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Assessment of available nutrient status of different agro-climatic jute (*Corchorus capsularis*) growing soils of Eastern India

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Abstract
Jute is one of the important fibre crops, playing a vital role in the livelihood of people of Eastern India. In the recent past, declining productivity trend of this crop has been observed due to various abiotic factors, prominent among them being poor soil nutrient management. To address the issue, four different agro-climatic situations (flood prone rainfed, undulated rainfed upland, high flood plain (*diara*) and flood prone situations) were selected and surface soil samples were collected from each of the sites, to identify the status and extent of soil major and micronutrient deficiency, trend of residual nutrient balance and the relationship between soil attributes and nutrients availability and their consequences /impacts on jute yield. The results showed that the extent of NPK deficiency in this jute growing region was 55.8, 82.7 and 73.1% respectively. Among the micronutrients Fe (1.92%), Mn (51.9%), Zn (25%) and B (75%) were also found to be deficient. Bivariate correlation coefficient analysis showed highly significant (P<0.01%) relationship between soil attributes and nutrient availability. Yield of jute significantly influenced by the soil NPK and other nutrients. Based on the study higher doses of NPK fertilization for the major jute growing areas will be needed to be advocated for sustainable jute production.

Keywords: Jute, livelihood, agro climatic situations, nutrient deficiency, fertilization

Introduction

Jute is the second most extensively grown fibre crop in India and its cultivation is confined to the eastern parts of the nation. Jute has a greater socio-economic role for the people of the region, as it provides a livelihood option to more than 4 million farm families of the country (Anonymous, 2016) [1]. Besides, jute cultivation has several virtues, respected in the present day global context, like high carbon sequestration ability, accumulation of high biomass, maintenance of soil health, enrichment of the soil and protects the environment. Currently, the productivity trend of jute (fibre) in Eastern India is declining. Various abiotic factors are responsible for this decline, out of which, poor nutrient management practice is an important one. Farmers of this region are mainly restricted to applying a limited amount of NPK inorganic fertilizers, and the application of organic sources of plant nutrient is negligible Mathur *et al.* 2006 [15]; Somasundaram *et al.* 2009 [25]; Sharma *et al.* 2009 [21]. Thus, long term application of inadequate amount of plant nutrients may deplete the native macro and micronutrient status of the soil thereby limiting jute yield.

Typically, to produce one tonne of fiber, jute crop removes about 35.2 kg N, 20.4 kg P_2O_5, 63.4 kg K_2O, 55.4 kg CaO, 13.2 kg MgO, 425 g Fe, 119 g Mn, 24 g Cu and 181g Zn from the soil (Tandon and Muralidharudu, 2010) [29]. Therefore, the critical understanding of the extent of the nutrient depletion in soils is very much important, not only for optimum jute production, but also for sustainable productivity in view of rapid socio-economic changes in a developing country like India. Besides the major (NPK) nutrients, micronutrients are required in a very small quantities for normal plant growth and involved in various enzymes (Gao *et al.* 2008) [10], and have a specific function in plants growth and microbial processes. Soil fertility is usually controlled by land use history, cropping pattern, nutrient management, relief position and parent material under both the specific and vague climatic conditions, which may also influence crop performance. Therefore, understanding the variability in available soil nutrients, extent of nutrient deficiency and simultaneously maintenance and improvement of nutrient management practice like timely, dose and sources of nutrients, etc., will be needed for sustainable agricultural production and for protecting environmental quality (Davatgar *et al.* 2012) [8].

There is scanty information on soil nutrient status at the different jute growing agro-climatic situations of Eastern India and farmers of this region are yet to understand the consequences of bad soil health from their apathy in proper soil management. The present investigation was undertaken to study the status of soil nutrients and nutrient balances at different agro-climatic jute growing situations of Eastern India, and elucidate the relationship between different soil attributes and nutrient availability and finally to find the role of available soil nutrient on jute yield in order to suggest precise nutrient dose for the sustainable economic crop productivity.

Materials and Methods

Climate and site description

The study was conducted at four different agro-climatic jute growing areas, namely, flood prone rain-fed (ACS-I), undulated rain-fed upland (ACS-II), recent alluvial high flood plain (*Diara*) (ACS-III) and recent alluvial flood prone land (ACS-IV) located in between $24^0 30.417''$ to $25^0 28.484''$N latitude and $087^0 52.106''$ to $088^0 38.255''$E longitude of the Eastern part of the India (Fig. 1). Mean maximum temperature during summer months ranged from 39 to 41°C and the mean minimum temperature during winter months varied from 5 to 10°C in the study area. Annual normal mean rainfall during last five years ranged from 1156 to 2087 mm. The details soil sampling locations with respective agro-climatic situations, annual rainfall distribution, textural classes, average fertilizer application pattern and the average yield is presented in Table 1.

Study methods

To assess the available soil nutrient status in the jute growing areas of Eastern India, fifty two (52) surface soil samples (0-20 cm) were collected from the four different agro-climatic situations. A public relation appraisal (PRA) was conducted to collect information related to the existing jute cultivation practice of the region. On an average, 15 farmers from each agro-climatic situations were interviewed on the nutrient use pattern, type and amount of manure or/and inorganic fertilizer that were being used for jute cultivation. The survey highlighted that all the jute growing farmers applied only inorganic NPK fertilizers through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) respectively as broadcasting during cultivation. One third of urea was applied during sowing and remaining part during the growing period in two split doses. Survey also indicated that the average quantities of NPK application at the different agro-climatic situations was 132:40:30 (ACS-I), 104:34:36 (ACS-II), 80:32:20(ACS-III) and 130:20:20(ACS-IV) kg ha^{-1} respectively. A PRA and crop cutting was conducted at harvest and the average jute fibre yields were 2006.6 (ACS-I), 1770.7 (ACS-II), 2182.5 (ACS-III) and 1678.8 (ACS-IV) kg ha^{-1} respectively (Table 1).

Annual nutrient balance

Apparent balances of available nutrients were estimated at different agro-climatic situations of wheat- jute growing situations. The average soil nutrient application rate was considered as fertilizer input for the wheat-jute cropping sequence as per the PRA (participatory rural appraisal) conducted at different agro-climatic situations and nutrient output was calculated considering the average biomass removed during the cropping sequence.

Analytical methods

Collected composite (15-20 cores) surface soil samples were air dried and passed through a 2 (two) mm sieve for determination of soil pH, electrical conductivity (EC) in a 1:2.5 soil: water suspension (Page *et al.*1982)[17], oxidizable soil organic carbon (SOC) by the method of Walkley and Black (1934)[1], available soil nitrogen by the alkali $KMnO_4$ method (Subbaiah and Asija, 1956)[26], available phosphorus, NH_4OAc extractable potassium (Jackson, 1973)[13], DTPA extractable Fe, Mn, Cu, Zn (Lindsay and Norvell, 1978)[14] and hot water soluble boron (Berger and Truog, 1939)[2]. Soil texture was determined by using a Bouyoucos hydrometer method. The cation exchange capacity (CEC) was measured by the ammonium saturation method using 1N NH_4OAc (Jackson, 1973) [13].

Statistical and geostatistical analysis

All the data were analyzed for their descriptive parameters, such as minimum, maximum, mean, median and standard deviation. The Shapiro–Wilk (S-W) method, together with skewness and kurtosis values was used to evaluate the normality of the datasets using SPSS software (version 16.0).

A base map was built for the district boundaries of West Bengal (Fig. 1). A geo-database was created to hold all the primary data layers and to build relationship among them. Feature classes of point, line and polygon were digitized using ArcGIS application software. The input data in tabular form from excel sheet was used to create latitude and longitude event and a point feature class. Coordinate system was specified by defining a projection as Geographic Coordinate Systems and datum as WGS 1984 for the study area.

Sample data were then transformed into GIS maps by different geo-processing tools, such as projecting a dataset from one map projection to another, adding a field to a table, creating a buffer zone around the study area, spatial analyst techniques, *etc.* Geographic Coordinate system used is WGS 1984. Different vector and raster layers were used. Polygon, line and point features were digitized for the study.

For the spatial modeling, the inverse distance weighting (IDW) method was used to interpolate the different parameters of soil nutrients across the study area using spatial analyst tool to predict values for unmeasured locations. Using this technique, different thematic maps were prepared for each soil nutrient parameters like soil available N, P_2O_5, K_2O, Fe, Mn, Cu, Zn and B that specified different ranges for each class.

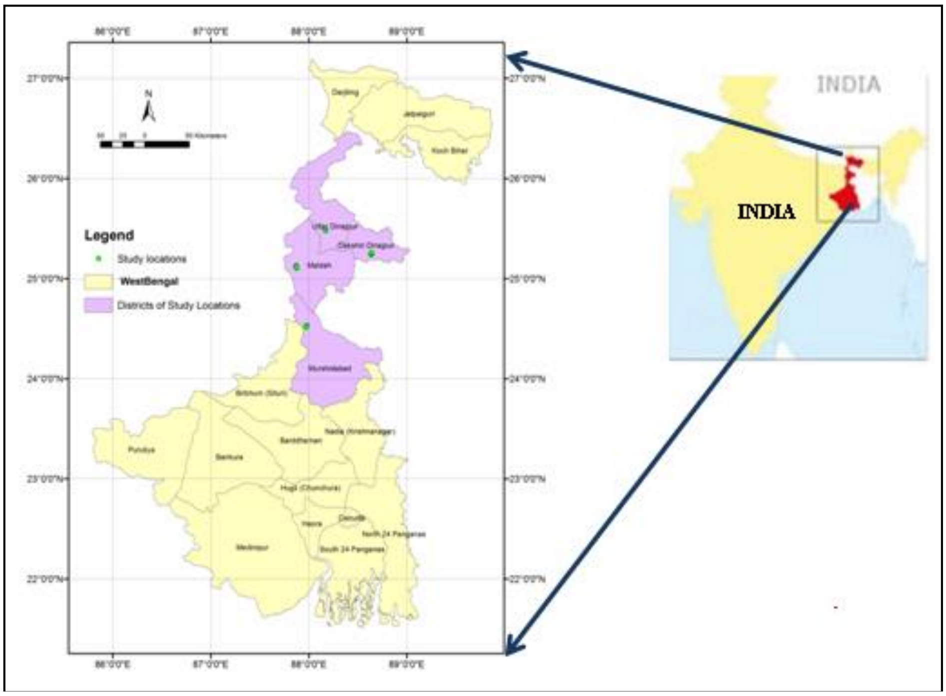

Fig 1: Thematic map of jute growing area under study.

Results and Discussion

Exploratory data analysis

Descriptive statistics for the analyzed soil samples of different soil attributes are summarized in Table 2. The frequent textural classes of the jute growing soils were sandy loam, loam, sandy clay loam, clay loam, sandy clay and clay, these wide variations in textural classes (Table 1) reflected in the ratio of sand, silt and clay particle of the soil samples. Soil pH was ranged varied from 4.58 to 6.97 with mean value of 5.802. The mean value of the electrical conductivity (EC) content in the soils was 0.344 dSm^{-1} with a standard deviation of 0.149 dSm^{-1}. Soil organic carbon (SOC) content were low to high with a mean value of 7.056 g kg^{-1} and ranged from 3.30 to 10.80 g kg^{-1}. The mean CEC of the soil samples was 7.544 Cmol(p+)kg^{-1} with a standard deviation of 1.483 Cmol(p+)kg^{-1}. The variation in soil pH reaction (very strongly acidic to neutral) in between different land agro climatic situation may be due to parent material; rainfall distribution in between the different sites of the study area. It was noticed that the entire soils of jute-rice cropping systems were salt free in nature, which might be due to frequent flood prone situation. Soil organic carbon (SOC) content were found low to high (3.30 to 10.80 g kg^{-1}) and this variation of SOC in different agro-climatic situations might be due to dissimilarity in topography, cultivation and nutrient management practices. Maintenance of soil organic matter is subtropical region is very difficult because of its rapid decomposition due to high temperature, therefore, split application of organic manure may be recommended to increase soil organic carbon content and nutrient use efficiency by improving soil physical, chemical and biological properties of soil.

Available primary nutrient status

Soil available N status of the study area was low with a mean value of 252.52 kg ha^{-1} (Table 3) with the value ranged from 86.55 to 575.77 kg ha^{-1}. The pictorial presentation of available nitrogen in four agro-climatic situations is given in Fig. 2. It was also found that 55.77% soil samples in the region were deficient in available N with ranged from 46.57 to 61.54 % in between the agro-climatic situations (Fig. 3).

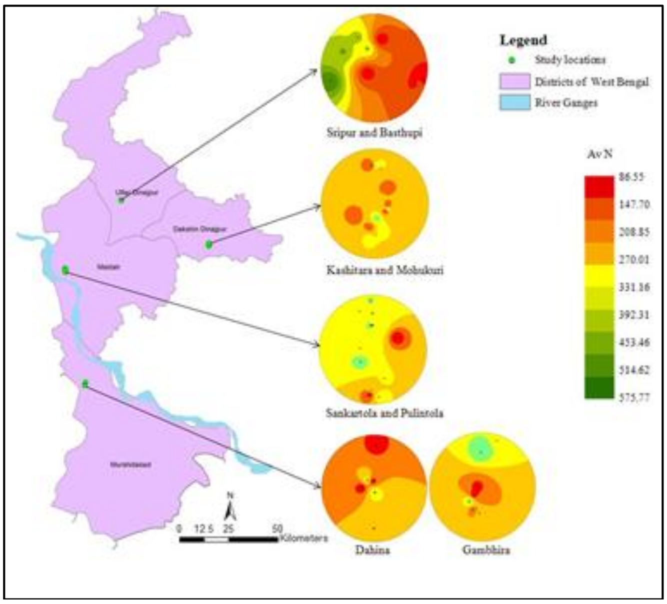

Fig 2: Spatial map of soil N availability in study area.

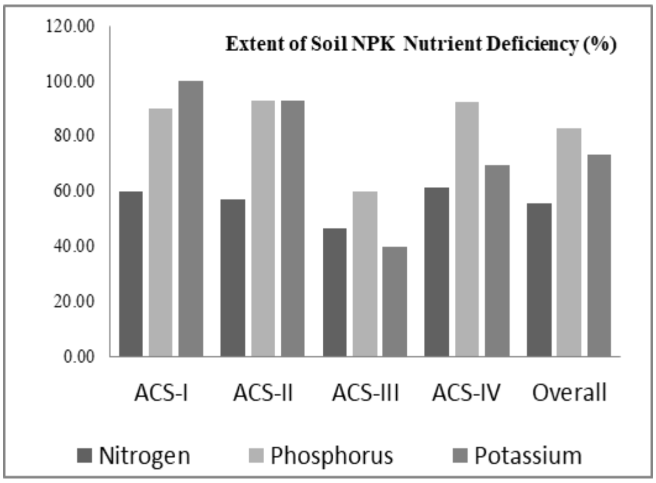

Fig 3: Extent of the soil NPK nutrient deficiency.

Nitrogen is usually considered as a mobile nutrient in the soil system and this variation might be due to the variation in SOC content, rainfall distribution and topographical situation within and in between the agro-climatic situations. It was also found that on an average 55.77% soil sample in the region is deficient in available N with ranged from 46.57 to 61.54 % in between the agro-climatic situations. In contrast, input and output N balance were found positive for the entire agro-climatic situations (6.93 to 120.56 kg $ha^{-1}year^{-1}$), which indicated the jute growing farmers are being applying relatively higher amount of nitrogenous fertilizer than the requirements of crops. But low soil test value of available N, indicated that the higher leaching and volatilization losses of applied nitrogen is involved. Higher losses of applied N may be due to light texture soils, heavy rainfall and surface application of nitrogenous fertilizers during the cropping periods. Based on this study, it can be suggested to apply slow release notrogenous fertilizers such as isobutylidenediurea (IBDU), polyolefin-coated urea (POCU) and neem (*Azadirachita indica*) coated urea @ 125 to 150% of recommended doses of nitrogen (RDN) for achieving optimum jute yield for this region, particularly for those soils containing a low and very low level of N.

Available phosphorus content in the jute growing zone was low, with a mean value of 14.97 kg ha^{-1} (Table 3), ranged from 3.26 to 29.50 kg ha^{-1}. Pictorial appearance of the available phosphorus in four agro-climatic situations is showed in Fig. 4. There was wide variation in soil available P in the different agro-climatic situations and ACS-wise mean value ranged from 12.3 (ACS-I & II) to 21.3 (ACS-III) kg ha^{-1}. About 82.69% of the soil samples in this region (Fig. 3) were deficient in available phosphorus. Out of the four agro-climatic situations ACS-I, II and IV were found highly deficient (90% or more) in available P content as compared to ACS-III. Phosphorus is generally considered as immobile nutrients in soil system and its fixation is the major mechanism for conversion of plant available form to unavailable form into the soil system. It was also observed that on an average 82.69% of the soil samples of the jute growing region (Fig. 3) were deficient in available phosphorus. Out of this four agro-climatic situations, ACS-I, II and IV were found highly deficient (90% or more) in available P, than ACS-III (60%), though the phosphorus input and output balance was also found positive (1.51 to 40.4 kg $ha^{-1}year^{-1}$). Phosphorus is often the most limiting plant nutrient in soil, but it has low availability in this region might be due to high fixation in soils (Shen *et al.* 2011) [24] as majority of the soil samples were acidic in nature. Soil phosphorus availability plays an indispensable biochemical role in photosynthesis, respiration, storage and energy transfer, reactions, cell division, development of reproductive structures, crop maturity, root growth, protein synthesis and other process (Yao *et al.* 2011) [33]. Hence, limited availability of P may leads to severe growth retardation, reduced yield and quality of crops. Plants are only able to absorb P from the soil solution as orthophosphate anions (HPO_4^{2-} and H_2PO_4), however, this P form is extremely reactive and can be immobilized by precipitation with cations (Ca^{2+}, Mg^{2+}, Fe^{3+}, and Al^{3+}), reducing its availability to plants (Gyaneshwas *at al.* 2002) [11]. Therefore, P deficiency problem can be solved by applying phosphatic fertilizer through different phosphorus sources advocating with 125 to 150% of the recommended dose of phosphorous (RDP) particularly under the rainfed and flood prone agro climatic situations, where having the low level (ACS-I, II & IV) of available P.

The soil available K content of the region ranged from 15.46 to 202.27 kg ha^{-1} (Fig. 5), where, about 73.08% samples were found deficient in available potassium content (Table 3). Considering the mean value at different agro-climatic situation, soil available K content varied widely from 46.6 to 147.1 kg ha^{-1}. The mean values indicated that only ACS-III is sufficient in available K content. But the extent of soil available potassium deficiency at different agro-climatic situations ranged from 40 to 100%. Spatial pictorial look of the available potassium content at different agro-climatic situations is illustrated in Fig. 4.

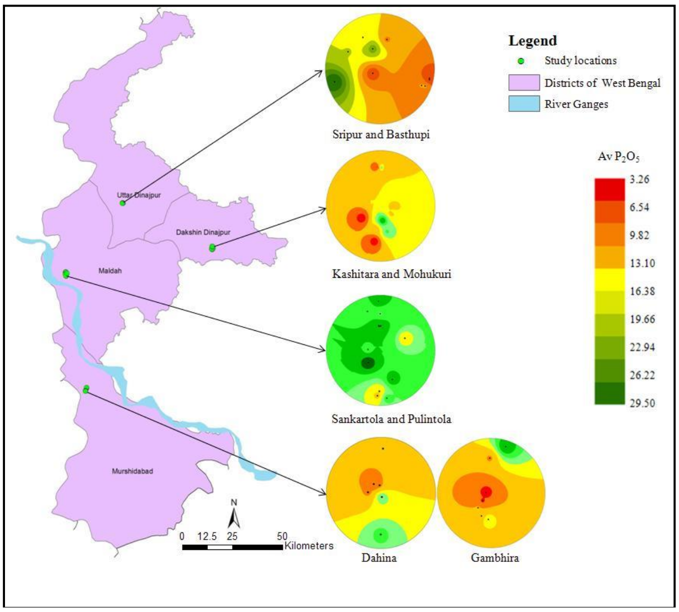

Fig 4: Spatial map of soil P_2O_5 availability in study area.

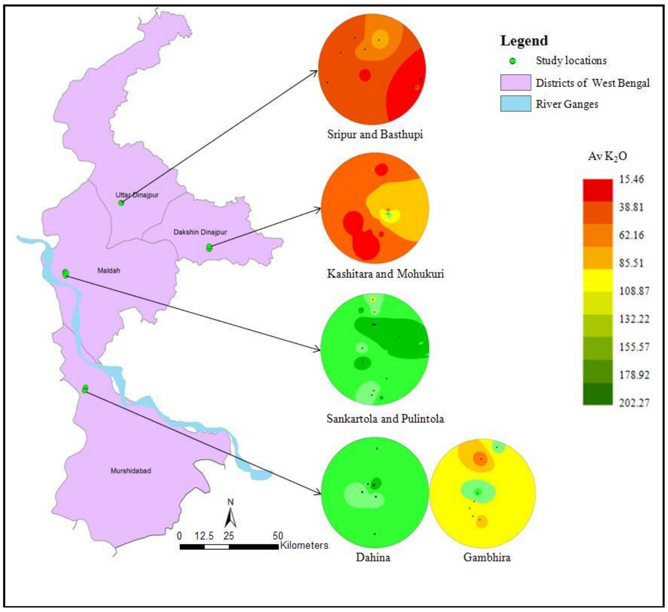

Fig 5: Spatial map of soil available K in study area.

Potassium activates about 60 enzymes involved in various metabolism processes and improves quality and stress tolerance of crops. K also involved in osmo-regulation, turgor driven movements and maintenance of the plasma membrane potential (Mitra, 2017) [16]. The extent of soil available potassium deficiency at different agro-climatic situations of the study areas ranged from 40 to 100%. The input and output balance of potassium was also found negative (-152.85 to -179.72 kg $ha^{-1}year^{-1}$) in all the agro-climatic situations that indicated that the farmers are applying relatively less amount of potassium fertilizer than the requirement of crop. This deficiency of potassium might be further aggravated due to absence of K bearing minerals, textural classes and the long-term deficit application of potassium fertilizer into the soils. Out of the four agro-climatic situations ACS-I & II were found severely affected by the potassium deficiency (92.86 to 100%). But relatively less soil K deficiency was noticed in ACS-III and that might be due to the presence of higher K bearing minerals in soil. It was reported that the rrecovery of the applied K is generally higher than that of P, with exception of some strongly K-fixing soils (Debermann, 2007)[9]. Therefore, it can also be suggested to apply 100 and 150% of recommended doses of fertilizer for the very low and low level of available K containing soils respectively, for enhancing the crop yield and potassium use efficiency.

Available micronutrient status

The DTPA extractable cationic micronutrients (Fe, Mn, Cu, Zn) and hot water soluble boron content of the soil samples for various agro-climatic situations are also summarized in Table 3.

Soil DTPA-extractable iron content was sufficient in all the agro-climatic situations ranged from 5.27-12.44, 4.98-12.41, 5.78-13.14 and 4.33- 2.42 mg kg^{-1} with mean value of 8.17, 8.63, 9.42 and 7.11 mg kg^{-1} in the soils of ACS-I, II, III and IV, respectively. Pictorial presentation of the soil DTPA-Fe in four agro-climatic situations is showed in Fig. 7.

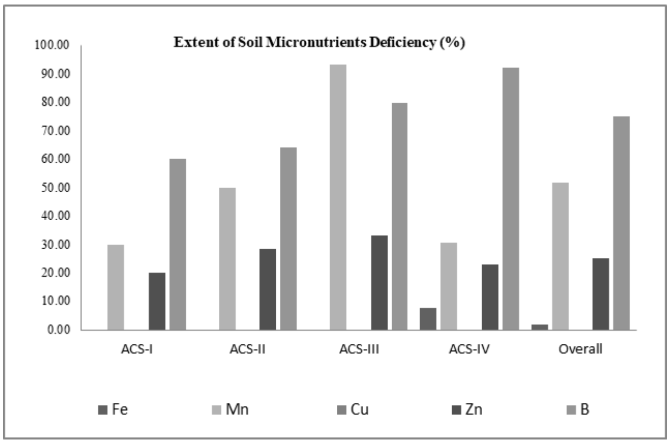

Fig 6: Extent of soil micronutrient deficiency.

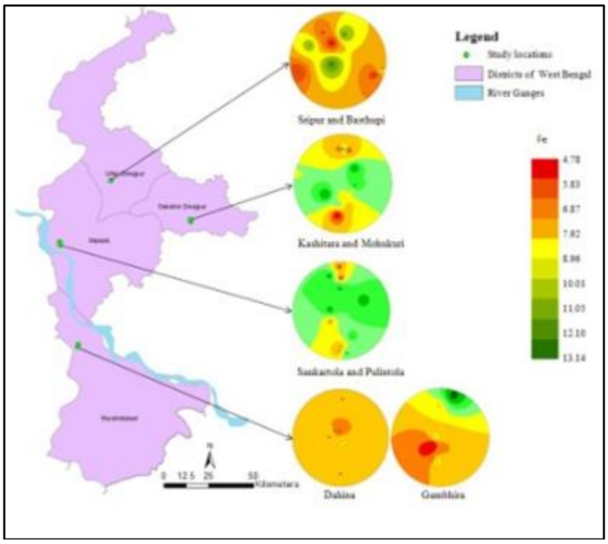

Fig 7: Spatial map on soil Fe.

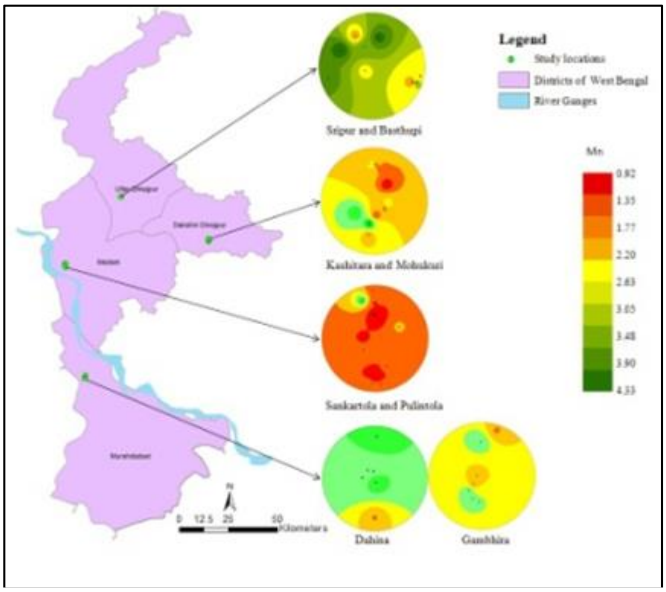

Fig 8: Spatial map on soil Mn.

Considering the critical limits of Fe (4.5 mg kg^{-1}), proposed by Lindsay and Norvell (1978)[14], only 7.69% of the samples of ACS-IV were deficient in Fe content. The Fe content was found to be relatively higher in ACS-III (recent alluvial high flood prone situation) as compared to the other agro-climatic situations. This may attributed to the reduction of Fe resulting in lower adsorb ability in the clay surfaces because of the prolonged moist condition of soil in the flood prone situation and may also for the release of Fe in longer periods of submerged condition in soil (Das and Talukdar, 2003)[7]. Therefore, application of Fe containing fertilizers is essential in ACS-IV for precise cellular respiration, synthesis of chlorophyll and photosynthetic electron transport (Rout and Sahoo, 2015) [20].

Manganese availability among the jute growing soils varied from 0.92 to 4.33 mg kg^{-1} (Fig. 8) with a mean value of 2.23 mg kg^{-1}. Considering 2.0 mg/kg as critical value for Mn, the extent of Mn deficiency among the different agro-climatic situations varied from 30 to 93.33% (Fig. 6). However, considering the mean value only ACS-III felt under Mn deficient zone (situation) with value of 1.50 mg kg^{-1}. Spatial map of the soil DTPA-Mn in four agro-climatic situations is showed in Fig. 8. Considering 2.0 mg/kg as critical value for Mn, only ACS-III felt under Mn deficient (mean value 1.50 mg kg^{-1}) zone (situation). Higher ratio of Fe than Mn in the agro-climatic situation might be the reason of lower availability of soil Mn. The variability of Mn deficiency in between the different agro-climatic situations may be due to difference in soil management in relation to non-application of organic and inorganic Mn nutrient sources into the soils. Therefore, application of recommended doses of Mn fertilizer may be useful particularly for very low and low available Mn containing soils.

Availability of Cu in the soils under study ranged from 0.56 to 1.61 mg kg^{-1} (Fig. 9). Considering the critical value of Cu (0.2 mg kg^{-1}), all the samples of the region were found sufficient in soil DTPA-extractable Cu. Spatial map of the soil DTPA-Cu in four agro-climatic situations is showed in Fig. 9. Copper plays important role in photosynthesis, respiration, ethylene perception, reactive oxygen metabolism, and cell wall remodeling (Burkhead *et al.* 2009)[4]. Considering the critical value of Cu (0.2 mg kg^{-1}), all the samples of the region were found sufficient in soil DTPA-extractable Cu.

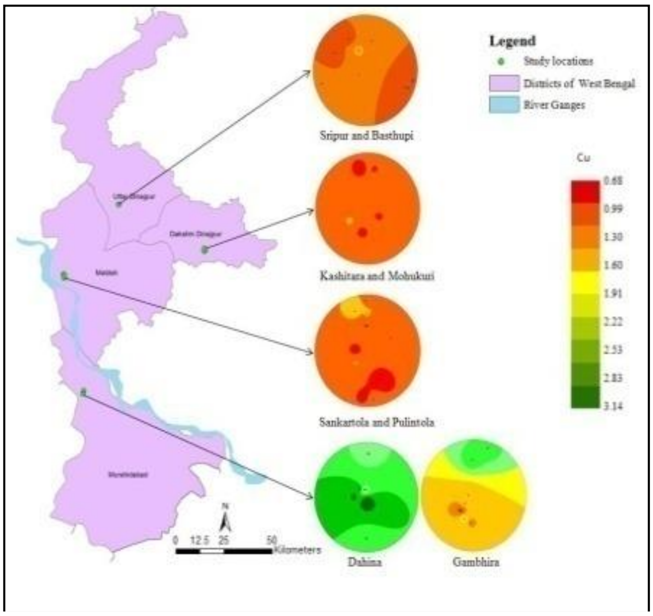

Fig 9: Spatial map on soil Cu.

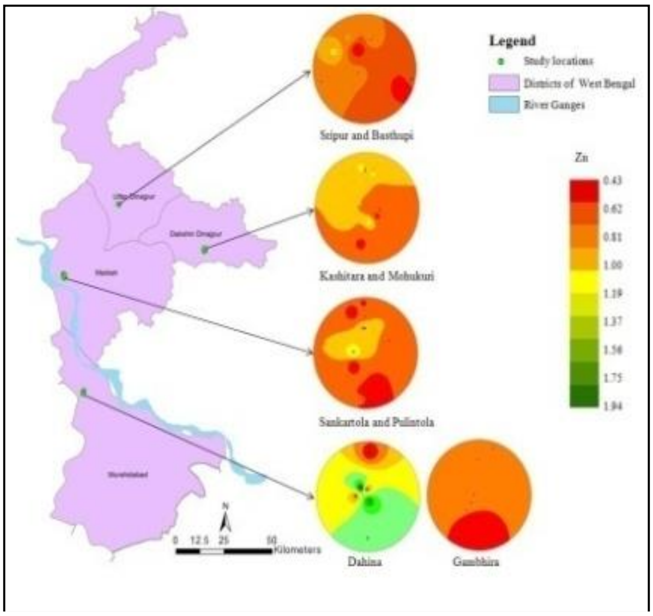

Fig 10: Spatial map on soil Zn.

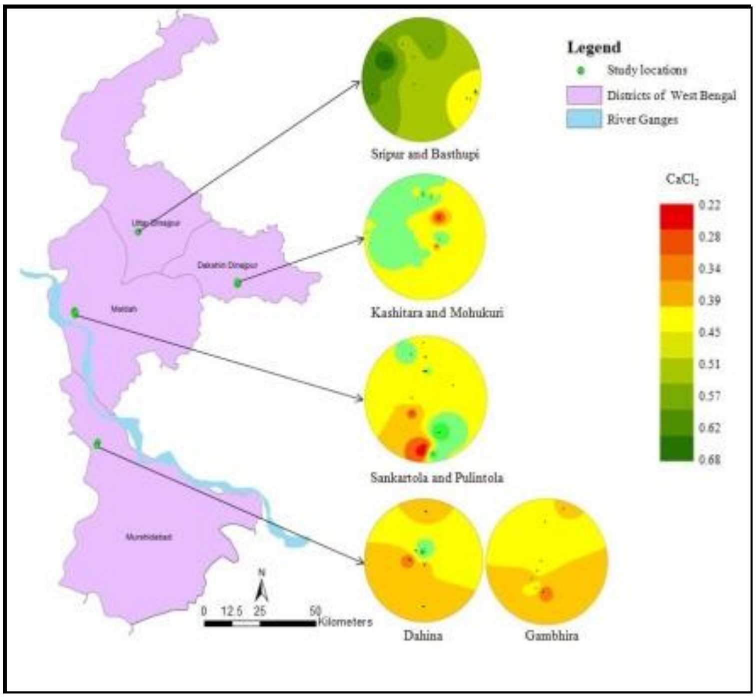

Fig 11: Spatial map on soil B.

Soil DTPA-extractable Zn content of the study area ranged from 0.43 to 1.94 mg kg^{-1}. Considering the value of 0.6 mg kg^{-1} as critical limits of DTPA-extractable zinc, as suggested by Takkar and Mann (1975) [27]. It was observed that about 20, 28.57, 33.3 and 23.07% soil samples of ACS-I, II, III and IV were found deficient in Zn respectively (Fig. 6). Zinc play important role as functional components of enzymes (200 nos.), biomass production, chl formation, pollen function, and fertilization (Hafeez *et al.* 2013) [12]. But in different ACSs, it was observed that about 20-33.3% soil samples of were deficient in Zn. Pictorial presentation of the extent of soil DTPA-Zn deficiency in four agro-climatic situations is illustrated in Fig. 10. The higher degree of Zn deficiency might be due to the limited application of Zn fertilizers and continuous removal of Zn by crops from the soils. Therefore, addition of Zn containing customized fertilizer in adequate quantities (100% RDF), both from organic and inorganic sources will be needed, particularly for the Zn deficient soils to correct the Zn deficiency, fertilizer use efficiency, promote nutrient balance and to enhance crop yield.

Hot water soluble B of the study area ranged from 0.22 to 0.68 mg kg^{-1}. The study also indicated that about 60 to 92.3% soil samples were found deficient (Fig. 6) in soil boron at different agro-climatic situations, and overall 75% of the jute growing soil samples felt under B deficiency. The relatively higher deficiency was observed in ACS-I (80%) and ACS-IV (92.3%). Considering the mean values of B (0.32-0.49 mg kg^{-1}) of different agro-climatic situations, this region can be regarded as B deficient region. The primary function of B is its structural role in the cell wall (Brown *et al.* 2002)[3] and also important for root elongation, leaf expansion, viability of pollen grains and elongation of pollen tubes (Cheng and Rerkasem, 1993) [6]. Considering the mean values of B (0.32-0.49 mg kg^{-1}) at different agro-climatic situations, this jute growing region can be regarded as B deficient region. Among all the micronutrients, boron was noticed to be more deficient micronutrient (60-92.3%) in this region. The spatial map of the boron (hot water soluble) deficiency in four agro-climatic situations is given in Fig. 11. Higher intensity of rainfall and coarse texture soil may leach down boron below the surface soil or root zone, as the B form boric acid in soil which is highly water soluble resulting B deficiency. Therefore, inclusion of boron fertilizer into the nutrient management programme should be considered particularly for very low and low level of boron containing soils.

Soil macro and micronutrient balance in wheat-jute cropping sequence

Chemical fertilizer is solely applied during jute cultivation and farmers are having a tendency to apply only NPK fertilizers therefore, micro-nutrient input is negligible or zero. It was calculated that the N balance is positive for the entire agro-climatic situations with value ranging from 6.93 to 120.56 kg $ha^{-1}year^{-1}$. Phosphorus balance was also positive but relatively less as compared to the nitrogen balance with ranged from 1.51 to 40.4 kg $ha^{-1}year^{-1}$. Potassium balance was noticed negative in the entire agro-climatic region with ranged from -152.85 to -179.72 kg $ha^{-1}year^{-1}$.

Correlation Coefficient between Available Nutrients and Soil Attributes

Pearson correlation coefficients (Table 4) between the available nutrients and soil attributes indicated that the soil available K (r = 0.35**) and Zn (r = 0.42**) was positively and significantly correlated with soil organic carbon (SOC) at 1% level of significance, which indicated the availability of K and Zn in soil system is directly influenced by the SOC content. Soil available P (r = 0.54**) and K (r = 0.63**) were also significantly correlated with pH at 1% level of significance, whereas negative correlation was observed in between the soil pH and Mn (r= -0.37**) at 1% level of significance. Percentage sand content was significant (1% level) negatively correlated with available K (r = -0.50**) and Cu (r = -0.42**), however silt percentage had significant (1% level) positive correlation with available K (r =0.45**) and Cu (r =0.41**). Percentage clay particles had positive significant (5% level) correlation with Mn (r = 0.28*) and B (r = 0.28*), this might be the formation of soluble Mn-organic complexes on the clay surfaces, clay has also positive but non-significant correlation with available P, K, Fe and Cu. The correlation study indicated that the increment of finer soil separates can absorb more amounts of the metallic cations due to the increase in net negative charges in soil. The similar results were studied by Patiram *et al.* (2000) [19] and Vijayakumar *et al.* (2011) [31]. Electrical conductivity had significant (5% level) positive correlation with available P (r = 0.35*) and K (r = 0.33*) and significantly (1% level) negative correlation with Mn (r = -0.37**). Cation exchange capacity (CEC) was positively and significantly correlated with available K (r = 0.38**) at 1% level and also significant positively correlated with available P (r = 0.29*) and B (r = 0.29*) at 5% level of significance respectively. The findings were supported by the Sharma and Chaudhary, (2007) [22]. The available boron content increased with the CEC of the soil showed the significant positive correlation and might be due the more availability of B as anion in the soil with higher CEC indicting less sorption of boron on negatively charged clay surfaces.

Correlation Coefficient between Availability of Soil Nutrients and Jute Yield

The jute yield in the eastern part of India was positively and significantly influenced by the soil available N (r = 0.52**), P (r =0.68**) and K (r = 0.38**) at 1% level of significance, whereas, yield also negative significantly influenced by the soil Cu (r =-0.35*) content at 5% level of significance. Further, the yield of jute at different agro-climatic situations were also influenced by the different soil available nutrients. In the flood prone rainfed situation (ACS-I) jute yield was significantly and positively influenced by the soil available N (r = 0.96**), P (r = 0.94**) and K (r = 0.88**) at 1% level of significance and also with Zn (r = 0.66*) at 5% level of significance. Yield of jute had non-significant positive correlation with available N, P, K, Fe, Mn, Cu and B in the undulated rainfed upland situation agro-climatic situation (ACS-II). In the recent alluvial high flood plain situation, jute yield was significantly and positively influenced by the soil available N (r = 0.56*) and P (r = 0.61*) at 5% level of significance. In the recent alluvial flood prone situation (ACS-IV) yield was also significant positively influenced by the available N (r = 0.76**) at 1% level of significance and also positively influenced by the available P (r = 0.56*) at 5% level of significance.

Table 1: Characteristics of soil sampling site, agro-climatic situations, rainfall distribution, textural classes, crop rotation, nutrient management system and jute (fibre) productivity of the jute growing areas.

Agro climatic situation (ACS)	Sampling location (Latitude, Longitude, District)	No. of sample (n)	Mean annual rainfall (mm)	Mean Temperature Max & Min (^{o}C)	Soil textural groups	Crop rotation practice	Average Jute (fibre) yield (kg ha^{-1})
Flood prone rainfed situation (ACS-I)	25^{0}28ˋ416" - 25^{0}28ˋ484" N 088^{0}10ˋ026" - 088^{0}10ˋ160" E Dist- Uttar Dinajpur	n=10	2087	Max. 39 Min. 10	Sandy loam, sandy clay loam and sandy clay	Wheat-Jute	2006.6
Undulated rainfed upland situation (ACS-II)	25^{0}15ˋ063"- 25^{0}14ˋ502"N 088^{0}37ˋ588" - 088^{0}38ˋ255" E Dist- Dakshin Dinajpur	n=14	1156	Max. 39 Min. 10	Sandy loam, sandy clay loam, clay loam and sandy clay	Wheat-Jute	1770.7
Recent alluvial high flood plain (*Diara*) situation (ACS-III)	25^{0}07ˋ131"- 25^{0}07ˋ251"N 087^{0}52ˋ106" - 087^{0}52ˋ257" E Dist- Malda	n=15	1850	Max. 41 Min. 5	Loam, sandy clay loam, clay loam, sandy clay and clay	Wheat-Jute	2182.5
Recent alluvial flood prone situation (ACS-IV)	24^{0}30ˋ417" - 24^{0}31ˋ474"N 087^{0}58ˋ299" - 087^{0}58ˋ522" E Dist-Murshidabad	n=13	1645	Max. 40 Min. 8	Loam, clay loam and clay	Wheat-Jute	1678.8

Table 2: Descriptive statistics of soil properties in the jute growing areas of Eastern India.

Soil attributes	Mean	SD	Median	Min	Max	Skewness	Kurtosis
						Original attributes	Original attributes
Sand (%)	49.946	14.19	48.85	25.00	77.10	0.185	-0.960
Silt (%)	23.775	11.00	22.85	1.60	44.30	-0.134	-0.960
Clay (%)	26.310	8.23	27.45	10.50	42.60	-0.061	-0.846
pH	5.802	0.779	5.69	4.58	6.97	0.270	-1.201
EC (dSm^{-1})	0.344	0.149	0.31	0.12	0.92	1.224	2.913
SOC (g/kg)	7.056	1.869	7.35	3.30	10.80	-0.095	-0.938
CEC [Cmol(p+)kg^{-1}]	7.544	1.483	7.50	5.22	11.23	0.577	0.159

Table 3: Variation of soil major and micronutrients at different Jute growing situations of Eastern India.

Agro climatic situations (ACs)	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		DTPA-Fe (mg kg^{-1})		DTPA-Mn (mg kg^{-1})		DTPA-Cu (mg kg^{-1})		DTPA-Zn (mg kg^{-1})		Boron (mg kg^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
ACS-I	99.10-575.77	260.9	3.26 -29.22	12.3	15.59-104.16	46.6	5.27-12.44	8.17	1.42-4.33	2.93	0.77-1.40	1.04	0.43-1.22	0.78	0.39-0.68	0.49
ACS-II	124.19 -400.15	237.9	4.81-26.12	12.5	15.46-164.10	54.6	4.98-12.41	8.63	0.98-3.90	2.14	0.74-1.40	1.05	0.49-1.30	0.81	0.27-0.64	0.45
ACS-III	86.55-425.24	284.8	12.00-29.50	21.3	104.16-202.27	147.1	5.78-13.14	9.42	0.92-3.60	1.50	0.56-1.61	1.12	0.47-1.24	0.73	0.22-0.60	0.42
ACS-IV	99.10-387.61	224.5	6.88-26.23	12.3	48.38-183.46	117.6	4.33-12.42	7.11	1.72-3.44	2.62	0.89-3.14	2.03	0.48-1.94	0.87	0.28-0.55	0.39
Overall	86.55-575.77	252.52	3.26-29.50	14.97	15.46-202.27	95.49	4.33-13.14	8.39	0.92-4.33	2.23	0.56-1.61	1.31	0.43-1.94	0.80	0.22-0.68	0.44

Table 4: Correlation coefficient between available nutrients and other soil attributes.

Parameters	N	P	K	Fe	Mn	Cu	Zn	B
Sand	0.13	-0.09	-0.50**	-0.12	-0.11	-0.42**	0.14	0.08
Silt	-0.16	0.01	0.45**	0.04	-0.07	0.41**	-0.07	-0.31*
Clay	-0.01	0.16	0.27	0.15	0.28*	0.17	-0.15	0.28*
pH	0.22	0.54**	0.63**	0.02	-0.39*	-0.20	-0.05	-0.05
EC	0.21	0.35*	0.33*	-0.02	-0.37**	-0.19	0.155	-0.03
SOC	0.14	0.13	0.37**	0.13	0.06	0.15	0.42**	0.25
CEC	0.09	0.29*	0.38**	0.14	0.10	0.02	-0.13	0.29*

**, * Correlation is significant at the 0.01level and 0.05 level respectively (2-tailed).

Table 5: Relationship between available soil nutrient and fibre yield at different agro-climatic jute growing situations of Eastern India.

Yield-ACS	N	P	K	Fe	Mn	Cu	Zn	B
Yield-I	0.96**	0.94**	0.88**	-0.40	0.12	0.30	0.66*	0.22
Yield-II	0.40	0.66	0.54	0.25	0.11	0.23	-0.38	0.42
Yield-III	0.56*	0.61*	0.31	-0.06	-0.03	-0.02	-0.11	0.04
Yield-IV	0.76**	0.56*	-0.31	-0.36	0.05	-0.09	-0.20	0.36
Yield-Overall	0.52**	0.68**	0.38**	0.17	-0.25	-0.35*	-0.13	0.19

**, * Correlation is significant at the 0.01 level and 0.05 level respectively (2-tailed).

Conclusion

The present study undertaken to outline the variability of the available soil nutrient status and the extent of deficiency or toxicity at the different jute growing situations of Eastern India to help a great deal the for optimum fertilizer management for sustainable production for the region. Solely application of limited amount of major (NPK) inorganic nutrient resulted in huge major (NPK) and micronutrient deficiency particularly Mn, Zn and B in different agro-climatic jute growing areas of eastern India. The results showed that the extent of NPK nutrient deficiency in this jute growing region was 55.8, 82.7 and 73.1% respectively. Among the micronutrients Fe (1.92%), Mn (51.9%), Zn (25%) and B (75%) were also found deficient. Fertilizer application scenario conclude positive nitrogen and phosphorus balance but negative balance was observed in application of K, Fe, Mn, Cu, Zn and B fertilization.

Availability of the soil nutrients regulated significantly by the different soil attributes. Further, the jute yield was significantly influenced by both the major and micronutrients at different agro-climatic situations and therefore optimum nutrient management in these study areas was suggested for judicious utilization of chemical fertilizers for sustainable and economic crop productivity.

References

1. Anonymous. Jute-The Golden Fibre of India. Message from Director. CRIJAF, 2016 www.crijaf.org.in assessed on 11th July, 2016.
2. Berger KC, Truog E. Boron determination in soils and plants. Industrial and Eng. Chem. Anal. Edition. 1939; 11:540-545.
3. Brown PH, Bellaloui N, Wimmer MA, Bassil ES, Ruiz J, Hu H *et al*. Boron in plant biology. Plant Biol. 2002; 4:205-223.
4. Burkhead JK, Reynolds KA, Abdel-Ghany SE, Cohu CM, Pilon M. Copper homeostasis. The New Phytol. 2009; 182:799-816.
5. Camacho-Tamayo JH, Luengas CA, Leiva FA. Effect of agricultural intervention on the spatial variability of some soils chemical properties in the eastern plains of Colombia. Chil J Agric Res. 2008; 68:42-55.
6. Cheng C, Rerkasem B. Effect of boron on pollen viability in wheat. Plant and Soil. 1993; 155:313-315.
7. Das J, Talukdar MC. Available copper, manganese, iron and zinc in five different soil associations of Barpeta district of Assam. New Agriculturist. 2003; 14:23-25.
8. Davatgar N, Neishabouri MR, Sepaskhah AR. Delineation of site specific nutrient management zones for a paddy cultivated area based on soil fertility using fuzzy clustering. Geoderma. 2012; 173-174:111-118.
9. Dobermann A. Nutrient use efficiency-Measurement and management. In IFA international workshop on fertilizer best management practices Brussels, Belgium: IFA, 2007, 1-28.
10. Gao S, Yan R, Cao M, Yang W, Wang S, Chen F. Effects of copper on growth, antioxidant enzymes and phenylalanine ammonia-lyase activities in *Jatropha curcas* L. seedling. Plant, Soil and Environ. 2008; 54:117-122.
11. Gyaneshwar P, Kumar GN, Parekh LJ, Poole PS. Role of soil microorganisms in improving P nutrition of plants. Plant and Soil. 2002; 245:83-93.
12. Hafeez B, Khanif YM, Saleem M. Role of zinc in plant nutrition: A review, American J of Agric. Econ. 2013; 3:374-391.
13. Jackson ML. Soil Chem. Anal., Prentice hall of India Pvt. Ltd, New Delhi, 1973.
14. Lindsay WL, Norvell WA. Development of DTPA soil tests for Zn, Fe, Mn and Cu. Soil Science Society of America J. 1978; 42:421-428.
15. Mathur GM, Ram Deo, Yadav BS. Status of zinc in irrigated north-west plain soils of Rajasthan. Journal of the Indian of Society Soil Science. 2006; 53:359-361.
16. Mitra, G. Essential plant nutrients and recent concepts about their uptake. Essential plant nutrients, uptake use efficiency and manage. Naeem, Ansari, Gill Eds. Springer, 2017, 1-36.
17. Page AL, Miller RH, Keeney DR. Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. 2nd Edition. ASA and SSSA, Madison, Wisconsin, 1982.
18. Pati R, Mukhopadhyay D. Distribution of Cationic Micronutrients in Some Acid Soils of West Bengal. J of the Indian Society of Soil Sci. 2011; 59:125-133.
19. Patiram R, Upadhyaya C, Singh CS, Munna R, Ram M. Micronutrient cation status of mandarin (*Citrus reticulata* Blanco) orchards of Sikkim. J of the Indian Society of Soil Sci. 2000; 48:246-249.

20. Rout GR, Sahoo S. Role of iron in plant growth and metabolism. Rev. in Agric. Sci. 2015; 3:1-24.
21. Sharma BD, Raj K, Singh B, Sethia M. Micronutrients distribution in salt-affected soils of the Punjab in relation to soil properties. Archives of Agron. and Soil Sci. 2009; 55:367-377.
22. Sharma JC, Chaudhary SK. Vertical Distribution of Micronutrient Cations in Relation to Soil Characteristics in Lower Shiwaliks of Solan District in North-West Himalayas. J of Indian Society of Soil Sci. 2007; 55:40-44.
23. Singh RD, Kumar S, Pande H. Micronutrient status of soils under different vegetations in Uttaranchal Hills. J of the Indian Society of Soil Sci. 2006; 54:115-116.
24. Shen J, Yuan L, Zhang J, Li H, Bai Z, Chen X *et al*. Phosphorus dynamics; form soil to plant. Plant Physiol. 2011; 156:997-1005.
25. Somasundaram J, Singh RK, Parandiyal AK, Prasad SN. Micronutrient status of soils under different land use systems in Chambal ravines. J Indian Soc. Soil Sci. 2009; 57:307-312.
26. Subbiah BV, Asija GL. A rapid procedure for the determination of available Nitrogen in Soils. Curr. Sci. 1956; 25:259-260.
27. Takkar PN, Mann MS. Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab. Agrochemica. 1975; 19:420-430.
28. Talukdar MC, Basumatary A, Dutta SK. Status of DTPA–extractable Cationic Micronutrients in Soils under Rice and Sugarcane Ecosystems of Golaghat Dictrict in Assam. J of the Indian Society of Soil Sci. 2009; 57:313-316.
29. Tandon HLS, Muralidharudu Y. Nutrient uptake removal & recycling by crops, Fertilizer Development and Consultation Organization, New Delhi, India ISBN 81-85116-61-X, 2010.
30. Venkatesh MS, Majumdar B, Kumar K, Patiram. Status of micronutrient cations under various land use systems of Meghalaya. J of the Indian Society of Soil Sci. 2003; 51:60-64.
31. Vijayakumar R, Arokiaraj A, Martin DPP. Micronutrients and their Relationship with Soil Properties of Natural Disaster Proned Coastal Soils. Research J of Chem. Sci, 2011; 1:8-12.
32. Yadav RL, Meena MC. Available Micronutrient status and their relationship with soil properties of Degana soil series of Rajasthan. J of the Indian Society of Soil Sci., 2009; 57:90-92.
33. Yao YA, Sun HY, FS X, Zhang XJ, Liu SY. Comparative proteome analysis of metabolic changes by low phosphorus stress in two *Brassica napus* genotypes. Planta. 2011; 233:523-537.
34. Zingore S, Murwira HK, Delve RJ, Giller KE. Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. Agric Ecosys Environ. 2007; 119:112-126.