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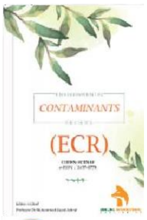

RESEARCH ARTICLE

BIOSORPTION POTENTIALS OF SELECTED AQUATIC PLANTS IN THE REMEDIATION OF FERTILIZER CONTAMINATED WATER

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ABSTRACT

The aim of this study was to investigate the biosorption potentials of duckweed (Lemma minor) and water lettuce (Pistia stratoites) in the treatment of water contaminated with synthetic fertilizer. The complete randomized design (CRD) was used with 34 experimental units and 5 independent sections that lasted for 5 weeks. Experimental water samples containing test plants were analysed for heavy metals (Pb, Cr, Mn), nutrient enrichment (N, P, K) and physicochemical parameters while test plants were evaluated for growth features. Indices of aquatic phytoremediation were computed including HPI (heavy metal pollution indices), PRI (phytoremediation index) and PE (phytoremediation efficiency). Data analysis was done using multivariate analysis tool while mean separation of ANOVA was done using Fisher LSD at P≤005. Plant-fertilizer interaction showed a significant reduction in the concentrations of heavy metals and nutrient content of experimental water. Result showed that water lettuce was excellent at reducing Pb and Mn, characterized with a high PE (phytoremediation efficiency) of 76% (Pb) and 99.3% (Mn). HPI in water lettuce treated water was <1.0. Water lettuce caused a significantly lower reduction (P< 0.05) in level of K and N than duckweed. There was no effect of the on pH of water. Duckweed was found to possess a reducing effect on TDS and EC and increasing effect on temperature and DO. Among the plant growth parameters, height and root sizes were more enhanced in duckweed than water lettuce. However, stem diameter, biomass and leaf sizes were more enhanced in water lettuce. The two test plants demonstrated capacity to improve physicochemical properties of water contaminated with fertilizer. They also showcased high stability and adaptability in their growth features in polluted water.

KEYWORDS

Aquatic plants, biosorption, phytoremediation, heavy metals, fertilizer

1. INTRODUCTION

Increasing need for agricultural produce has increased the application of fertilizers and herbicide which are essential agrochemicals used in crop production to control weeds and enhance yield respectively (Weldeslassie et al., 2018). Input of heavy metal to agricultural land through the excessive use of agrochemicals is increasing apprehension about their probable hazard to the environment (Sardar et al., 2013). Synthetic chemicals are not easily biodegradable thus accumulate in the environment and cause pollution to soil and ground water Eutrophication of water bodies caused by excessive fertilization has hindered a lot of activities in the aquatic bodies and causes death of aquatic fishes (Calzadilla et al., 2011).

The conventional techniques for the remediation of heavy metals are generally costly and time-consuming. These treatment technologies require high capital investment and generate the problem of sludge disposal (Gall et al., 2015; Huang et al., 2017). For the remediation of wastewater polluted with heavy metals contaminants, an environmentally friendly and economical treatment technology is needed (Gall et al., 2015; Huang et al., 2017). Various treatment options are used to remove heavy metals from industrial/agricultural wastewaters (Gunathilakae et al., 2018). Phytoremediation with the use aquatic plants has gained significant consideration due to its elegance and cost-effectiveness. Some studies have shown that aquatic plants have the capability to eliminate heavy metals from different kinds of wastewater (Singh et al., 2012; Sharma et al., 2015; Bokhari et al., 2016).

In Benue State, farmers rely solely on intensive application of fertilizer to improve crop yield regardless of the negative impacts of this agrochemical on both underground and surface water bodies in the study area. The present study was designed to investigate the potentials of two common aquatic plants on remediation of water contaminated with synthetic fertilizer These plants were: duckweeds (Lemna minor) and water lettuce (Pistia stratoites). The plants were specifically chosen they are evasive, apart from their economic uses and good recovery from the aquatic environment (Abbas et al.,2018; Bokhari et al., 2016).

2. MATERIALS AND METHODS

2.1 Collection sample

Clean water was collected from the Water Works Unit of the Joseph Sarwuan Tarka University Makurdi using sterile 50L capacity can. Water was poured into plastic containers to 2.5 liters level each and arranged in a working bench in accordance with the experimental design. Phosphate liquid fertilizer (2L) was procured from agrochemical shop along Otukpo road, within Makurdi metropolis

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2.2 Preliminary collection and identification of two aquatic plants

Samples of two common aquatic plants namely: duckweed (Lemma minor) and water lettuce (Pistia stratoites) were collected from the River Benue and transported to the Botany Department of the Joseph Sarwuan Tarka University Makurdi, Benue State, for identification by taxonomic experts. Floral album of West Africa was also used in identification.

2.3 Collection of identified plants for experimentation

Twenty (20) stands each of duckweed and water lettuce of equal weight (using handy digital weighing instrument) and sizes (using meter rule) were collected from River Benue, and transported to the laboratory for experimentation. They were thoroughly rinsed in distilled water before introduction into plastic pots (Hegazy et al., 2011).

2.4 Experimental Design and Layout

Thirty-four (34) pots (P1-P34) were set up in the Biochemistry Laboratory of the College of Biological Sciences, Joseph Sarwuan Tarka University Makurdi. The Completely Randomized Design (CRD) of 4 replicates per plant treatment was used (Hegazy et al., 2011). The plant factor consisted of two treatments: duckweed and water lettuce. The experiments were grouped into 5 sections that ran concurrently and independently: week 1 (reference = 2 pots), week 2 (8 pots), week 3 (8 pots), week 4 (8 pots) and week 5 (8 pots). Each section terminated at the specified period of time (Ochekwu and Ezekwe, 2020).

2.5 Determination of reference values

The week 1 experiment was used for the determination of all reference values (when phytoremediation had not taken place). After introduction of agrochemicals into buckets, it was allowed to stand for 3 hours before reference values were taken for each of the parameters evaluated at day (week 1) of the experiment including plant growth features (Hegazy et al., 2011).

2.6 Evaluation of Water Quality and Plant Growth Parameters

Evaluation of phytoremediation was done at week 2-5 in the laboratory.

2.7 Heavy metal and mineral analysis

Heavy metals and minerals commonly present in fertilizers and herbicides were analyzed in the experimental water treated with aquatic plants. These were: Lead (Pb), Chromium (Cr) and Manganese (Mn). The amount of each heavy metal was determined using the Atomic Absorption Spectrophotometer (AAS). Potassium (K) content was measured using flame photometer (Bokhari et al., 2016).

2.8 Physicochemical analysis of experimental water

Physicochemical parameters of contaminated water samples were determined following standard methods (AOAC, 2016). Temperature (oC), pH and conductivity were determined with the aid of a combined portable digital HANNA instrument (APHA 46). Total dissolved solid (TDS) (in mg/L) was measured using Palintest conductivity meter. Dissolved oxygen was measured by dissolved oxygen meter. Amount of nitrate and phosphate were quantified using Hanna instruments HI 83200 benchtop multiparameter photometer. Result were expressed in mg/L. All readings were taken in triplicates.

2.9 Morphometric characterization of plant

This was done from plant samples at week 1 (reference) to week 5 experiments. The following features were evaluated suing metre rule and digital weighing balance: plant height, stem diameter, plant biomass, leaf length (cm), leaf width (cm) and root length (cm) following the procedures of (Zhang et al., 2014).

2.10 Computation of Biosorption Parameters

Indices of aquatic phytoremediation and biosoption potentials of aquatic plants were computed including HPI (heavy metal pollution indices), PRI (phytoremediation index) and PE (phytoremediation efficiency) values using standard formula (Akinbile et al., 2012; Bokhari et al., 2016). Heavy metal pollution index (HP) was computed as: $\sum Ci/Si * Wi$

Where Ci = concentration of heavy metals in experimental water

Si = regulatory permissible limit of exposure of the heavy metal

Wi= regulatory weighted value for the heavy metal under consideration

PRI was computed as initial heavy metal concentration (IHC) – final heavy metal concentration (FHC). PE = PRI/IHC x 100% (Bokhari et al., 2016).

2.11 Data Analysis

Data analysis was done on the Genstat application package (v17) for descriptive statistics and inferential statistics. The multivariate statistical tool will be applied. Mean separation of ANOVA was done using the LSD method at $P \leq 0.05$

3. RESULTS

Table 1 presents the effects of fertilizer and plant interaction on heavy metal concentrations in experimental water from week 2 to 5. The reference Lead (Pb) concentration was obtained as 0.025 ppm. It reduced to 0.006 ppm at week 2 of plant-fertilizer interaction but increased to 0.015pp, at week 3. There was a reduction in Pb concentration from this point to 0.012 ppm at week 5. The observed differences in level of Pb from week 2-5 were significant ($P<0.05$). Water lettuce caused a significantly lower reduction ($P< 0.05$) in lead level to 0.006ppm than duck weed (0.017 ppm).

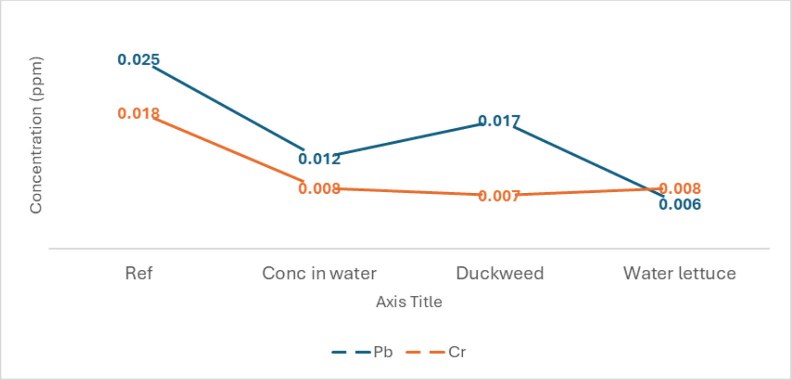
The reference Chromium (Cr) concentration was obtained as 0.018 ppm. There was a sharp reduction in the Cr level throughout the experiment from 0.007 ppm at week 2 to 0.012 ppm at week 5. The observed differences in level of Cr from week 2-5 were significant ($P<0.05$). Duckweed and water lettuce had similar reducing effects ($P>0.05$) on Cr level obtained as 0.007 and 0.008 ppm respectively. The reference Chromium (Mn) concentration was obtained as 0.682 ppm. The value reduced slightly to a range of 0.652 ppm at week 2 to 0.608 ppm at week 5. However, the observed differences were insignificant ($P>0.05$). Water lettuce caused a significant decrease in Mn level (0.005 ppm) than duck weed (1.265 ppm). As shown in figure 1, the average concentration of Lead (Pb) and Chromium (Cr) levels in water were 0.012 and 0.008ppm respectively. A sharp decline in Pb level to 0.006 ppm was observed in water lettuce plant medium only. Although, the two aquatic plants reduced Cr level to 0.008pm from the reference point, the effects produced by the plants were the same.

Table 2 gives the pollution indices of heavy metal in fertilizer contaminated water and plants. The reference value for HPI (Heavy metal pollution index) was calculated as 13.2. Plant based treatment reduced the HPI of water to 9.6. Duckweed based medium had an increased HPI of 21.7 while the value was <1 in water lettuce based medium. Table 3 gives the phytoremediation index (PRI) and efficiency (PE) of aquatic plants in fertilizer contaminated water. In Pb contaminated water, water lettuce had a higher PRI of 0.019 with PE of 76% than duckweed with PRI of 0.008 and PE of 32%. In Cr contaminated water, the two plants had a slight variation in their PRI and PE. In Mn contaminated water, water lettuce had a higher PRI of 0.677 with PE of 99.3% than duckweed with PRI of -0.583 and PE of 0.9%.

Table 1: Fertilizer and Plant Interaction Effect on Heavy Metal Concentrations in Experimental Water

Heavy metals (ppm)	W2	W3	W4	W5	P-value	LSD	Duckweed	Water lettuce	P-value
	Fertilizer						Plant		
Pb	0.006± 0.007^{b}	0.015± 0.009^{a}	0.013± 0.010^{ab}	0.012± 0.002^{ab}	0.009 $P<0.05$	0.005	0.017 ±0.01^{a}	0.006 ±0.01^{b}	P= 0.000 $P<0.05$
Cr	0.007± 0.004^{bc}	0.003± 0.003^{c}	0.008± 0.005^{ab}	0.012± 0.002^{a}	0.006 $P<0.05$	0.005	0.007 ±0.01^{a}	0.008 ±0.04^{a}	P =0.446 $P>0.05$
Mn	0.652± 0.712^{a}	0.631± 0.685^{a}	0.650± 0.707^{a}	0.608± 0.658^{a}	0.999 $P>0.05$	NA	1.265 ±0.05^{a}	0.005 ±0.00^{b}	P= 0.000 $P<0.05$

Ref: Pb= 0.025; Cr= 0.018; Mn= 0.682 (W = weeks; Pb = Lead; Cr = Chromium; Mn= Manganese)



Ref = reference; Conc.= concentration

Figure 1: Average Concentration of Fertilizer Induced Heavy Metals in Experimental Water and Aquatic Plants

Table 2: Heavy Metal Pollution Indices in Fertilizer Contaminated Water and Plants

Heavy metals	Si	Weighted	Reference value	HPI Reference	Concentration in water	HPI water	Duckweed	Duckweed HPI	Water lettuce	Water lettuce HPI
Pb	0.01	0.8	0.025	2	0.012	0.96	0.017	1.36	0.006	0.48
Cr	0.05	0.8	0.018	0.288	0.008	0.128	0.007	0.112	0.008	0.128
Mn	0.05	0.8	0.682	10.91	0.635	8.5	1.265	20.24	0.005	0.08
Σ				**13.2**		**9.588**		**21.71**		**0.688**

Si = WHO Permissible limit

HPI = Heavy metal pollution index (Ci/Si * Wi)

Table 3: Phytoremediation Index (PRI) and Efficiency (PE) of Aquatic Plants in Fertilizer Contaminated Water

	Heavy metal (HM)	Phytoremediation Index (PRI)	Phytoremediation Efficiency (PE) %
Duckweed	Pb	0.008	32
Water lettuce		0.019	76
Duckweed	Cr	0.011	61.1
Water lettuce		0.010	55.6
Duckweed	Mn	-0.583	0.9
Water lettuce		0.677	99.3

PRI = Initial HM conc (IHC) – Final HM conc (FHC)

PE= PRI/IHC *100%

Table 4 presents the effects of fertilizer and plant interaction on nutrient enrichment of experimental water from week 2 to 5. The reference Potassium (K) concentration was obtained as 15.35 ppm. It reduced slightly to 15.3 3 ppm at week 2 of plant-fertilizer interaction, with a further reduction to 14.40 and 14.84 ppm at week 3 and 4 respectively. It increased to higher level than reference and other experimental values were recorded at week 5 (15.57ppm). The observed differences in level of K from week 2-5 were significant ($P<0.05$). Water lettuce caused a significantly lower reduction ($P< 0.05$) in K level to 14.72 ppm than duck weed (15.35 ppm).

The reference Phosphorus (P) concentration was obtained as 11.50 ppm. There was an increase in the P level from week 3 (12.64ppm) to week 4 (12.74), with a slight reduction to 12.22ppm at week 5, although it was higher than the reference value. The observed differences in level of P level from week 2-5 were significant ($P<0.05$). Duckweed and water lettuce had the same increasing effects ($P>0.05$) on P level of experimental water obtained as 12.18 and 12.36 ppm respectively. The reference Nitrogen (N) concentration was obtained as 23.18 ppm. The value increased slightly to a range of 23.18 ppm at week 2 to 23.30 ppm at week 5. However, the observed differences were insignificant ($P>0.05$). Water lettuce caused a significantly lower level of N level (22.96 ppm) than duck weed (23.76 ppm).

As shown in figure 2, the average concentration of K, P and N in water were 15.04, 12.27 and 23.36 respectively. Potassium (K) and Nitrogen (N) levels (14.72 and 22.96 ppm respectively) in water lettuce media were slightly lower than duckweed medium (15.35 and 23.76 ppm respectively) while the latter plant medium contained lower Phosphorus level. Figure 3 shows that concentration of fertilizer-based elements in experimental water had a direct and significant relationship ($P<0.05$) with duckweed as deduced through a fitted regression line (figure 3) where R2 (coefficient of determination) was 99.9%. The linear regression equation is given as: Duckweed = 0.1635 + 1.005 Water. Figure 4 shows that concentration of fertilizer-based elements in experimental water had a direct and significant relationship ($P<0.05$) with water lettuce as deduced through a fitted regression line (figure 4) where R2 (coefficient of determination) was 99.9%. The linear regression equation is given as: Water lettuce = -0.1646 + 0.9946 Water

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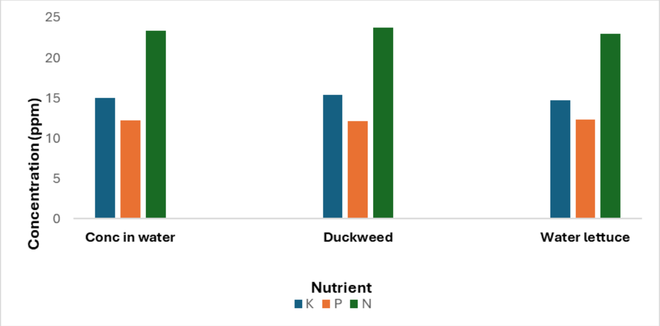
Table 4: Fertilizer and Plant Interaction Effect on Nutrient Enrichment of Experimental Water

Nutrients	W2	W3	W4	W5	P-value	LSD	Duckweed	Water lettuce	P-value
	Fertilizer						Plant		
K	15.33± 0.56^{ab}	14.40± 0.12^{c}	14.84± 0.07^{bc}	15.57± 1.02^{a}	0.011 $P<0.05$	0.41	15.35 ±0.90^{a}	14.72 ±0.20^{b}	$P= 0.027$ $P<0.05$
P	11.49± 0.182^{c}	12.64± 0.231^{a}	12.74± 0.101^{a}	12.22± 0.371^{b}	0.000 $P<0.05$	0.29	12.18 ±0.64^{a}	12.36 ±0.46^{a}	$P =0.414$ $P>0.05$
N	23.47± 0.356^{a}	23.17± 1.096^{a}	23.51± 0.384^{a}	23.30± 0.100^{a}	0.740 $P>0.05$	NA	23.76 ±0.36^{a}	22.96 ±0.49^{b}	$P= 0.000$ $P<0.05$

Ref: K= 15.35; P= 11.50; N=23.18 (W = Weeks; K= Potassium; P= Phosphorus; N= nitrogen)



Ref = reference; Conc.= concentration; Potassium; P= Phosphorus; N= nitrogen)

Figure 2: Average Concentration of Fertilizer Induced Nutrients in Experimental Water and Aquatic Plants

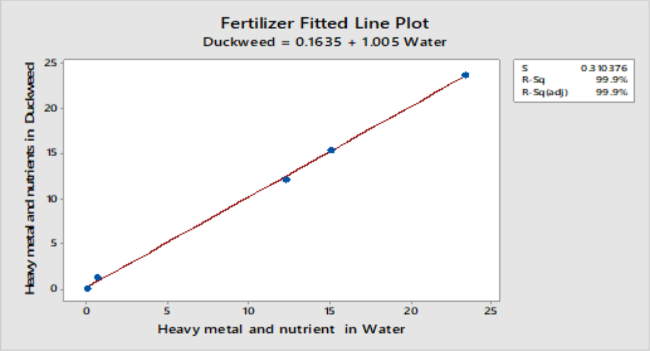


Figure 3: Regression Model Fitted Line of Elements (Heavy Metal and Nutrients) in Fertilizer Contaminated Water and Duckweed Plants

Duckweed = 0.1635 + 1.005 Water (F = 5075.82, $P<0.05$)

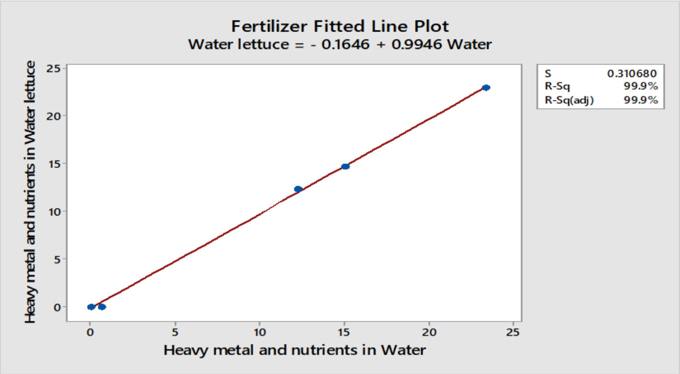


Figure 4: Regression Model Fitted Line of Elements (Heavy Metal and Nutrients) in Fertilizer Contaminated Water and Water Lettuce Plants

Water lettuce = - 0.1646 + 0.9946 Water (F = 4958.17, $P<0.05$)

Table 5 presents the effects of fertilizer and plant interaction on physicochemical properties of experimental water. Results on pH gave 8.5 as the reference value. It increased to 8.9 at week 2 and decreased to 8.6 at week 3 and 4 while the final value at week 5 was 8.48. However, the observed differences in pH readings in the course of the experiment from week 2-5 were insignificant ($P>0.05$). Although higher pH values were obtained than the reference value in the both duckweed and water lettuce (8.6), the plants gave the same effects ($P>0.05$) on the pH of the experimental water Total dissolved solid (TDS) of experimental water had a reference value of 185.5 mg/L. A decrease in TDS content was observed across the durations except at week 4 where a higher value (198.2 mg/L) than the reference TDS was recorded. However, the observed differences in TDS readings in the course of the experiment from week 2-5 were insignificant ($P>0.05$). Effects of plant alone on TDS of experimental water showed that TDS in duckweed-based medium was significantly different from water lettuce as the former reduced the TDS to 158.5 mg/L. Electrical conductivity (EC) of the experimental water had a reference value of 213.9 µS/cm. It increased across the durations except at week 2 where a lower value (197.0 µS/cm) than the reference EC was recorded. However, the observed differences in EC readings in the course of the experiment from week 2-5 were insignificant ($P>0.05$). Effects of plant alone on EC of experimental water showed that EC in duckweed-based medium was significantly different from water lettuce as the former increased the EC to 259.17µS/cm

The temperature of the experimental water had a reference value of 26.4oC. A steady temperature range (26.2 -26.7oC) was recorded from week 2-5, with insignificant differences ($P>0.05$). Effects of plant alone on temperature of experimental water showed that the value in duckweed-based medium was significantly different from water lettuce as the latter increased the temperature to 26.8oC. Dissolved oxygen (DO) of experimental water had a reference value of 3.68 mg/L. A decrease in DO content was observed across the durations, ranging between 3.03 to 3.50 mg/L. However, the observed differences in DO readings in the course of the experiment from week 2-5 were insignificant ($P>0.05$). Result showed that the two plants reduced the DO content of the media to 3.55 mg/L in duckweed and 3.08 mg/L in water lettuces. The performances of plants on DO of water were significantly different ($P<0.05$) as duckweed gave higher value than water lettuce

Table 5: Fertilizer and Plant Interaction Effect on Physicochemical Properties of Experimental Water

Physico chemical parameter	W2	W3	W4	W5	P-value	LSD	Duckweed	Water lettuce	P-value
	Fertilizer						Plant		
pH	8.68 ±0.10^{a}	8.62 ±0.13^{ab}	8.60 ±0.06^{ab}	8.48 ±0.17^{b}	0.071 P>0.05	NA	8.60 ±0.18^{a}	8.59 ±0.08^{a}	P= 0.885 P>0.05
TDS (mg/L)	165.70 ±40.9^{b}	174.67 ±23.83^{ab}	198.17 ±11.94^{a}	173.33 ±8.87^{ab}	0.159 P>0.05	NA	158.50 ±22.31^{b}	197.42 ±10.93^{a}	P=0.000 P<0.05
EC (µS/cm)	225.30 ±54.4^{ab}	197.00 ±45.80^{b}	255.20 ±49.7^{a}	224.33 ±7.81^{ab}	0.182 P>0.05	NA	259.17 ±31.96^{a}	191.75 ±29.51^{b}	P=0.000 P<0.05
Temp (℃)	26.65 ±0.55^{a}	26.22 ±0.61^{a}	26.45 ±0.54^{a}	26.23 ±0.30^{a}	0.443 P>0.05	NA	25.94 ±0.23^{b}	26.83 ±0.25^{a}	P=0.000 P<0.05
DO (mg/L)	3.38 ±0.40^{a}	3.50 ±0.31^{a}	3.03 ±0.12^{b}	3.35 ±0.24^{ab}	0.590 P>0.05	NA	3.55 ±0.27^{a}	3.08 ±0.14^{b}	P=0.000 P<0.05

Ref: pH=8.53; TDS =185.5; EC= 213.9; Temp = 26.38; DO= 3.68

W= weeks, TDS =total dissolved solid; EC =electrical conductivity; Temp= temperature; DO = dissolved oxygen

Table 6 presents the effects of fertilizer and plant interaction on growth parameters of experimental plants. The reference plant height was 16.3cm for duckweed and 7.3cm for water lettuce. Percentage increase in height was higher in duckweed (42.7%) than water lettuce (23.9%). The reference stem diameter was 0.53cm for duckweed and 0.11 for water lettuce. Percentage increase in stem diameter was higher in water lettuce (71.1%) than duckweed (32.9%). The reference plant biomass was 1.69g for duckweed and 1.15g for water lettuce. Percentage increase in biomass was higher in water lettuce (32.4 %) than duckweed (16.7 %). Effects of fertilizer-based media on leaf sizes showed that water lettuce (57.7 % for leaf length; 48.6 % for leaf width) produced higher percentage increase than duckweed. (6.3 % for leaf length; 3.4 % for leaf width). However, root size was more improved in duckweed (50.2 %) than water lettuce (32.2 %).

Table 6: Fertilizer and Plant Interaction Effect on Growth Characteristics of Plants in Experimental Water

Growth parameter	Duckweed	% increase	Water lettuce	% increase
Plant height (cm)	28.36 ±1.22^{a}	42.7%	9.53 ±0.17^{b}	23.9%
Stem diameter (cm)	0.79 ±0.07^{a}	32.9%	0.38 ±0.05^{b}	71.1%
Biomass (g)	2.03 ±0.23^{a}	16.7%	1.70 ±0.15^{b}	32.4%
Leaf length (cm)	6.28 ±0.27^{a}	7.6%	5.37 ±0.12^{b}	57.7%
Leaf width (cm)	3.38 ±0.18^{b}	4.7%	3.85 ±0.34^{a}	48.6%
Root length	16.47 ±1.14^{a}	50.2%	5.18 ±0.65^{b}	32.2%

Duck weed Ref: Height=16.25; Diameter = 0.53; Biomass = 1.69; Leaf length = 5.80; Leaf width = 3.22; Root length = 8.21

Water lettuce Ref: Height=7.25; Diameter = 0.11; Biomass = 1.15; Leaf length = 2.25; Leaf width = 1.98; Root length = 3.51

4. DISCUSSION

The outcome of this investigation revealed the potencies of two aquatic macrophytes (duckweed and water lettuce) in the remediation of water contaminated with fertilizer as demonstrated in a well-structured laboratory experiment. The outcome was aligned with previous findings that explored the live biomass of aquatic plants to remove heavy metals (Karmakar et al., 2016; Kim et al., 2020). Plant-fertilizer interaction showed a significant reduction in the concentrations of heavy metals of experimental water. This outcome revealed that water lettuce was excellent at reducing Pb and Mn. In fertilizer medium, water lettuce was characterized with a high PE (phytoremediation efficiency) of 76% (Pb) and 99.3% (Mn). Also, HPI in water lettuce treated water was <1.0 in fertilizer contaminated water. In general, media with pollution indices that are <1 are considered decontaminated while plants with phytoremediation efficiency of >70% are hyper accumulators and excellent phytoremediants (Bonanno et al., 2017). The ability of the two test plants to decontaminate heavy metal polluted might possibly be to their abilities to accumulate contaminants through their roots and then translocate these contaminants in part of their body as shown in other reports (Sharma et al., 2015; Ashraf et al., 2018).

In the 5 weeks of laboratory experiments, the most noticeable physical change in the two plant was the development of branching root. This might account for the high heavy metal uptake as reported. It was previously established that aquatic plants always develop an extensive system of roots which helps them and makes them the best option for the accumulation of contaminants in their roots and shoots. Reduction in heavy metals were noticeable from week 2 of the experiment. The timing of removal of heavy metals and the phytoremediation efficiencies of duckweed add water lettuce (>70%) in fertilizer medium were in tandem with the findings of (Pedescoll et al., 2015).

One of the effects of excessive fertilizer application on land is nutrient enrichment of water bodies known as eutrophication. This is associated with proliferation algal bloom and perturbed physicochemical condition of water including anoxic condition whereby oxygen level is depleted, leading to loss of aquatic lives. In this study, water lettuce caused a significantly reduction in level of potassium and nitrates in fertilizer based medium, although the effects on phosphate removal was not established. Duckweed was found to possess a reducing effect on total dissolved solid while improving dissolved oxygen level of the fertilizer pot experiment. It was reported that duckweed and water lettuce could easily inhibit the growth of algae and fungi in different ponds because they have the ability to cover the ponds due to their widespread high growth rate (Krishna et al., 2008). They also diminished nitrogen from these ponds by taking up ammonia and denitrification. Removal of the nutrient with the application of duckweed and water lettuce biomass will help to upgrade the quality of water and degradation of water ecology. In other studies, duckweed and water lettuce showed higher removal aptitude for chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN), total suspended solid (TSS) and NH3 than other aquatic plants, from wastewater under favorable environmental circumstances (Krishna et al., 2008). In fertilizer-based experiment, water lettuce caused a significantly lower reduction in level of K and N than duckweed while the latter was found to possess a reducing effect on TDS and increasing effect on temperature and DO. In pesticide treatment, levels of nutrients (N, P, K) were reduced in duckweed treatment only while the two test plants demonstrated potentials in improving physicochemical parameters of pesticide contaminated water.

The two test plants showcased high tolerance and adaptability to polluted condition. As typical of enriched nutrient media of fertilizer, high growth rate was expected. Among the plant growth parameters, height and root sizes were more enhanced in duckweed than water lettuce in fertilizer based medium. However, stem diameter, biomass and leaf sizes were more enhanced in water lettuce. Plants should have the following characteristics in order to make the phytoremediation an eco-sustainable technology: native and quick growth rate, high biomass yield, the uptake of a large amount of heavy metals, the ability to transport metals in above ground parts of plant, and a mechanism to tolerate metal toxicity (Arslan et al., 2017; Burges et al., 2018). Both duckweed and water lettuce plants tested in this work have met the above conditions and therefore could be considered for phytoremediation of Pb, Cr and Mn contaminated water.

5. CONCLUSION

Water lettuce showcased high potentials in the remediation of HMs and excessive nutrients in fertilizer polluted water. The two test plants demonstrated capacity to improve physicochemical properties of water contaminated with fertilizer. They also showcased high stability and adaptability in their growth features in polluted water.

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