Pak. J. Bot., 53(6): 2085-2092, 2021. DOI: http://dx.doi.org/10.30848/PJB2021-6(24)

INFLUENCE OF SOIL AND WATER PHYSICO-CHEMICAL PROPERTIES ON VEGETATION STRUCTURE OF ARTIFICIAL PONDS ESTABLISHED WITHIN BAMBOO PLANTATIONS

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Abstract

The distribution of aquatic plants in artificially established aquatic ponds was studied. Four ponds were selected based on variations in water and soil composition, and, vegetation type. A soil and water analysis of these ponds were carried out for the determination of macro-nutrients (Na^+, K^+, Ca^+), pH, ECe and soil texture. Relative density, relative frequency, relative cover and importance value was recorded for the vegetation growing in these aquatic ponds. The results regarding plants association with different levels of salinity showed significant relationships between soil, water and plant species. *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon dactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn)* and *Fumaria indica (Fi)* were found on relatively higher salinity levels (Na, ECe and pH) and low potassium and calcium content. *Typha domingensis (Ty), Tamarix dioica (Td), Azolla pinnata (Az), Eclipta alba (Ea)* and *Imperata cylindrica (Ic)* were recorded in ponds with slightly higher ionic content and low salinities (ECe=1.8 dS m^{-1}) indicating these species can tolerate both low salinity and pH. Species growing in other ponds did not show any significant link to soil or water physico-chemical properties. It was concluded that the distribution of plant species was significantly affected by salinity levels (ECe), pH and ionic concentration of aquatic ponds.

Key words: Aquatic ponds, Salinity, Distribution, ECe, pH.

Species abbreviation: Al: *Alternanthera sessilis;* **Ad:** *Arundo donax;* **Aa:** *Achyranthes aspera;* **As:** *Asparagus adscendens;* **Ar:** *Artemisia scoparia;* **Az:** *Azolla pinnata;* **At:** *Atriplex crassipes;* **Bh:** *Bambusa halepense;* **Cd:** *Cynodon dactylon;* **Cc:** *Cenchrus ciliaris;* **Cr:** *Cyperus rotundus;* **Er:** *Eichhornia crassipes;* **Ea:** *Eclipta alba;* **Fi:** *Fumaria indica;* **Ic:** *Imperata cylindrica;* **Ln:** *Launaea nudicaulis;* **La:** *Lathyrus aphaca;* **Me:** *Melilotus indica;* **Ns:** *Gnaphalium spathiolatum;* **Na:** *Nasturtium officinale;* **Pm:** *Phalaris minor;* **Pp:** *Polygonum plebejum;* **Pb:** *Polygonum barbatum;* **Pk:** *Phragmites karka;* **Pn:** *Phyla nudiflora;* **Po:** *Polygonum glabrum;* **Ph:** *Parthenium hysterophorus;* **Rd:** *Rumex dentatus;* **Si:** *Spergula flaccida;* **Ss:** *Saccharum spontaneum;* **Sa:** *Sonchus arvensis;* **Sb:** *Saccharum benghalensis;* **Su:** *Solanum surattense;* **Ty:** *Typha domingensis;* **Tt:** *Tribulus terrestris;* **Td:** *Tamarix dioica;* **Vo:** *Verbena officinalis;* **Vs:** *Vicia sativa*.

Introduction

Ecologically, ponds are an outstanding freshwater reserve covering almost twenty nine percent area of total standing water. Moreover, ponds show high biodiversity and have a great perspective for functions of ecosystem (Davidson *et al*., 2018). Vegetation in ponds occurs in permanently or seasonally wet environments. They include a diverse group of macrophytic, aquatic plants, including angiosperms, ferns, mosses, and liverworts, and some freshwater macro-algae (Goswami *et al*., 2017). Aquatic vegetation is classified into four groups. The emergent plants including shallow water species which extend above the water surface and mostly include species of sedges and bulrush. In comparison, floating hydrophytes are those species which are rooted in sediment but have leaves floating on water surface. It includes species of lotus and water lilies. Submerged hydrophytes are usually rooted in bottom substrate, but free-floating species of water-starwort, water milfoil and pondweed. Free-floating hydrophytes include species which float on the water surface but are not rooted in soil sediments. They freely move with water currents, and include species of water-lettuce, mosquito-fern, water hyacinth and duckweed (Cook, 2004; Fassett, 2006; Verma *et al*., 2016).

Water and soil physico-chemical properties of different sites have specific impacts on species composition and distribution. Differential nutrient availability influences the ability of plants to absorb nutrients leading to significant variations on diversity and distribution of species in water bodies (Ishaq *et al*., 2017). The difference in a real and quantitative occurrence of distinctive components of the vegetation in freshwater ponds and lakes is linked with environmental variability particularly pH and ECe (salts in the surroundings). The ponds hold up high diversity as they regulate hydrological regimes and nutrient interception (Fatima *et al*., 2018; Bolpagni *et al*., 2019). Therefore, ponds have been suggested as a perfect model to study such diverse vegetation system and can be used as sentinel systems in monitoring human impact (Kotuby-Amacher *et al*., 1990; Hill *et al*., 2017).

The study site is located in the Punjab at Head Ballokie at 31°11'25"N and 73°52'40" E and about 48 Km away from Lahore in district Kasur. In this area, an artificial bamboo plantation is established over an area of 250 acres where a number of permanent freshwater aquatic ponds are set up to irrigate the bamboo plantation. Some portion of this plantation also contains mixed plantation of *Dalbergia*, *Eucalyptus*, *Bambusa, Gnaphalium, Nerium, Saccharum* etc. The litter of bamboos and other mixed vegetation is continuously added to soil resulting in significant variation in soil physicochemical attributes throughout the year. Such variation can be observed as seasonal variation in humus deposition and nutrient concentration in soil that finally affects the aquatic and surrounding communities (Akhtar *et al*., 2014).

Keeping in view of these aspects, it was hypothesized that the diversity and distribution of freshwater aquatic ponds should have been significantly influenced by differential salinity levels and nutrient composition. Present research work was carried out to analyze the eco-physiological aspects of diversity and distribution of aquatic ponds located in artificial bamboo plantations near Ballokie, Punjab, Pakistan. In addition, the influence of various soil physico-chemical and water attributes on vegetation structure of freshwater ponds was also determined.

Materials and Methods

The vegetation dynamics of colonizers found within and around artificially established water ponds along salinity gradients were studied. Four ecologically diverse ponds having different soil and water salinity levels were selected for this study. The study area was extensively surveyed and the available species at selected sites were enlisted. The data was collected using quadrat method. Four quadrats were systematically setup in each pond. Eight ropes crossed perpendicular to each other passing over the ponds were used to mark square quadrates of $1m^2$ as given in layout of quadrates setup is presented in (Fig. 1). Ecological data was recorded, all individual plants in the quadrates were counted and used for the calculation of density, frequency, cover, relative density, relative frequency, relative coverage/dominance, importance value of species according to formulae given by Ludwig & Reynolds (1988).

The soil samples from ponds were also collected in three replicates from each quadrate along with water samples. Soil texture was recorded by hydrometer method using USDA textural triangle. A saturation paste of the soil was prepared and used to analyze various attributes of soil and water sample such as pH and ECe by using a combined pH and EC meter (WTW series InoLab pH/Cond 720, USA). The concentration of various ions such as Na^+, K^+ and Ca^{2+} was determined for soil extract and water by flame photometer (PFP-7, Jenway, UK). Nitrogen content was estimated for both water and soil samples by micro-Kjeldahl method using the UDK-139 semiautomatic ammonia distillation unit (UDK-139, VELP Scientific Inc., NY, USA). The results of soil physico-chemical properties and water are presented in Tables 1 and 2.

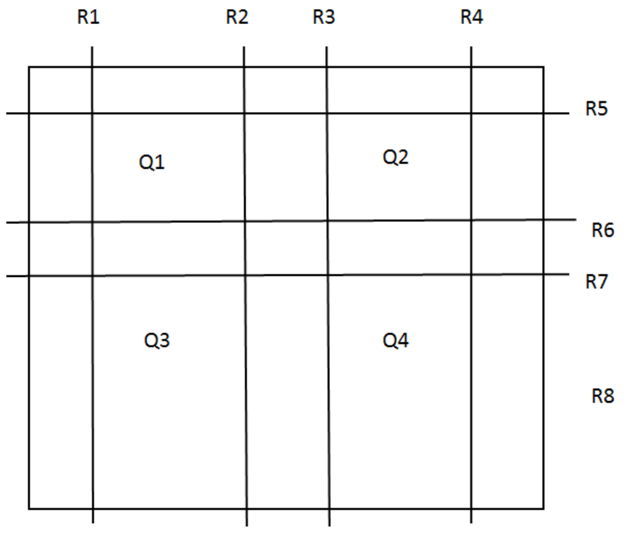


Fig. 1. Experimental design to layout regular quadrates for vegetation sampling along different ponds (R = ropes drawn to mark quadrats Q).

Table 1. Physico-chemical characteristics of soil collected from ponds located in artificial bamboo plantations.

Attribute	Control	0.56 dS m^{-1}	0.85 dS m^{-1}	1.18 dS m^{-1}
Soil texture	Loamy sand	Sand	Loamy sand	Sandy loam
pH	7.5	7.6	7.8	7.9
ECe (dS m^{-1})	1.8	2.5	3.7	4.3
Na^+ (mg g^{-1} dry soil)	29	30	46	75
K^+ (mg g^{-1} dry soil)	12	15	20	22
Ca^{2+} (mg g^{-1} dry soil)	43	39	35	19
N (mg g^{-1} dry soil)	0.27	0.25	0.24	0.18

Table 2. Physico-chemical characteristics of water collected from ponds located in artificial bamboo plantations.

Attribute	Control	0.56 dS m^{-1}	0.85 dS m^{-1}	1.18 dS m^{-1}
pH	7.9	8.3	8.4	8.5
ECe (dS m^{-1})	0.26	0.56	0.85	1.18
Na^+ (mg L^{-1})	2	6	13	19
K^+ (mg L^{-1})	8	12	18	19
Ca^{2+} (mg L^{-1})	1	2	5	7
N (mg L^{-1})	0.02	0.02	0.02	0.02

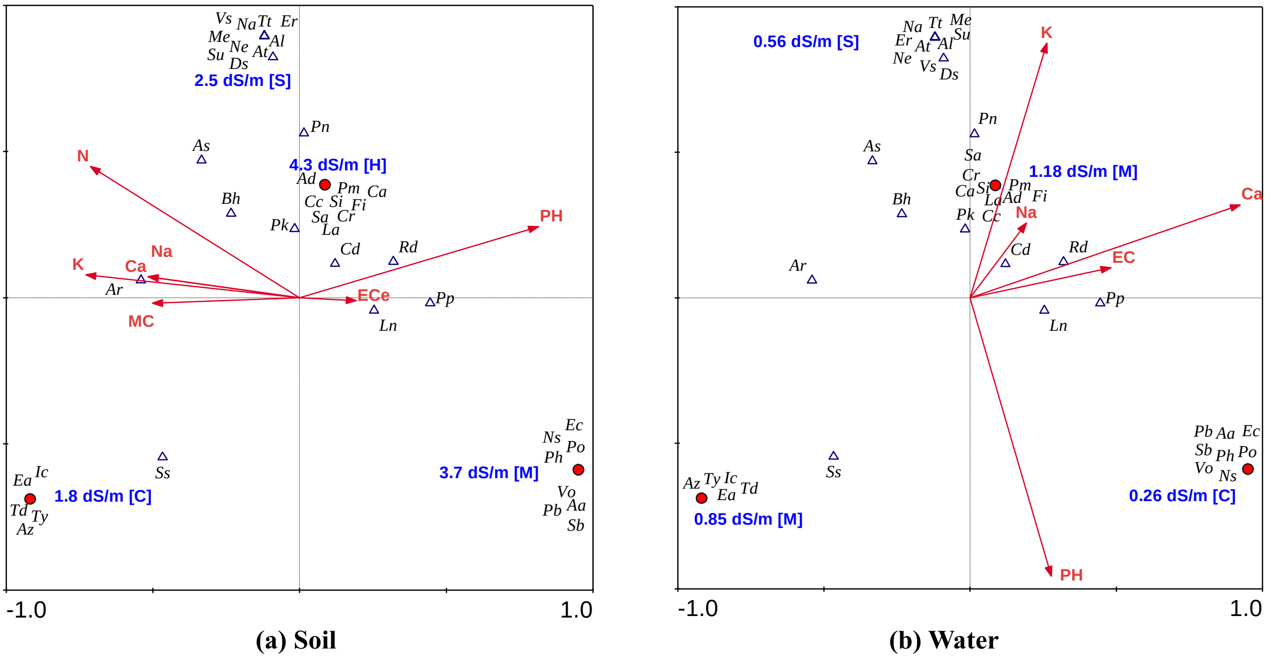


Fig. 2. Canonical correspondence analysis (CCA) triplot showing influence of a) soil and b) water properties on *relative density (RD)* of plant species growing around ponds located in artificial bamboo plantations (Species abbreviations are presented at start of paper).

RDA analysis and construction of RDA triplots: The data was analyzed using multivariate canonical correspondence analysis (CCA) and triplot (species against environmental attributes of different sites) were constructed using CONACO for windows (Version 4.5).

Results

Relative Density (RD): The canonical correspondence analysis (CCA) ordination triplot for *relative density (RD)* of different plant species as influenced by soil (Fig. 2a) traits of different saline ponds indicated that control pond (ECe=1.8 dS m^{-1}) contained *Azolla pinnata (Az), Eclipta alba (Ea), Typha domingensis* (Ty), *Imperata cylindrica (Ic)* and *Tamarix dioica (Td)* which were mostly influenced by soil moisture content and other major nutrients like K and Ca. The species influenced by slightly saline pond (ECe=2.5 dS m^{-1}) were *Eichhornia crassipes (Er)*, *Melilotus indica (Me), Solanum surattense (Su), Alternanthera sessilis (Al), Nasturtium officinale (Na), Atriplex crassipes (At), Vicia sativa (Vs)* and *Tribulus terrestris (Tt)* but these species showed no clear influence of any soil physico-chemical attributes. The species associated with moderately saline pond (ECe=3.7 dS m^{-1}) were *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Parthenium hysterophorus (Ph), Verbena officinalis (Vo), Gnaphalium spathulatum (Ns), Saccharum bengalense (Sb)* and *Polypogon glabrum (Po)* though soil of this pond showed a week influence of soil ECe on RD values of these species. The species associated with highly saline pond (ECe=4.3 dS m^{-1}) were specifically influenced by soil ECe and pH and included *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon dactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn)* and *Fumaria indica (Fi)* (Fig. 2a).

The RDA triplot for *relative density (RD)* of different plant species influenced by water (Fig. 2b) properties of different saline ponds indicated that control pond (ECe=0.26 dS m^{-1}) contained *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Parthenium hysterophorus (Ph), Verbena officinalis (Vo), Gnaphalium spathulatum (Ns), Saccharum bengalense (Sb)* and *Polypogon glabrum (Po)* but their RD values were not linked to properties of water. The species influenced by water properties of slightly saline pond (ECe=0.56 dS m^{-1}) were *Eichhornia crassipes (Er), Melilotus indica (Me), Solanum surattense (Su), Alternanthera sessilis (Al), Nasturtium officinale (Na), Atriplex crassipes (At), Vicia sativa (Vs)* and *Tribulus terrestris (Tt)*. Species fund in moderately saline pond (ECe=0.85 dS m^{-1}) i.e. *Azolla pinnata (Az), Eclipta alba (Ea), Typha domingensis* (Ty), *Imperata cylindrica (Ic)* and *Tamarix dioica (Td)* showed a strong influence of water Na, ECe, K and Ca on their distribution. The species influenced by water EC and pH of highly saline pond (ECe=1.18 dS m^{-1}) were *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon doactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn)* and *Fumaria indica (Fi)* affected by sodium, potassium, calcium and electrical conductivity of water associated with this pond (Fig. 2b).

Relative frequency (Rf): The *relative frequency (Rf)* of species associated with control pond (ECe=1.8 dS m^{-1}) including *Typha domingensis (Ty), Tamarix dioica (Td), Azolla pinnata (Az), Eclipta alba (Ea)* and *Imperata cylindrica (Ic)* were influenced by soil MC, and nutrient contents (mainly Ca and K). The species associated with slightly saline pond (ECe=2.5 dS m^{-1}) *Atriplex crassipes (At), Melilotus indica (Me), Solanum surattense (Su), Eichhornia crassipes (Er)* and *Vicia sativa (Vs)* did not show any significant effect of soil physico-chemical attributes. The species associated with moderately saline pond (ECe=3.7 dS m^{-1}) were *Achyranthus aspera (Aa), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Rumex dentatus (Rd), Polygonum barbatum (Pb), Saccharum bengalense (Sb), Verbena officinalis (Vo),* and *Gnaphalium spathulatum (Ns)* those showed a week link of soil ECe and pH. The species associated with highly saline pond (ECe=4.3 dS m^{-1}) i.e. *Arundo donax (Ad), Cynodon dactylon (Cd), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Fumaria indica (Fi), Phyla nodiflora (Pn), Spergula flaccida (Si),* and *Lathyrus aphaca (La)* were strongly influenced by the soil electrical conductivity, sodium and nitrogen content (Fig. 3a).

The effect of water properties of different ponds on *relative frequency (Rf)* of different plant species is shown in Fig. 3b. The species associated with control pond (ECe=0.26 dS m^{-1}) including *Achyranthus aspera (Aa), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Rumex dentatus (Rd), Polygonum barbatum (Pb), Saccharum bengalense (Sb), Verbena officinalis (Vo)* and *Gnaphalium spathulatum (Ns)* did not showed any significant influence of water properties. The species associated with slightly saline pond (ECe=0.56 dS m^{-1}) *Atriplex crassipes (At), Melilotus indica (Me), Solanum surattense (Su), Eichhornia crassipes (Er)* and *Vicia sativa (Vs)* were strongly influenced by K in particular and Ca in general. The species associated with moderately saline pond (ECe=0.85 dS m^{-1}) were *Typha domingensis (Ty), Tamarix dioica (Td), Azolla pinnata (Az), Eclipta alba (Ea)* and *Imperata cylindrica (Ic)* but they did not showed any clear link to any water properties. The species associated with highly saline pond (ECe=1.18 dS m^{-1}) were *Arundo donax (Ad), Cynodon dactylon (Cd), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Fumaria indica (Fi), Phyla nodiflora (Pn), Spergula flaccida (Si),* and *Lathyrus aphaca (La)* mainly influenced by the concentration of sodium ion of water (Fig. 3b).

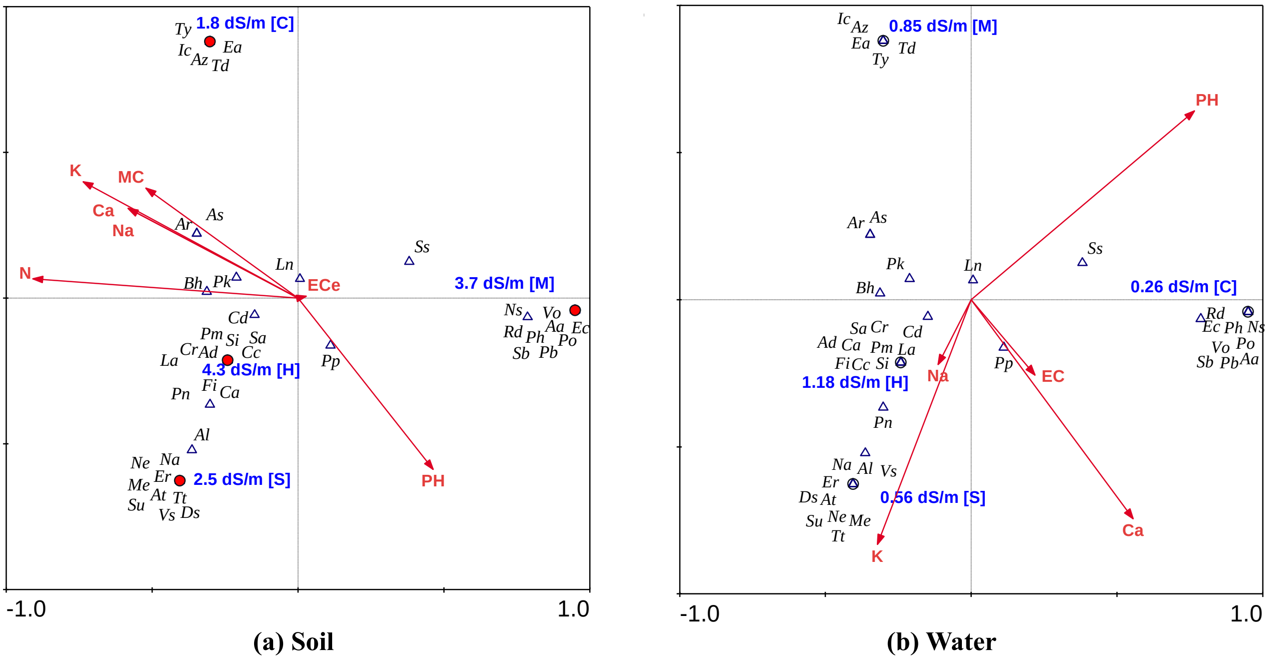


Fig. 3. Canonical correspondence analysis (CCA) triplot showing influence of a) soil and b) water properties on *relative frequency (Rf)* of plant species growing around ponds located in artificial bamboo plantations (Species abbreviations are presented at start of paper).

Relative cover (RC): A canonical correspondence analysis (CCA) ordination triplot for *relative cover (RC)* of different plant species as influenced by soil (Fig. 4a) traits of different saline ponds showed that the species of control pond (ECe=1.8 dS m^{-1}) i.e. *Tamarix dioica (Td), Typha domingensis (Ty), Imperata cylindrica (Ic), Eclipta alba (Ea)* and *Bambusa helepense (Bh)* and highly saline pond (ECe=4.3 dS m^{-1}) *Arundo donax (Ad), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Phalaris minor (Pm), Fumaria indica (Fi), Spergula flaccida (Si), Lathyrus aphaca (La)* and *Sonchus arvensis (Sa)* were mainly affected by the sodium, calcium, potassium and moisture content of soil. The species linked to slightly saline pond (ECe=2.5 dS m^{-1}) were *Alternanthera sessilis (Al), Asparagus adscendens (As), Atriplex crassipes (At), Melilotus indica (Me), Nasturtium officinale (Na), Vicia sativa (Vs), Solanum surattense (Su),* and *Tribulus terrestris (Tt)* but did not showed any clear influence of soil properties . The species of moderately saline ponds (ECe=3.7 dS m^{-1}) i.e. *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Saccharum spontaneum (Ss), Gnaphalium spathulatum (Ns)* and *Verbena officinalis (Vo)* were mainly influenced by soil pH values (Fig. 4a).

Water properties had a similar effect on *relative cover (RC)* of different species growing in saline ponds. Results showed that the species associated with control pond (ECe=0.26 dS m^{-1}) were *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Saccharum spontaneum (Ss), Gnaphalium spathulatum (Ns)* and *Verbena officinalis (Vo)* were influenced by calcium content of water. The species associated with slightly saline pond (ECe=2.5 dS m^{-1}) i.e.

Alternanthera sessilis (Al), Asparagus adscendens (As), Atriplex crassipes (At), Melilotus indica (Me), Nasturtium officinale (Na), Vicia sativa (Vs), Solanum surattense (Su), and *Tribulus terrestris (Tt)* did not showed any clear link to the water properties. The species associated with moderately saline ponds (ECe=0.85 dS m^{-1}) were *Tamarix dioica (Td), Typha domingensis (Ty), Imperata cylindrica (Ic)* and *Eclipta alba (Ea)* and mainly influenced by water pH. The species associated with highly saline pond (ECe=1.18 dS m^{-1}) were *Arundo donax (Ad), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Phalaris minor (Pm), Fumaria indica (Fi), Spergula flaccida (Si), Lathyrus aphaca (La)* and *Sonchus arvensis (Sa)* mainly influenced by the sodium content of water (Fig. 4b).

Importance value (IV): The canonical correspondence analysis (CCA) ordination triplot for *importance value (IV)* of different plant species as influenced by soil (Fig. 5a) traits of different saline ponds showed that the species associated with control pond (ECe=1.8 dS m^{-1}) were *Azolla pinnata (Az), Typha domingensis (Ty), Imperata cylindrica (Ic), Tamarix dioica (Td)* and *Eclipta alba (Ea)*. Soil properties of slightly saline pond (ECe=2.5 dS m^{-1}) did not showed any clear influenced on importance values of *Alternanthera sessilis (Al), Atriplex crassipes (At), Eichhornia crassipes (Er), Nasturtium officinale (Na), Vicia sativa (Vs), Solanum surattense (Su), Tribulus terrestris (Tt)* and *Melilotus indica (Me)*. The species associated with moderately saline pond (ECe=3.7 dS m^{-1}) *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Saccharum bengalense (Sb), , Gnaphalium spathulatum (Ns)* and *Verbena officinalis (Vo)* were weekly influenced by the soil pH. The species associated with highly saline pond (ECe=4.3 dS m^{-1}) *Arundo donax (Ad), Asparagus adscendens (As), Cynodon dactylon (Cd), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Fumaria indica (Fi), Phalaris minor (Pm), Phragmites karka (Pk), Sonchus arvensis (Sa), Spergula flaccida (Si), Bambusa helepense (Bh)* and *Lathyrus aphaca (La)* were affected by the sodium, potassium, calcium, nitrogen and moisture content of soil (Fig. 5a).

The *importance value (IV)* of species associated with MC and nutrient contents of control pond (ECe=0.26 dS m^{-1}) were *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Saccharum bengalense (Sb), , Gnaphalium spathulatum (Ns)* and *Verbena officinalis (Vo)*. The species associated with slightly saline pond (ECe=0.56 dS m^{-1}) were *Alternanthera sessilis (Al), Atriplex crassipes (At), Eichhornia crassipes (Er), Nasturtium officinale (Na), Vicia sativa (Vs), Solanum surattense (Su), Tribulus terrestris (Tt)* and *Melilotus indica (Me)* but were not affected by soil physico-chemical properties. The species associated with moderately saline pond (ECe=0.85 dS m^{-1}) were *Azolla pinnata (Az), Typha domingensis (Ty), Imperata cylindrica (Ic), Tamarix dioica (Td)* and *Eclipta alba (Ea)*. Highly saline pond (ECe=1.18 dS m^{-1}) species included *Arundo donax (Ad), Asparagus adscendens (As), Cynodon dactylon (Cd), Cenchrus ciliaris (Cc), Cyperus rotundus (Cr), Fumaria indica (Fi), Phalaris minor (Pm), Phragmites karka (Pk), Sonchus arvensis (Sa), Spergula flaccida (Si), Bambusa helepense (Bh)* and *Lathyrus aphaca (La)* and mainly affected by the ECe and sodium content of water (Fig. 5b).

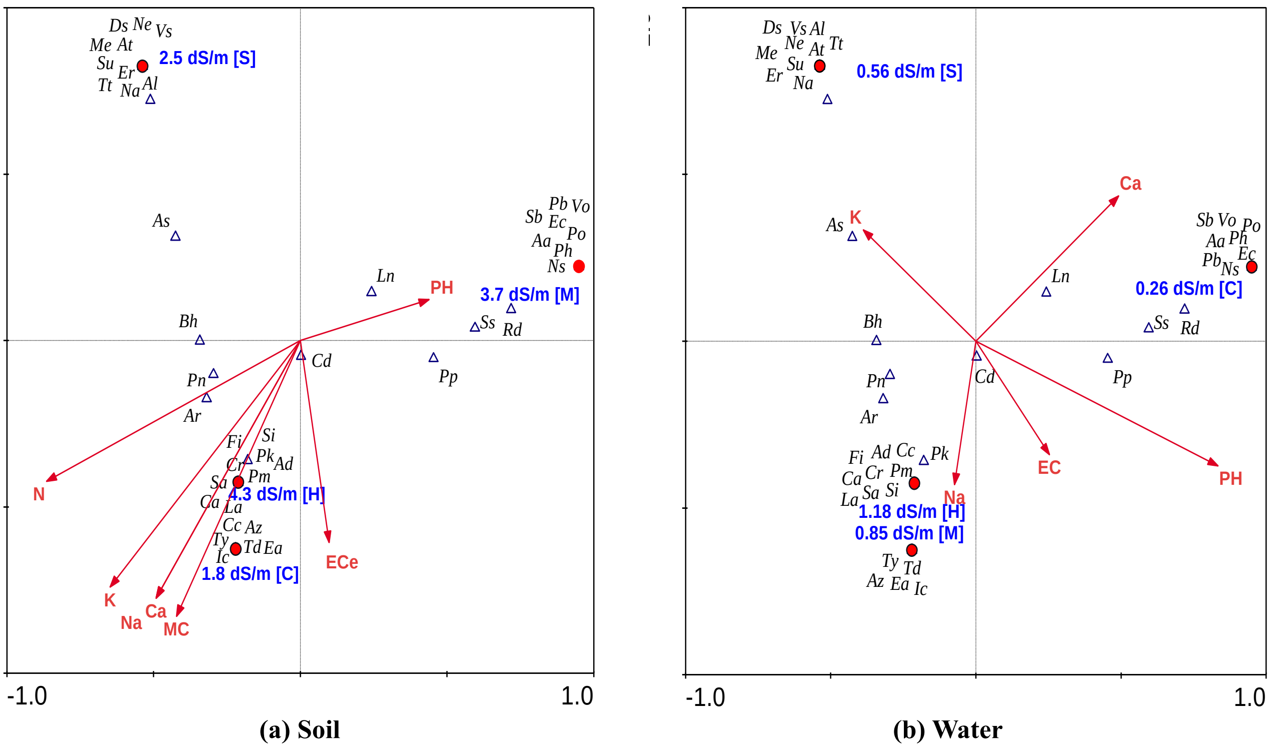
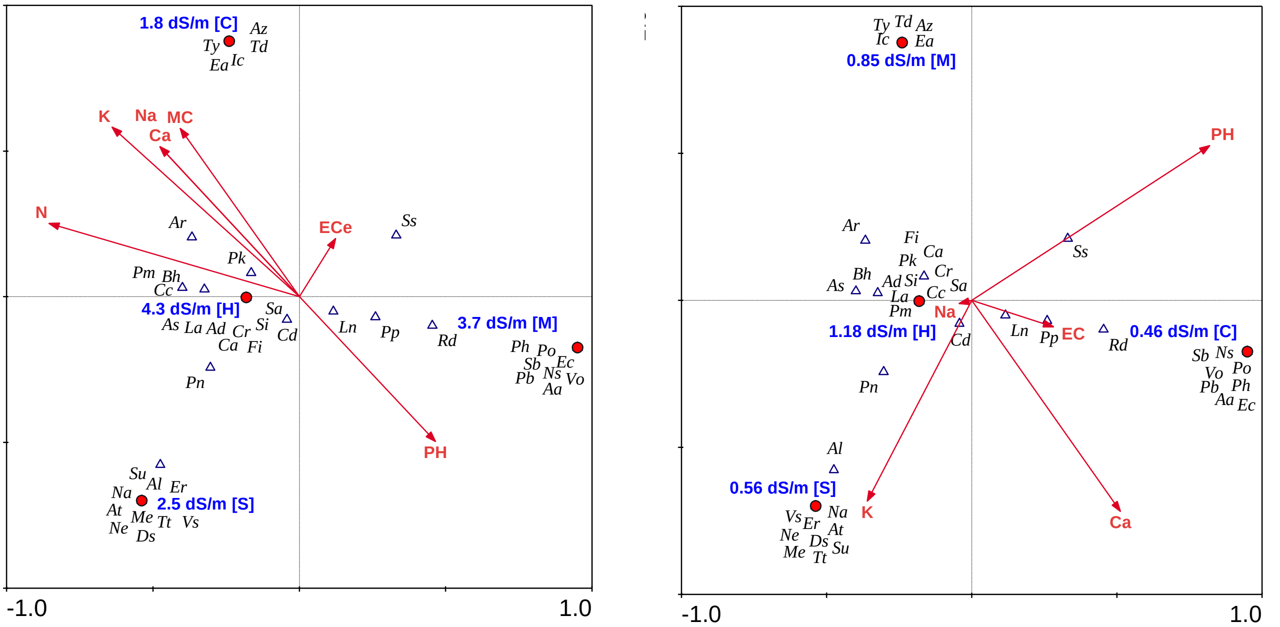


Fig. 4. Canonical correspondence analysis (CCA) triplot showing influence of a) soil and b) water properties on *relative cover (RC)* of plant species growing around ponds located in artificial bamboo plantations(Species abbreviations are presented at start of paper).



(a) Soil **(b) Water**

Fig. 5. Canonical correspondence analysis (CCA) triplot showing influence of a) soil and b) water properties on importance value (IV) of plant species growing around ponds located in artificial bamboo plantations (Species abbreviations are presented at start of paper).

Discussion

Saline pond water usually contains both inorganic salts, other contaminants and accompanied by high pH ranging from 7 to 10. The pH level in this study showed a narrow variation between four ponds, with the highest pH (8.5) recorded at highly saline pond and the lowest (7.5) in control pond (Bhatnagar & Devi, 2013). In the current study, pH of 8.5 (basic), electrical conductivity of 1.18 dS m^{-1}, Na^+ and K^+ (19 mg/L) and Ca^{2+} (7 mg /L) were noted in the highly saline pond. However, no significant difference in nitrogen level of ponds water between the four ponds was observed (Table 1). Electrical conductivity levels varied significantly between the four ponds showing significantly higher conductivity levels in highly saline ponds compared to all the other ponds. Soil salinity is a measure of the total amount of soluble salt in soil. High soil salinity can also cause nutrient imbalance, resulting in the accumulation of elements such as sodium in levels toxic to plants (Sun *et al.*, 2019). The average conductivity in each of the four ponds ranged between 1.8 and 4.3 dS/m (Table 2). Given that conductivity in aquatic ecosystems with pH 6.1 to 8.3 is mostly driven by soil composition (Ritvo *et al.*, 1998), the varying conductivity levels observed in the four ponds could be attributed to the pond's soil bed (pH ranges from 7.9 to 8.5 and ECe 1.8 to 4.3 dS/m) on which the ponds were sited but could also be a result of mixed vegetation litter composition (Stone & Thomforde, 2004; Hemati *et al.*, 2017).

Ecological characteristics, responsible for plant distribution around the ponds seem to be salinity (ECe), pH and ionic concentration (Sarvade *et al.*, 2016; Metcalfe *et al.*, 2019). The results regarding plants association with different levels of salinity showed significant relationships between soil traits and plant species. *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon dactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn)* and *Fumaria indica (Fi)* were found on higher salinity levels (sodium, electrical conductivity and pH) and low potassium and calcium content. *Typha domingensis (Ty), Tamarix dioica (Td), Azolla pinnata (Az), Eclipta alba (Ea)* and *Imperata cylindrica (Ic)* were recorded in ponds with slightly higher ionic content and low salinities (ECe=1.8 dS m^{-1}). These findings showed a differential response of aquatic vegetation towards soil and water properties indicating their differential distribution in different ponds (Duarte, 1995; Midwood & Chow-Fraser, 2010; Van der Perk, 2014).

Relative density, relative frequency, relative cover and importance value for the plant species around the four ponds were different. The data from four ponds was used to estimate density indices for the plant communities from the study ponds (Chao & Jost, 2012; Colwell, 2010). Multivariate analysis showed that highly salt tolerant species *Aeluropus lagopoides, Tamarix dioica, Suaeda fruticosa, Crotalaria burhia, Cyperus conglomeratus, Indigofera argentea, Haloxylon salicornicum, Haloxylon stocksii, Neurada procumbens* and *Salsola baryosma* were associated highly saline areas (Hameed & Ashraf, 2008). *Aristida adscensionis, Lasiurus scindicus* and *Sporobolus iocladus* were categorized as moderately salt tolerant species (Naz *et al.*, 2010b). In current study, relative density, relative frequency, relative cover and importance value of species as influenced by soil traits of different saline ponds indicated their selective distribution in various ponds (Ye *et al.*, 2019; Buri *et al.*, 2020). The species associated with moderately saline pond (ECe=3.7 dS m^{-1}) *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Parthenium* *hysterophorus (Ph), Verbena officinalis (Vo), Gnaphalium spathulatum (Ns), Saccharum bengalense (Sb),* and *Polypogon glabrum (Po).* The species associated with highly saline pond (ECe=4.3 dS m^{-1}) were *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon dactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn),* and *Fumaria indica (Fi)* and affected by the soil sodium, electrical conductivity and pH. These findings showed that soil pH, ECe and Na were the major soil and water properties influencing distribution of these plants in these aquatic ponds (Santamaría, 2002; Bornette & Puijalon, 2011; Kokulan *et al.*, 2018).

Conclusion

It was concluded that the distribution of plant species was significantly affected by salinity levels (ECe), pH and ionic concentration of aquatic ponds. A significant relationship between soil, water and plant species was observed. *Phragmites karka (Pk), Phalaris minor (Pm), Cynodon dactylon (Cd), Cyperus rotundus (Cr), Cenchrus ciliaris (Cc), Sonchus arvensis (Sa), Phyla nodiflora (Pn)* and *Fumaria indica (Fi)* were found on higher salinity levels (sodium, electrical conductivity and pH) and low potassium and calcium content. *Typha domingensis (Ty), Tamarix dioica (Td), Azolla pinnata (Az), Eclipta alba (Ea)* and *Imperata cylindrica (Ic)* were recorded in ponds with slightly higher ionic content and low salinities (ECe=1.8 dS m^{-1}) while species associated with slightly saline pond (ECe=2.5 dS m^{-1}) were *Alternanthera sessilis (Al), Atriplex crassipes (At), Eichhornia crassipes (Er), Nasturtium officinale (Na), Vicia sativa (Vs), Solanum surattense (Su), Tribulus terrestris (Tt)* and *Melilotus indica (Me).* The moderately saline pond (ECe=3.7 dS m^{-1}) contained *Achyranthes aspera (Aa), Polygonum barbatum (Pb), Polypogon glabrum (Po), Parthenium hysterophorus (Ph), Saccharum bengalense (Sb), Gnaphalium spathulatum (Ns)* and *Verbena officinalis (Vo).*

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(Received for publication 17 April, 2020)