils are fine grained and therefore, plastic due to their water content and typically associated with very low energy (Wikipedia, 2015a). This nature of low (or poor) porosity of clay soils greatly prevents or limits root penetration into deeper soil layers and so, also reduces root growth, water and nutrient intake.

Table 1: Selected water quality parameters of the water bodies sampled for soils

	pH	Odour	Turbidity	TDS	DO1 (mg l^{-1})	DO2 (mg l^{-1})	BOD (mg l^{-1})	COD (mg l^{-1})	TOD (mg l^{-1})
BBL EF.DP	5.7	0	116.4	54.8	4.5	1.6	176	372	548
BBL 2	5.8	0	154.6	64.2	4.3	1.2	184	372	556
Abattoir	6.6	0	106.0	51.8	4.5	2.4	128	256	384
Adubu	6.5	1	450.8	77.4	4.6	3.4	71	144	215
A.Adubu	6.2	1	168.4	66.4	4.6	2.6	112	228	340
Tyumugh1	6.8	1	56.8	20.8	5	3.9	64	130	194
Tyumugh2	6.5	0	142.8	58.2	4.4	2.3	126	266	392
Berbesa 1	6.7	1	658.6	8.7	4.5	2.5	118	234	352
Berbesa 2	6.6	1	482.6	79.4	4.5	3.2	76	158	234
Agongul	6.4	1	23.2	14.2	5.4	4.4	58	118	176
R.Benue	7.8	1	24.1	19.7	6.1	4.8	78	156	234

0 = objectionable odour; 1 = unobjectionable odour. TDS= total dissolved solids, BOD= biological oxygen demand, COD= chemical oxygen demand, TOD= total oxygen demand

Source: Jimin and Ibrahim, A. J. (2018)

Table 2: Relationships between soil properties, occurrence and population density of identified weeds

	pH	Clay (%)	O.M (%)	N (%)	Bray 1 P	K	Na	Ca	Mg	CEC	BS (%)
E. crassipes	-0.022	-0.195	0.511	-0.383	0.420	-0.495	-0.640*	0.112	0.401	-0.075	-0.164
C. difformis	-0.493	0.092	-0.006	-0.314	-0.094	-0.607*	-0.176	-0.369	-0.218	-0.414	-0.426
C. erecta	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
K. pumilla	-0.448	0.272	-0.005	0.095	0.193	-0.497	-0.249	-0.199	-0.151	-0.308	-0.326
P. lanigerum	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
R.nasturtium	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
L. abbysinica	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
S. naumanniana	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
E. calva	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
L. flava	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
P.lanceolatus	-0.570	0.007	-0.096	-0.330	-0.139	-0.626*	-0.203	-0.378	-0.255	-0.442	-0.468
C. haspan	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
L. decurrens	0.113	-0.234	-0.087	0.316	0.401	0.462	0.006	0.712*	0.468	0.596	0.474
S. nymphellula	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
A. cordifolia	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
M. aquaticum	-0.839**	-0.637*	-0.664*	-0.309	-0.333	-0.483	-0.351	-0.290	-0.403	-0.467	-0.579
L. caerulenscens	-0.011	0.509	0.408	-0.145	0.096	-0.357	0.038	-0.216	0.017	-0.153	-0.094
L. hyssopifolia	0.494	-0.232	0.359	0.027	0.450	0.427	-0.087	0.683*	0.683*	0.623*	0.534
H. indicum	-0.048	-0.196	-0.291	-0.227	-0.468	0.331	0.435	-0.138	-0.484	-0.053	0.042
A. pinnata	0.584	0.190	0.091	0.218	0.248	0.670*	0.315	0.479	0.630*	0.661*	0.647*
C. helicacabum	0.596	0.085	0.128	0.146	0.207	0.434	0.104	0.319	0.707*	0.507	0.459
M. aquaticum	0.400	0.105	0.214	0.461	0.589	0.483	-0.015	0.670*	0.569	0.608*	0.547
P. esculentum	0.476	-0.231	0.367	0.033	0.450	0.423	-0.084	0.689*	0.649*	0.614*	0.530
P. decipens	-0.131	-0.314	-0.314	-0.333	-0.631*	0.052	0.272	-0.402	-0.604*	-0.321	-0.234
P. stratiotes	0.100	0.105	-0.007	0.093	0.132	0.403	0.270	0.319	0.077	0.332	0.356
M. longibracteatus	0.328	0.341	-0.032	0.262	-0.074	0.266	0.267	-0.031	0.171	0.166	0.208
H. indica	0.591	0.131	0.111	0.174	0.176	0.435	0.136	0.284	0.666*	0.485	0.448
S. zeylonica	0.325	-0.191	-0.182	-0.170	-0.403	0.364	0.322	-0.124	-0.011	0.090	0.133
M. cordifolia	0.196	0.086	-0.231	0.010	-0.468	0.264	0.402	-0.283	-0.250	-0.066	0.028

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

a Cannot be computed because at least one of the variables is constant

Plant growth, development and increased population may also be reduced or suppressed as observed in this study. Reports have shown that high water and soil salinity is generally associated with disturbances in plant growth, nutrient imbalance and reduced plant growth (Tzortzakis, 2010). Besides, low quality water (such as that in which this study was done) causes increase in water salinity, which could adversely affect growth and yield of crops.

The inverse relationship of *Rorippana sturtum-aquaticum*, *Ludwigia abbysinica* A.Rich, *Sclerianaum anniana* Boek., *Eleocharis calva*, *Limnocha risflava*, *Cyperus haspan*, *Salvinanym phellula* Desv., *Anredera cordifolia* and *Myriophyllum aquaticum* with soil pH, soil texture and the soil's organic matter content leading to the suppression or sparse distribution of these macrophytes may be the result of a complex of actions (either singly or in combination) of soil acidity, inhibited microbial activity under low pH conditions. This has the likely consequence of causing accumulation rather than breakdown of organic matter (which breakdown often, leads to availability and supply of nutrients), very poor soil porosity due to the clay contents (or mixtures) in the soils and the fibrous nature of the roots of some of these weeds which succulent nature, most likely prevented soil penetration or nutrient absorption.

There was a negative but significant relationship between *Polygonium lanigerum* (lady's thumb), and Bray 1 P (r=-0.667) and the content of magnesium (r=-0.655) present in the soil. There was a negative and significant (r=-0.626) relationship between *Pycreus lanceolatus* (Poir.) and potassium content in the soil. No other relationship was observed between this weed and the other soil properties. The negative relationship of *Polygonium lanigerum* (lady's thumb) to phosphorus must have been caused either by the relatively low amounts of phosphorus contents in the soils of the studied area or its low solubility mainly because of the low pH of the soils. Being generally a limiting nutrient to macrophytes, its presence in low amounts and its poor solubility consequently inhibited the occurrence or density of this macrophyte. The low availability of phosphorus was probably also compounded (or complimented) by the generally unfavorable textural class (sandy clay loam) of the soils at the studied area. Phosphorus adsorption is associated more with clay soils. This assumption agrees with reports by Wikipedia, (2015b) that phosphorus is a limiting nutrient for aquatic organisms and also, that phosphate is adsorbed more to clay surfaces and organic matter particles. Brady and Well, (2002) reported that phosphorus concentration in soil solution is very low (0.001-1 mg/ L) and its solubility very much depends on soil pH, the optimum being 6.5.*Cyperuserecta* and *Cyperus haspan*, are emergent aquatic macrophytes, while *Salvinanym phellula* Desv. and *Anredera cordifolia* are floating aquatic macrophytes all of which have roots that are extensive with a complex system of fine, fibrous roots, rhizomes and basal bulbs (Wikipedia, 2015c), while *Pteridium esculentum* grows from creeping rhizomes covered with hairs. The implication is that their roots are only superficial (lacking a tap root) and so nutrient intake will also be limited, consequently, also suppressing occurrence and density as was observed in the study. Also the positive relationship that existed between phosphorus and *Persicaria decipens* must have been caused either by adequate concentrations of phosphorus for it to thrive in the soils of the studied area or its solubility in amounts sufficient for the weed. Being generally a limiting nutrient to macrophytes, its solubility and presence in sufficiently available amounts in the water present in the soil's root zone consequently increased the occurrence and density of this plant. This assumption agrees with reports by Wikipedia, (2015c) that phosphorus is a limiting nutrient for aquatic organisms. Its presence or availability and intake in the amount needed by a plant will therefore, also enhance density.

A positive and significant (0.670) relationship existed between *Azolla pinnata* R.Br. var. *africana* Desv. and Potassium. There was also a positive and significant relationship between this weed and Magnesium (r=0.630) and base saturation (BS), (r=0.647). No other relationship existed between this weed and the other soil properties. The assumption in this study was that being naturally occurring water bodies that are heavily infested with macrophytes, magnesium was present in amounts far more than was needed by *Polygonium lanigerum*, therefore, rather than promote the processes that enhance growth and photosynthesis, it became toxic or inhibitory to the plant thereby, suppressing growth and photosynthesis and consequently, the occurrence and density of the plant. Aqua-Rebell, (2015) had earlier indicated that magnesium plays a vital role in photosynthesis as the central atom of the chlorophyll molecule and is most highly concentrated in the growth areas of plants and that many natural water bodies contain far more magnesium than is needed by the plants. Potassium is vital to plants in several ways. Its absorption by plants from soils determines the extent of enzymes activation, regulates the opening of stomates (pores through which leaves exchange carbon dioxide, water vapour and oxygen with the atmosphere).

The proper functioning of stomates is essential for photosynthesis, water and nutrient transport. Potassium also plays a major role in the transport of water and nutrients throughout the plant xylem. When potassium supply is reduced, translocation of nitrates, phosphates, calcium (Ca), magnesium (Mg), and amino acids is depressed (Better Crops, 1998).As with phloem transport systems, the role of K in xylem transport is often in conjunction with specific enzymes and plant growth hormones. An ample supply of potassium is essential to efficient operation of these systems (Better Crops, 1998). This could have been one of the influential reasons for the flourishing growth of *Azolla pinnata* R.Br. var. *africana* Desv.

There was a positive and significant relationship between *Ludwigia hyssopifolia* (G.Don) Exell and Calcium (Ca), (r=0.683) and Magnesium (Mg), (r=0.683). No other relationship existed between this weed and the other soil properties. There was a positive and significant relationship (r=0.670) between *Myriophyllum aquaticum* and the Ca in the soil. No other relationship existed between the weed and other soil properties. A positive and significant relationship (r=0.707) existed between *Cardiospermum heliocacabum* and soil Magnesium. No other relationship existed between the weed and other soil properties. A similar trend was observed on *Heliotropium indicum* where a positive and significant relationship (r=0.666) existed with Magnesium. No other relationship existed between the weed and other soil properties.

A positive and significant and relationship existed between *Sacciolepis africana* Hubb. & Snowden, Calcium (r=0.689) and Magnesium (r=0.649). No other relationship existed between the weed and other soil properties. No significant relationships existed between *Azolla pinnata, Kyllinga pumila, Leptochloa caerulescens* Steud. *Heliotropium indicum, Pistia stratoites, Mariscus longibracteatus, Sphenoclea zeylonica* and *Melochia corchorifolia* and Magnesium.

Aqua-Rebell (2015) had also earlier indicated that magnesium plays a vital role in photosynthesis as the central atom of the chlorophyll molecule and is most highly concentrated in the growth areas of plants. College of Tropical Agriculture and Human Resources (CTAHR), (2015)ranked calcium and magnesium among the top four (4) soil cations that are essential for plant growth and further reported that mobility of nutrients within the soil is closely related to Cation Exchange Capacity (CEC) and Anion Exchange Capacity (AEC) as well as soil conditions such as moisture.

This study assumed that the strong (or positive) and enhanced relationship between *Ludwigia hyssopifolia* with calcium and magnesium, *Myriophyllum aquaticum* with calcium and between *Cardiospermum heliocacabum* and *Heliotropium indicum,* respectively, boosted or augmented their occurrence and density. This may be attributed to the individual and complimentary effect of these nutrient elements to induce the physical (aiding and regulating the intake of nutrients into plant for growth), biochemical (enzyme activation) and physiological (membrane structure and function) attributes of this plant for enhanced occurrence and development through increased mass flow (transportation of nutrients to the surface of roots by the movement of water in the soil) due to their presence or abundance in the soils of the study area (Ag Vita, 2008). The implication is that *Ludwigia hyssopifolia*, *Ludwigia hyssopifolia Myriophyllum aquaticum*, *Cardiospermum heliocacabum* and *Heliotropium indicum* are effective utilizers of these nutrient elements, therefore, their presence is most likely to promote their occurrence and cause them to flourish and out-compete other macrophytes that may occur alongside these weeds. Many nutrients such as calcium and magnesium may be supplied to plants solely from reserves held in the soil Mengel, (2010). And since potassium also plays a major role in the transport of water and nutrients throughout the plant xylem Better Crops, (1998), an increased supply would also have probably increased intake and translocation of nitrates, phosphates, calcium (Ca), magnesium (Mg), and amino acids. This in conjunction with specific enzymes and plant growth hormones (due to ample supply from the soil reserves) or their efficien tutilization, enhanced the biochemical and physiological systems of *Azolla pinnata* also, and therefore, increased its occurrence and density. Generally, cation desorption increases with an increase in ECEC and this also increases availability of nutrients to plants. This agrees with the reports of AgVita (2008), that larger cation exchange capacity (CEC) values indicate that a soil has greater capacity to hold cations and offers a larger (higher) nutrient reserve. AgVita (2008) further observed that base saturation (and acidity) is a tool to predict a soil's ability to provide adequate crop nutrients and indicate fertilizer lime requirements. The positive responses or increases in occurrence and density of these macrophytes (or weeds) indicated that the soils in the study area had sufficient base cation exchange sites to support the intake (absorption and translocation) of available nutrients (especially potassium, magnesium, calcium and sodium). It also suggested that these nutrient elements are probably the most critical (or limiting).

CONCLUSION AND RECOMMENDATIONS

There is a dangerous and threatening trend in the rate at which aquatic macrophytes are colonizing or invading River Benue and its prominent water rich waterbodies. These waterbodies have high economic importance to the riparian populace, other stakeholders and dependents for their daily economic activities, yet, they have been heavily infested by diverse populations of aquatic macrophytes, caused mainly by the water and soils' nutrient-rich status. It is therefore, recommended that there should be dredging of the bed soils that have been observed by this study to serve as stores and reservoirs for some of the nutrients required by macrophytes or complimenting their occurrence and distribution in the study area in order to mitigate their occurrence andincresased distribution in the study area. Also, rather than use organic herbicides to control some of these weeds, especially those that have had negative relationships with some of the nutrients, flush quantities of these nutrient elements may be deliberately introduced into these waterbodies to mitigate the occurrence and distribution of these weeds.

REFERENCES

Adesina, G.O., Akinyemiju, O.A. and Moughalu, J.I.2011. Checklist of the Aquatic Macrophytes of Jebba Lake, Nigeria. *Ife Journal of Science* vol. 13, No. 1 pp 93-105.

Adkins, C., Alexander, D., Beckman, J., Butts, S., Gaines, M., Huffer, D., Hurtt, J., Johns, T., aunders, D., Smiyh, L., Stepney, A., Stroud, T., Walker, W. and Walls K. 2009. Effect of Sodium Chloride on *Brassica rapa*. Wisconsin Fast Plant ™. Pp.1-16.

AgVita Analytical. 2008.Cation Exchange Capacity (CEC).ExpressSoil Manual. Pp.1-4.

Aloo, P. Ojwang, W., Omondi, R., Njiru, J. M. andOyugi, D. 2013.A review of the impacts of invasive aquatic weeds on the biodiversity of some tropical water bodies with special reference to Lake Victoria (Kenya).*Biodiversity Journal*.4 (4): 471-482.
Aqua-Rebell. 2015. Magnesium (mg).www.aqua-rebell.com/aquatic-plant. (Downloaded 14th June,2015).

Belinda, L. 2000. Understanding Soil pH.Acid-Soil Action for *New South Wales Agriculture*. Leaflet 1:1-32.

Better Crops. 1998. *Functions of Potassium in Plants, 82,(3): 1-5.*
Bini, L. M., Oliveira, L. G., Souza, D. C.,Cavalho, P. and Pinto, M. P. 2005. Patterns of the aquatic macrophysics cover in *Cachoeira dourada* Reservoir. *Brazil. Journal of Biology*,65 (1): 19-24.

Brady, N. C. and Well, R. R. 2002. The nature and properties of soil. Ed 13. Prentice Hall, Upper Saddle River, NJ. CAST. Long Term Viability of U. S. Agriculture in Council for Agricultural Science and Technology, Ames, IA.

Busulwa, H. S. and Bailey, R. G. 2004. Aspects of the Pysico-chemical Environment of the Rwenzari Rivers, Uganda. *Afr. J. Ecol. 42: (2) 87-92.*

College of Tropical Agriculture and Human Resources (CTAHR). 2015. Soil Nutrient Management for Maui County: *Soil-Nutrient Relationships*, The University of Hawai'i Publication, pp. 1-65.

Comparative Cost of Rock Salt and Calcium Magnesium Acetate, 1991.Highway deicing: Comparing Salt and Calcium Magnesium acetate (special report 255). Washington DC: Transportation Research Board.

Department of Environmental Protection (DEP). 2012.Nuisance Aquatic Vegetation Management: A Guidebook. Pesticides Management Program, 79 Elm Street Hartford, CT 06106-5127, Edited by Gina McCarthy, Commissioner.

Donald, H. 1996. Evolution of aquatic angiosperm reproductive systems.*BioScience*, (11): 813-826. 46.

Gasith, A. and Hoyer, M. V. 1998. Structuring role of macrophytes in lakes: changing influence along lake size and depth gradients. Pages 381-389 *in* Jeppesen, E., Søndergaard, M., Christoffersen K. (editors), The structuring role of submerged macrophytes in lakes. *Springer, New York*.

Gettys, L. A Haller,W.T. and Bellaud, M. 2009 (ed.). Biology and Control of Aquatic Weeds; best managent practices, Marrietta, Georgia, USA.

Gettys, L. A., Haller, W. T. and MacDonald, G. E. 2013.Herbicides in Aquatic Systems.http://dx.doi.org/10.5772/56015(Downloaded may 29, 2014). Pp. 1-32.

Hudon C., Lalonde S., and Gagnon, P. 2000. Ranking the effects of site exposure, plant growth form, water depth, and transparency on aquatic plant biomass. *Canadian Journal of Fisheries and Aquatic Sciences.57: 31-42.*

Jimin, A. A.,Magani, E. I. and Usman, H. I. 2014. A Comparative Identification and Species Characteristics of Aquatic Macrophytes in the Benue Floodplains of River Benue. *J. Bio. &Env. Sci., 5: 4.pp. 479-496.*

Jimin, A. A. and Ibrahim, A. J. 2018. Effect of Selected Water quality Properties on the Occurrence and Distribution of Aquatic Macrophytes in the Floodplains of River Benue at Makurdi. *International Journal of Innovative Approachesin Agricultural Research: Vol.2, Issue 2, pp. 111-122.*

Kalff, J. 2002. Limnology: Inland water ecosystems. Pretence House Inc. upper Saddle River, New Jersey.Pp. 592.

Lembi, C. A. 2003. Aquatic Plant Management.Purdue University. E-mail: lembi@purdue.edu. (Downloaded 13th June 2014).

Masser, M. P, Tim R. Murphy and Shelton, J.L. 2001.Aquatic Weed Management Herbicides. Southern Regional Aquaculture Center. Publication No. 361, pp 1-6.

Masser, M. P., Murphy, T.R. and Shelton, J.L. 2013.Aquatic Weed Management. *Southern* Regional Aquaculture Center, Publication No. 361. 12-18.

Mengel, D. B. 2010. Fundamentals of Soil Cation Exchange Capacity (CEC). Agronomy Guide, Purdue University Cooperative Extension Service, West Lafayette, IN. 47907. www.extension.purdue.edu (Downloaded 14th June, 2015).

Ngodhe, S. O., Raburu, P. O. and Achieng, A. 2013. The Impact of Water Quality on Species Diversity and Richness of Macroinvertebrates in Small Water Bodies in Kenya.*Journal of Ecology and Natural Environment.* Pp. 33-43.

Okayi, R. G and Abe, O. M. 2001. Preliminary study of the aquatic macrophytes of selected fish ponds and reservoirs in Makurdi, Benue State, Nigeria Pp 165-168.*In:* A. A Eyo and E. A. Ajao (eds.). Proceedings of the 16th annual conference of the fisheries, Society of Nigeria (FISON) Maiduguri, 4th- 9th November, 2001.

Patil, S. G., Chonde, S. G., Jadhav, A. S. and Raut, P. D. 2012. Impact of physcio – chemical characteristics of Shivaji University lakes on phytoplankton communities, Kolhapur, *India Research J. of Recent Sciences,* 1: 56 -60.

Poff, N.L., Brinson, M. M. and Day, J.W. (jr.), 2002. Aquatic Ecosystems and Global Climate Change.*Potential Impact on Inland Freshwater and Costal Wetland Ecosystems in the United States.*Pew Centre on Global Climate Change.

Tzortzakis, N. G. 2010. Potassium and Calcium Erichment Alleviate Salinity-induced Stress in hydroponically Grown Endives. *Hort. Sci*. vol. *37, No.4: 155-162*.

United Nations Environment Programme (UNEP). 2012. Fifth Global Environment Outlook (GEO5): Environment for the future we want. United Nations Environment Programme, Nairobi.

United Nations Environment Programme/World Health Organization (UNEP/WHO). 2013.Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. (Jamie Bartram and Richard Balance), pp. 1-348.

Vossen, P. 2001. Changing pH in Soil. Cooperative Extension, University of California, 2604, Ventura Ave. Santa Rosa, CA95403.*Acid Action*, *Leaflet No.2, pp.1-4.*

Wikipedia Atom Feed. 2015a. Clay. (Modified on 2nd June 10th, 2015), pp. 1-4.

Wikipedia Atom Feed. 2015b. *Cyperus*Spp. (Modified on 5th June 10, 2015), pp. 1-6.

Wikipedia Atom Feed. 2015. Phosphorus cycle. (Modified on16th May 2015), pp. 1-5.

Wu, L., X. Guo, A. Harivandi, R. Waters, and Brown, J. 1999. Study of California native grasses and landscape plant species for recycled water irrigation in California landscapes and gardens. Oakland: University of California Division of Agriculture and Natural Resources.