Pak. J. Agri. Sci., Vol. 51(2), 341-351; 2014
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

EXPLORING THE DYNAMICS OF PHYSICO-CHEMICAL PROPERTIES OF SOIL WATERS IN THE RHIZOSPHERE OF RICE PLANTS

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Rice cultivation under submerged conditions results in a very dynamic system and quick changes in physico-chemical properties can be observed. It is very important to examine the short term dynamics of physico-chemical properties of soil waters at different phenological stages to understand the long term changes in rice culture system. The objective of this study was to observe the possible relation between plant physiological activities and physico-chemical properties in the soil waters at various phenological stages of rice. Samples of surface water layers (LS) and soil solutions (SS) from rice field were collected with modified and improved methods to determine the non-stable parameters (pH, electrical conductivity (EC), temperature and redox potentials), concentrations of major elements, alkalinity and dissolve organic carbon (DOC). Sampling was carried out during a complete day at two different phenological stages. It was observed that rhizospheric activity under the influence of atmospheric conditions (temperatures and light intensity) produced the diurnal patterns of various physico-chemical parameters in SS due to sudden absorption of some elements during particular hours. These diurnal patterns were more visible at vegetative stage as compared to reproductive stage. Furthermore, it was noticed that continuous absorption during the vegetative stage resulted in lower concentrations of major cations and anions in SS at reproductive stage. A strong correlation (R^2 value above 90) was observed among EC and major cations and anions.
Keywords: rice, soil waters, rhizosphere, paddy soils, diurnal patterns

INTRODUCTION

Rice as a crop is cultivated in more than 114 countries and rice is the staple grain food for more than 50% of the world's population. Traditionally, rice crop is cultivated under submerged conditions; involving the puddling of flooded soils and then either seeds are directly sown or rice plants are transplanted in the flooded fields from the raised nurseries (Mae, 1997; Abd Allah *et al., 2010*). Due to these submerged conditions during the rice cultivation period, rice fields are now commonly referred as artificial wetlands rendering various ecological services to the environment (Yoon, 2009; Kirk *et al.*, 2014). Continuous cultivation of rice crop on a farmland brings several anthropogenic changes in the soil and makes the paddy soils different from the soils under the other crops due to distinguished horizons (Kögel-Knabner *et al.,* 2010). According to FAO (2006) nomenclature, the first pedogenetic horizon of paddy soils is the thin layer of standing water (W), second horizon is oxic and partly oxic zone near rice roots (Ap), third reduced horizon is the upper part of plough pan (Arp) and last compacted horizon is the lower part of plough pan (Ardp). In other words, paddy fields can be simply divided into three separate layers: water column, soil and soil solution and hardpan/ plough pan (Nawaz, 2010). The rhizoshpere (the area near to rice plant roots) in the soil and soil solution layer can range from some millimeters to centimeters depending upon the germination stage of rice plants (Flessa and Fischer, 1992).

There exist all three phases in the flooded soil system: solid (soil), liquid (water layer and soil solution) and gas (respiration and exchange from atmosphere). Before the transplantation of rice plants in the field, system dynamics depends on all the geochemical and geophysical processes among liquid-solid-gas phases and soil life (Mandal *et al.,* 2004), so physico-chemical composition of the solution is the result of mobilization, immobilization and transport of elements as well as physico-chemical reactions in the solution and at different interfaces (Cary and Trolard, 2006). After the transplantation of rice plants in the flooded field, major modifications in the system are carried out through rice roots in the rhizosphere (Gao *et al.,* 2002; Murtaza *et al.,* 2005). The rhizosphere in this system is the point of exchange between soil, soil solution, roots and microflora. These exchanges are diverse in nature: release of organic compounds and ions, root respiration and microbial synthesis of varied and diverse metabolites (López-Bucio *et al.,* 2000). The rhizosphere is very dynamic point where physico-chemical properties of soil waters can be largely different as compared to away from the roots in the bulk soil (Nawaz *et al.,* 2012; Nawaz *et al.*, 2013). In spite of the fact that dynamicity of the rhizosphere of various plants is highly studied but the study of this zone without anthropogenic changes is always methodologically problematic (Green and Etherington, 1977; Cary and Trolard, 2006; Kögel-Knabner *et al.*, 2010).

The agronomic growth of rice plant can be divided into three stages: vegetative growth stage (from germination to the initiation of panicle), reproductive growth stage (from panicle initiation to heading) and grain filling stage (from heading to maturity) (Mae, 1997). The uptake of nutrients is maximum during the vegetative stage and minimum to nil during the grain filling stage (Ramanathan and Krishnamoorthy, 1973; Yang *et al*., 2013). Moreover, plants absorb the nutrients only during daytime and absorption of nutrients by roots is dependant on the intensity of sunlight, stomata opening and photosynthetic activity (Ishihara and Saito, 1987). During the peak hours of a summer day, too much intensity of sunlight may result in the stomata closure, decrease in photosynthetic rate and decreased nutrients absorption rate for a short period of time which can result in the diurnal patterns in the physico-chemical properties of soil waters in the rhizosphere and in the surface water layer. The presence of diurnal patterns in rice plants rhizosphere has been observed and reported by some authors for redox potentials, microbial activity and nitrogen contents (Clement *et al.*, 1978; Nikolausz *et al.*, 2008; Nawaz *et al.*, 2012; Qamar *et al*., 2012). However, very rare studies are carried out in field conditions and no particular study is carried out to analyze the evolution of other than above mentioned physico-chemical parameters of the soil waters during a day in rice culture. Furthermore, there is no research yet on the transfer between surface waters and soil waters.

The objectives of this study were to (1) compare the composition of surface waters and soil solutions in a day at two different growth stages in rice culture and eventually to understand the nutrients uptake by rice plants, (2) analyze the dynamics of the physico-chemical parameters in the soil solutions (rhizosphere) and in surface waters of rice plants in a day, in order to characterize the water-soil-plant interactions in flooded conditions, and (3) observe the relation between physiological activities and solution concentrations in the rhizosphere. In this study, modified sampling methods have been employed for the sampling of soil solution from the rhizosphere in field conditions without disturbing the system.

MATERIAL AND METHODS

Site**:** The research was carried out in 2009 at Camargue (southern France) under the Mediterranean climate. The Camargue soils are saline with hydromorphic conditions deposited in the Holocence by Rhone River and also referred as anthropogenically transformed soils because these soils have continuously been under rice culture for about 50 years. The study site was located at 31° 62` E and 48° 29` N at the altitude of 0.24 m. The soil was alluvial clay loam with about 40% clay, 56% silt and 4% sand. Physico-chemical properties of study site were determined from 3 homogenized samples representative of 10 randomly collected soil samples: average organic matter (OM, (2.29±0.46%), C/N ration (8.34±0.39), EC (787.3±120.1 dS m^{-1}), cation exchange capacity (CEC, 10.11±0.76 cmol kg^{-1}) and pH (8.14±0.01). Calcium (Ca), Mg, K and Na in cmol kg^{-1} were found 41.02±0.41, 4.52±0.57, 0.56±0.08 and 1.71±0.70 respectively.

Agronomic practices**:** Agronomic cycle in the studied site started with the harvesting of rice crop under wet conditions (to combat with the salinity problem) in mid-September. Crop residues were incorporated in the soil using caged wheels. Two cover crops are cultivated in late February and March without ploughing. In late March rotary harrow is carried out after fertilizer application of NPK (16:16:16) at the rate of 300 kg ha^{-1} to burry the fertilizer and to prepare the seedbed. In April, site is flooded and herbicide (Glyphosate at the rate of 3L ha^{-1}) was applied on 15 April. In our study, direct sowing of pre-germinated seeds with broadcast method was carried out on 5 May in the presence of water at the rate of 220 kg ha^{-1}. Flooded water was drained 15 days after the sowing for the rooting of plants and then again plots were flooded after 5 days. Herbicides like Clincher (1L ha^{-1}) and BOA (2L ha^{-1}) with Gulliver (20g ha^{-1}) were applied on 20 May and 7 June. Urea fertilizer was applied at rate of 250 kg ha^{-1} in mid-June. A layer of surface water was maintained at 8-10 cm height throughout the rice cultivation period except during the first half month of May.

Sampling methods**:** In rice culture, surface water layer (LS) is in direct contact with atmospheric oxygen but soil solution waters (SS) are in the reductive environment and any contact with the atmosphere could alter their physico-chemical properties. So, sampling of LS and SS was carried out in different ways. Samples from LS were collected directly with the help of a polypropylene bottle while system for SS sampling was used as described by Bourrié *et al.* (1999). The decontaminated and perforated lysimeters covered with inert tissue were used for sampling (Fig. 1B). These polypropylene made lysimeters were installed in the rice field 10 days before sampling to allow that chemical equilibrium can be reached between the solution of lysimeters and SS. In a set of installation, 15 lysimeters were installed manually at the depth range of 5-10 cm in a square shaped structure (Fig. 1A) and 3 such sets were installed randomly in a one hectare plot. A PVC tube was used to collect the SS from lysimeters but before the sampling this tube was kept airtight with rubber bands, threads and catcher

(A)

(B)

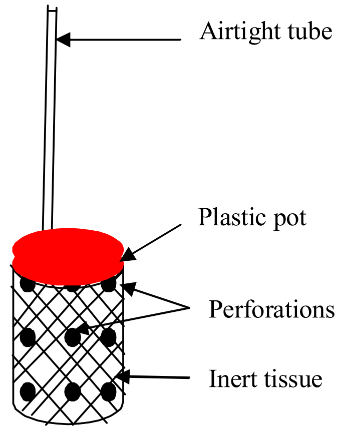

Figure 1. Demonstration of sampling. A): installation structure of lysimeters in the field for the sampling of soil waters (SS). B): An example of modified lysimeter.

so that no air could enter from the atmosphere into the lysimeters.

Sampling of SS and LS was carried out at vegetative stage (02 July) and at maturation stage (03 September) from 06h00 to 18h00. For SS, 3 samples from 3 lysimeters of different installation sets were collected randomly every hour by a syringe with great care to avoid from oxygen and light contact. For LS, samples were collected from 3 sites near the installations randomly at the same time. Collected samples of SS and LS were filtered: at 0.70 µm (optical filter) for dissolved organic carbon (DOC) and at 0.2 µm for others analysis and were transferred in 4 low density polypropylene small bottles separately marked for analysis of cations, total dissolved carbon, alkalinity and anions. One drop of HNO_3 acid was added to collected solutions for cations to stop the further chemical reactions.

Some non-conservative parameters like Temperature (T), pH, redox potential and Electrical Conductivity (EC) were measured using calibrated electrodes and portable multimeter in the field. The performance of pH electrodes was verified according to standard protocols (Nawaz and Bourrie, 2012). The values of redox potentials were converted to the normal hydrogen scale (NHE) with temperature correction and then converted into pe values as described by Nawaz (2010). Filtered solutions were covered with aluminium paper and were conserved in ice-bag. After arrival in laboratory they were preserved in refrigerator.

Analysis of samples**:** Alkalinity was determined by using the Gran method (Bourrié, 1976). Anions (fluoride, chloride, nitrate, and sulphate) were analysed by ion chromatography (INRA-Géochimie des sols et des eaux, Aix en Provence). Cations (sodium, calcium, potassium, magnesium, aluminium, zinc, manganese and iron) were analyzed by ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy) in CEREGE. Dissolved organic carbon (DOC) was analyzed by TOC-meter (Total organic carbon) Shimadzu "TOC-5050A" (INRA-UAPV EMMAH, Avignon). All the concentrations were converted in mmol/L using standard atomic weights (Laeter and Heumann, 1991).

Statistical tools**:** Results of physico-Chemical parameters of 3 samples collected at the same time for of LS and SS were averaged separately with standard deviation to make one representative point of SS and one of LS. Correlation tables were developed to see the relation among different physico-Chemical parameters using the SPSS software. Piper diagrams were made in the freeware "Diagrammes" to determine the facies of surface waters (LS) and Soil waters (SS).

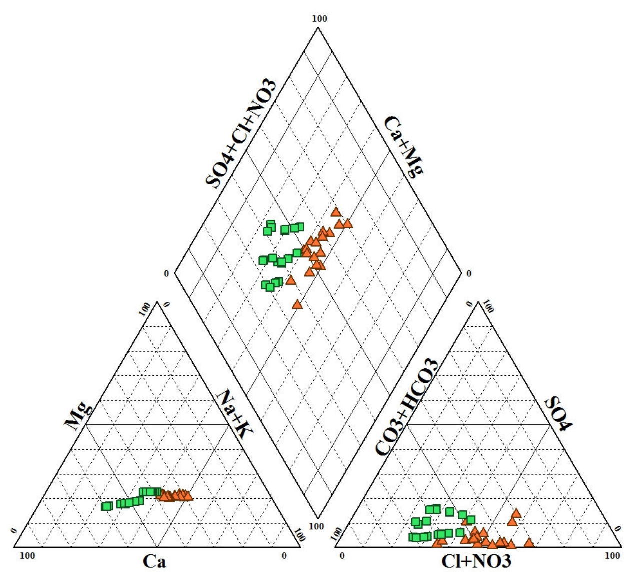

Figure 2. Piper diagram for the studied plot; Red triangles: Soil solution (SS), Green squares: water surface layer (LS).

RESULTS

The facies of soil solution (SS) and surface water layers (LS) in rice culture showed a different chemical composition when they were analyzed in Piper diagram (Fig. 2). It was observed that facies variation between two phenological stages is small as compared to within a given stage (diurnal variations). The facies of SS, collected from rhizosphere, was found bicarbonated/chloridic with no dominant cations while it was slightly calcic and bicarbonated in LS. Piper diagram is widely used to determine the facies of samples but it can hide important information/processes which will be discussed in following paragraphs.

The dynamics of non-conservative parameters like Electrical Conductivity (EC), Temperature (T), redox potential (pe) and pH during a day at two phenological is presented in Fig. 3. No significant difference was observed in the EC of surface waters (LS) between two phenological stages but EC of soil solution (SS) was more at vegetation stage as compared to ripening stage. During the day at vegetative stage, a large variation of EC was observed (from 2.36 to 5.36 dS m^{-1}); it is remarkable that minimum value was observed at 11h15 and maximum at 17h30. It was also observed that EC decreased rapidly two times a day in SS: at

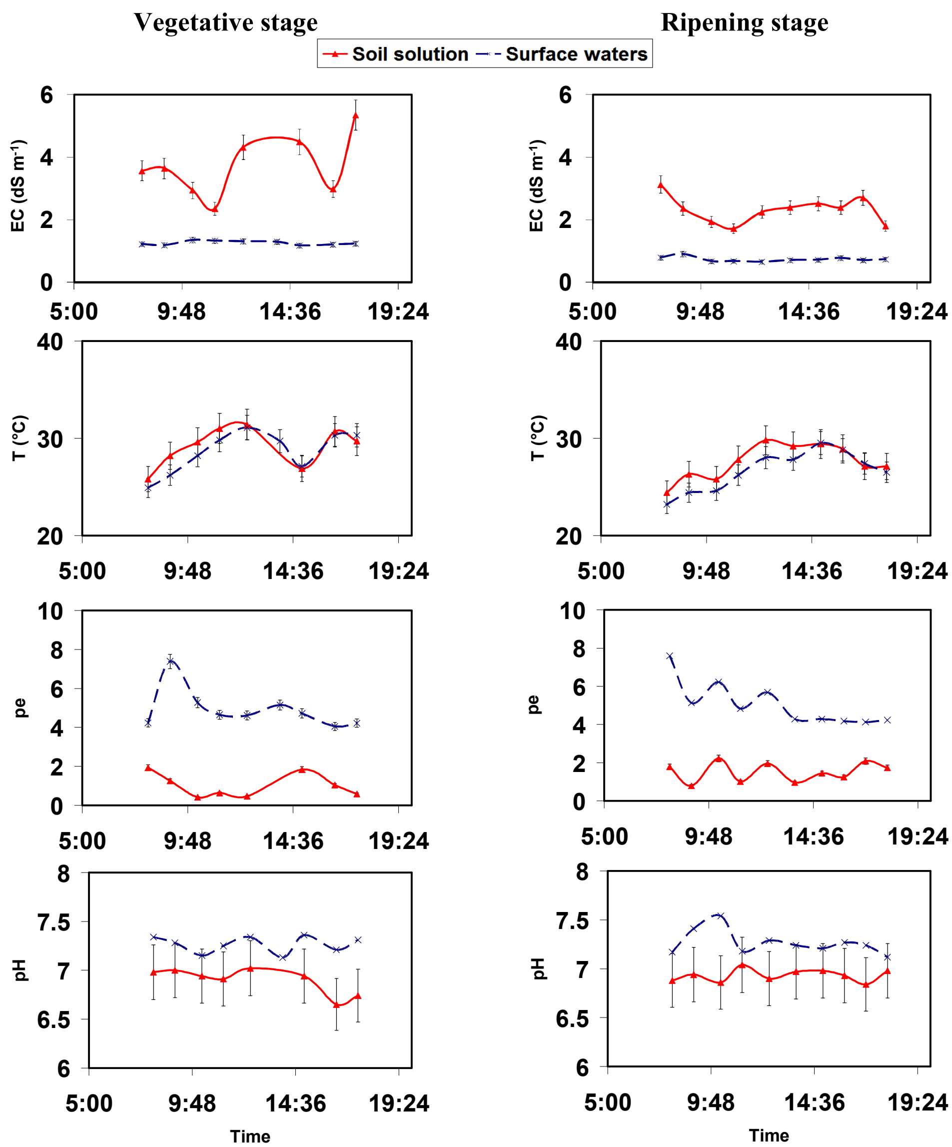

Figure 3. Dynamics of electrical conductivity, temperature, redox potential (pe) and pH during two stages of rice culture.

11h15 and 16h00 at vegetative stage and about similar trends were observed during the day at ripening stage but intensity of decrease was small and curve is comparatively smooth. Temperature of SS and LS show similar behaviour at both stages (Fig. 3). Early in the morning, temperatures of SS at both growth stages were higher than the LS temperatures but in the evening both LS and SS temperatures were the same. This difference is due to the direct contact of atmosphere with LS. However, it was observed that temperatures of soil waters (SS and LS) followed well the atmospheric temperatures at vegetative stage but increase and decrease at ripening stage is smooth and slow.

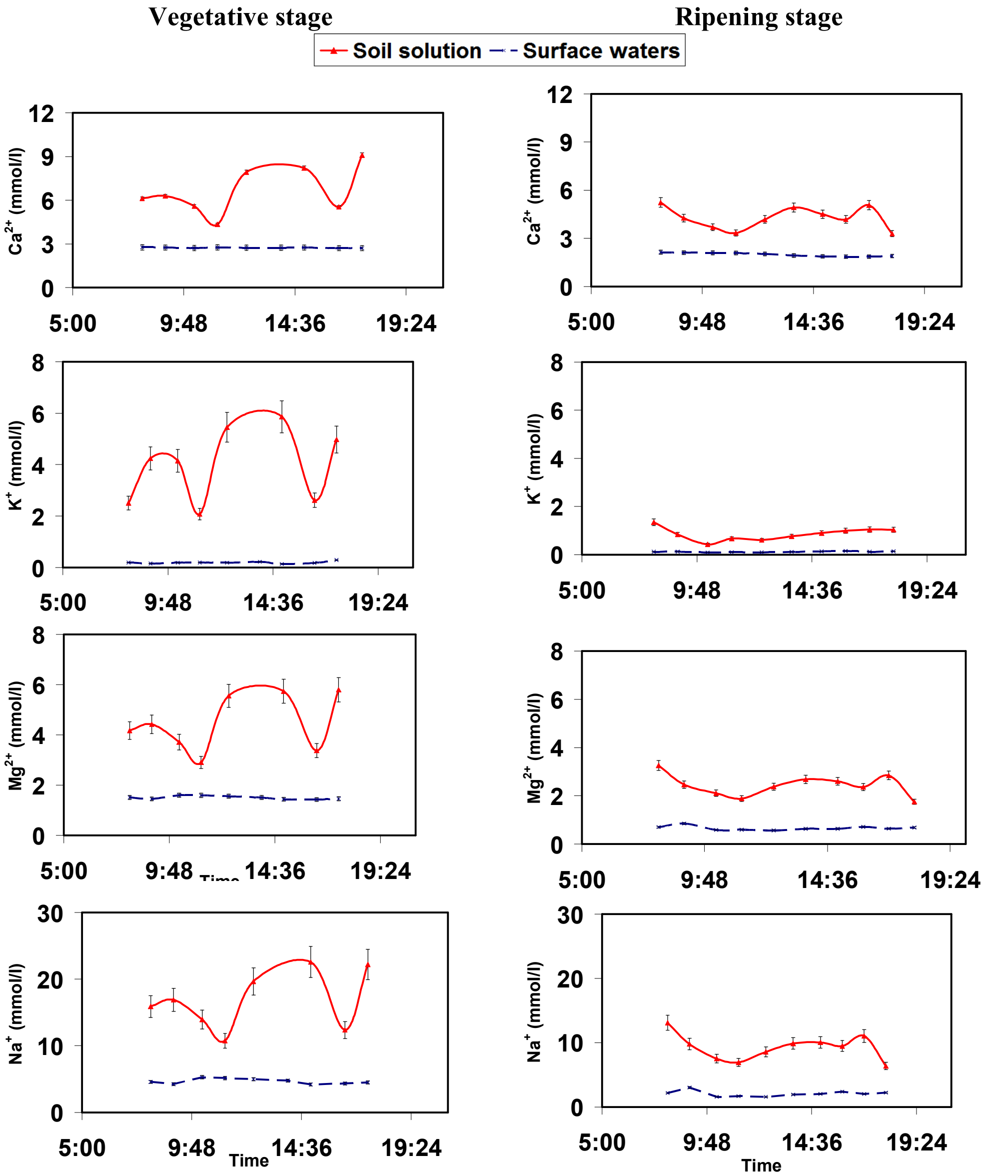

Figure 4. Dynamics of major cations during two different phenological stages of rice culture.

This rhythmic increase/decrease is due to shading effect of rice plants on soil waters which intercepts the sunlight at later stages of their growth. Furthermore, it can be observed that points of maximum temperature are the points of minimum EC. The redox potentials (represented by pe values) of the SS were lower than the LS because LS is in direct contact of atmospheric oxygen. The pH of the SS was comparatively acidic (range from 6.4 to 7) as compared to LS (above 7) that can be attributed to acidic root exudates in rhizosphere (López-Bucio *et al.*, 2000). It was observed from the results that increase in temperatures of SS most often resulted in the decrease of EC, pe and pH. Inverse relations between temperature and other parameters (EC, pe and pH) are more significant at vegetative stage as compared to ripening stage. Following the concentration in soil waters, dynamics of major cations (Ca^{2+}, Na^{+}, Mg^{2+} and K^{+}) and minor cations (Al^{3+}, total Fe, total Mn and Zn^{2+}) are presented in Fig. 4 and Fig. 5 respectively. It was observed that concentrations of all major cations in SS were more at vegetative stage as compared to ripening stage (Fig. 4). Furthermore, dynamics of all major cations in SS during the day at vegetative stage are similar to each other and in accordance to EC. However, in LS, same concentrations of major cations were observed at two different phenological stages. It was noticed that no sudden increase or decrease in concentrations of SS was noticed during the day at ripening stage and the order of concentrations in SS was $Na^{+} > Ca^{2+} > Mg^{2+} \geq K^{+}$. The concentrations of minor cations in LS remained near to zero or lower than detection limit during at both phenological stages (Fig. 5). The concentrations of minor cations in SS were more during the day at vegetative stage as compared to day during ripening stage except total

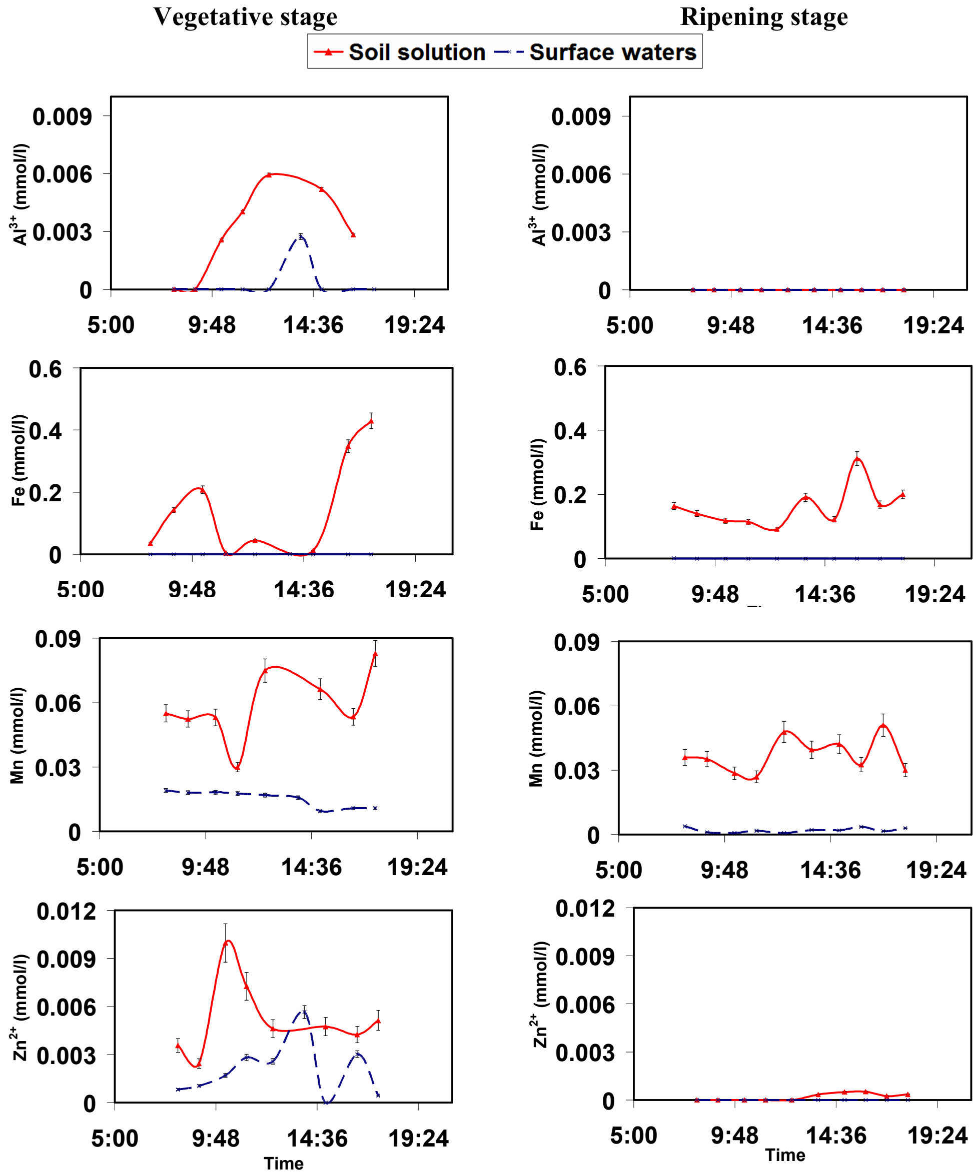

Figure 5. Dynamics of minor cations during two different growth stages of rice culture.

Fe which remained same. In fact, total Fe is the oxidized form of Fe^{2+} that was present in samples during field sampling and converted to Fe^{3+} during sampling storage because same concentrations of Fe^{2+} were observed *in situ* (not presented here). Average concentrations for Mn and Zn^{2+} were lower than 0.01 mmol/l, for Al^{3+} were lower than 0.006 mmol/l and for total Fe were about 0.15 mmol/l at both stages. During the day at vegetative stage, the dynamics of 3 minor cations (total Fe, Mn and Zn^{2+}) in SS have visually similar patterns to redox potentials (pe values) (Fig. 3 and 5). One day dynamics of SS and LS at vegetative stage and ripening stage for anions is presented in Fig. 6. Timings of decrease or increase in Cl^-, SO_4^{2-} and Br^- concentrations of SS were in accordance with EC and major cations at vegetative stage but no trend or particular patterns were observed at ripening stage.

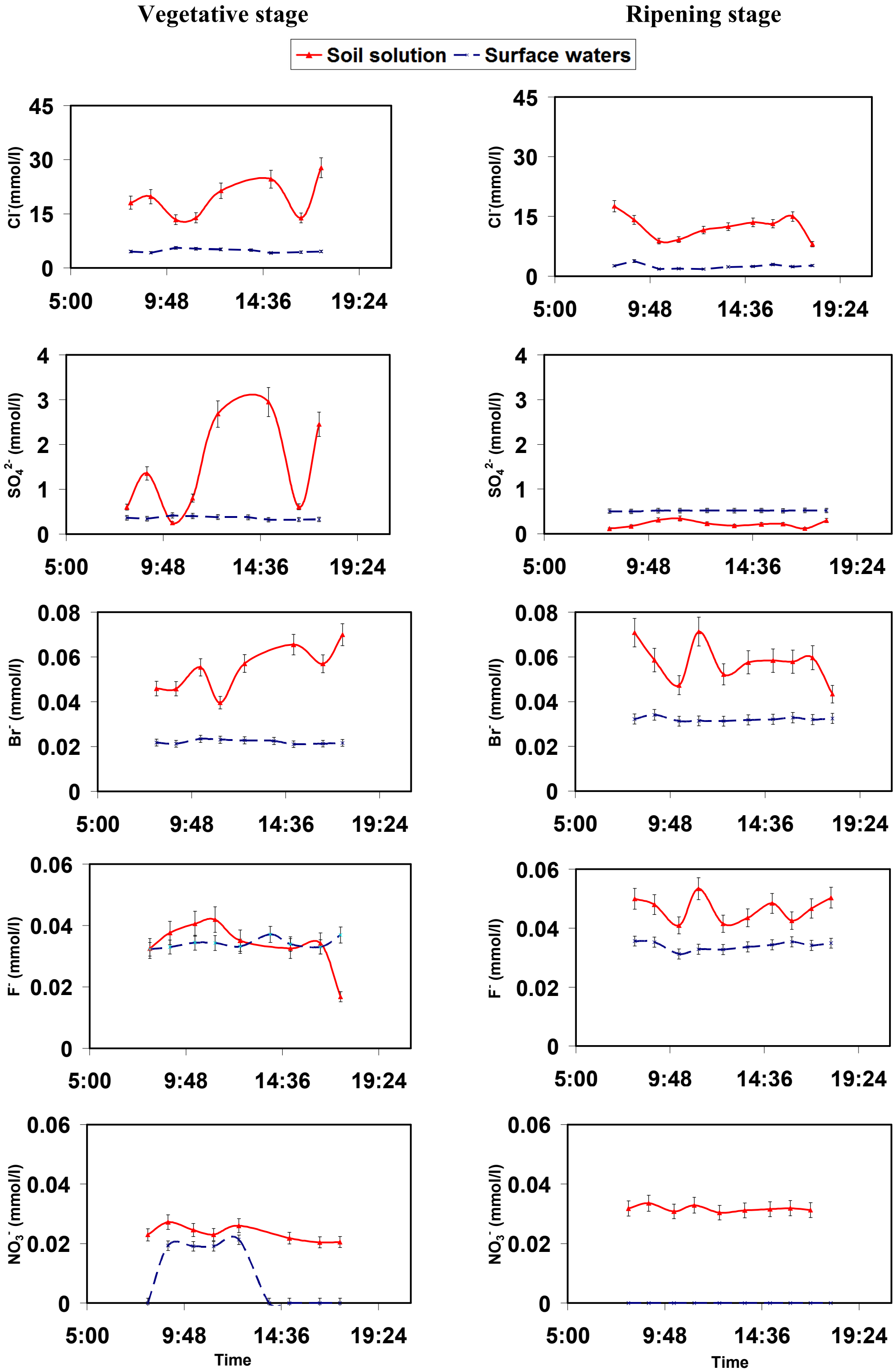

Figure 6. Dynamics of anions during two different stages of rice culture.

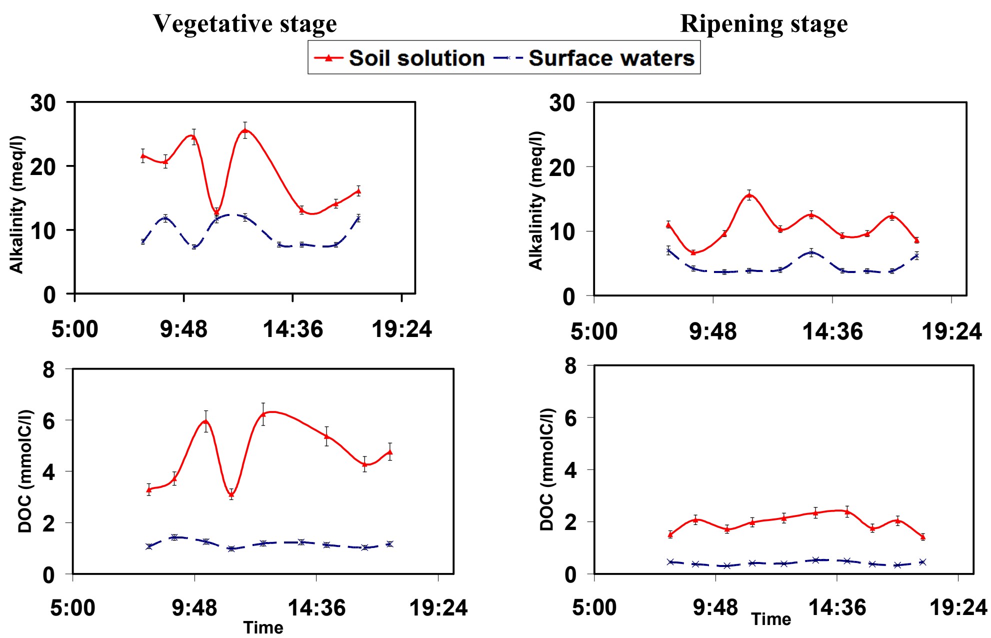

Figure 7. Dynamics of Alkalinity and Dissolve Organic Carbon (DOC) during two different stages of rice culture.

Table 1. Correlation matrix of major cations and anions showing significant correlations with Electrical Conductivity.

	EC	F	Cl	SO4	Ca	K	Mg	Mn	Na
EC	1	-.838**	.976**	.849**	.990**	.879**	.976**	.922**	.981**
F	-.838**	1	-.765**	-.718**	-.835**	-.730**	-.808**	-.826**	-.794**
Cl	.976**	-.765**	1	.829**	.957**	.825**	.945**	.853**	.964**
SO_4	.849**	-.718**	.829**	1	.870**	.884**	.892**	.787**	.874**
Ca	.990**	-.835**	.957**	.870**	1	.902**	.985**	.942**	.983**
K	.879**	-.730**	.825**	.884**	.902**	1	.944**	.837**	.930**
Mg	.976**	-.808**	.945**	.892**	.985**	.944**	1	.911**	.994**
Mn	.922**	-.826**	.853**	.787**	.942**	.837**	.911**	1	.892**
Na	.981**	-.794**	.964**	.874**	.983**	.930**	.994**	.892**	1

**. Correlation is significant at the 0.01 level
*. Correlation is significant at the 0.05 level

The average concentrations of Cl^- in SS at vegetative stage were observed about 19 mmol/l and at ripening stage 12.4 mmol/l. The average concentrations of SO_4^{2-} during the day at vegetative stage in SS were 1.46 mmol/l while they were 0.22 mmol/l at ripening stage. It is remarkable that at vegetative stage the concentrations of SS were higher than LS but at ripening stage the concentrations of LS were higher than SS. The concentrations of Br^-, F^- and NO_3^- remained lower than 0.08 mmol/l and insignificant difference was observed at vegetative stage and ripening stage in SS and LS (Fig. 6). Alaklinity of SS was observed higher than LS at both growth stages but decreased from the average of 14.14 meq/l at vegetative stage to 10.55 meq/l at ripening stage (Fig. 7). It is remarkable that during vegetative stage, diurnal patterns of SS showed a similarity with LS which demonstrate the quick transfer between SS and LS. Dissolve Organic Carbon (DOC) concentrations also decreased in SS at ripening stage (1.94 mmolC/l) as compared to vegetative stage (4.6 mmolC/l). Again same diurnal patterns were observed between alkalinity and DOC (Fig. 7). The concentrations of other elements like silicon, ammonium, nitrite and phosphate were also measured but their concentrations were lower and no particular diurnal patterns/variations were observed during two phenological stages, so, they are not presented here. Correlation matrix of SS at both phenological stages was made to observe the correlations among different parameters but to reduce the noise, only parameters with significant correlations are presented in Table 1. Strong correlations were found among calcium, magnesium, manganese, potassium, sodium,sulphate, chloride, fluoride and EC that means that these elements were absorbed at the same time. Strong correlations between sodium and chloride shows the salinity origin of both elements (here is primary salinity due to seawater). For the data of only vegetative stage, reverse correlations between temperature and other physico-chemical parameters (EC, pe and pH) were also observed (not presented here) which indicated a interaction of temperature with physiological activities of plants such as photosynthesis and absorption of nutrients in the rhizosphere. Alkalinity was not strongly correlated with a singly cation or anion in the samples as it is also dependant of the pH and CO_2 concentrations as well as anions and cations in the soil.

DISCUSSION

Chemical composition of Surface Water Layer (LS) is directly dependant on source of irrigation and then mixing with the Soil Solution (SS). Furthermore, physico-chemical properties of soil waters (LS + SS) in rice culture is the result of various nature of processes like oxydo-reduciton reactions (affect the concentrations of Fe^{2+}, Mn^{2+}, SO_4^{2-} etc.), dissolution-precipitation reactions (maintain the equilibrium between soil and soil waters for the concentrations of various elements), nitrification and denitrification processes (affect the concentrations of nitrogen), liberation and absorption of certain elements by roots and transfer of elements and/or physico-chemical parameters between SS and LS through diffusion (Green and Etherington, 1977; Bodelier and Frenzel, 1999; Nawaz, 2010). Main source of change of physico-chemical properties of SS in the rhizosphere are the atmospheric temperatures which affect the temperatures of SS and LS as well as stomatal conductance, photosynthesis and absorption of nutrients by roots (Ishihara and Saito, 1987). The temperatures of SS at vegetative stages were regulated by LS temperatures while at ripening stage, long rice plants' shadow reduced the effects of atmospheric temperatures. This explains the larger temperature variation in LS than SS and decrease in the variation of both SS and LS during ripening stage. Sudden decrease of LS and SS temperatures at vegetative stage at 14h00 was due to the high speed cool winds and cloudy weather that prevailed during 10 minutes.

Remarkable variation of EC in SS at vegetative stage was due to absorption of major elements by plant roots and/or micro-organisms then restoration of these elements by diffusion or dissolution process in the rhizosphere. Lower EC values of SS at ripening stage as compared to vegetative stage were the result of continuous uptake of major elements by plants in the early stages. A huge variation of EC values during the day at vegetative stage can be the result of interaction among variation of atmospheric temperature-light intensity, opening or closing of stomata, increase or decrease in photosynthetic activity and absorption of nutrients (Ishihara and Saito, 1987): air temperatures started rising from 7h and were maximum between 12h to 16h except cool winds lower down the air temperatures for 10 minutes at 14h00. So, photosynthetic activity and absorption of nutrients increased with the increase of temperature until the temperatures were the maximum which resulted in the closure of stomata and lowering of photosynthetic activity. In the evening, with the optimum temperatures, photosynthetic activity as well as absorption of nutrients restarted and resulted in sudden decrease of EC values. Variation of pH during a day can be attributed to liberation of protons by the roots during elements absorption (López-Bucio *et al.* 2000). Transfer of oxygen from shoots to roots in rice plant is a continuous process while during the period of root absorption of elements this transfer can increase and can result in the increase of redox potentials or pe values in soil solutions. The above mentioned processes describe the possible relation between temperature, EC, pH and pe values.

The dynamics of major cations and anions is similar to the dynamics of EC that is due to their absorption at specific hours. The concentration of all the cations and anions decreased at ripening stage as compared to vegetative stage except total iron. In fact, during vegetative stage, massive absorption of these cations and anions was so rapid and continuous that soil was unable to maintain equilibrium between supply and uptake that resulted in smaller concentrations of the most of the elements in the soil solution during the latter stages of rice cultivation. The absorption of these elements by rice plants was significantly reduced during ripening stage, however, with decreased variations, diurnal patterns still existed due to interactions of well established other forms of life in rice culture.

The concentrations of all elements in SS were more than LS except for SO_4^{2-} at ripening stage where the concentrations of SO_4^{2-} were higher in LS. In fact, slight increase in the sulphate concentrations in LS was due to evapotranspiration while decrease in the sulphate concentrations in SS at lower redox potentials values is the result of the complex reactions involving the reduction of SO_4^{2-} to S^{2-}, Fe^{3+} to Fe^{2+} and formation then precipitation of amorphous iron sulphides (FeS) as reported in literature (Boulègue, 1978; Gao *et al.,* 2002).

Massive absorption of various cations and anions during a day can change the concentrations of several elements and the equilibrium of Calcite, CO_2 and pH in the rhizosphere which can influence the alkalinity (Bourrié, 1976; Jaillard, 1987). Similarity in diurnals patterns of alkalinity again suggests a link between solar cycles and biotic life in the soil waters. Major source of Dissolved Organic Carbon (DOC) in soil waters are the root derived materials that include root exudates, mucilage, soughed-off cells and litter (Lu *et al.,* 2000). DOC is a relatively mobile and labile form of the soil organic C and biodegradable fraction of this DOC is believed to serve as direct source of energy for heterotrophic microorganisms. So the diurnal patterns during two different stages are the result of absorption of DOC by biotic life or exudations by roots to mobilise the different elements. The loss of DOC, under reduced conditions, in the form of CH_4, as reported by (Lu *et al.,* 2000), can also be responsible for the decrease in the concentrations of DOC during ripening stage.

The coherence of diurnal patterns between LS and SS of is often observed in the results. Furthermore, these relations are to be found for both physical and chemical parameters. This quantitative and qualitative relation between LS and SS shows that there is a strong interaction of LS and SS with rhizosphere and other forms of life in rice culture. Mostly, this quick relation between LS and SS can only be assured by diffusion which is the quick process for the exchange of elements from SS to LS.

Conclusion: Rice cultivation system under submerged conditions is very complex and dynamic system and it is easy to notice the long term changes as compare to short term changes in the field conditions. These short term and quick changes are due to the link between atmospheric conditions (temperature and light intensity) and several forms of life in soil that can result in diurnal patterns of physico-chemical parameters. These interactions are dominated by rice plants during vegetative phase of rice plants. Concentrations of major anions and cations decrease in all plots with time but the variations of concentrations during a day at vegetative phase are so important in rhizosphere that one measurement per day, as done in current practice by many authors in literature, is not sufficient to interpret the chemical processes in the soil solution. It can also be concluded that coherence of evolution in Water Surface Layer (LS) with Soil Solution (SS) elements can be due to transport of elements by diffusion processes.

Acknowledgments: The support from the Higher Education Commission (HEC) of Pakistan for the grant of scholarship is gratefully acknowledged. We are also highly thankful to Jean-Claude Mouret, Monique Mayor and Marc Conryut for their cooperation and help during the field visits.

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