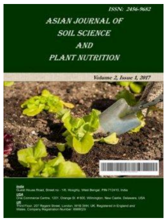

Asian Journal of Soil Science and Plant Nutrition

4(1): 1-10, 2019; Article no.AJSSPN.44930
ISSN: 2456-9682

Variability of Soil Chemical Properties in Rice Field of South-Western Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MTS managed the analyses of the study and wrote the final draft of the manuscript. Author SMB managed the literature searches as well as supervised. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2019/44930
Editor(s):
(1) Dr. Paola Angelini, Professor, Department of Chemistry, Biology and Biotechnology, University of Perugia, Perugia, Italy.
(2) Dr. Tancredo Souza, Professor, Department of Life Sciences, Centre for Functional Ecology, University of Coimbra, Portugal.
Reviewers:
(1) Aliva Patnaik, School of Life Sciences, Sambalpur University, India.
(2) Rebecca Yegon, University of Embu, Kenya.
Complete Peer review History: http://www.sciencedomain.org/review-history/27457

Original Research Article

Received 19 August 2018
Accepted 02 November 2018
Published 28 November 2018

ABSTRACT

Chemical properties of soil of an area control the type of crops to be grown. Chemical characteristics of soil represent the nature of genetic process, its development and nutrient status. Crop production in the saline soil is constrained by salt accumulation in the root zone. Soil salinity has adverse effects on the physical and chemical properties of soil as well as on plant growth and yield. This research showed that the pH of soil in the Rice Fields of south western part of Bangladesh was slightly acidic to neutral (6.38 to 6.68), soil salinity (EC) contents were in the range of slight to moderately saline (2.31 to 4.52 dS m^{-1}). Though, the concentration of total N (0.08 to 0.117%), K^+ (1354.05 to 2206.6 ppm), SO_4^{2-} (0.005 to 0.009 ppm), Mg^{2+} (0.006 to 0.016%), Ca^{2+} (0.035 to 0.122%) and Fe^{2+} (13.31 to 33.5 ppm) had been observed low but available PO_4^{3-} (142.9 to 373.5 ppm) and Na^+ content (643 to 1802.3 ppm) were high. To get high yield from these Fields, the constraints should be minimised by supplying or preserving the nutrients by integrated soil fertility management using organic and inorganic fertilisers followed by salinity control through proper drainage, use of salt free water and fertilisers (eg. Chloride).

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Keywords: Chemical properties; salinity; fertility status; paddy Field.

1. INTRODUCTION

Bangladesh has a wider range and greater complexity of lands. There is thirty percent coastal land in Bangladesh. Out of 2.85 million hectares of coastal and off-shore areas about 0.833 million hectares are arable lands, which constitutes about 52.8 per cent of the net cultivable land and is affected by varying degrees of soil salinity [1]. Salinity has emerged as a major factor responsible for the crop production at a lower rate in Bangladesh. Various agricultural regions have significantly lost their productivity due to soil salinity in last several decades [2]. Satkhira as coastal district is prone to cyclone, salinity, sea water, flood and other natural and anthropogenic disasters [3]. The main crops of Satkhira District are Rice (*Aus, Aman* and *Boro*), wheat, jute, sugarcane and vegetables. The predominant Rice crops in Satkhira are the rain fed *Aman* (60%) followed by the winter Rice *Boro* (35%) and *Aus* (5%) [4].

For evaluating the characteristics of soil profile and present fertility status of soil, chemical analysis has got much importance [5]. A person dealing with soil should be acquainted with the physical and chemical properties and he has to take a decision whether the soil is suitable for crop production or other non-agricultural purposes. In this study, we reviewed the soil chemical, physical, and biological properties of Rice-based cropping systems and identified the aspects that need special attention and consideration to gain guiding references for future research and to contribute to the sustainable development of paddy-upland rotation. The main objectives of this study were to determine the level of soil salinity as well as assessing current soil fertility status of paddy Fields.

2. METHODS AND MATERIALS

The study has conducted in Kaliya, Parulia and Shakhipur villages in Debhata thana in Satkhira District. Soil samples were collected from seven different Fields while these Fields were cultivated for Rice crop.

The experimental area was under the tropical monsoon climate which is characterised by high temperature, high humidity and heavy rainfall of three main season, in Kharif -2 season (June to October) and Kharif-1 season (March-May) are high rainfall respectively 1353mm and 253mm associated with moderately low temperature during the Rabi season (November to February), the annual rainfall is 77mm. Weather information regarding temperature, relative humidity, rainfall prevailed at the experimental site during the cropping season of late Rabi season (November-April). The top soil (0-15cm) samples were collected from three different locations of Kaliya, Parulia and Shakhipur villages in Debhata thana in Satkhira district within a Field with different cropping pattern. Soil samples had taken from each different Field.

Table 1. Description of sampling sites

Sample no.	Cropping pattern	Location	GPS	Physiography	Land type	Fertiliser used
Field-1	Rice-Vegetables	Shakhipur	22º42.25´ N 89º31.57´ E	Coastal tidal floodplain	Medium High land	Urea, TSP, Cow dung
Field -2	Rice-Fallow-Rice	Shakhipur	22º42.383′ N 89º31.676´E	Coastal tidal floodplain	Medium high land	Urea, TSP, Cow dung.
Field-3	Rice-Shrimp.	Shakhipur	22º44.565′N 89º31.062´E	Coastal tidal floodplain	Medium high land	Urea, TSP, Cow dung.
Field-4	Rice-Vegetables-Fallow	Parulia	22034.756´N 88058.364´E	Coastal tidal floodplain	Medium high land	Urea, TSP, Cow dung
Field-5	Rice-Rice-Robi Crops	Parulia	22056.673´N 88096.675´E	Coastal tidal floodplain	Medium high land	Urea, TSP, Cow dung
Field-6	Rice-Jute-Robi Crops	Kaliya	22076.23´N 22027.69´E	Coastal tidal floodplain	High land	Urea, TSP, Cow dung
Field-7	Rice-Jute-Robi Crops	Kaliya	22058.29´N 22021.47´E	Coastal tidal floodplain	High land	Urea, TSP, Cow dung

The collected soil samples were transported to the laboratory of the Soil, Water and Environment Discipline, Khulna University and air dried by spreading the soils on separate sheet of papers. After drying in air, the larger aggregates were broken through gentle crushing with a wooden hammer. A portion of the crushed soils was passed through a 2.0 mm sieve. The sieved soils were then preserved in plastic bags and labeled properly. These samples were later used for various chemical analyses.

Measurements of selected chemical properties of the soils sample as pH, EC, N, PO_4^{3-}, K^+, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+ and Fe^{2+} were carried out in triplicate according to conventional methods. The Soil pH was determined electrochemically with the help of glass electrode pH meter maintaining the ratio of soil to water of 1: 2.5 [6]. Electrical conductivity (EC) of soil was estimated by EC meter maintaining the ratio with of soil to water of 1:5 (soil: water) [7]. Total Nitrogen of the soil was determined by Micro- Kjeldahl's method following H_2SO_4 acid digestion [6]. Available Phosphorus was determined Molybdophosphoric blue color method in sulfuric acid system [8]. Available Potassium (K^+) was extracted from the soil samples by 1N NH4OAc (pH-7) followed by Flame emission spectrophotometer at 769 nm wave length [9]. The Available Sulfur content of soil samples was determined by turbidimetric method [9] at 420 nm wavelength. The Available Calcium (Ca^{2+}) and Mg^{2+} was determined was determined by EDTA Complexometric titration method [9] from NH_4OAc (pH-7) extract. Sodium (Na^+) content in soil samples was determined separately by Flame emission spectrophotometer [9]. Iron (Fe^{3+}) content in soil samples was determined by Spectrophotometer at 420 nm wavelengths [8]. The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. LSD and DMRT were carried out by using computer programs and IBM.SPSS software.

3. RESULTS AND DISCUSSION

The research carried out in order to find out the effect of different land use practices in different saline soil. Proper nutrition is essential for satisfactory crop growth and production. An understanding of general nutrient status can be obtained for a Field if soil tests are done. The essential nutrient elements are N, PO_4^{3-}, K^+, Ca^{2+}, Mg^{2+}, and SO_4^{2-}. Among these nutrient elements, N ranks first in plant requirement and phosphorus ranks second followed by potassium. N, PO_4^{3-}, and K^+ are referred to essential nutrients because nearly all plants use them for growth and development [10].

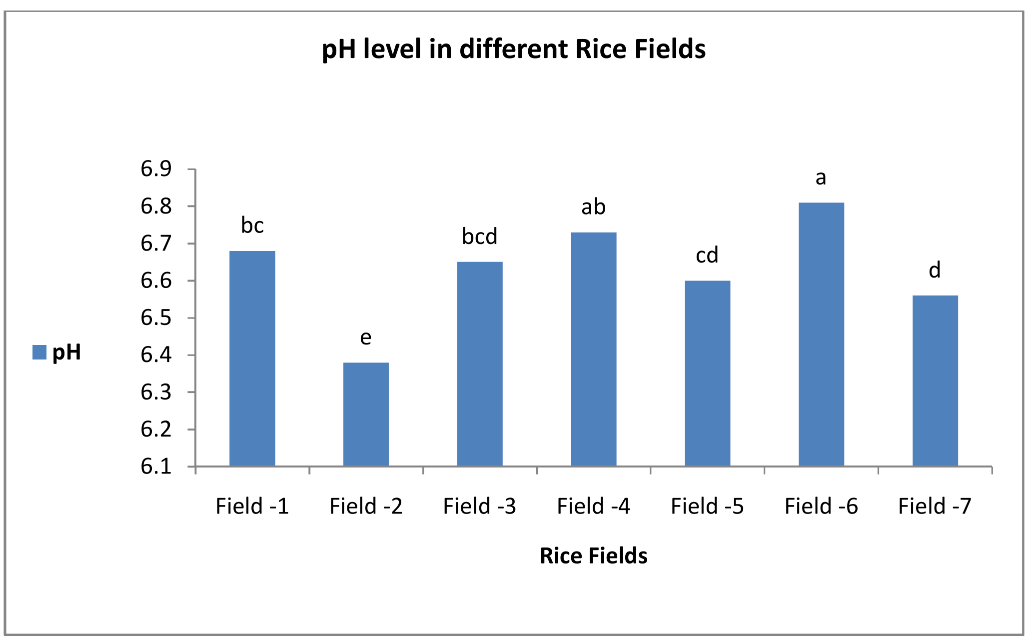

Fig. 1. Distribution of pH values in different Rice Fields

pH level is significantly *($p \leq 0.05$)* high (6.81) at the Rice Field-6 in Parulia. The lowest amount of pH level (6.38) was associated with the sample of Rice Field-2 in Shakhipur. Fig. 1 shows that pH level significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. PH among different Rice Field is in order of Field-5> Field-4> Field-1> Field-7> Field-3> Field-6> Field-2. According to the standard of universal scale, soil pH of the paddy Field was slightly acidic in all the study areas. Soil pH value ranges from 5.39 to 6.02 in the topsoil of Asasuni which are slightly acidic in reaction [11]. Most soil pH ranges 2 to 8.5 of the Coastal soils of Bangladesh [12]. Soil pH value is of 6.7 to 8.5 in the coastal zone of Khulna region [13]. Soil pH range of 6.0-7.5 is optimum for the adequate availability of nutrients in the soil [14]. Thus it can be stated that all the seven Rice Fields have an optimum pH range for adequate nutrient availability as the pH values ranged from 6.38 to 6.81. It also can be stated that among all of them Rice Field-6 of Kaliya village is best at pH (6.81) (Fig. 1) for adequate nutrient supply.

Significantly *($p \leq 0.05$)* high level of electrical conductivity (4.52 dS m^{-1}) has found in the Rice Field-5 of Parulia. The lowest amount of electrical conductivity level (2.31) was observed with the sample of Rice Field-2 in Shakhipur. Fig. 2 shows that electrical conductivity level significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur and Parulia. Electrical conductivity among different Rice Field is in the order of Field-5> Field-4> Field-1> Field-7> Field-3> Field-6> Field-2. According to SRDI, EC value presented that Rice Fields, situated in Shakhipur (Field-1, Field-2, Field-3) and Kaliya (Field-6, Field-7) are slightly saline while Rice Fields in Parulia (Field-4, Field-5) are moderately saline [15]. Coastal and south-east districts of Bangladesh are affected by salinity with EC values ranging between 4 and 16 dS m^{-1} which cover 3 million hectares of land [16]. 13 percent yield reduction of T-Aman due to the use of salt concentration of 4-8 (dS m^{-1}) [17]. This may indicate that Rice yield in Field-4 and Field-5 of Parulia is affected by salinity as they have EC level of 4.3 dS $m^{-1}$and 4.52 dS m^{-1}respectively (Fig. 2). Salt-sensitive plants may be affected by conductivities less than 4 mS/cm and salt tolerant species may not be impacted by concentrations of up to twice this maximum agricultural tolerance limit [18].

Nitrogen content is significantly *($p \leq 0.05$)* high (0.117%) in the Rice Field-5 of Parulia. The lowest amount of nitrogen content (0.08%) was associated with the sample of Rice Field-3 in Shakhipur. Fig. 3 shows that nitrogen content significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. The descending order of the amount of nitrogen percentages among different Rice Field is as follows, Field-5> Field-2> Field-4> Field-6> Field-1> Field-7> Field-3 (Fig. 3). Optimum limit of percentage of total nitrogen (N) is four categories such as low (< 0.180%), medium (0.180-0.360%), high (0.361-0.450%) and very high (> 0.450%) [19]. According to their standard, Nitrogen level is low in all of the experimental Fields which may be due to leaching and de-nitrification under the waterlogged conditions in the paddy Fields. Rahman et al. observed low level of Nitrogen of 0.1-0.3% and stated that the low Nitrogen content may be attributed to low organic matter contents of most of the soils of Khulna [13]. 100% of the soils studied in saline areas were deficient in available nitrogen [20], which was similar to the present findings. The poor nitrogen status of salt affecting soil is due to high cropping intensity, high rates of decomposition of organic matter and inadequate application of organic matter in terms of manure, compost, and high volatilisation of ammonium nitrogen [11].

Results exhibits that, Phosphorus content is significantly *($p \leq 0.05$)* high (373.5 ppm) in Rice Field-2 of Shakhipur. The lowest amount of phosphorus content (142.9 ppm) has found in the sample of Rice Field-5 in Parulia. Fig. 4 shows that phosphorus content significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. Phosphorus content among different Rice Fields is in the order of Field-2> Field-4> Field-1> Field-7> Field-3> Field-6> Field-5 (Fig. 4). SRDI has set four categories for optimum limit of total Phosphorus percentage is such as low (< 12 ppm), medium (12.1-24.00 ppm), high (24.0-30.00 ppm) and very high (> 30. 0 ppm) [15]. Thus, Content of available Phosphorus is very high in the sample of all Rice Fields [15]. 41% of the soils of Bangladesh contained Phosphorus below the critical level and 35% of the soils contained Phosphorus above the critical level but below the optimum level [19]. High range of available Phosphorus in soil under study area might be due to the effect of past fertilisation, pH, organic matter content, texture and various soil management and agronomic practices [21].

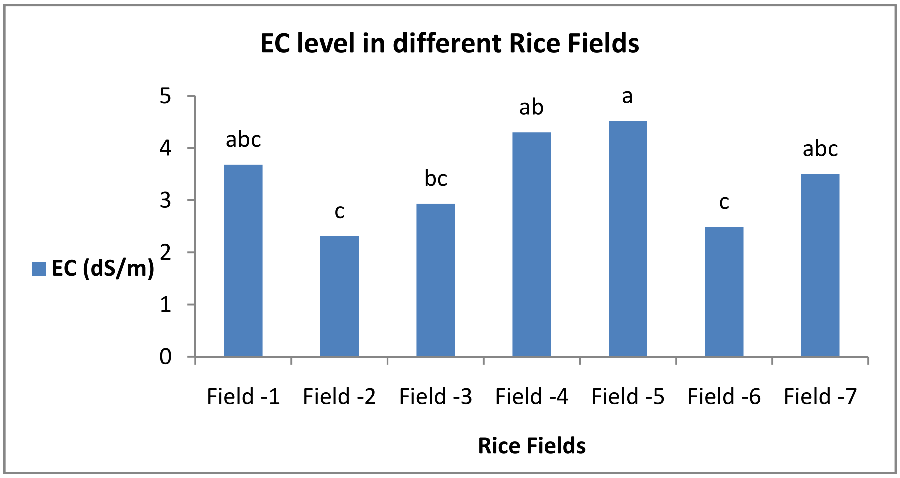

Fig. 2. Distribution of EC values in different Rice Fields

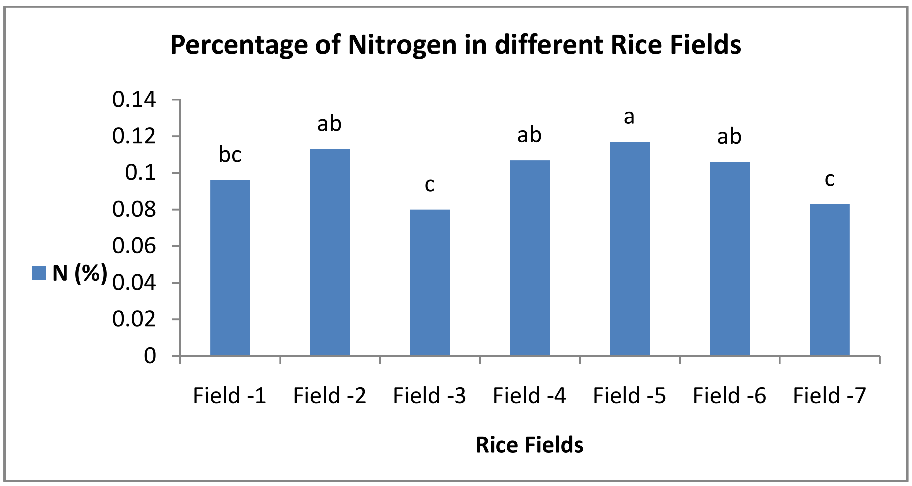

Fig. 3. Distribution of Nitrogen content in different Rice Fields

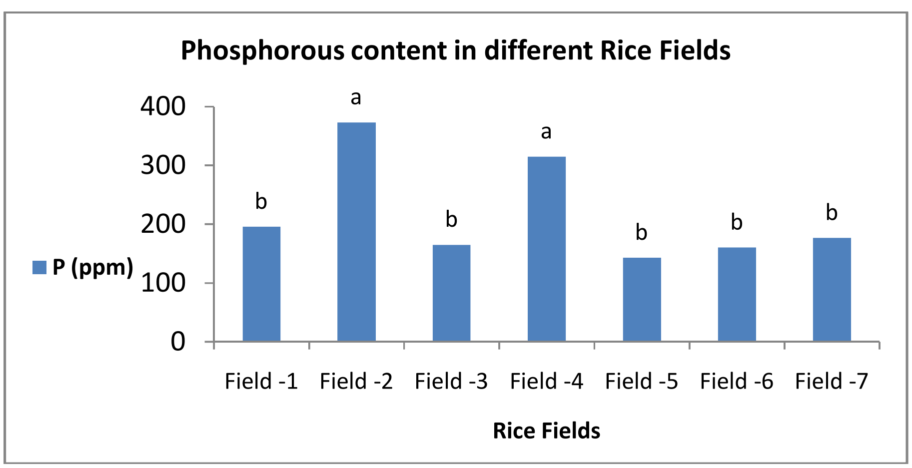

Fig. 4. Location wise distribution of Phosphorus content in different Rice Fields

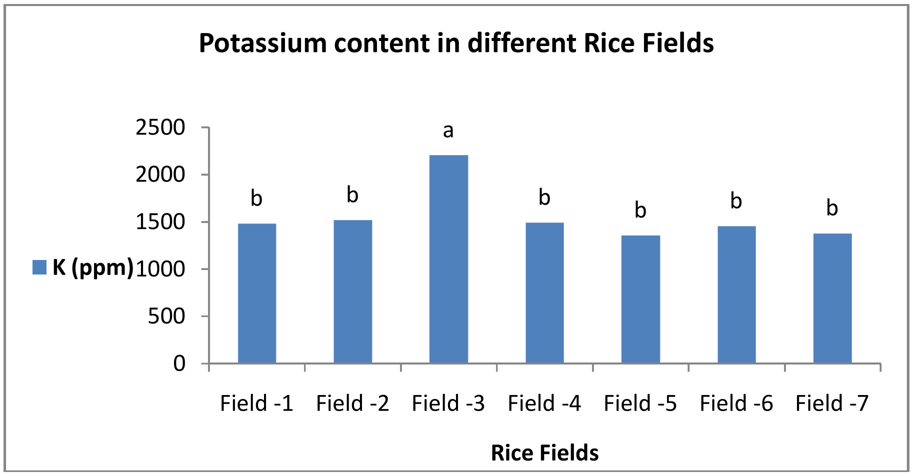

Fig. 5. Distribution of potassium content in different Rice Fields

Results shows that, sample of Rice Field-3 (2206.6 ppm) in Shakhipur has the maximum Potassium content while the minimum has been found in the Field-5 (1354.05 ppm) of Parulia. Statistically similar results were found in all the Fields except at Rice Field-3. Expression of Potassium content in descending order among different Rice Field is as follows, Field-3> Field-2> Field-4> Field-1> Field-6> Field-7> Field-5 (Fig. 5). Agricultural Fields having Potassium level of (2000 to 10400 ppm) represents fertile condition [22]. Thus Rice Field-3 in Shakhipur is fertile as it has a Potassium concentration of 2206.6 ppm. Adequate Potassium in Field-3 may be due to the application of different types of organic and inorganic fertilisers, especially potash fertiliser and the decomposition of the minerals containing potassium [22]. Other six experimental Rice Fields have lower Potassium content. Naher et al. also found low Potassium content in salt affected soil of Assasuni of Satkhira and stated that low Potassium content might be attributed to high cropping intensity, inadequate application of potash fertiliser and limited scope of tidal water inundation [11]. Potassium is rarely a limiting factor in saline soils [23]. Thus it can be stated that Rice cultivation may not be inhibited by lower Potassium content in the study area.

Sulfur was measured in different Rice Fields of Debhata thana, Satkhira and the result was 0.005, 0.009, 0.005, 0.007, 0.007, 0.006 and 0.009 ppm respectively for Field-1, Field-2, Field-3, Field-4, Field-5, Field-6 and Field-7 (Fig. 6). Results exhibits that, Sulfur content is significantly *($p \leq 0.05$)* high (0.009 ppm) at the Rice Field-2 and Field-7 respectively in Shakhipur and Kaliya. The lowest amount of sulfur content (0.005 ppm) has been found in the sample of Rice Field-3 in Shakhipur. Fig. 6 shows that sulfur content significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. Sulfur among different Rice Fields is in the order of Field-2 and Field-7> Field-4 and Field-5> Field-6> Field-1 and Field-3. Results of this study have shown that available sulfur content is very low in all of the experimental Rice Fields. Our observation has been supported by Islam [24] who reported that the sulfur deficiency in Bangladesh soils is becoming wide spread and acute. 68% soils of Bangladesh contained sulfur below critical level and 14% below optimum level [20]. Sulfur plays an important role in determining the yield and S concentration in Rice shoots. Application of S increased Rice grain yield and shoot S concentration significantly [25].

The measurement of nutrient content as calcium ($Ca^{2+)}$ in different Rice Fields of Debhata thana, Satkhira and the result was 0.061, 0.035, 0.122, 0.062, 0.062, 0.059 and 0.056% respectively for Field-1, Field-2, Field-3, Field-4, Field-5, Field-6 and Field-7. Significantly *($p \leq 0.05$)* high content of Calcium (0.122 %) has been found in the Rice Field-3 in Shakhipur. The lowest amount of calcium content (0.035 %) was associated with the sample of Rice Field-2 in Shakhipur. Statistically similar results were found in all the Fields except at Rice Field-2 and Field-3. Calcium content among different Rice Fields is in order of Field-3> Field-4, Field-5> Field-1> Field-6> Field-7> Field-2 (Fig. 7). Ca^{2+} percentages among the Rice Fields varied from 0.006 to 0.016 % in according to the standard of BARC [14]. Soil Ca^{2+} content was too low in the paddy Fields of the study area. This lower Ca content might be due to changes in osmotic and ionspecific effects that can produce imbalances in plant nutrients, including deficiencies of several nutrients or excessive levels of Na [26]. The low Ca contents may be due to the pH levels whereby the exchangeable bases would be low.

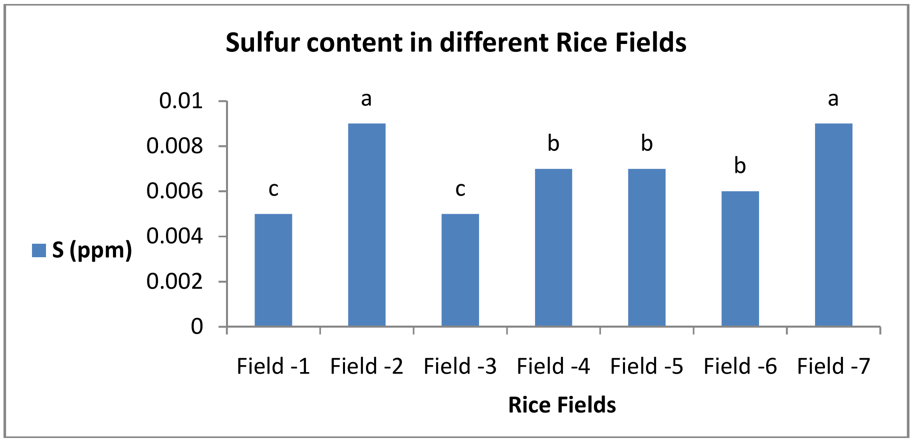

Fig. 6. Distribution of Sulfur in different Rice Fields

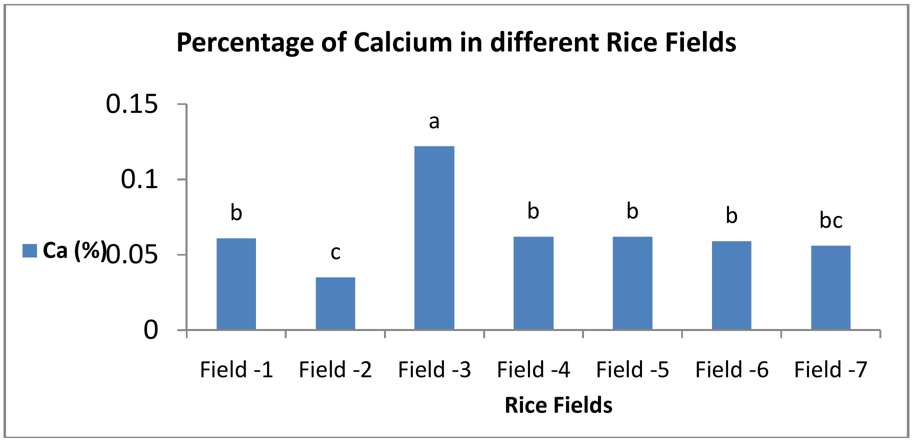

Fig. 7. Distribution of Calcium content in different Rice Fields

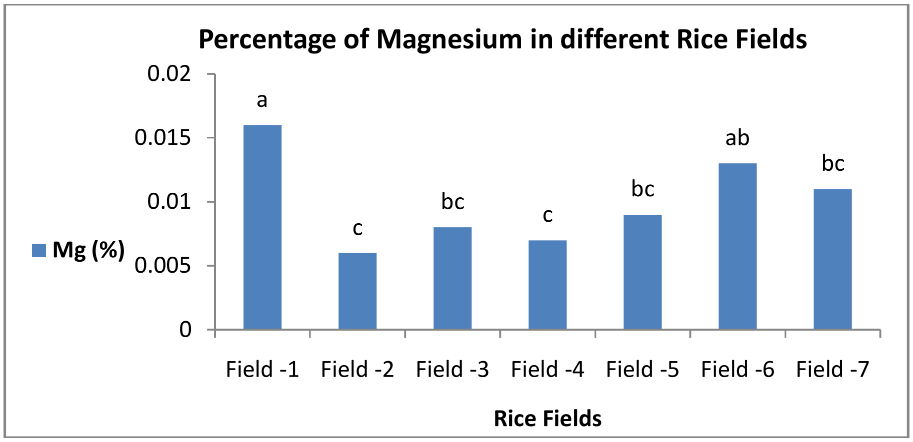

Fig. 8. Distribution of Magnesium content in different Rice Fields

Magnesium was measured in different Rice Fields of Debhata thana, Satkhira and the result was 0.016, 0.006, 0.008, 0.007, 0.009, 0.013 and 0.011% respectively for Field-1, Field-2, Field-3, Field-4, Field-5, Field-6 and Field-7 (Fig. 8). Results exhibits that, Magnesium content is significantly *($p \leq 0.05$)* high (0.016 %) at the Rice Field-1 in Shakhipur. The lowest amount of magnesium content (0.006 %) has been found in the sample of Rice Field-7 in Kaliya Fig. 8 shows that magnesium content significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. Magnesium among different Rice Fields is in the order of Field-1> Field-6> Field-7> Field-5> Field-3> Field-4> Field-2. Perfect limit of percentage of available Mg^{2+} is four categories such as low (< 0.75), medium (0.751-1.5), high (1.51-1.87) and very high (> 1.875) [14,15,19]. Thus Mg content was low in everywhere of the studied samples may be due to the pH levels whereby the exchangeable bases would be low.

The measurement of nutrient content as Sodium (Na^+) in different Rice Fields of Debhata thana, Satkhira and the result was 1802.3, 876.8, 1110.6, 1227.5, 1091.1, 867.08 and 643 ppm respectively for Field-1, Field-2, Field-3, Field-4, Field-5, Field-6 and Field-7 (Fig. 9). Significantly *($p \leq 0.05$)* high content of sodium (1802.3 ppm) has been found in the Rice Field-1 in Shakhipur. The lowest amount of sodium content (643 ppm) was observed with the sample of Rice Field-7 in Kaliya. Fig. 9 shows that Sodium content significantly *($p \leq 0.05$)* varied among the Fields of Shakhipur, Parulia and Kaliya. Na^+ among different Rice Field is in theorder of Field-1> Field-4> Field-3> Field-5> Field-2> Field-6> Field-7. All of seven experimental Field have exhibited higher amount of Na^+ content which

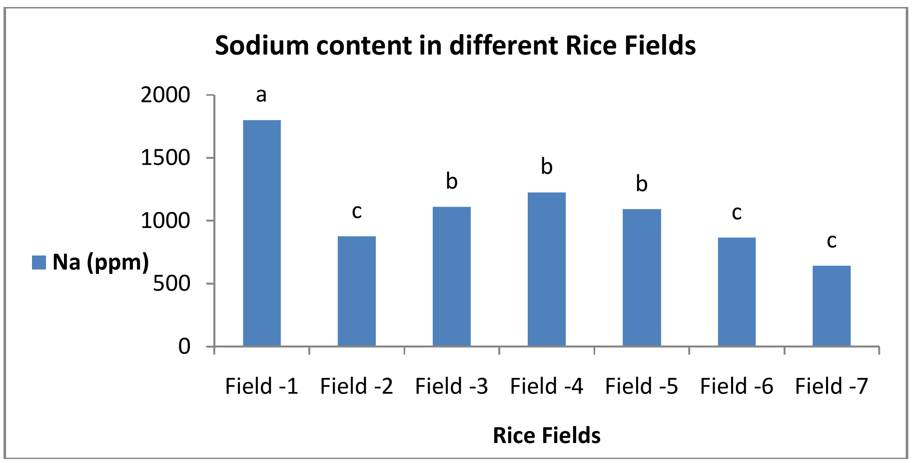

Fig. 9. Distribution of Sodium content in different Rice Fields

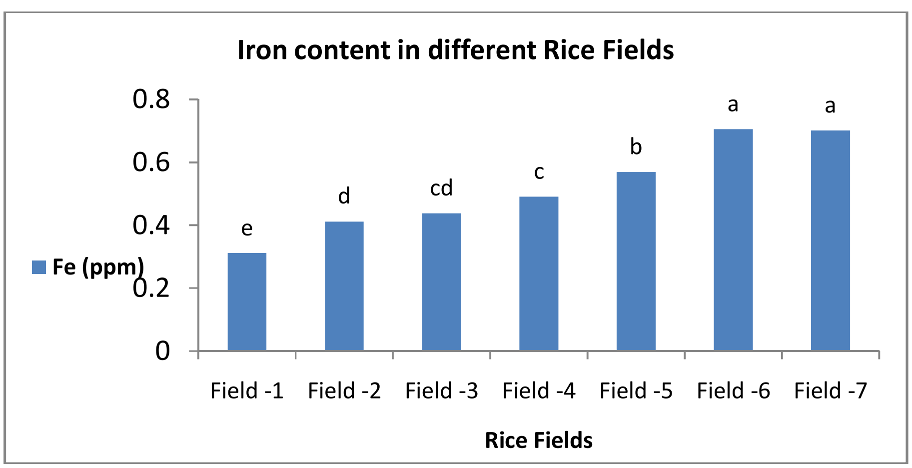

Fig. 10. Iron content in different Rice Fields with their location

might be attributed to the intrusion of saline water from the sea and capillary rise of saline water from the underground [27]. A higher level of Na^+ content of 16000 to 330000 ppm is in the coastal zone of Khulna Region [13]. Naher et al. reported lower Na^+ content of 119.6 to 128.8 ppm in Assasuni Thana of Satkhira District. High Na^+ content disperses the soil structure as well as retards the production [11].

The measurement of nutrient content as Iron ($Fe^{2+)}$ in different Rice Fields of Debhata thana, Satkhira and the result was 0.311,0 .412, 0.438, 0.491, 0.569, 0.705 and 0.701 ppm respectively for Field-1, Field-2, Field-3, Field-4, Field-5, Field-6 and Field-7 (Fig. 10). The highest amount of Iron content (33.5 ppm) has been found at the Rice Field-6 in Kaliya and the lowest value of Iron content (13.31 ppm) was observed at the Rice Field-2 Shakhipur. The amount of iron significantly varied among seven different Rice Fields, which has been presented in order Field-6>Field-7> Field-5> Field-4> Field-3> Field-2> Field-1. Result exhibits that, all of seven experimental Rice Fields of this study are very low in Fe^{2+} content. Soil pH relates positively with Fe content in the form of power function and not show in linear relationship because Fe content in the soil is also influenced by the soil conditions (saturated, compacted, poor aerated soil, the presence of other nutrients, leaching and soil erosion) [28]. The activity of Fe decreases with increase in soil pH [29]. The amount of available Fe in Batiaghata and Dumuria of Khulna district is 101.05 ppm and 164.29 ppm, respectively [27]. They also reported that Fe content in Kaligonj and Assasuni Thana of Satkhira district is 97.00 ppm and 14.12 ppm, respectively. They also reported that, Liming generally decrease the availability of this nutrient in soil.

4. SUMMARY AND CONCLUSION

Rice Field soils of Devhata Thana of Satkhira district of Bangladesh is characterised under slightly acidic in soil reaction, soil salinity (EC) content comes under slight to the moderately saline range. The soils of this area showed low concentrations of total N, available SO_4^{2-}, Ca^{2+}, Mg^{2+} and Fe^{2+}. Low level of exchangeable K^+ has been observed in six sample Fields among seven, although one have an adequate amount. Soils exhibited higher Na^+ and PO_4^{3-} content. If the constraints are reclaimed through integrated soil fertility management, the area of Debhata Thana will be the high yielding Rice production area. The effect of high Na^+ can be minimised by proper drainage, use of salt free water and organic manures and deficiency of other nutrients by using organic and inorganic fertilisers. As, soil properties are affected by many environmental factors, further research may continue to observe these effects on Rice performance then it will be a better attempt for controlling these factors. So, soils require attention regarding integrated nutrient management approaches associated with applying integrated coastal zone management and regular monitoring of soil health for better crop productivity and sustainable agriculture to ensure the food security for future generation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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