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Short Term Influence of Salinity on Uptake of Phosphorus by *Ipomoea aquatica*

Md. Zulfikar Khan[1*], Md. Ariful Islam[1], Md. Golam Azom[1] and Md. Sadiqul Amin[1]

[1]Soil, Water and Environment Discipline, Khulna University, P.O.Box: 9208, Khulna, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A pot experiment was conducted to investigate the short-term influence of different levels of salinity on the growth, yield and phosphorus (P) uptake of *Ipomoea aquatica* during the period of 03rd September to 03rd October, 2015. Two non-saline soils with different textural classes were collected from the Ganges Tidal Floodplain (Dumuria soil series) and Ganges Meander Floodplain sites (Barisal soil series). The experiment was laid to fit a completely randomized design (CRD) with four treatments (0 dS m^{-1}, 3 dS m^{-1}, 6 dS m^{-1}, 12 dS m^{-1}) each having three replications for this experiment. After plant harvesting, the laboratory investigation was carried out in the Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh. For both soil series, yield contributing characters like plant height, shoot length, root length, number of leaves, fresh weight and dry weight were significantly *(P* < 0.05*)* influenced by different levels of salinity treatments. In Dumuria soil series, all yield character was decreased in order to 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} salinity level for *Ipomoea aquatica* which was the same sequence for Barisal soil series. In addition, Phosphorus (P) uptake, the sequence was 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1}, respectively for both (Dumuria and Barisal) soil series. The sequence clearly indicates that salinity level reduces the uptake of P and ultimately reduces the yield. The changes were statistically significant (*P* < 0.05) in case of both soil series.

**Corresponding author: E-mail: Zulfikar.ku11@gmail.com;*

Keywords: Phosphorus uptake; dry matter content; soil series; salinity; yield; Ipomoea aquatica.

1. INTRODUCTION

Salinity is one of the most important abiotic stresses, limiting crop production in arid and semi-arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching [1]. Salt stress leads to suppression of plant growth and development at all growth stages, however, depending upon plant species, certain stages such as germination, seedling or flowering stage could be the most critical stages for salts stress.

Soil salinity can suppress plant growth via specific (ionic stress) and non-specific (osmotic stress) effects [2]. Salinity also decreases the availability of nutrients, particularly P, and depresses microbial activity. In addition to salinity, low P availability and uptake by plants are major limitations for plant growth in many soils around the world [3]. Low P availability results from precipitation, transformation, fixation of P with soil minerals [4] and presence of high amounts of soluble salts [5], and also occurs in the soil having low total P concentration. Salinity may also reduce the P flux through the xylem [6], reducing plant P content and concentration. Increasing phosphorus (P) availability and enhancing phosphorus (P) nutrition of plants through fertilisation may enhance plant salt tolerance and growth. In nutrient deficient soils, P fertilisation can increase P availability, but may not efficiently enhance plant growth, unless plants are sufficiently supplied with nutrients, particularly N. Adequate supply of N, in combination with P, may influence plant-nutrient-salinity relationships [7] and thus enhance plant growth under saline conditions. This may, however, be effective only up to a certain salinity level above which the negative salinity effect is dominant.

Despite its importance in plants growth and metabolism, phosphorus is the least accessible macronutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilisers. The low availability of phosphorus is due to the fact that it readily forms insoluble complexes with cations such as aluminum and iron under acidic soil conditions and with calcium and magnesium under alkaline soil conditions whereas the poor P fertiliser recovery is due to the fact that the P applied in the form of fertilisers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations. Moreover, global P reserves are being depleted at a higher rate and according to some estimates, there will be no soil P reserve by the year 2050 [8,9].

Water spinach (*Ipomoea aquatica*), a leafy vegetable is commonly known as Kalmi shak, is widely cultivated in Bangladesh and meets the nourishment here, especially in the rural areas. The plant has creeping, hollow, water-filled stems and shiny green leaves, and large purple or white 2-5 cm long funnel-shaped flowers [10]. It is used as human food and animal feed throughout Southeast Asia. Crude fibre and ash concentrations are around 12% and 19% of dry matter, respectively. The fresh leaves and stems contain 20 to 31% crude protein (CP) on a dry matter (DM) basis [11] with balanced essential amino acids, i.e. 1.3% lysine, 0.4% methionine and 1.1% threonine on a DM basis [12]. The main objective of this research was to observe the influence of different levels of salinity on the uptake of phosphorus in Dumuria and Barisal soil series.

2. MATERIALS AND METHODS

All the soil samples were collected at a depth of 0-15 cm from a square area of 1 km^2 under Dumuria and Barisal soil series. Then sample were mixed together to form a composite sample. After drying in air, the larger aggregates were broken gently by crushing it in a wooden hammer, and passed through a 2 mm sieve. The sieved soils were preserved in plastic bag for pot experiment and also preserved in plastic pot for determining their various physical and chemical properties and both were labeled properly. Two soil series use in the present investigation are described below and general information of sampling sites is given in Table 1.

2.1 Design and Layout of the Experiment

The experiment was carried out in completely randomized design (CRD) with three replications per treatment. The total number of pots used in this study was 24. Soil samples were treated with different concentrations of saline water to create field condition. The salinity levels were 0 dSm^{-1}, 3 dSm^{-1}, 6 dSm^{-1} and 12 dSm^{-1}. The levels of the salinity of this experiment were created by using NaCl mixing with distilled water and stored in a plastic bottle.

Table 1. General information about sampling sites

Soil series	GPS	Location	Physiography
Dumuria	$22^0$44.981′ N $89^0$31.406′ E	Vill: Dauniafand Union: Jalma Upazilla: Baitaghata	Ganges Tidal Floodplain
Barisal	$22^0$57.470′ N $89^0$27.457′ E	Vill: Garakhola Union: Damuda Upazilla: Fultola	Ganges Meander Floodplain

2.1.1 Pot experiment

A pot experiment with water spinach (*Ipomoea aquatica*) was carried out during kharif-2 season (03/09/2015 to 03/10/2015) in front of the digestion lab of Soil Science Discipline at Khulna University. Dumuria and Barisal soil series were used for the experiment. One kg of air-dried soil was taken in 16 cm high and 10.5 cm diameter earthen pot. The soil was fertilised according to the calculation by following the Fertiliser Recommendation Guide [13]. Half of the urea, full of TSP and MoP were mixed with the soil. The remaining urea was applied after twenty days of seedling.

2.1.2 Water treatment

The levels of the salinity of this experiment were created by using NaCl mixing with distilled water and stored in a plastic bottle. After that the pots were kept wet in everyday by different levels of saline containing irrigation water and a total amount of water added for irrigation was 10 L Pot^{-1}.

2.2 Collection and Preparation of Plant Samples

The plants were uprooted after 30 days of germination and the whole plants were washed with distilled water. The parts of the plants were separated by using a scissor to cut larger parts of the plant in to smaller size. The samples were kept in paper bags and date, location of the sampling, treatment number was written on the paper bags. The Paper bags were put in an oven at 65^0C for 48 hours until a constant dry weight was obtained. After completion of the drying the dry weight was measured. The samples were cut in to smaller pieces and powdered in a grinding mill and passed through 0.5 mm sieve. The powder was mixed thoroughly. The powdered samples were preserved in plastic pots and tagged properly for chemical analysis of P.

2.3 Analytical Procedure

After sieving, soil samples were analysed for physical and chemical properties. The particle size analysis of the soils was carried out by hydrometer method as described by Bouyoucos [14] and Day [15]. Textural classes were determined using Marshall's Triangular Coordinate. Soil pH was determined electrochemically with the help of glass electrode pH meter maintaining the ratio of soil to water was 1: 2.5 as suggested by Jackson [16]. The electrical conductivity of the soil was measured at a soil: water ratio of 1: 5 by the help of EC meter [17]. The organic carbon content of the samples was determined by Walkley and Black's wet oxidation method as outlined by Jackson [16]. Available Phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ at pH 8.5 [18] and Molybdophosphoric blue colour method was employed for determination [19].

2.3.1 Phosphorus content of plant samples

Plant samples were digested with HNO_3-$HClO_4$ (2:1) mixture and were determined by vanadomolybdate yellow colour method as described by Jackson [20].

2.4 Statistical Analysis

Analysis of variance (ANOVA) was calculated by using Minitab (16.0) to determine the effects of salinity and graphs were drawn by using Microsoft Excel version, 2013 [21].

3. RESULTS AND DISCUSSION

The results of the study on the effect of salinity levels on uptake of phosphorus are presented and possible interpretations are made in this chapter. Important physical and chemical properties are presented at Table 2.

3.1 Change in Yield Parameters Due to Treatment

Higher levels of salinity in irrigation water cause some morphological changes along with yield of *Ipomoea aquatica*.

Table 2. Important physical and chemical properties of the soils

Properties		EC (dS m^{-1})	pH	Textural class	Soil organic carbon (%)	Total P (%)	Available P (µg g^{-1})	Calcareousness
Soil Series	Dumuria	5.21	7.74	Silty clay	0.20	0.06	22.15	Calcareous
	Barisal	5.32	7.17	Clay	0.39	0.05	13.06	Non-calcareous

For Dumuria soil series (Table 3), results indicate that. The maximum plant height (65.12 cm) was observed in salinity level 0 dS m^{-1} and lowest plant height (50.06 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum plant shoot length (53.31 cm) was observed in salinity level 0 dS m^{-1} and lowest shoot length (44.25 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum plant root length (11.32 cm) was observed in salinity level 0 dS m^{-1} and lowest root length (6.12 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum leaves per plant (10.82) were observed in salinity level 0 dS m^{-1} and lowest leaves per plant (6.95) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum fresh weight per plant (17.91 gm) was observed in salinity level 0 dS m^{-1} and lowest fresh weight per plant (8.45 gm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. Therefor found that the all yield parameters (plant height, shoot length, root length, leaves per plant, fresh weight and dry matter content) of *Ipomoea aquatica* was significantly (P < 0.05) influenced by different level of salinity (Table 3).

For Barisal soil series (Table 4), results indicate that the maximum plant height (67.00 cm) was observed in salinity level 0 dS m^{-1} and lowest plant height (52.00 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum plant shoot length (55.21 cm) was observed in salinity level 0 dS m^{-1} and lowest shoot length (46.00 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum plant root length (11.81 cm) was observed in salinity level 0 dS m^{-1} and lowest root length (6.00 cm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum leaves per plant (11.47) were observed in salinity level 0 dS m^{-1} and lowest leaves per plant (7.33) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. The maximum fresh weight per plant (18.52 gm) was observed in salinity level 0 dS m^{-1} and lowest fresh weight per plant (8.19 gm) was obtained in salinity level 12 dS m^{-1}. Therefore, observations were as 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1} in the experiment. Therefor found that the all yield parameters (plant height, shoot length, root length, leaves per plant, fresh weight and dry matter content) of *Ipomoea aquatica* was significantly (P < 0.05) influenced by different level of salinity (Table 4).

3.2 Dry Matter Yield of *Ipomoea aquatica* of Dumuria Soil Series

The dry weights of vegetative portions of water spinach are presented in Fig. 1. Total dry matter yield was significantly (P < 0.05) affected by salinity levels. Result showed that dry matter yield (g pot^{-1}) decreased with the increasing salinity levels. The highest dry matter yield was observed at 0 dS m^{-1} (1.12 g pot^{-1}) and the lowest dry matter yield was recorded in 12 dS m^{-1} (0.61 g pot^{-1}) in Dumuria soil series.

Table 3. Effect of salinity level on the growth of *Ipomoea aquatica* for Dumuria soil series

Treatment	Plant height (cm)	Shoot length (cm)	Leaves per plant	Fresh weight per plant (gm)	Dry matter content(gm)	Root length (cm)
0 dS m^{-1}	65.12a	53.31a	10.82a	17.91a	1.12a	11.32a
3 dS m^{-1}	59.01b	48.13b	9.63b	12.43b	0.87b	9.89b
6 dS m^{-1}	54.00c	47.92c	7.51c	10.31c	0.79c	8.32c
12 dS m^{-1}	50.06d	44.25d	6.95d	8.45d	0.61d	6.12d

(Means followed by different letters in each column are significantly different (P ≤ 0.05) according to Duncan Multiple Range Test)

Table 4. Effect of salinity level on the growth of *Ipomoea aquatica* for Barisal soil series

Treatment	Plant height (cm)	Shoot length (cm)	Leaves per plant	Fresh weight per plant (gm)	Dry matter content (gm)	Root length (cm)
0 dS m^{-1}	67.00a	55.21a	11.47a	18.52a	1.26a	11.81a
3 dS m^{-1}	60.10b	48.72b	9.81b	11.33b	1.01b	10.47b
6 dS m^{-1}	57.00c	48.43c	7.85c	9.41c	0.70c	8.61c
12 dS m^{-1}	52.00d	46.00d	7.33d	8.19d	0.63d	6.00d

(Means followed by different letters in each column are significantly different ($P \le 0.05$) according to Duncan Multiple Range Test)

3.3 Dry Matter Yield of *Ipomoea aquatica* of Barisal Soil Series

The dry weights of vegetative portions of water spinach are presented in Fig. 2. Total dry matter yield was significantly (P < 0.05) affected by salinity levels. Result showed that dry matter yield (g pot^{-1}) decreased with the increasing salinity levels. The highest dry matter yield was observed at 0 dS m^{-1} (1.265 g pot^{-1}) and the lowest dry matter yield was recorded in 12 dS m^{-1} (0.63 g pot^{-1}) in Barisal soil series. Reduced total dry matter yield under salinity condition might be due to inhibited photosynthesis under salinity stress that causes less amount of nutrient uptake by plant [3].

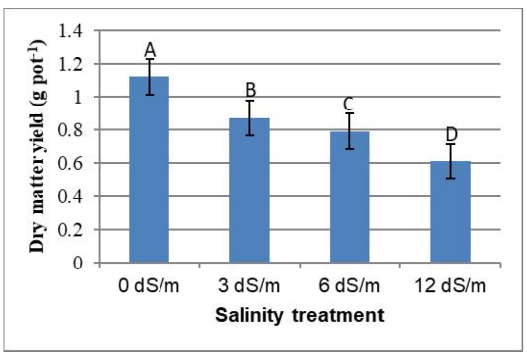

Fig. 1. Effect of salinity on dry matter yield of *Ipomoea aquatic* of Dumuria series

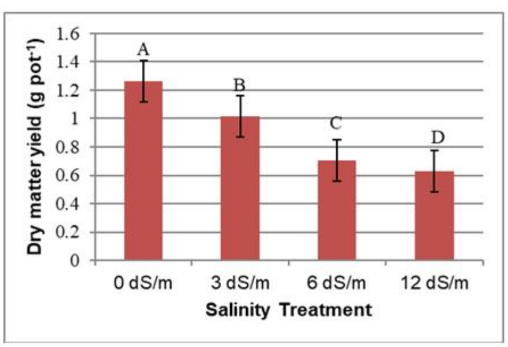

Fig. 2. Effect of salinity on dry matter yield of *Ipomoea aquatic* of Barisal series

As a result, plant growth was slow as well as shorter plant height and produced fewer leaves $plant^{-1}$. That is why, lower dry matter was produced under salinity condition compared to control. Similar result was also reported by Rahman [22] for *Ipomoea aquatic*. They observed that stem weight, leaf weight as well as total dry matter per plant decreased with increased salinity.

3.4 Phosphorus Uptake by *Ipomoea aquatica* in Dumuria Soil Series

The uptake of P calculated as µg $plant^{-1}$ from dry weight of Ipomoea aquatica is presented in Fig. 3. Phosphorus uptake was not affected by salinity level up to 3 dS m^{-1}. Phosphorus uptake was decreased significantly (P < 0.05) at 6 dS m^{-1} and remained same at 12 dS m^{-1}. Highest Phosphorus uptake was recorded at salinity levels 3 dS m^{-1} (122.66 µg $plant^{-1}$) lowest phosphorus uptake was recorded at 12 dS m^{-1} (88.60 µg $plant^{-1}$) in Dumuria soil series.

3.5 Phosphorus Uptake by *Ipomoea aquatica* in Barisal Soil Series

The uptake of P calculated as µg plant-1 from dry weight of Ipomoea aquatica is presented in Fig. 4. Result showed that Phosphorus uptake decreased with the increasing salinity levels. Phosphorus uptake was significantly (P < 0.05) affected by salinity levels. Phosphorus uptake was not significantly affected by salinity levels 0 dS m^{-1} to 3 dS m^{-1} and 3 dS m^{-1} to 6 dSm^{-1}. Phosphorus uptake was significantly decreased at salinity level 6 dS m^{-1} compared to control, but phosphorus uptake was not significantly affected by salinity levels 6 dS m^{-1} to 12 dS m^{-1}. Highest phosphorus uptake was recorded at salinity levels 0 dS m^{-1} (170.98 µg $plant^{-1}$) lowest phosphorus uptake was recorded at 12 dS m^{-1} (96.53 µg $plant^{-1}$) in Barisal soil series.

The final impact of salinity of soil solution on the concentration of phosphorus in plants depends heavily on plant species, phase of ontogenesis, the type and level of salinity and concentration of phosphorus that is already present in the soil [23]. In most cases, excess of salts in soil solution leads to a reduction in phosphorus concentration in the tissues of plants, but the results of some studies show that salinity may increase but that does not affect the uptake and accumulation of phosphorus [24]. Kochian [25] suggests that the reduction of the availability of phosphorus in saline soils is the result of the activity of ions antagonists, which can reduce the activity of phosphate and phosphate transporters of both high and low affinity, which are necessary for the uptake of phosphorus. Reduced uptake of phosphorus can also be a consequence of the strong influence of sorption processes that control the concentration of phosphorus in the soil and low solubility of Ca-P minerals [26].

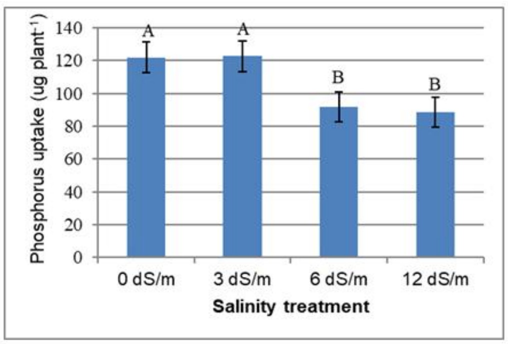

Fig. 3. Effect of salinity on phosphorus uptake of *Ipomoea aquatica* of Dumuris series

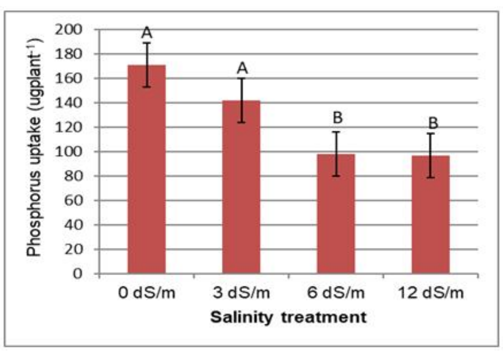

Fig. 4. Effect of salinity on phosphorus uptake of *Ipomoea aquatic* of Barisal series

4. CONCLUSION

A pot experiment was conducted to investigate the short-term influence of different levels of salinity on the growth, yield and phosphorus (P) uptake of *Ipomoea aquatica.* This experiment revealed that the yield contributing characters like plant height, shoot length, root length, number of leaves, fresh weight and dry weight were significantly *(P* < 0.05*)* influenced by different levels of salinity treatments for both (Dumuria and Barisal) soil series. Dry matter yield was decreased with the increasing salinity level and the sequence was 0 dS m^{-1}>3 dS m^{-1}>6 dS m^{-1}>12 dS m^{-1}, respectively for both soil series. For both soil series, phosphorus uptake was decreased gradually with increasing salinity, but statistics revealed that uptake was not significantly affected by salinity level up to 3 dS m^{-1}, compared to 0 dS m^{-1}. Phosphorus uptake was decreased significantly ($P < 0.05$) at 6 dS m^{-1} and 12 dS m^{-1} as compared to 0 dS m^{-1}. The sequence clearly indicates that salinity level reduces the uptake of P and ultimately reduces the growth and yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDICES

Appendix Table I. One-way ANOVA: Dry matter yield g pot^{-1} versus treatment (Dumuria soil series)

Source	DF	SS	MS	F	P
Treatment	3	0.40343	0.13448	99.61	0.000
Error	8	0.01080	0.00135		
Total	11	0.41423			

Treatment	N	Mean	Grouping
0 dS m^{-1}	3	1.12000	A
3 dS m^{-1}	3	0.87000	B
6 dS m^{-1}	3	0.79000	C
12 dS m^{-1}	3	0.61000	D

(Means followed by different letters in each column are significantly different ($P \leq 0.05$) according to Duncan Multiple Range Test)

Appendix Table II. One-way ANOVA: P uptake versus Treatment (Dumuria soil series)

Source	DF	SS	MS	F	P
Treatment	3	3109	1036	7.51	0.010
Error	8	1104	138		
Total	11	4213			

Treatment	N	Mean	Grouping
0 dS m^{-1}	3	121.93	A
3 dS m^{-1}	3	122.66	A
6 dS m^{-1}	3	91.77	B
12 dS m^{-1}	3	88.60	B

(Means followed by different letters in each column are significantly different ($P \leq 0.05$) according to Duncan Multiple Range Test)

Appendix Table III. One-way ANOVA: Dry matter yield g pot^{-1} versus treatment (Barisal Soil Series)

Source	DF	SS	MS	F	P
Treatment	3	0.76527	0.25509	182.21	0.000
Error	8	0.01120	0.00140		
Total	11	0.77647			

Treatment	N	Mean	Grouping
0 dS m^{-1}	3	1.26333	A
3 dS m^{-1}	3	1.01333	B
6 dS m^{-1}	3	0.70667	C
12 dS m^{-1}	3	0.63000	D

(Means followed by different letters in each column are significantly different ($P \leq 0.05$) according to Duncan Multiple Range Test)

Appendix Table IV. One-way ANOVA: P uptake versus treatment (Barisal Soil Series)

Source	DF	SS	MS	F	P
Treatment	3	11744	3915	6.22	0.017
Error	8	5037	630		
Total	11	16781			

Treatment	N	Mean	Grouping
0 dS m^{-1}	3	170.98	A
3 dS m^{-1}	3	141.71	AB
6 dS m^{-1}	3	98.09	B
12 dS m^{-1}	3	96.53	B

(Means followed by different letters in each column are significantly different (P ≤ 0.05) according to Duncan Multiple Range Test)

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