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Accumulation and Uptake of Nitrogen and Phosphorus by Four Species of Aquatic Plants under Arid and Semi-Arid Conditions of Dezful, Iran

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Abstract: There are various aquatic plants in the world for using in domestic wastewaters treatment but plant species selection and its management may enhance nutrient removal efficiency in constructed wetlands. This paper studies the capability of *Phragmites australis*, *Typha latifolia, Scirpus (Bulrush)* and *Alisma plantago* to uptake nitrogen and phosphorus from simulated domestic wastewater. The accumulation capacity of these aquatic plants in three treatments consisting of 3 level of nitrogen (low 10, medium 40 and high 100 mg L^{-1} in 1:1 NO_3-N and NH_4-N) and 3 levels of phosphorus (low 5, medium 20 and high 50 mg L^{-1}) in soil with three replicates were studied under the semi-arid conditions of Dezful, Southwest Iran. Also the interaction effects of nitrogen and phosphorus on nutrients uptake were investigated. Results showed that nitrogen accumulation by *Phragmites australis*, *Typha latifolia, Scirpus (Bulrush)* and *Alisma plantago* in high N and P treatment was 31.1, 22.7, 15.3 and 9.9 g m^{-2} respectively. For phosphorus, *Phragmites australis* had highest accumulation with 10.8 g m^{-2} followed by *Typha latifolia; Alisma plantago* and *Scirpus (Bulrush)* were 8.6, 7 and 5.9 g m^{-2} respectively. Results indicated significant differences in accumulation of nitrogen and phosphorus in the *Phragmites australis* tissues rather than other three species. The overall conclusion being that by *Phragmites australis* and *Typha latifolia* have high potential to uptake nutrients from domestic wastewater under arid and semi-arid conditions such as Dezful in Iran.

Key words: Nutrients accumulation · *Phragmites australis* · Domestic wastewater and Dezful

INTRODUCTION

Fresh water is limitation resource in Iran; hence there is scope to make better use of recycled water as additional water resources. As discharge the untreated wastewaters into water bodies' resources causes to pollution these resources. Eutrophication continues to be one of the problems in many water bodies. Nitrogen and phosphorus, the important nutrients implicated in eutrophication, enter water bodies via a variety of pathways [1]. One of this is the discharge of the wastewater into water bodies. Review of the literature shows that wastewater was reused as a source of irrigation for agricultural products more than 5000 years ago. Various researches have been conducted on the use of constructed wetlands to treat wastewater form municipal, industrial, agricultural and mining sources in recent years [2]. Although constructed wetlands are being developed in many parts of the world for various functions, there have been widespread problems in their performance with respect to nitrogen transformations and removal as well as phosphorus removal [3]. In general, use of constructed wetlands for domestic wastewater treatment diminished in the late 1990s. The large number

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of constructed wetlands has been used around the world to treat of wastewater including domestic sewage [4-8]. The advantages and limitations of the constructed wetlands for wastewater treatment have been summarized in many reports [2, 9]. Many species of aquatic plants can be used in constructed wetlands designed for domestic wastewater treatment [10-13]. Frequently used aquatic plants species are *Typha sp. Phragmites ap. Scirpus sp.* and *Carex sp.* [9]. Wetland aquatic plants are able to tolerate high concentrations of nutrients and some cases even to accumulate more nutrients then are needed for growth when supplemental nutrients are available. Eight common wetland plant species were investigated from both high-nutrient load and control wetlands [14]. Results showed high level of nitrogen and phosphorus in treatment wetlands comparison by the control wetlands. The accumulation of nitrogen and phosphorus in plant tissues such as *Phragmites australis*, *Typha sp.* etc in constructed wetlands in high nutrients loads were studied by many researchers [15, 16]. Studying the nutrient content of mixed litter including *Phragmites australis*, *Typha orientalis* and *Echinochloa crus-galli* in a constructed wetland at Australia showed high the nutrient accumulation in live tissues for these plants [17]. Removal of nitrogen and phosphorus by constructed wetlands is a complex cyclic process that may be physical, chemical or biological. In this process happened removal by water column, sediments, plant roots, stems and leaves [18]. Plants have effective role in constructed wetlands particularly in nitrogen and phosphorus removal [19]. Research reports indicated that constructed wetlands with planted treatments had higher nitrogen and phosphorus removal compared with unplanted treatments [19-23]. However in some reports did not found any significant difference between planted and unplanted systems [24, 25]. Purpose of this paper was to study the uptake and accumulate of nitrogen and phosphorus from simulated domestic wastewater onto four aquatic macrophtes consisting of *Phragmites australis*, *Typha latifolia, Alisma plantago* and *Scirpus (Bulrush)* under arid and semi-arid conditions of Dezful region in southwest Iran.

MATERIAL AND METHODS

Study Location: All experiments were conducted at the open site adjacent to the Faculty of Agriculture, Islamic Azad University, Dezful (48° 25′ E, 32° 16′ N) under natural conditions. The minimum and maximum temperatures during the growing season ranged between 24 and 50 degrees centigrade.

Experiment Treatments: Plants were grown in a factorial experiment with nine treatments consisting of 3 level of nitrogen (low 10, medium 40 and high 100 mg L^{-1} in 1:1 NO_3-N and NH_4-N) and 3 levels of phosphorus (low 5, medium 20 and high 50 mg L^{-1}) with three replicates in the 84 day test period. As Dezful wastewater network was in primary conditions of establishment, average concentrations of nitrogen and phosphorus in municipal wastewater was selected for guideline. Then 2 level above and below of these amounts was added too. Potassium was 25 mg L^{-1} (K) in all treatments. These treatments were added to pots two week after re-planted. The other macro- and micronutrients (mg L^{-1}) show in Table 1.

Sampling and Measurements

Plant Selection: Four aquatic plants of *Phragmites australis, Typha latifolia, Alisma plantago* and *Scirpus (Bulrush)* were selected because of their availability and accessibility in the study area. The samples were collected from The Dez River, Safiabad and Senjar main drains and other stream margins in Dezful, Iran during spring 2008.

Planted Bed: Four aquatic plant investigated in this research replanted in nurtured environment of the plastic pot bed with 100 cm diameter and 60 cm height in the following June. Approximately 200 kg of river sediment materials (sands) of between 4 to 12 mm diameters were subsequently added to each pot providing a sand depth of about 0.25 m. Some properties of sand that used in this study were presented in Table 2.

Plant Sampling: After nutrient treatments applied, plant samples were collected after two week. One herb from each pot was completely disposed of every two weeks and then the samples were transported to laboratory after slow wash by water. Plant samples were then weighed and dried at 70°C for 5 days. The dried samples were further weighed, grounded into ball mill and sieved by a 0.75 mm sift. They were analyzed for determination of TN and TP by kjeldahl and spectrometry methods [26].

Statistical Analyses: The statistical analyses were based on a factorial design using the SPSS (Version 13).

Table 1: Some macro- and micronutrients (mg L^{-1}) concentrations in solution

Element	Fe	B	Cu	Zn	S	Mn	Mg	Ca
Application amount	0.4	0.3	0.02	0.05	0.03	0.06	7	10

Table 2: Some properties of sand that used in pots

Parameters	Sand size (mm)	Conductivity (dS m^{-1})	pH	Sulphur (mg kg^{-1})	Organic carbon (g kg^{-1})
Value	1-5	0.03	7.3	5.5	0.83

RESULTS AND DISCUSSION

Effects of N and P Levels on Uptake of the Nitrogen and Phosphorus over Four Plant Species: Tables 3, 4, 5 and 6 show the statistical analysis of the effects of various P and N levels and their effects on accumulation of the N and P the plant tissues over four plant species (g m^{-2} of cultural environment) and daily uptake each element for *Phragmites australis, Typha sp. Scirpus sp.* and *Alisma sp.* respectively. It was generally observed that accumulation of the nutrients (N and P) in all plant tissues under study showed an increased trend in the consumption of the N and P. Results further indicated a significant influence of various N levels on N and P accumulation in plant tissues. The difference was significant for *Phragmites australis* at $P \leq 0.01$, whereas this was significant for other species at $P \leq 0.001$. This trend was similar for the daily uptake of two elements. The effect of various P levels on N accumulation in plant tissues and its daily uptake was not significant, except for *Alisma sp.* at $P \leq 0.05$. This was shown to be significant ($P \leq 0.01$ or $P \leq 0.001$) for the accumulation of P in plant tissues and daily uptake.

Results further indicated the capability of the four varieties for accumulating the nutrients in plant tissues. However, *Phragmites australis* and *Typha sp.* shown to have a greater accumulation of N and P than other varieties. The findings of the paper is more or less congruent with research findings elsewhere [27] where they reported the rate of nitrogen accumulation in organs of *Phragmites australis* and *arundinacea Phragmites* planted in constructed wetlands raged between 8.5 to 84 and 3.7 to 46.7 g m^{-2} respectively. This was reported for the natural wetlands to be between 0.04 to 63.4 and 2 to 15.5 g m^{-2} respectively. The nitrogen and phosphorus accumulations in plant tissues of *Typha, Phragmites, Scirpus* and *Juncus* were reported to be between 14 to 156 and 1.4 to 37.5 g m^{-2} respectively [28]. Experimental work by [29] showed the accumulation of P on various varieties aquatic plants cultured in 30 different constructed wetlands in Europe, North America and Australia between 0.2 to 10.5 g m^{-2}.

The Interaction Effects of N and P: The interaction effect of N and P on their accumulation and uptake in the investigated varieties was significant for all plant species (Tables 3, 4, 5 and 6). This is in the context of little data availability in the literature about the subject matters under investigation. It was observed for example [30], that interaction effects of N and P has a great influence on plant growth and uptake rate of the nutrients by the aquatic plant varieties such as *Typha latifolia,*

Table 3: Effects of N and P treatments on nutrient accumulation and nutrient uptake in plant tissues of *Phragmites australis* after 84 days of growth in pots

		Nutrient accumulation (g m^{-2})		Nutrient uptake (mg m^{-2} day^{-1})	
	Treatments	Nitrogen	Phosphorus	Nitrogen	Phosphorus
Low P	Low N	2.2e	1.19d	26.19e	14.17e
	Medium N	15.7cd	3.78c	186.90cd	45.00d
	High N	19.8c	2.94cd	235.71c	35.00d
Medium P	Low N	2.3e	1.42d	27.38e	16.90e
	Medium N	16.7cd	5.75bc	198.81cd	68.45c
	High N	24.7b	7.05b	294.05b	83.93bc
High P	Low N	2.1e	1.53d	25.00e	18.21e
	Medium N	12.3d	7.20b	146.43d	85.71b
	High N	31.1a	10.80a	370.24a	128.57a
Source of variation	N	**	**	**	**
	P	NS	**	NS	**
	N×P	*	**	*	**

Means with different letters within columns are significantly different based on LSD (P<0.05). NS: not significant. *** Significant at P<0.001

Table 4 : Effects of N and P treatments on nutrient accumulation and nutrient uptake in plant tissues of *Typha sp.* after 84 days of growth in pots

	Treatments	Nutrient accumulation (g m^{-2})		Nutrient uptake (mg m^{-2} day^{-1})	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Low P	Low N	1.5d	0.9d	17.98e	10.71e
	Medium N	10.8c	3c	128.57cd	35.71d
	High N	14.7b	2.7c	175.00c	32.14d
Medium P	Low N	1.6d	1.1cd	19.05e	13.10e
	Medium N	11.9c	4.3b	141.67c	51.19c
	High N	17.8b	5.4b	211.90b	64.29b
High P	Low N	1.5d	1.1d	17.86e	13.10e
	Medium N	9.4c	5.6b	111.90d	66.67b
	High N	22.7a	8.6a	270.24a	102.38a
Source of variation	N	***	***	***	***
	P	NS	***	NS	***
	N×P	**	***	**	***

Means with different letters within columns are significantly different based on LSD (P<0.05). NS: not significant. *** Significant at P<0.001

Table 5: Effects of N and P treatments on nutrient accumulation and nutrient uptake in plant tissues of *Scirpus sp.* after 84 days of growth in pots

	Treatments	Nutrient accumulation (g m^{-2})		Nutrient uptake (mg m^{-2} day^{-1})	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Low P	Low N	0.8d	0.6c	10.0d	6.7d
	Medium N	8.0c	2.0c	95.2c	23.8c
	High N	10.0bc	1.5c	118.6bc	17.9c
Medium P	Low N	0.9d	0.7c	11.2d	8.7d
	Medium N	9.4c	3.0b	112.3bc	35.7bc
	High N	11.7b	3.6b	139.8b	42.9b
High P	Low N	0.7d	0.8c	8.7d	9.5d
	Medium N	6.2c	3.7b	73.8c	44.0b
	High N	15.3a	5.9a	182.1a	70.2a
Source of variation	N	***	***	***	***
	P	NS	***	NS	***
	N×P	**	***	**	***

Means with different letters within columns are significantly different based on LSD (P<0.05). NS: not significant. *** Significant at P<0.001

Table 6: Effects of N and P treatments on nutrient accumulation and nutrient uptake in plant tissues of *Alisma plantago* after 84 days of growth in pots

	Treatments	Nutrient accumulation (g m^{-2})		Nutrient uptake (mg m^{-2} day^{-1})	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Low P	Low N	0.6c	0.8d	6.7c	9.0d
	Medium N	5.2b	2.5c	62.1b	30.2c
	High N	6.4b	3.0bc	75.8b	35.1c
Medium P	Low N	0.6c	1.0d	7.3c	12.1d
	Medium N	4.6b	3.6bc	54.8b	42.6bc
	High N	7.7b	4.5b	92.0ab	53.1b
High P	Low N	0.5c	1.0d	6.0c	11.9d
	Medium N	3.9b	2.9bc	46.9b	34.8c
	High N	9.9a	7.0a	117.9a	83.3a
Source of variation	N	***	***	***	***
	P	*	**	*	**
	N×P	**	**	**	**

Means with different letters within columns are significantly different based on LSD (P<0.05). NS: not significant. *** Significant at P<0.001

Table 7: Nutrients accumulation (g m^{-2}) in treatment of high N and P level by four aquatic plant species

Macrophytes	*Phragmites sp.*	*Typha Sp.*	*Scirpus sp.*	*Alisma sp.*
Nitrogen	31.1a	22.7b	15.3bc	9.9c
Phosphorus	10.8a	8.6ab	5.9b	7b

Table 8: Nutrients uptake (mg m^{-2} day^{-1}) in treatment of high N and P level by four aquatic plant species

Macrophytes	*Phragmites sp.*	*Typha Sp.*	*Scirpus sp.*	*Alisma sp.*
Nitrogen	370.24a	270.24b	182.1bc	117.9c
Phosphorus	128.57a	102.38ab	70.2b	83.3b

Typha angostifolia and *Phragmites australis*. However, this was not found to be the case by [31] on *Phragmites australis* and *Typha oreintalis* species.

Nutrients Accumulation and Daily Uptake in Treatment of High N and P Level: Comparison of the mean effects of the high nitrogen and phosphorus level in uptake of these nutrients by the plants from the simulated wastewater showed greatest accumulation for *Phragmites australis* with 31.1 g m^{-2}, followed by *Typha Sp. Scirpus sp.* and *Alisma sp.* with 22.7, 15.3 and 9.5 g m^{-2} respectively. The N accumulation difference between *Phragmites australis* and other species was significant. For phosphorus *Phragmites australis* was highest accumulation with 10.8 g m^{-2} followed by *Typha sp. Alisma sp.* and *Scirpus sp.* with 8.6, 7 and 5.9 g m^{-2} respectively. These occurred in treatment at high P and N levels (Tables 7 and 8).

CONCLUSION

The research was carried out to identify the appropriate aquatic plant varieties with potentially high nutrients uptake from domestic wastewater in arid and semi-arid regions of the Greater Dezful region. Overall conclusion being that all four species of the aquatic plants showed to have a potentially high capability to uptake available N and P from the simulated wastewater under study. However, the two varieties of *Phragmites australis* and *Typha sp.* shown to have a greater potential to uptake the nutrients from the domestic wastewater body. The paper recommendation being that these plant varieties can therefore be cultivated in constructed wetlands in order to act as treating agent in domestic wastewaters of rural communities.

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