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Zinc fractions and their dynamic relationship with physico-chemical properties of rice growing soils of Boko block, Kamrup (rural) district Assam

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ABSTRACT

Distribution of various pools of soil zinc (Zn) and their active and strong relationships with some specific and distinct physico-chemical parameters of soil in sixty (60) geo-referenced rice growing soils samples (0-15 cm) namely (Ahu) rice growing soils, (Sali) rice growing soils and (Boro) rice growing soils from Boko block, Kamrup, Assam along with the available Zn status of those samples. The distribution of Zn-fractions followed a general order of dominance as WSEX-Zn<CRYOX-Zn<COMP-Zn<AMOX-Zn<RES-Zn<TOT-Zn in all the rice growing soils and was regulated by soil characteristics, dominantly, soil pH, CEC, soil organic carbon and clay content in all the soils studied. The transformation of zinc in these soils showed that for Ahu rice growing soils 94.9% of the zinc remained as residual zinc which will eventually go back to different mineral fractions leaving only 0.4%, 1.2%, 1.5%, 0.5% of the soil zinc as WSEX-Zn, COMP-Zn, AMOX-Zn and CRYOX-Zn,respectively. Similarly, for Sali rice growing soils it was seen that 96.3% remained as residual zinc whereas 0.5%, 1.5%, 2.0% and 0.6% were found as WSEX-Zn, COMP-Zn, AMOX-Zn and CRYOX-Zn respectively. For Boro rice growing soils 95.1% of the soil zinc went back to the residual zinc fraction leaving 0.8%, 1.6%, 2.1% and 0.7% of the zinc as WSEX-Zn, COMP-Zn, AMOX-Zn and CRYOX-Zn respectively. The fraction WSEX-Zn, COMP-Zn, AMOX-Zn and CRYOX-Zn was comparatively high in Boro rice while RES-Zn and TOT-Zn were higher in Sali rice. Comparatively, high amount of DTPA extractable zinc was observed in Boro rice growing soils (1.25 mg kg $^{-1}$, mean) followed by Sali rice (1.08 mg kg $^{-1}$) and Ahu rice (1.01 mg kg $^{-1}$). Overall contribution of DTPA-Zn was only 0.67% towards total zinc in these soils. Soils under Ahu rice cultivation contained the lowest amount of all the Zn fractions. All the Zn-fractions were significantly and negatively correlated with soil pH and positively with SOC and clay. Stepwise multiple regression indicated that in Ahu rice growing soils, SOC contributed the highest variations towards the plant available pools of zinc i.e., WSEX-Zn (64.2%) fraction and COMP-Zn (44.9%) while for Sali rice, clay contributed maximum variation for WSEX-Zn (36.8%), while maximum contribution was noticed in CEC for COMP-Zn (39.4%). In Boro rice growing soils, CEC showed maximum contribution towards WSEX-Zn fraction (64.2%) while it was SOC for COMP-Zn (56.8%) that contributed maximum towards the variability of zinc. All the soil properties together account for 30.6% to 78.1% variation for all the fractions in Ahu rice growing soils, 22.9% to 69.3% in Sali rice and 51.1% to 87.5% in Boro rice growing soils. Among all the soil samples studied (N=60) under Ahu, Sali and Boro rice growing areas, overall, 58% of the samples were found to be below critical level in DTPA extractable Zn.

Keywords: WSEX-Zn, CRYOX-Zn, COMP-Zn, AMOX-Zn, RES-Zn, TOT-Zn, DTPA-Zn

INTRODUCTION

One of the most widespread and frequent micronutrient deficiency problem in crop plants worldwide is that of zinc deficiency which leads to severe losses in yield and it renders the crop from its nutritional quality. Zinc deficiency was first identified as a field problem in rice in 1966 (Nene, 1966). Next to nitrogen (N) and phosphorus (P) deficiency, Zn deficiency is now considered the most prevalent nutrient disorder in lowland rice (Quijano-Guerta *et al.,* 2002). It was found that 36.93% of Zn deficiency exists in soils of Kamrup (rural) district of Assam (Anonymous, 2018). Deficiency of zinc explicitly in lowland rice is very common particularly in fields where fertilizer responsive HYVs of crop are mostly grown. Even the recovery of the fertilizer zinc applied as a measure to correct such deficiencies in rice is extremely negligible due to the transformation of it to different pools (Mandal and Mandal, 1987). These forms differ significantly in their relative solubilities and hence availability to plants due to sorption-desorption reactions held at the surfaces of soil colloidal materials (Swift and McLaren, 1991). Desorption of Zn into soil solution depends on the soil characteristics, particularly pH, cation-exchange capacity (CEC), clay content and oxides of minerals (Harter, 1991; Hazra and

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Mandal, 1996). Rice fields are often subjected to different moisture regimes vis-a-vis continuously flooded, intermittent flooding and drying and preflooded condition before transplanting, when there is an early monsoon. These different soil moisture regimes bring about varying changes in soil physico-chemical and electro-chemical properties such as pH, EC, and amorphous and crystalline oxides of Fe and Mn, which are further accentuated by application of organic matter or manures, a common practice followed by rice farmers in this region. Hazra *et al.* (1987) observed that a small fraction of the total zinc occurred as water soluble plus exchangeable, organic complexed, amorphous sesquioxide-bound, and crystalline sesquioxide-bound forms. Hence, we conducted the present investigation with the aim to study the distribution of different fractions zinc and their close relationship with some physico-chemical properties of purely rice growing soils vis-à-vis *(Ahu)* rice growing soil, (*Sali)* and (*Boro)* rice growing soils.

MATERIALS AND METHODS

Laboratory experiments were conducted with soil samples collected from surface layer (0-15 cm) of lowland *Ahu* rice, *Sali* rice and *Boro* rice fields situated in Boko block, Kamrup district of Assam, a major rice growing state in India. The samples were grounded, sieved, and analysed for various physico-chemical properties such as particle size analysis by International pipette method as described in ISSS (1929) using sodium hydroxide as dispersing agent, Soil pH (Jackson, 1973), Electrical Conductivity (Jackson, 1973), Organic Carbon by Walkley and Black's wet oxidation method as described by Jackson (1973) and CEC (Jackson, 1973). The mean values of those properties are given in Table 1. The soil samples were analysed for different pools of zinc following the procedure of Murthy (1982). The flowchart of the same has been shown in (Fig. 1). For DTPA-Zn estimation mixed the soil with DTPA extractant at a ratio of 1:2 and shaked for 2 hours and filtered with Whatman No. 42 filter paper and analysed the aliquot in AAS following extraction procedure of (Lindsay and Norvel, 1978). For Total Zn estimation, 0.1g soil was digested with few drops of H_2SO_4 along with 5 ml of HF+0.5 ml of $HClO_4$ in a 30ml capacity platinum crucible. The residue to be digested with 6N HCl and analysed in AAS.

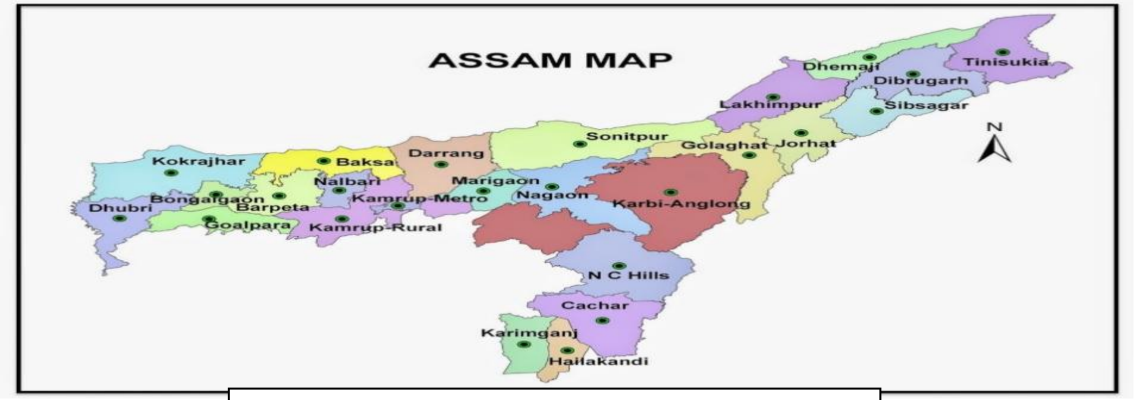

Fig: 3.1 Map showing Kamrup (rural) district, Assam

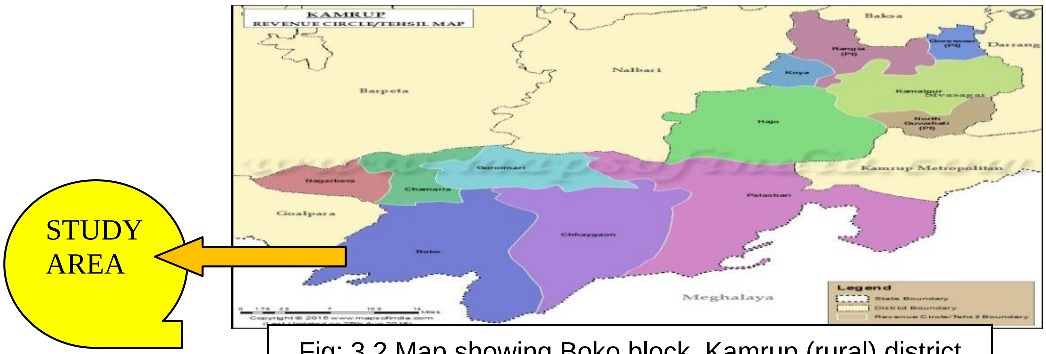

Fig: 3.2 Map showing Boko block, Kamrup (rural) district

Fig. 1: Flowchart for Zinc Fractionation

RESULTS AND DISCUSSIONS

Water-soluble plus exchangeable zinc (WSEX-Zn)

This fraction ranged from 0.36 mg kg^{-1} to 1.28 mg kg^{-1} for *Ahu* rice, 0.33 mg kg^{-1} to 1.22 mg kg^{-1} for *Sali* rice and 0.57 mg kg^{-1} to 1.29 mg kg^{-1} for *Boro* rice growing soils. It was observed that WSEX-Zn fraction contributed the lowest in case of *Ahu* rice growing soils i.e., 0.4% towards total zinc, whereas, for *Sali* rice it was 0.5% and 0.8% for *Boro* rice growing soils which is quite high. These may be due to the consequence of high buffering capacity of these soils which resulted in low amount of WSEX zinc (Deb, 1977) or due to precipitation of soluble zinc as hydroxide and carbonates upon submergence (Kumar and Basavaraj, 2008). This fraction was found to have significant positive correlation with clay content (r = 0.698**), SOC (r = 0.802**) and CEC (r = 0.580**), for *Ahu* rice growing soils whereas it was negatively and significantly correlated towards soil pH (r = -0.480*). Similarly, it was found that for *Sali* and *Boro* rice growing soils this fraction had a significant and positive correlation with clay content (r = 0.607**), SOC (r = 0.517*), CEC (r = 0.552*) and (r = 0.478*) for clay, SOC (r = 0.787**) and CEC (r = 0.801**), respectively suggesting that clay and organic matter provided more exchange sites for adsorption of zinc (Dhane and Shukla, 1995). Strong and positive correlation coefficient of this fraction with COMP-Zn, AMOX-Zn, CRYOX-Zn, TOT-Zn and DTPA-Zn indicates their interdependence.

Table 1: Mean values of physico-chemical properties of 60 rice growing soils in 3 ecosystems (20 each ecosystem)

Parameters	*Ahu* rice	*Sali* rice	*Boro* rice
Sand (%)	39.59±11.53	40.33±8.13	34.09±6.03
Silt (%)	33.05±9.29	26.95±5.23	29.11±6.81
Clay (%)	27.37±7.86	33.18±7.30	36.81±1.97
pH	5.27±0.41	4.94±0.23	5.07±0.15
EC (dS m^{-1})	0.09±0.01	0.06±0.02	0.09±0.02
SOC (%)	0.77±0.16	1.02±0.10	1.09±0.06
CEC{cmol (p+)kg $^{-1}$}	8.66±0.92	8.80±1.03	8.90±0.86

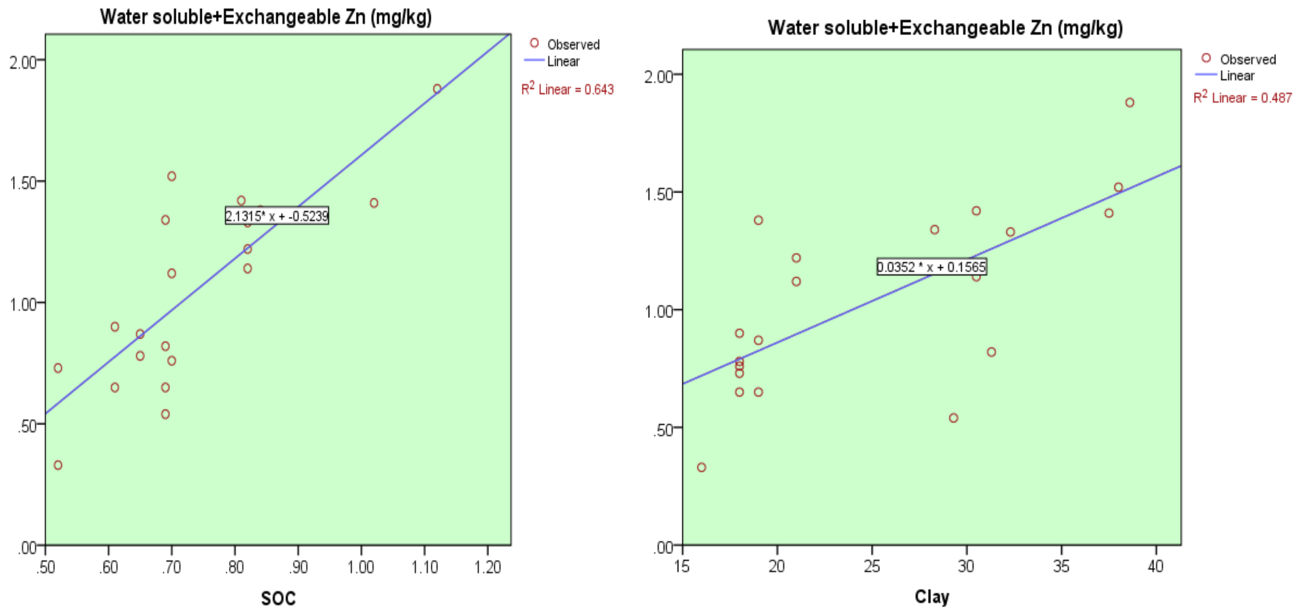

Fig 4.1: Water soluble plus exchangeable zinc vs SOC, sand and clay (*Ahu* rice growing soils)

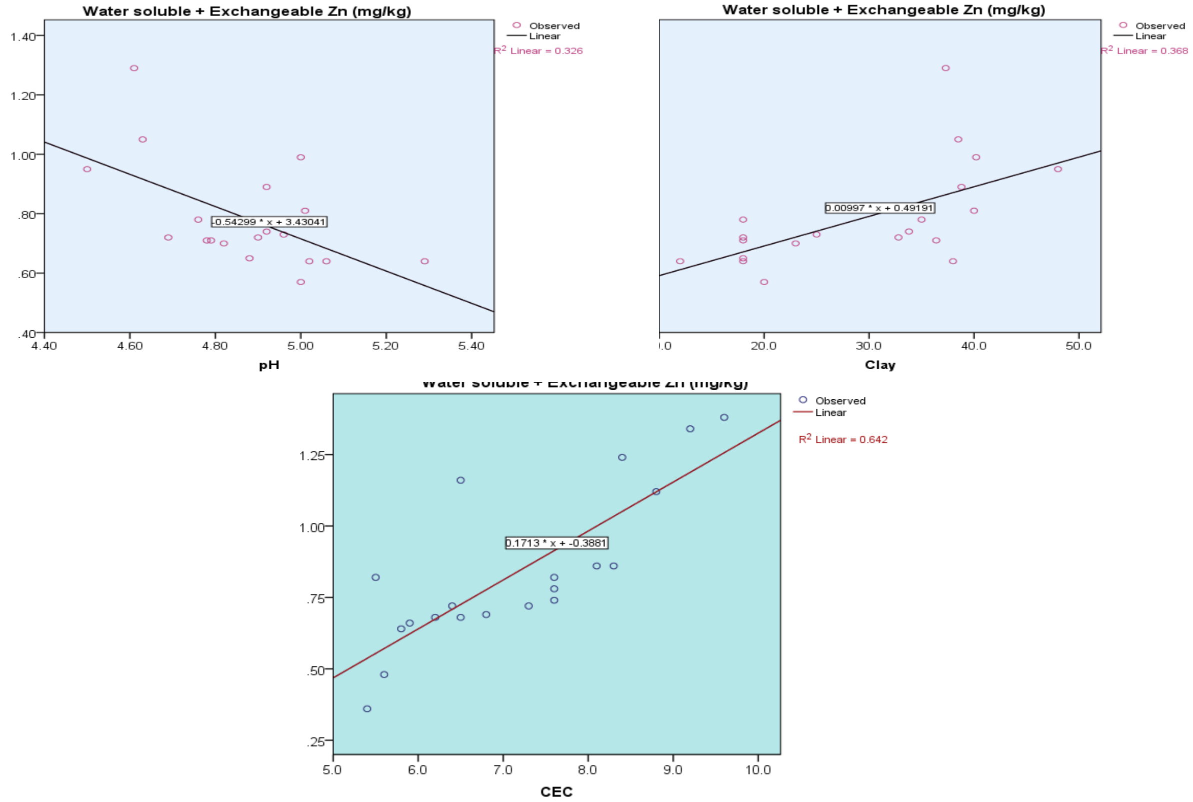

Fig 4.2: Water soluble plus exchangeable zinc vs pH, clay and SOC (*Sali* rice growing soils)

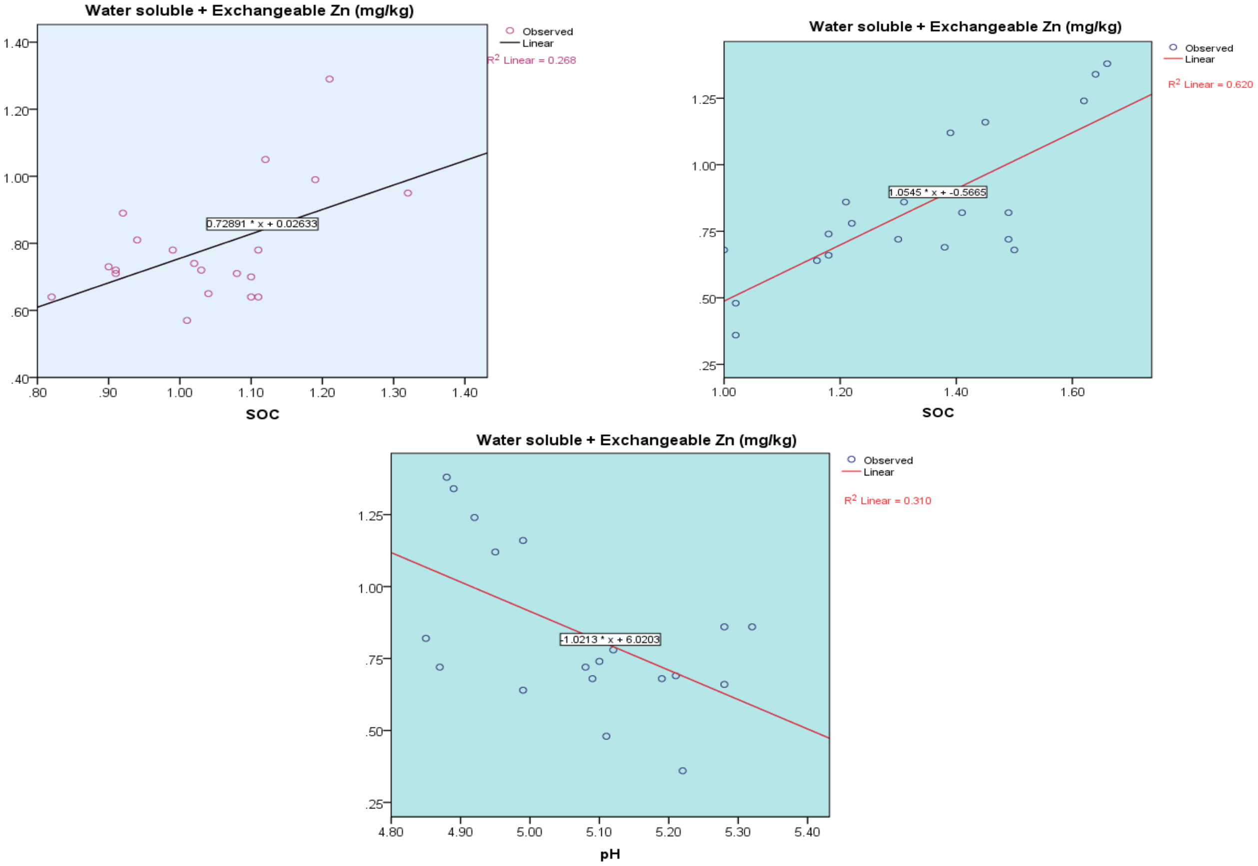

Fig 4.3: Water soluble plus exchangeable zinc vs CEC, pH and SOC (*Boro* rice growing soils)

Complexed zinc (COMP-Zn): The Cu $(OAc)_2$ extractable fraction for *Ahu* rice growing soils varied from 1.12 mg kg^{-1} to 3.50 mg kg^{-1}, 1.62 mg kg^{-1} to 3.68 mg kg^{-1} for *Sali* rice and 2.29 mg kg^{-1} to 4.15 mg kg^{-1} for *Boro* rice growing soils. This fraction contributed 1.2%, 1.5% and 1.6% towards total zinc in soils under *Ahu, Sali* and *Boro* rice cultivation, respectively. The variation in its contents might be due to degree of abundance of parent materials (Yaduvanshi *et al.,* 1988) under different rice cultivation. The decrease in this fraction might be due to microbial immobilization of zinc. COMP-Zn was found to have a positive significant correlation with SOC (r = 0.542*, 0.472*, r = 0.754**), clay (r = 0.525*, r = 0.553*, r = 0.495*) and CEC (r = 0.487*, r = 0.592**, r = 0.507*) for *Ahu*, *Sali* and *Boro* rice growing soils respectively. COMP-Zn depicted significant negative correlation with soil pH which can be due to complex formation and reducing solubility with increasing pH of the soil (Athokpam *et al.,* 2018).This fraction did show positive but insignificant correlation with all the fractions except for TOT-Zn (r = 0.470*) and DTPA-Zn (r = 0.467*) in *Ahu* rice growing soils and TOT-Zn (r = 0.470*) and DTPA-Zn (r = 0.502*) for *Sali* rice growing soils as well. However, for *Boro* rice growing soils COMP-Zn showed positive significant correlation with AMOX-Zn (r = 0.932**), CRYOX-Zn (r = 0.883**), RES-Zn (r = 0.967**), TOT-Zn (r = 0.968**) and DTPA-Zn (r = 0.738**) indicating the co-existence of all the fractions together and their interdependency on one another.

Table 2: Correlation coefficient among selected soil properties with zinc fractions of *Ahu* rice growing soils of Boko block, Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
pH	-0.480*	-0.470*	-0.710**	-0.484*	-0.529*	-0.452*	-0.449*
EC	0.398	0.316	0.431	0.423	0.164	0.112	0.114
SOC	0.802**	0.542*	0.686**	0.402	0.643**	0.465*	0.533*
CEC	0.580**	0.487*	0.420	0.410	0.356	0.664**	0.497*
Sand	-0.386	-0.379	-0.297	-0.257	-0.381	-0.421	-0.393
Silt	0.385	0.268	0.354	-0.042	0.108	0.070	0.201
Clay	0.698**	0.525*	0.656**	0.353	0.582**	0.714**	0.477*

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

Amorphous sesquioxide zinc (AMOX-Zn): The ammonium oxalate extractable zinc fraction ranged from 2.01 mg kg^{-1} to 3.42 mg kg^{-1}, 2.73 mg $kg^{-1}$to 3.90 mg kg^{-1}, 3.24 mg kg^{-1} to 4.64 mg kg^{-1} for *Ahu, Sali* and *Boro* rice growing soils respectively. From the data it also shows that this fraction availability is more in *Boro* rice growing soils succeeded by *Sali* and *Ahu* rice growing soils. The contribution of AMOX-Zn towards total zinc was recorded to be 2.1%, 2.0% and 1.5% for *Ahu, Sali* and *Boro* rice cultivation respectively which is quite high compared to CRYOX-Zn which can be attributed to the fact that more of the free iron oxides content of these soils may be present in AMOX-Zn form. This fraction has a significant negative correlation with soil pH at 1% level of significance for *Ahu* rice growing soils (r = -0.710**), *Sali* rice growing soils (r = -0.628**) and *Boro* rice growing soils (r = -0.563**) which is due to natural reduction in oxide solubility and concentration as pH increases (Shiowatana *et al.,* 2005; Ramzan *et al.,* 2014). Also, it was observed that it has a positive significant correlation with clay and SOC for all the three rice growing soils viz., *Ahu* (r = 0.656**, r = 0.686**), *Sali* (r = 0.613**, r = 0.606**) and *Boro* (r = 0.472*, r = 0.728**) rice, respectively. AMOX-Zn shows a strong positive and significant correlation with CRYOX-Zn (r = 0.525*, r = 0.593*, r = 0.903**) for *Ahu, Sali* and *Boro* rice, respectively. Similarly, for TOT-Zn this fraction showed significant positive correlation with *Ahu, Sali* and *Boro* rice growing soils viz., (r = 0.519*, r = 0.482*, r = 0.940**), respectively and for DTPA zinc as well with (r = 0.563**, r = 0.581**, r = 0.647**) for *Ahu, Sali* and *Boro* rice growing soils, respectively.

Table 3: Correlation coefficient among selected soil properties with zinc fractions of *Sali* rice growing soils of Boko block, Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
pH	-0.571**	-0.485*	-0.628**	-0.478*	-0.479*	-0.544*	-0.557*
EC	0.428	0.127	0.452*	-0.339	-0.004	0.003	0.203
SOC	0.517*	0.472*	0.606**	0.344	0.508*	0.515*	0.445*
CEC	0.552*	0.592**	0.221	0.302	0.314	0.524*	0.462*
Sand	-0.441	-0.327	-0.411	-0.223	-0.418	-0.332	-0.377
Silt	-0.106	0.331	0.017	-0.271	0.035	0.039	0.164
Clay	0.607**	0.553*	0.613**	0.347	0.610**	0.625**	0.478*

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

Crystalline sesquioxide bound zinc (CBD-Zn): The CBD-Zn extractable zinc was found to be very low and the percent contribution towards total zinc was only 0.5%, 0.6% and 0.7% for *Ahu, Sali* and *Boro* rice growing soils, respectively. The contribution of this fraction is always lower than AMOX-Zn which could be due to greater ability of AMOX-Zn to adsorb more amount of zinc due to its high specific surface area (Wijebandara *et al.,* 2011). Further the crystallinity of iron oxides might have interfered with trace metal extraction like zinc as suggested by Nolovic (1978). This fraction had a significant negative correlation with soil pH for *Ahu* (r = -0.484*), *Sali* (r = -0.478*) and *Boro* (r = -0.698**) rice growing soils but it did not have and other significant correlation with other soil properties even though it was found to be positive with some of those properties. This fraction has a significant positive correlation with RES-Zn (r = 0.494*) and TOT-Zn (r = 0.582**) for *Ahu* rice growing soils. Similarly, for *Sali* rice growing soils the values were (r = 0.474*) and (r = 0.490*) for RES-Zn and TOT-Zn respectively. In contrast, for *Boro* rice growing soils the correlation values were found to be (r = 0.910**) for RES-Zn and (r = 0.912**) and TOT-Zn, respectively at 1% level of significance.

Table 4: Correlation coefficient among selected soil properties with zinc fractions of *Boro* rice growing soils of Boko block of Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
pH	-0.557*	-0.572**	-0.563**	-0.698**	-0.626**	-0.626**	-0.469*
EC	0.421	0.318	0.352	0.405	0.544*	0.546*	0.419
SOC	0.787**	0.754**	0.728**	0.315	0.735**	0.736**	0.595**
CEC	0.801**	0.507*	0.302	0.353	0.362	0.562**	0.466*
Sand	-0.282	-0.153	-0.155	-0.019	-0.167	-0.166	-0.125
Silt	-0.149	-0.301	-0.244	-0.346	-0.260	-0.261	-0.333
Clay	0.478*	0.495*	0.472*	0.340	0.488*	0.498*	0.476*

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

Residual zinc: Perusal of data indicated that it is the dominant fraction contributing more than 95% of the total zinc. The residual zinc contributed the maximum towards the total zinc which shows that most part of zinc remain as unavailable to the plants in the soil. This fraction ranged from 86.52 mg kg^{-1} to 188.52 mg kg^{-1} for *Ahu* rice cultivated soils, 123.01 mg kg^{-1} to 285.92 mg kg^{-1} for S*ali* rice growing soils and for *Bor*o rice it is 105.45 mg kg^{-1} to 285.12 mg kg^{-1}. Under reduced condition some of the CBD-Zn might have undergone transformation to AMOX-Zn resulting in release of a part of the occluded zinc from the former. This fraction is asociated with the mineral fraction of zinc. Results also showed that water logging resulted in marked increase in the residual zinc in soil which indicated substantial mobilization of zinc to residual fraction (Rajini *et al.,* 2018).Analysis of data showed that this fraction had positive and significant correlation with clay (r = 0.582*) and SOC (r = 0.643**), SOC (r = 0.508*) and clay (r = 0.610**) and clay (r = 0.488*) and SOC (r = 0.735**) at 5% and 1% level of significance for *Ahu, Sali* and *Boro* rice growing soils, respectively which indicated residual zinc was also present with resistant organic matter and iron oxides (Singh *et al.,* 1998). This fraction has got positive and significant correlation with TOT-Zn (r = 0.590*), DTPA-Zn (r = 0.547*) for *Ahu* rice, whereas for *Sali* rice the significant correlation was established with TOT-Zn (r = 0.999**) and for *Boro* rice it was significantly and positively correlated with TOT-Zn (r = 0.999**) and DTPA-Zn (r = 0.697**) respectively.

Table 5: Correlation coefficient amongst zinc fractions of *Ahu* rice growing soils of Boko block of Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
WSEX-Zn	1	0.592**	0.539*	0.524*	0.348	0.475*	0.469*
COMP-Zn		1	0.432	0.401	0.312	0.470*	0.467*
AMOX-Zn			1	0.525*	0.785**	0.519*	0.563**
CRYOX-Zn				1	0.494*	0.582**	0.344
RES-Zn					1	0.590**	0.547*
TOT-Zn						1	0.482*
DTPA-Zn							1

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

Total zinc: The total zinc fraction varied from 93.43 mg kg^{-1} to 196.75 mg kg^{-1}, 129.94 mg kg^{-1} to 294.97 mg kg^{-1} and 111.91 mg kg^{-1} to 297.45 mg kg^{-1} in *Ahu, Sali* and *Boro* rice growing soils, respectively. The maximum value for total zinc has been witnessed in *Sali* followed by *Boro* and A*hu* rice cultivated soils. This variation might be attributed to the dissimilarity in their parent material (Krishnakumar and Patty, 1992).Total zinc exhibited positive and significant correlation with clay (r = 0.714**), SOC (r = 0.465*), CEC (r = 0.664**) for *Ahu*, (r = 0.625**), (r = 0.515*), (r = 0.524*), in case of *Sali* and (r = 0.498*) (r = 0.736**), (r = 0.562**) for*Boro* rice growing soils respectively. In general clay, SOC, CEC are the basic properties associated with total zinc. Total zinc was found to be positively and significantly correlated with DTPA extractable zincand statistically significant relationship was observed for all the rice growing soils viz., *Ahu* (r = 0.482*), *Sali* (r = 0.520*) and *Boro* (r = 0.680**).

Table 6: Correlation coefficient among different zinc fractions of *Sali* rice growing soils of Boko block of Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
WSEX-Zn	1	0.476*	0.640**	0.146	0.222	0.471*	0.615**
COMP-Zn		1	0.208	0.118	0.204	0.470*	.0.502*
AMOX-Zn			1	0.593*	0.252	0.482*	0.581**
CRYOX-Zn				1	0.474*	0.490*	-0.013
RES-Zn					1	0.999**	0.203
TOT-Zn						1	0.520*
DTPA-Zn							1

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

DTPA-Zinc: Diethylene Triamine Penta Acetic acid is universally employed to extract plant available fraction of zinc which is the crop available fraction and it was observed that this fraction is present in highest amount in *Boro* rice cultivation (0.78 mg kg^{-1} to 1.86 mg kg^{-1}) followed by *Sali* (0.89 mg kg^{-1} to 1.34 mg kg^{-1}) and *Ahu* (0.66 mg kg^{-1} to 1.62 mg kg^{-1}*)* rice. Taking into consideration of 1.12 mg kg^{-1} of DTPA-Zn as the critical limit for paddy soil, 70% of the samples were found to be deficient under *Ahu* rice cultivation, 55% under *Sali* and 50% under *Boro* rice cultivation. The DTPA- Zn negatively and significantly correlated with soil pH at 5% level of confidence (r = -0.449*) whereas positively and significantly correlated with clay (r = 0.477*) CEC (r = 0.497*) and SOC (r = 0.553*) in *Ahu* rice growing soils. For *Sali* rice this fraction significantly and negatively correlated with pH (r = -0.557*) and positively with clay (r = 0.478*), CEC (r = 0.462*) and SOC (r = 0.445*). In contrast, for *Boro* rice growing soils, DTPA-Zn showed significant positive correlation with SOC (r = 0.595**), CEC (r =

0.466*), clay (r = 0.476*) while with pH it was negatively significant with (r = -0.469*). The negative correlation indicated that at higher pH insoluble calcium zincate or higher oxides of zinc might have been formed, and zinc bound in these forms does not come into the solution easily. Negative correlation with DTPA-Zn and pH shows due to higher solubility of oxides and hydroxides of zinc with decrease in pH (Lins and Cox 1988). The positive correlation of zinc with organic carbon indicated release of zinc during mineralization of soil organic matter (Sarkar *et al.,* 2000). It could be attributed to the production of chelating agents that transform solid phase of zinc cations into soluble metallic complexes revealing the existence of positive relationship (Talukdar *et al.,* 2009).

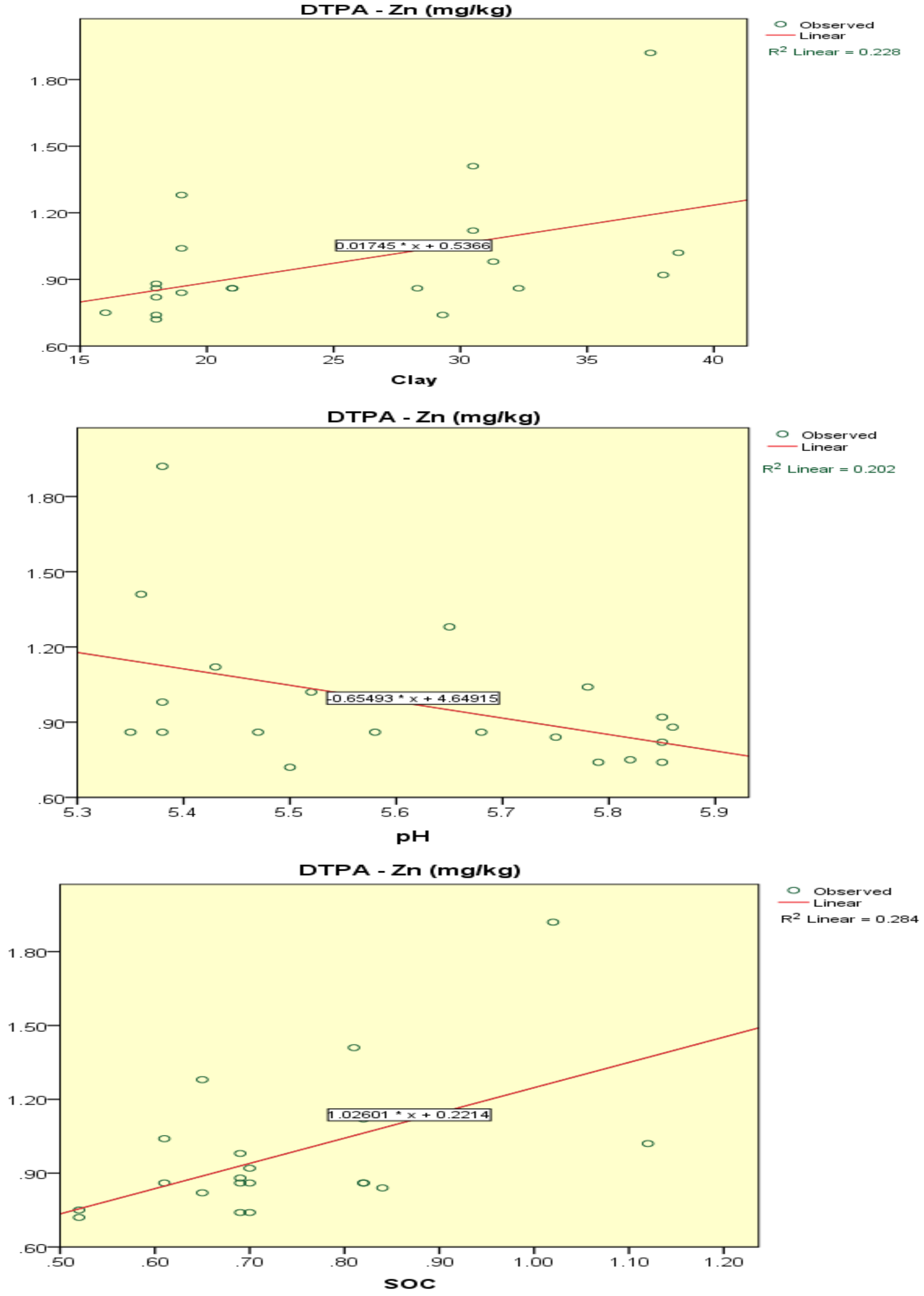

Fig 4.4: DTPA Zn vs SOC, clay, and pH (*Ahu* rice growing soils)

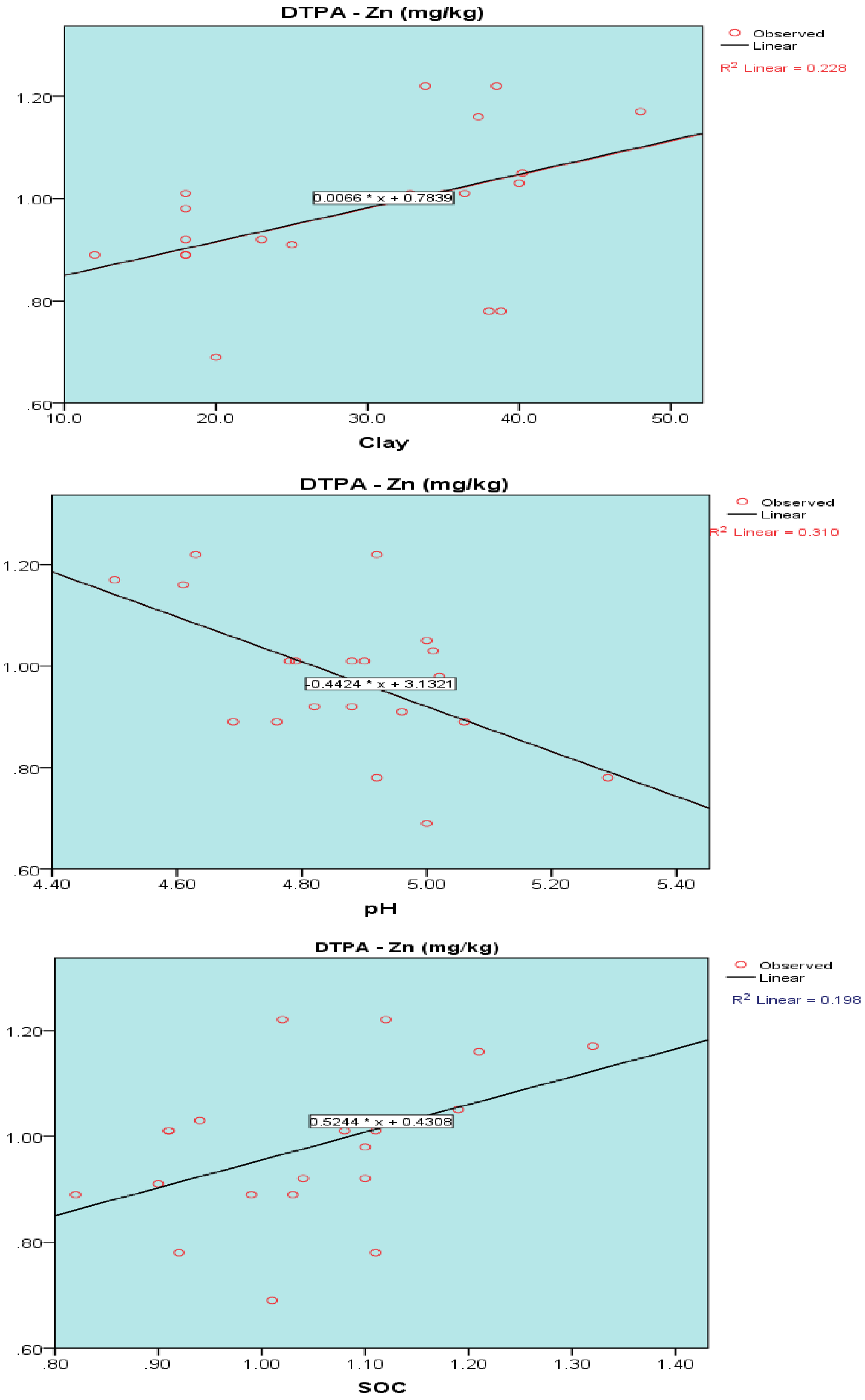

Fig 4.5: DTPA Zn vs pH, clay and SOC (*Sali* rice growing soils)

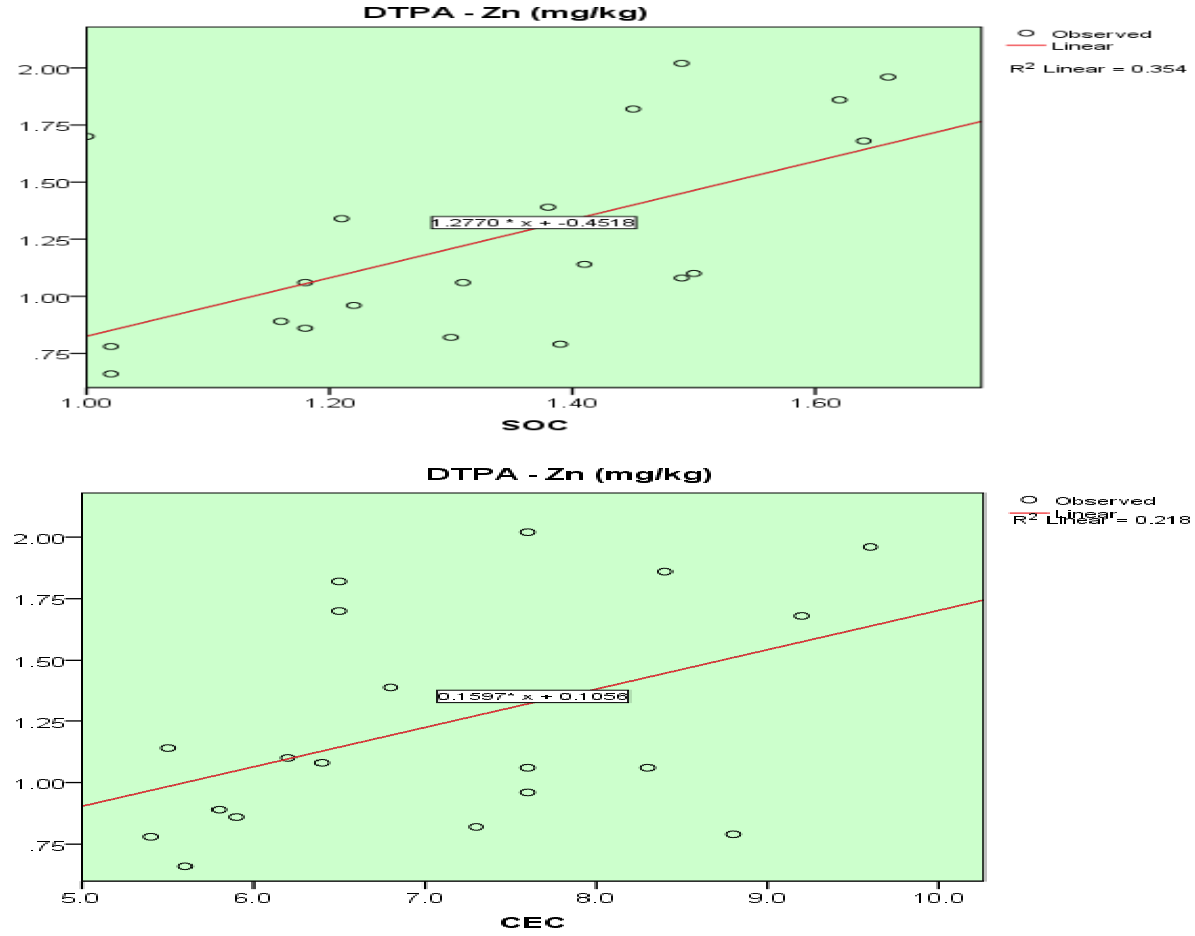

Fig 4.6: DTPA Zn vs SOC and CEC (*Boro* rice growing soils)

Table 7: Correlation coefficient among different zinc fractions of *Boro* Rice growing soils of Boko block of Kamrup (rural) district

	WSEX-Zn	COMP-Zn	AMOX-Zn	CRYOX-Zn	RES-Zn	TOT-Zn	DTPA-Zn
WSEX-Zn	1	0.856**	0.722**	0.709**	0.805**	0.905**	0.654**
COMP-Zn		1	0.932**	0.883**	0.967**	0.968**	0.738**
AMOX-Zn			1	0.903**	0.939**	0.940**	0.647**
CRYOX-Zn				1	0.910**	0.912**	0.628**
RES-Zn					1	0.999**	0.679**
TOT-Zn						1	0.680**
DTPA-Zn							1

**Correlation significant at 0.05 level **Correlation significant at 0.01 level*

Multiple regression analysis

Multiple regressions for *Ahu* rice growing soils showed 64.2% towards variation in this fraction. All the soil properties combinedly accounted for 78.1% variation towards WSEX-Zn in soil. Similarly, for complexed zinc it was seen that soil organic carbon is the dominant factor controlling the variability of this fraction with a contribution of 44.9% towards this pool. For amorphous sesquioxide bound zinc the highest contributing factor was soil pH (50.4%) whereas all the rest of the soil properties *viz.,* SOC, clay, sand, EC and CEC together had accentuated the contribution to 74.9%. In case of CBD-Zn it was found that pH alone contributed 30.6% towards the variability of this fraction while on addition of all the other independent variables like EC, CEC, SOC, clay, and sand jointly contributed 67.7% towards CBD-Zn. For residual zinc it was seen that SOC solely contributed 41.3% variation towards this fraction. The clay content of the soils under *Ahu* rice growing soils showed the highest contribution *i.e.,* 35.3% towards the variability of total zinc. In case of DTPA-Zn, the highest contribution was made by SOC (28.4%) whereas, SOC in combination with CEC and clay increased the per cent contribution upto 36.1%.

Stepwise multiple regression equations were calculated for *Sali* rice growing soils relating different zinc fractions with the physico-chemical properties of soil and it was observed that for water soluble plus exchangeable zinc 36.8% contribution was made by the clay fraction alone towards the variability of zinc. It was also seen that on addition of soil pH the percent contribution rose to 59.0%. Likewise, for complexed zinc, it was seen that the CEC alone contributed 39.4% towards the variability of complexed zinc while on the adding clay and pH the per cent contribution was found to increase upto 47%. For amorphous sesquioxide bound zinc fraction, it was observed that soil pH alone contributed upto 39.5% towards the variability of zinc. For residual zinc, it was found that the major contributing factor was the clay with 37.2% contribution. In case of DTPA zinc, the most notable contribution was made by soil pH (31%) towards the variability of DTPA zinc while on adding clay the per cent was seen to raise upto 45.8%.

Multiple regression equations for *Boro* rice growing soils were analysed using different zinc fractions relating to various soil properties and it was recorded that for WSEX-Zn fraction, CEC contributed the maximum upto 64.2% towards the variability of water soluble plus exchangeable zinc while on adding soil organic carbon the per cent rose upto 80.3%. For complexed zinc, it was seen that organic carbon made the highest contribution of 56.8% towards the variability of this fraction whereas on combining the rest of the soil properties the final per cent contribution was noted as 68.7%. For crystalline sesquioxide bound zinc fraction, it was found that the pH contributed upto 51.1% towards the variability of this fraction. Residual zinc fraction, on the other hand, showed a contribution of 54% by soil organic carbon while on adding soil pH the per cent increased upto 61.5%. On taking all the soil properties into account the final per cent contribution was found as 71.2% towards the variability of zinc under the residual pool. Total zinc recorded a contribution of 54.2% towards the accountability of zinc by soil organic carbon alone while the influence noted to raise upto 61.7% on addition of soil pH. The final contribution was recorded to be 71.4% on taking all the rest of the soil properties into consideration. For DTPA zinc, it was seen that SOC contributed of 35.4% towards the variability of zinc while on addition of all the other soil properties the final contribution was found to be 51.5%.

CONCLUSIONS

The distribution of Zn-fractions are regulated dominantly by soil characteristics namely soil pH, CEC, soil organic carbon and clay content in all the three rice growing soils and the fractions follow the order, in general, as WSEX-Zn<CRYOX-Zn<COMP-Zn<AMOX-Zn <RES-Zn<TOT-Zn. The highest amount of zinc in the soils existed in residual pool (>95%) out of the total content and the lowest was in water soluble plus exchangeable fraction. Soil reaction (pH) exerted significant influence on relative distribution of zinc fractions accountable for plant availability in all the soils studied. Along with that, a marked contribution was also made by clay as well as soil organic carbon towards the variability of different fractions of zinc in these soils. Statistically significant inter-relationship amongst various fractions of zinc suggests the existence of dynamic equilibrium in soil. Multiple regression study on various fractions of zinc as influenced by soil properties suggests that clay as well as soil organic carbon were the dominant contributing factors towards the variability of different fractions of zinc of the rice growing soils under Boko block of Kamrup district of Assam. Nevertheless, soil pH and CEC also played a crucial role towards the variation in zinc fractions.The foregoing description of experimental findings reveals that the highest amount of zinc in the soils existed in residual pool (>95%) out of the total content of zinc. Soil reaction (pH) exerted significant influence on relative distribution of zinc fractions accountable to plant availability in all the soils studied. Along with that, a marked contribution was also made by clay as well as soil organic carbon towards the variability of different fractions of zinc in these soils. The physico-chemical properties of soils combinedly account for 30.6% to 78.1% variation towards all the fractions in *Ahu* rice growing soils, 22.9% to 69.3% in *Sali*rice growing soils and 51.1% to 87.5% in *Boro* rice growing soils. Among all the soil samples studied (N=60) under *Ahu*, *Sali* and *Boro* rice growing areas, overall, 58% of the samples were found to be below critical level in DTPA extractable Zn. Hence, appropriate soil zinc management strategies need to be adopted.

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