Original Paper

Release behaviour of iron and zinc in different textured soil and its distribution in rice plant (*Oryza sativa* L.) in North West of India

Chetan Kumar Jangir*[1], PS Sangwan[2], Dheeraj Panghaal[2], Sandeep Kumar[3], Ram Swaroop Meena[4], Bharti[5], Ram Dhan Jat[6], Narendra Singh[7]

[1]*ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan India*
[2]*Chaudhary Charan Singh Haryana Agriculture University, Hisar, Haryana India*
[3]*ICAR-Indian Agricultural Research Institute, Regional Station, Karnal India*
[4]*Institute of Agricultural Sciences, Banaras Hindu University India*
[5]*ICAR-Indian Agricultural Statistics Research Institute, New Delhi India*
[6]*Chaudhary Charan Singh Haryana Agricultural University, Hisar India*
[7]*ICAR – Indian Agricultural Research Institute, New Delhi, India*

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The present study aimed to assess the relationship of soil properties with extractable zinc (Zn) and iron (Fe) in soil as well as rice plant at different incubation period. The soil and plant samples were collected from 10 districts (Yamuna Nagar, Sonipat, Jind, Panipat, Karnal, Panchkula, Kaithal, Rohtak Ambala, and Kurukshetra) of RWCS (Rice wheat cropping system) of northwest Haryana of India. The effects of soil properties especially soil texture with the micronutrient in soil and rice plant at different incubation period have not been well studied. In the lab-cum-survey study, the analysis of grain samples collected from different districts of Haryana under varied soil texture showed a positive correlation between Zn/Fe concentration in grain and mean release rate of Zn/Fe in soil (Zn – 0.80; Fe – 0.98). The highest Fe concentration in grain was found in clayey soils (59.74–60.41 mg/kg) having a maximum mean soil Fe release rate (17.98–18.03 mg/kg). Likewise, the highest Zn concentration in grain was recorded in clayey soils (29.71–30.57 mg/kg) of Yamuna Nagar and Panchkula, which has the highest mean soil Zn release rate (1.03–1.14 mg/kg). Univariate and multivariate analysis under principal component analysis (PCA) was carried out to determine the linear relationship between soil properties and extractable soil Zn and Fe concentration as well correlogram correlation matrix using for soil properties with grain Zn and Fe concentration. Hence, the study concluded that the detection for Zn and Fe are more successful in soils with a higher proportion of clay particles than in sandy soils. Plant uptake potential is highly influenced by soil micronutrient interactions with soil properties, especially soil texture, which can be predicted by extractable soil micronutrients.

Keywords: rice, zinc, iron, release behavior and soil texture

1 Introduction

A micronutrient is a trace element that plants, animals, and humans need in order to develop, grow, and reproduce physiologically. In soil, such as iron, copper, manganese, molybdenum, boron, and zinc are among the micro elements considered essential. Micronutrient absorption and accumulation abilities differ among plant species, depending on soil type and geochemical characteristics (Kumar, Suri, and Choudhary, 2014; Choudhury and Mandal, 2021). Metals accumulate in plants through a metabolic process based on several factors, including transport processes, nature of the soil, plant variety, nutrient concentration, soil pH, redox potential, nutrient efficiency, and organic carbon (Oliver and Gregory, 2015). A variation in uptake behavior was also observed across plant stages, climate conditions, and seasons (Choudhary and Suri 2014; Paul and Dey, 2015).

A plant's roots can absorb substantial amounts of micronutrient when they're present in high concentrations in the soil, but higher efficiency of micronutrient uptake by plant through the foliar

***Corresponding Author:** Chetan Kumar Jangir, ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan – 305006 India; chetan.jangir@ icar.gov.in ORCID: https://orcid.org/0000-0003-3315-4105

application. A plant's components can be analyzed to evaluate the functional connections between metal transport, accumulation, and uptake (Eskandari, 2011; Efe and Yapuzi, 2011,). In this study, Fe and Zn have been studied during different stages of plant growth, as well as their accumulation within the plant and dependency of soil texture (Cakmak and Kutman, 2017).

As inorganic nutrients are generally limited to the soil, there is an important relationship between nutrient application and accumulation that controls plant productivity and diversity. It has not been extensively studied how nutrients are collected or redistributed between different organs of rice plants throughout the year. In addition to providing information on the uptake of potentially dangerous elements, which have become increasingly important contaminants in recent years, this information will ensure more efficient use of fertilizers by more precisely matching supply and demand of these nutrients (Bailey, West and Black, 2015).

Micronutrients also play a significant role in the physiology of plants because they show intricate interactions that affect their availability for absorption and accumulation (Kiwan, Watfa and Saleem, 2014). A study was undertaken to investigate whether micronutrients accumulate in the tissues before and after seed reserves are mobilized.

Plant productivity will be lower and the quality of the produce will be lower if soils are not able to supply micronutrients to plants. Changing land use, soil management, and cropping systems all affect plant availability of soil micronutrients. Micronutrient availability is also influenced by soil properties including pH, soil texture, organic matter, and other nutrients (Talukdar, Basumatary and Dutta, 2009; Dhaliwal, 2019). A soil's texture has a significant impact on plant accessibility to micronutrients (Vijaya, Arokiaraj and Martin, 2011; Sachan and Krishna, 2018). There are several competing reactions that affect the solubility of micronutrients in soil, such as precipitation, adsorption and even chelation with clay (Alloway, 2008). Therefore, from an agricultural standpoint, it is more important to have micronutrients in ‚the plant available' form than in their total form.

As a result, in this study, the following key questions were addressed:

1. determine the concentration of plant-available micronutrients, as determined by DTPA at different incubation days, in the rice wheat cropping systems of northwest India;
2. how does soil texture affect the concentration of micronutrients available to plants;
3. how strong is the correlation between soil and plant micronutrient content (Zn and Fe) and soil properties.

2 Material and methods

2.1 Sampling

To explore the release behavior of micronutrients under diverse textured soils, three surface soil samples (0–15 cm) were collected from each North-Eastern district (10) of Haryana under the rice wheat cropping system (RWCS) using Global Positioning System (GPS) after harvest of wheat crop. These districts include Yamuna Nagar (clay loam with 2.25 &5.65 mg/kg of Zn and Fe, respectively), Sonipat (loamy sand with 1.40 & 4.93 mg/kg of Zn and Fe, respectively), Jind (sandy with 0.67 & 3.60 mg/kg of Zn and Fe, respectively), Panipat (loamy with 1.30 & 2.84 mg/kg of Zn and Fe, respectively), Karnal (loamy with 0.68 & 4.17 mg/kg of Zn and Fe, respectively), Panchkula (clay sand with 0.88 & 7.14 mg/kg of Zn and Fe, respectively), Kaithal (sandy loam with 2.01 & 8.17 mg/kg of Zn and Fe, respectively), Rohtak (sandy loam with 0.69 & 9.9 mg/kg of Zn and Fe, respectively), Ambala (sandy loam with 0.72 & 7.16 mg/kg of Zn and Fe, respectively), and Kurukshetra (loamy with 2.32 & 8.47 mg/kg of Zn and Fe, respectively), given in Figure 1. These samples were brought to the laboratory of CCS HAU, Hisar for further analysis. The incubation study was carried out without the addition of these nutrients (Zn, Fe) by maintaining soil moisture at field capacity. Also collected the rice plant samples from the same field of soil survey. The sampling was done at periodical intervals for the estimation of DTPA (Diethylene Triamine Penta Acetic Acid) – extractable micronutrients (Fe and Zn) at periodical incubation of 0, 10, 20, 30, 40, 50, 60 days and at harvest.

2.2 Soil sample preparation and analysis

Form farmer field, one common soil sample after crop harvest was collected from the top 15 cm soil with the help of a soil sampling auger. For this, about 3 samples per districts (cores) were taken randomly from different physiographic positions of the farmer field in a zig-zag manner and mixed to make a representative (composite) sample to cover the entire field The collected soil samples were thoroughly mixed on a clean polythene sheet and the bulk was reduced by the quadrating so that about 0.5 kg of composite sample was retained and kept in a clean polythene bag after tagging and labelling. The collected samples were spread out on plastic paper in the shade for air drying. After air-dried soil samples were crushed gently with a wooden mortar and pestle and sieved through a 2 mm sieve. The top 15 cm soil of farmer field had a pH determined with a calibrated

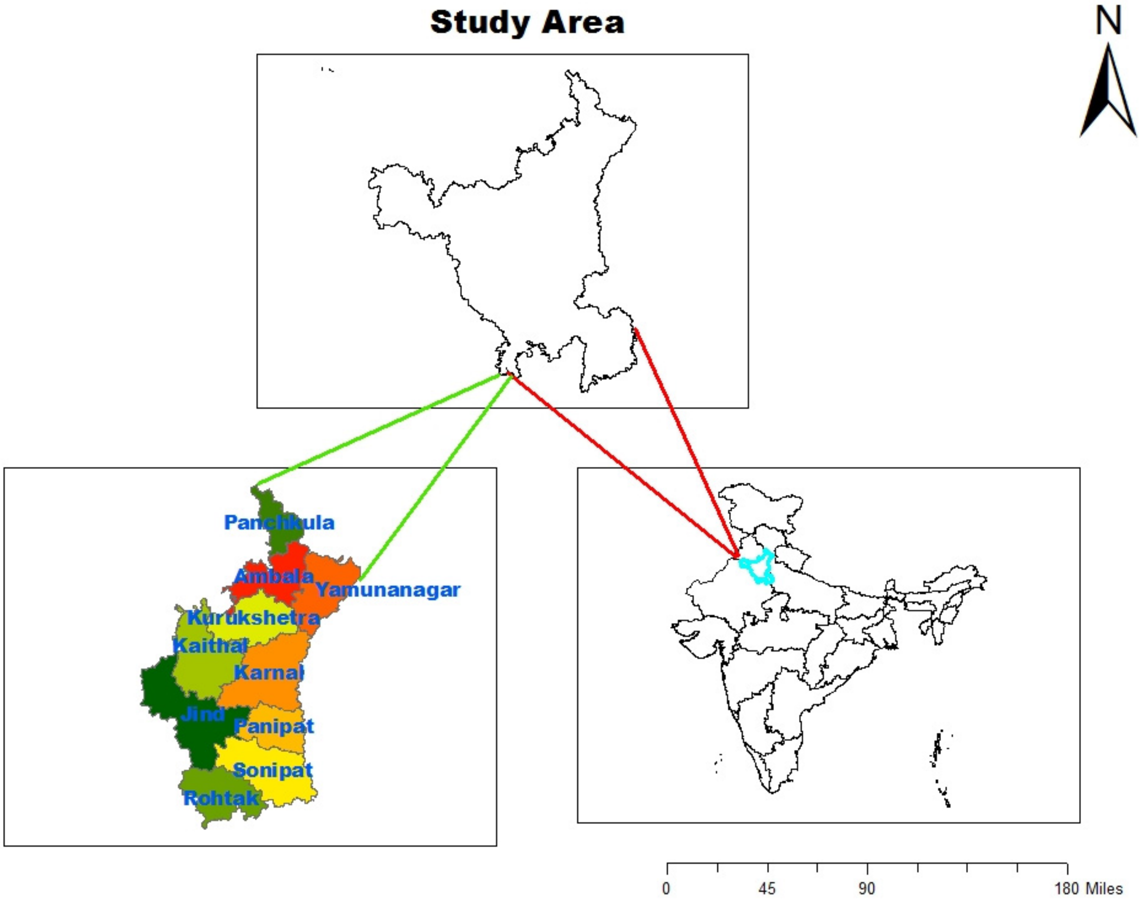

Figure 1 Sampling sites in different districts of Haryana

Glass electrode pH meter (10 g soil: 25 mL deionized H_2O) (Jackson, 1973), $EC_{(1:2)}$ determined by Conductivity bridge meter (Richard, 1954), organic carbon analyzed by Walkley and Black,1934, soil texture determined with help of International Pipette Method (Piper 1966), available nitrogen (N), phosphorus (P) and potassium (K) were analyzed with Subbiah and Asija, 1956; Olsen et al., 1954; and Jackson, 1973, repsectively. DTPAextractable Zn and Fe were analyzed with DTPA (Lindsay and Norvell, 1978) extraction method. Atomic Absorption Spectrophotometer (Model: Varian AA240z) was used for the determination of Zn and Fe.

2.3 Plant sample preparation and analysis

Proper plant sampling is the key to reliable plant analysis results. For the lab study, plant samples were collected (from the same field where Zn and Fe release behaviours were studied) under the RWCS periodically (10, 20, 30, 40, 50, 60, 80 DAS, at harvest) for analysis in the laboratory to understand the partitioning of Zn and Fe mineral nutrients to grain and plant. The samples were kept in the oven for drying at 65 °C for 24–72 hours to obtain a constant weight. The mechanical grinding of plant materials was carried out with stainless mills usually to pass a 60-mesh sieve. The collected grinded samples were used for further laboratory analysis for different nutrients. Zn and Fe were determined by Atomic Absorption Spectrophotometer (Model: Varian AA240z).

2.4 Statistical analysis

For each of the ten rice wheat cropping systems, the mean differences of soil properties were tested using a one-way analysis of variance. A normal distribution assumption was tested for the data. The descriptive statistics (mean, median, standard deviation, variance and coefficient of variation, skewness, and kurtosis) were calculated for all soil parameters using R Studio v1.1.463. To remove redundant variables and extract factor components, the principal component analysis (PCA) was used. To examine the relationship among the 13 soil properties with relation to soil extractable Zn and Fe, we used the PCA with Varimax rotation to statistically group them into four principal components (PCs). The pairwise Pearson's correlation between the soil chemical properties with relation to grain Zn and Fe concentration was calculated in R Studio v1.1.463.

2.5 Ethics approval

This study was approved by the CCSHAU, Haryana for ethical purposes. While collecting soil and plant samples, the researchers protected the confidentiality of respondents. The norm is to access and take soil and plant samples from sampling sites after presenting CCSHAU's (Haryana) approval proposal for village farmers and introducing the research's objective. Farmer permission was obtained before soil and plant samples were taken.

3 Results and discussion

3.1 Statistical description of soil properties (13) within the study area

The results of the Kolmogorov-Smirnov test indicated that most variables had a normally distributed distribution, confirming their normality. It is also evident that the constraint values differ between the fields. There are essentially differences in the mean and median values of soil properties measured in the study area, which indicates dominant measures of central tendency in the soil properties (Table 1). According to the coefficient of variation, soil properties with the highest variability are $CaCO_3$, CEC, electrical conductivity (EC), exchangeable N, K and available zinc, iron and clay (CV ≥30%). Instance, the higher variability (CV ≤5%) was measured for soil pH, while the moderate variability (CV = 5–30%) was measured for the remaining soil properties, according to the guidelines of Warrick 1998 for soil properties variability. In addition, skewness and kurtosis indices for soil variables differed noticeably from the 0 and 3 standard values, respectively, at 0–15 cm. A number of factors account for these variations in chemical properties, including soil management practices in the study area, soil parent material, and the role of groundwater depth and irrigation water quality (Anderson, Mitsch,and Nairn, 2005; Wani, Shaista and Wani, 2017). Numerous other studies have shown the same results, such as Cambardella and Karlen, 2000.

3.2 Release behaviour of DTPA-extractable iron in soil

The soil samples collected from ten different districts of Haryana was analysed in the laboratory for analysing release of Fe at 0, 10, 20, 30, 40, 50, and 60 days after incubation (DAI) (Figure 2). The amount of DTPA-extractable Fe in general increased initially up to 30 DAI (3.24 to 21.62 mg/kg) and then a consistent decrease (21.62 to 5.87 mg/kg) was observed towards the later period of incubation. However, in Sonipat, Ambala and Kurukshetra soils, the increase in the amount of DTPA-extractable Fe was noticed up to 20 DAI (4.49 to 20.62 mg/kg). It was further observed that the amount of DTPA-extractable Fe was initially higher (at 0 days) in Kurukshetra (14.42 mg/kg) followed by Karnal (13.83 mg/kg) and Ambala (13.56 mg/kg) as compared to the rest of the soils. In Yamuna Nagar and Rohtak soils, the highest amount of DTPA-extractable Fe (21.62 and 21.22 mg/kg, respectively) was recorded at 30 DAI while in Panchkula soil it was noticed at 40 DAI (22.06 mg/kg). The amount of DTPA-extractable Fe varied from 8.58 to 11.25, 4.49 to 6.92, 3.73 to 9.32, 4.03 to 11.81, 3.24 to 9.53, 8.38 to 11.68, and 10.03 to 18.76 mg/kg in soils of Yamuna Nagar, Sonipat, Jind, Panipat, Kaithal, Rohtak and Panchkula during the incubation period (from 0 to 60 days), respectively. Whereas in the rest of the soils, the corresponding values for soils of Ambala, Karnal and Kurukshetra were 13.56 to 5.87, 13.83 to 8.38, and 14.42 to 12.64 mg/kg, respectively. It was further observed that

Table 1 Descriptive statistics for physico-chemical parameters of soil samples (n = 30)

Properties	Min.	Median	Mean	Max.	Variance	SD	CV (%)	Skewness	Kurtosis
pH	7.3	7.9	7.9	8.7	0.1	0.3	4.1	0.2	2.8
EC	0.1	0.2	0.2	0.6	0.0	0.1	50.5	1.0	3.2
CEC	4.7	8.5	9.4	16.6	9.9	3.2	33.6	0.6	2.1
CaCO3	0.0	0.0	0.6	5.2	1.6	1.3	54.4	2.3	7.5
SOC	0.2	0.4	0.4	0.7	0.0	0.1	27.7	0.5	2.5
N (kg/ha)	42.0	154.0	155.3	273.0	3471.4	58.9	37.9	0.1	2.5
P (kg/ha)	5.6	14.8	14.4	24.0	14.9	3.9	26.8	-0.3	3.0
K_2O (kg/ha)	84.8	223.3	221.0	353.3	4743.1	68.9	31.2	-0.1	2.4
Zn (mg/kg)	0.3	0.9	1.3	7.1	1.6	1.3	97.1	2.7	11.4
Fe (mg/kg)	0.5	5.0	6.3	19.8	17.6	4.2	67.1	1.0	3.6
Sand (%)	35.3	62.5	59.3	85.4	174.0	13.2	22.3	-0.3	2.6
Clay (%)	3.3	14.7	17.0	35.3	51.9	7.2	42.5	0.5	2.8
Silt (%)	9.5	22.9	23.9	38.2	41.6	6.5	26.9	0.4	3.2

the amount of DTPA-extractable Fe was higher in these soils as compared to the rest of the soils.

3.3 Release behaviour of DTPA-extractable zinc in soil

As the period of incubation increased, a gradual decrease in DTPA-extractable Zn in soils was noticed up to 60 DAI (Figure 3). During this period, the DTPA-extractable Zn was decreased from its initial concentration of 3.29 to 0.38, 2.42 to 0.31, 1.16 to 0.19, 2.40 to 0.27, 1.93 to 0.41, 1.42 to 0.20, 1.46 to 0.13, 1.49 to 0.29, 1.22 to 0.15, and 0.98 to 0.11 mg/kg in soils of Yamuna Nagar, Sonipat, Jind, Panipat, Kaithal, Rohtak, Ambala, Panchkula, Karnal and Kurukshetra, respectively which showed a decrement to the extent of 78 to 91%. The amount of DTPA-extractable Zn was higher in soils of Yamuna Nagar followed by Panipat soil. The least amount of DTPA-extractable Zn was observed in Kurukshetra soil. The decreased soil Zn at the later period of incubation especially between 40–50 days of incubation (3.29 to 0.13 mg/kg) was observed to be more or less at par in all the soil except soils of Panipat, Kaithal and Kurukshetra soils where it was noticed between 50–60 days of incubation (2.4 to 0.11 mg/kg). The decrement in soil Zn was observed to be more pronounced between 0 to 10 or 15 DAI in the soils under study. It was also observed that a decrease in soil Zn was highly consistent with an increase in the incubation period in most of the soils under study. Based on the results, the release pattern of Zn metal was initially rapid but then slowed significantly varied.

The magnitude of the inherent release of Fe and Zn may be governed by many factors, i.e., type and amount of clay, micronutrient status, alternate wet and dry cycles, soil pH, moisture content etc. The results, by and large, are in line with those of Zheng and Zhang (2011), who

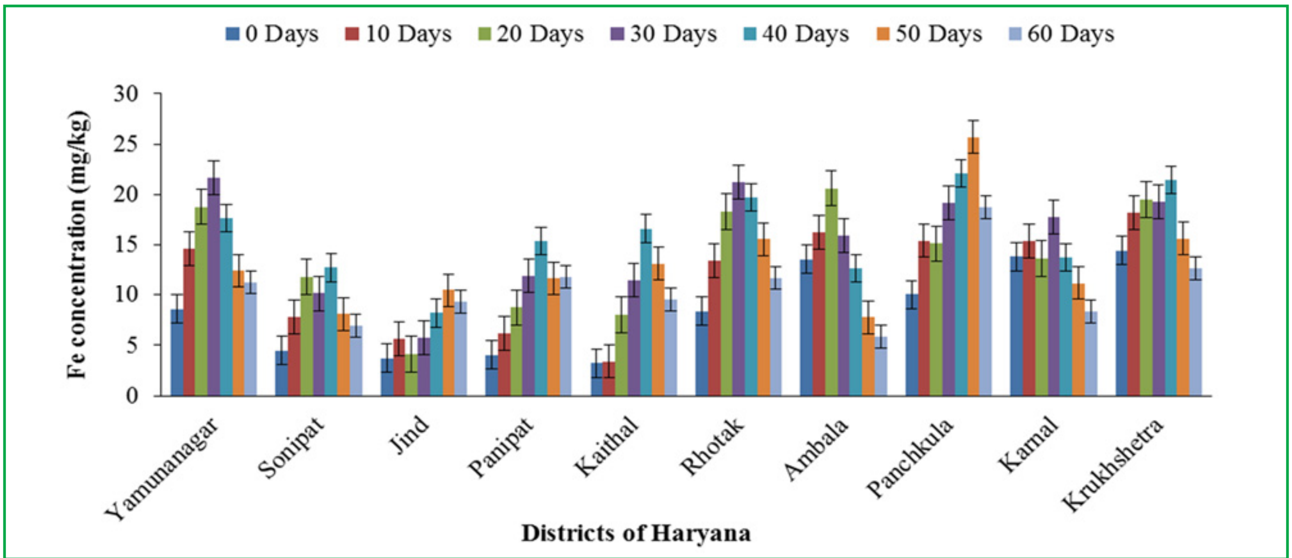

Figure 2 Release of DTPA-extractable Fe at different days after incubation

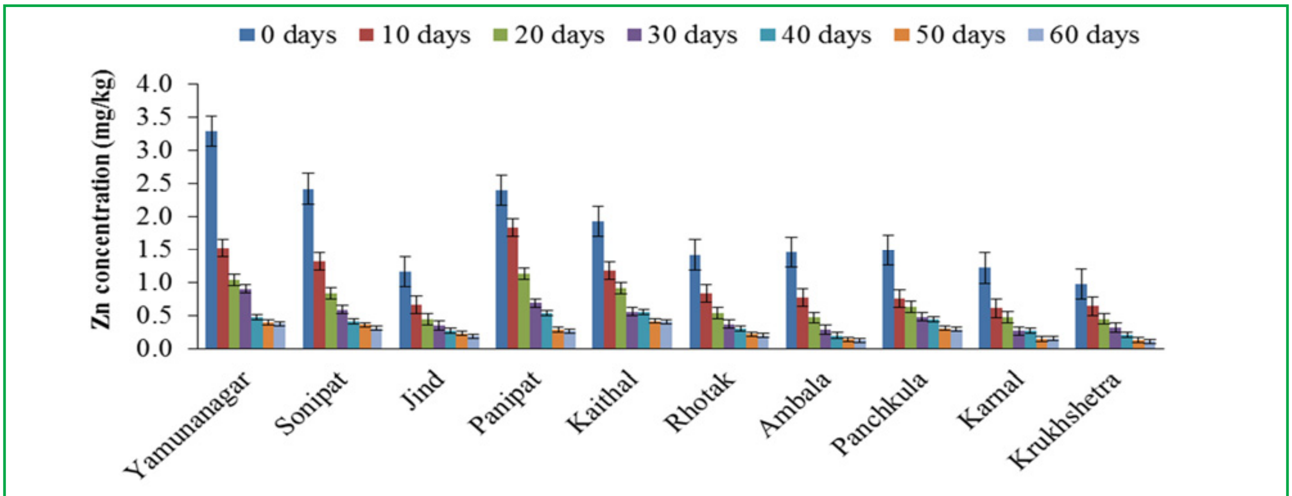

Figure 3 Release of DTPA-extractable Zn at different days after incubation

found that metals in the exchangeable form fraction decreased consistently during 150 days of incubation in all different moisture regimes. Sachan and Krishna, (2018) noticed that there was a sharp increase in exchangeable-Zn found only up to 15 DAI but quickly reduced at 30 DAI. During early incubation, higher release rates were obtained, but they gradually declined as incubation progressed to 90 days. The results of our study also showed a very similar trend for all the studied soils. The release rate and extent of release for Fe were greater than Zn. This trend suggests that the studied soils are more capable of replenishing soil solution Fe than Zn. The finding indicated that the clay loam soils (Panchkula soils) release Zn and Fe at much higher rates than sandy clay soils (Yamuna Nagar soil) because of their higher initial values of Zn and Fe. There is evidence that an early cycle may be associated with enhanced nutrient uptake and use, as the earliest fruit maturation may facilitate a greater need for metabolic sinks, thereby intensifying transport of photo-assimilates, affecting plant nutrient concentration (Ma and Rao, 1997).

3.4 Iron and zinc concentration in plant at different stages

Fe concentration slowly increased in the micronutrient's evaluations (July–September/October) due to a seasonal variation in the micronutrients. After that, the concentration decreased, in November and December (Figure 4). During August of the pre-flowering period, Fe concentrations increased (15.09 to 72.76 mg/kg) and reached their highest level at 80 days after sowing, but then steadily decreased during the grain-filling period (72.76 to 71.36 mg/kg). It has been observed that maximum Fe concentration was reported in plant samples (without panicle) of Kurukshetra (27.56 mg/kg) followed by Karnal (24.63 mg/kg) and Ambala (23.76 mg/kg) as compared to the rest of the soils. Whereas minimum concentration of Fe was reported in Jind plant samples (15.09 mg/kg). About 40–50% of the iron absorbed during the vegetative and reproductive stages was present in the shoots, while only 25–35% of the iron absorbed during the harvesting (ripening) stage was found in the shoots.

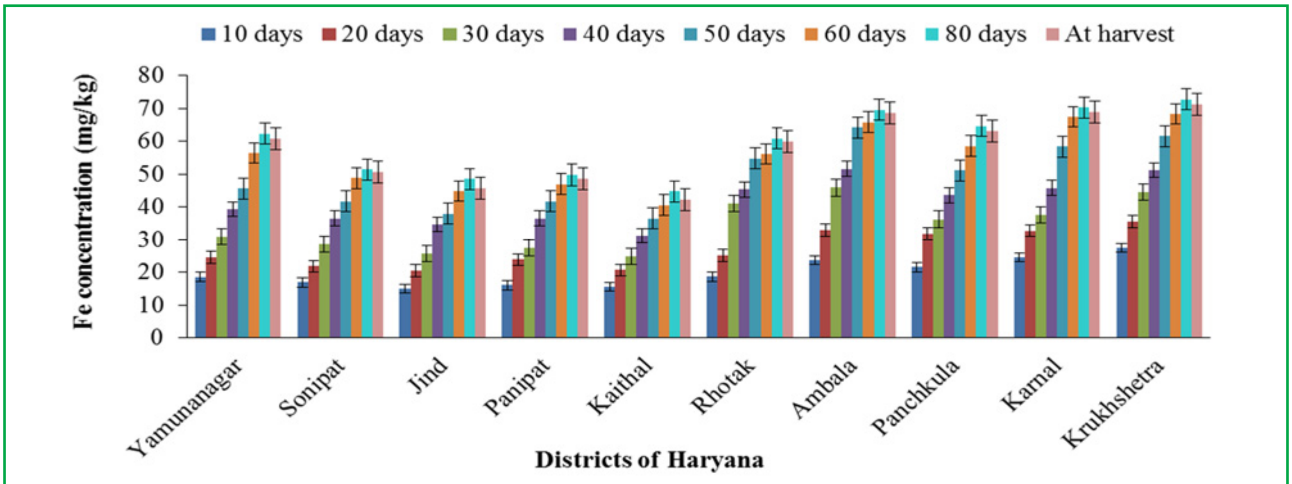

Figure 4 Iron concentration in rice plant samples at different stages under RWCS

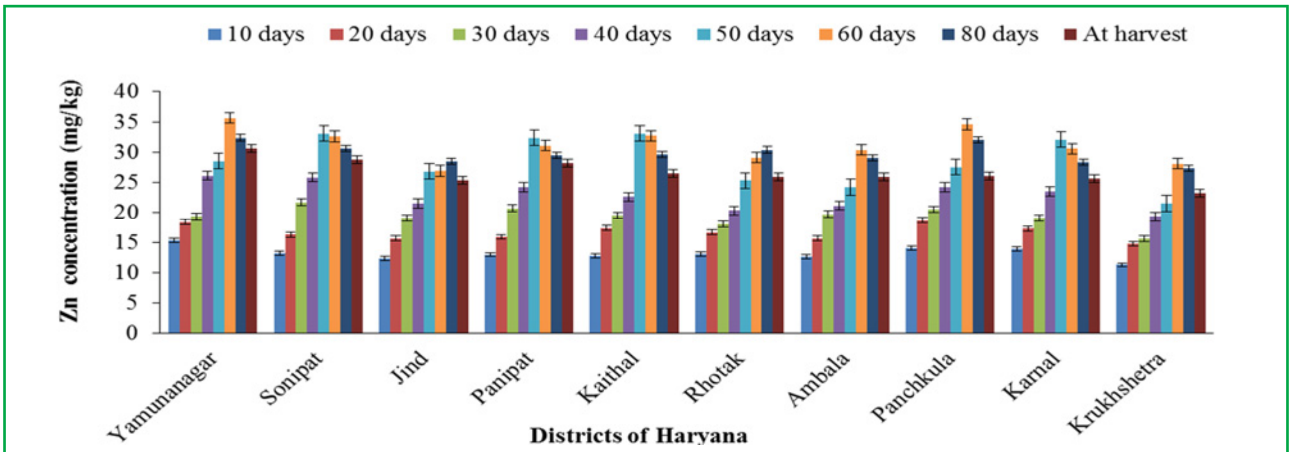

Figure 5 Zinc concentration in rice plant samples at different stages under RWCS

The highest Zn concentration (32.40 mg/kg) was noted at 80 DAS, and the trend in the Zn concentration in the plant was virtually steady throughout the evaluation period after 80 DAS (11.3 to 32.4 mg/kg) had decreased the concentration (Figure 5). Comparative studies were conducted between plant samples taken at different times and soil release of Fe and Zn from the same area of soil. According to our analysis, the highest Zn and Fe content was found in grain and plant parts on different days when higher Zn and Fe had been released in different soil districts. Nearly half of the zinc absorbed during the vegetative and reproductive stages was present in the shoots, whereas only 23–35% of the zinc absorbed during the ripping (harvesting) stage was found in the shoots due to Zn content transferred from shoots to grain. More than 80% of the zinc absorbed was found in the shoots regardless of the growth stage.

Coarse-textured soils provide easier passage through their aggregation, retaining less nutrients and releasing most of the nutrients initially at one time, therefore may not meet the needs of the plants, particularly during the grain development stage. In contrast, clay soil holds more nutrients than sandy soil, and release nutrients less at one time but release continuously and thus provides a satisfactory amount of nutrients to plants to store in grains. Clay minerals affects soil fertility by regulating nutrient availability and supplies, carbon sequestration and stabilization, micro-aggregate formation, and soil microbial functionaries and population (Alloway, 2008). Dissolution-precipitation and adsorption-desorption processes are the key processes associated in these relationships. Mineral adsorption reactions are more crucial in regulating plant nutrient availability as compared to the release of nutrient elements by mineral weathering. While the concentration of Zn and Fe in soil solution are primarily controlled by the oxidation and precipitation reactions. Plants trigger biochemical responses such as the release of reducing and chelating chemicals, as well as rhizosphere acidification, which can enhance the availability of Zn, Fe, and other micronutrients (Singh and Schulze, 2015). In the RWCS of Haryana, the same result was observed when micronutrients (Fe and Zn) were evaluated in clay and sandy soil.

A linear correlation study was carried out between average release rate of Zn and Fe under different textured soils with mean Zn and Fe buildup in rice grain (Figure 6 and 7). It was found that the Zn and Fe concentration was higher in the grains of the same soil in which average Zn and Fe release rate was more. In this regard, the Fe concentration in grain under clay sand (60.41 mg/kg) and clay loam (59.74 mg/kg) was highest having maximum mean Fe release rate of 18.03, and 17.98 mg/kg, respectively. The minimum Fe content in grain was recorded 51.92 mg/kg in sandy soils having lowest Fe release rate (3.75 mg/kg). Furthermore, the highest Zn concentration in grain was recorded in clay loam (30.57 mg/kg) and clay sand (29.71 mg/kg) soils of Yamuna Nagar and Panchkula, respectively having a respective Zn release rate of 1.14, and 1.03 mg/kg. The minimum Zn concentration (22.42 mg/kg) in rice grain was noted in sandy soils of Jind which has the lowest mean Zn release rate (0.47 mg/kg). There was a prefect positive correlation between Fe concentration in grain and average Fe release rate in soil (0.98), as well as in Zn content in grain and average Zn release rate in soil (0.80).

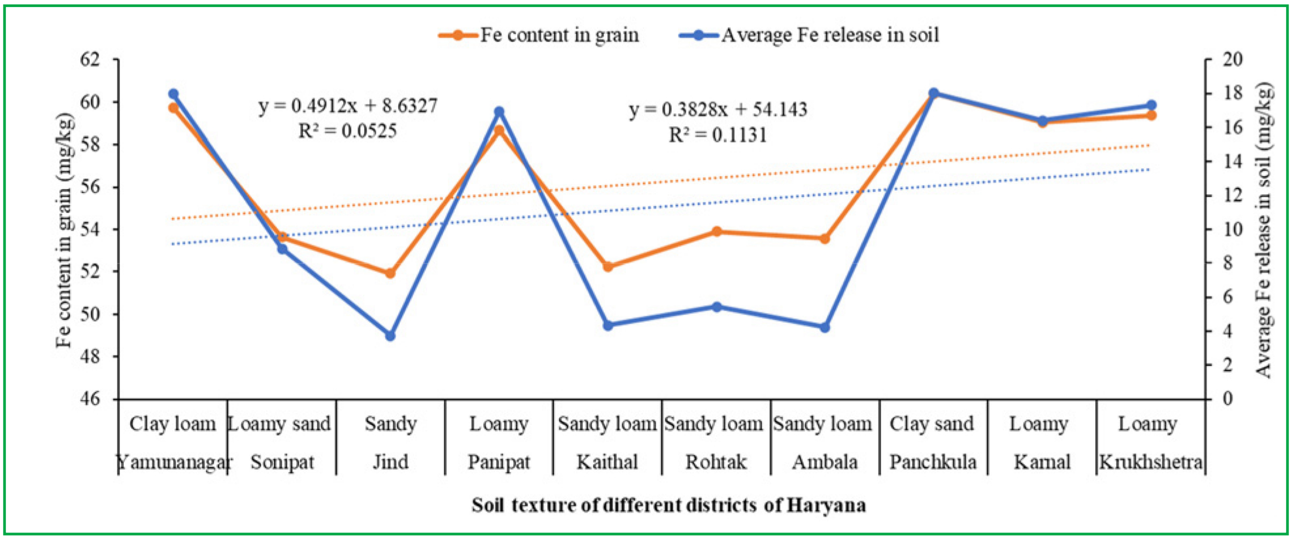

Figure 6 Iron concentration in rice grain under diverse textured soils of different districts of Haryana

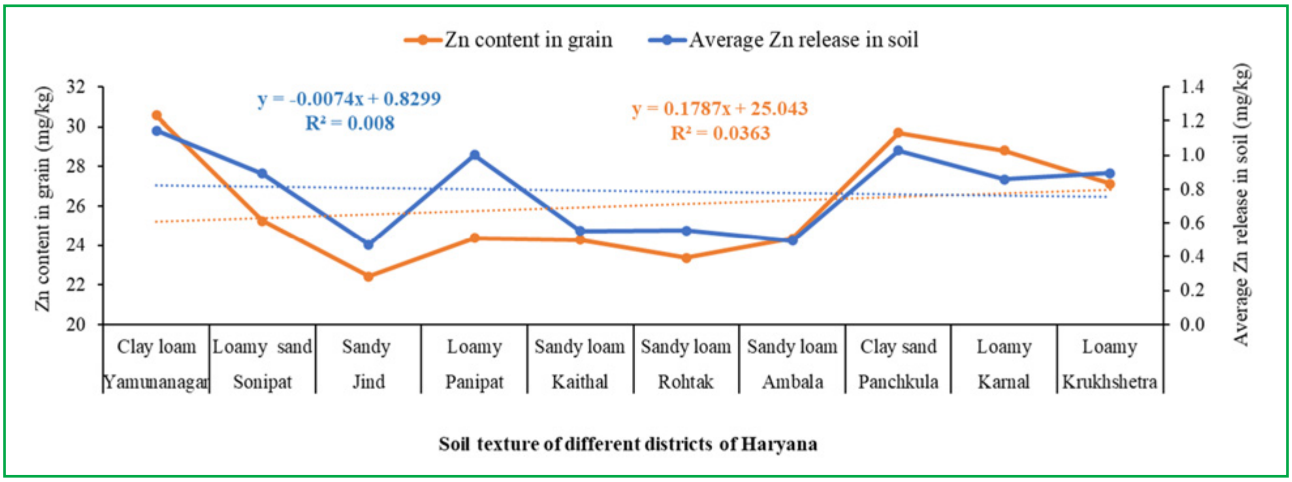

Figure 7 Zinc concentration in rice grain under diverse textured soils of different districts of Haryana

3.5 Analysis of soil properties variability with soil extractable Zn and Fe by principal component analysis (PCA)

Principal component analysis (PCA) and partial correlation were used to analyze the effects of multicollinearity and group soil properties into four principal components (PCs). Accordingly, PC1, PC2, PC3 and PC4 have eigenvalues of 4.67, 2.31, 1.41 and 1.11 & 4.48, 2.31, 1.44 and 1.15 found soil properties in relation to soil extractable Zn and Fe concentration, respectively (Table 2). The four PCs with eigenvalues >1 account for a considerable portion of the variance in soil properties in relation to soil extractable Zn and Fe concentration among the RWCS. There are 38.89, 19.23, 11.75 and 9.21% & 37.36, 19.25, 11.98 and 9.62% variances explained by PC1, PC2, PC3, and PC4, respectively, which accounts for 79.09% and 78.21% of the variance explanation soil properties in relation to soil extractable Zn and Fe concentration, respectively. Brejda et al. (2000) reported that PCs with at least 5% variance explaining the best variability of a factor component.

Basically, the left and bottom axes are the PCA plot – use them to read the PCA scores of the samples. Loading plot axes on top and right indicate how strongly a characteristic impacts the principal components. We calculated the PCA using the prcomp command of the R statistical software. The PCA was applied in order to observe possible correlations between soil physical properties and soil extractable micronutrient Zn and Fe at different locations. When compared, Zn and Fe soil concentration showed sand% and EC of soil, while some positive interaction with clay%, SOC and CEC was observed (Figs 8–9).

Most of the information has already been captured by the first three to four PCs, so we can ignore the rest without losing anything. According to the scree plot, each PC captures a certain amount of variation from the data. The y axis represents the eigenvalues, which in essence represent the amount of variation. Use a scree plot to select the principal components to keep. The ideal curve should be steep, bend at an elbow – this is your cutting-off point – and then flatten out. The scree plot (Figure 10) can be used as a graphical tool to choose

Table 2 Results of principal component analysis of soil properties in relation to soil extractable Zn and Fe concentration responses to the rice wheat cropping system

	Soil properties in relation to soil extractable Zn			
Principal component (PC)	PC1	PC2	PC3	PC4
Eigen value	4.67	2.31	1.41	1.11
Variance (%)	38.89	19.23	11.75	9.21
Cumulative variance (%)	38.89	58.13	69.88	79.09
	Soil properties in relation to soil extractable Fe			
Eigen value	4.48	2.31	1.44	1.15
Variance (%)	37.36	19.25	11.98	9.62
Cumulative variance (%)	37.36	56.61	68.59	78.21

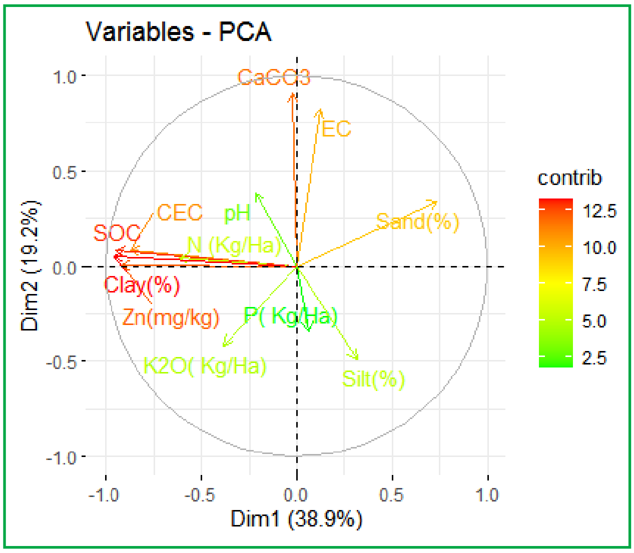

Figure 8 Principle component analysis load plot of soil properties in relation to soil extractable Zn concentration

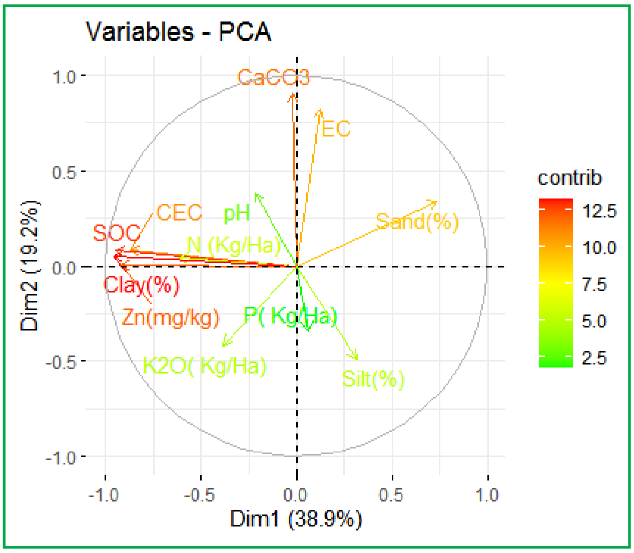

Figure 9 Principle component analysis load plot of soil properties in relation to soil extractable Fe concentration

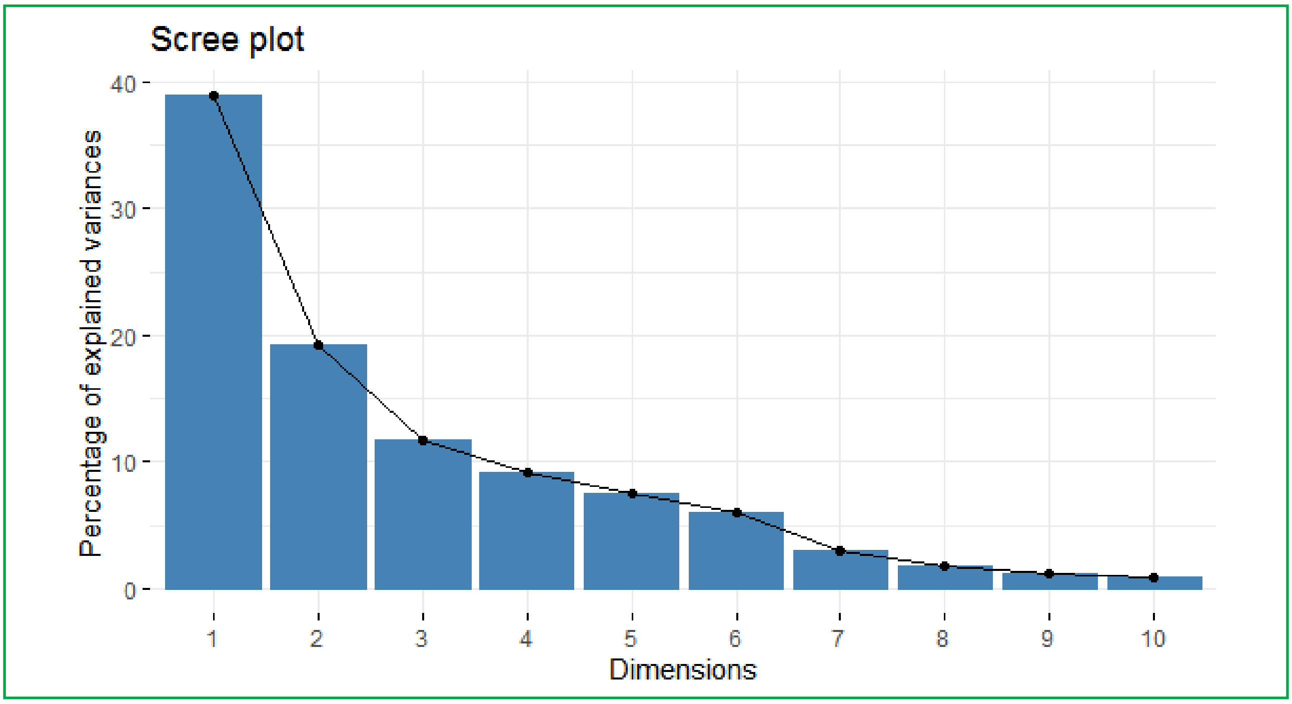

Figure 10 Illustration of PCA scree plot of soil properties with relation to soil extractable Zn and Fe

how many PCs to retain. The scree plot for the iris data showed (on the "Variance Explained" plot) that the first four eigenvalues explain 79% of the variance. In this plot explain around 38% of explained variances by the first component of PC.

3.6 Correlogram correlation of soil properties with relation to grain Zn and Fe

Correlations that are positive are displayed in blue while correlations that are negative are displayed in red. The correlation coefficients determine the color intensity and the size of the circle (Figure 11). Correlogram's correlation test showed that significant positive correlation (Grain Zn & Fe ~ clay (%), CEC, SOC, extractable soil Zn; *p* <0.005) and negative correlation (Grain Zn & Fe ~ sand (%), EC, pH; *p* <0.005). Srinivasan et al. (2017) studied that Micronutrient like Mn, and Cu showed significant correlations with chemical properties (pH, EC, CEC, and OC).

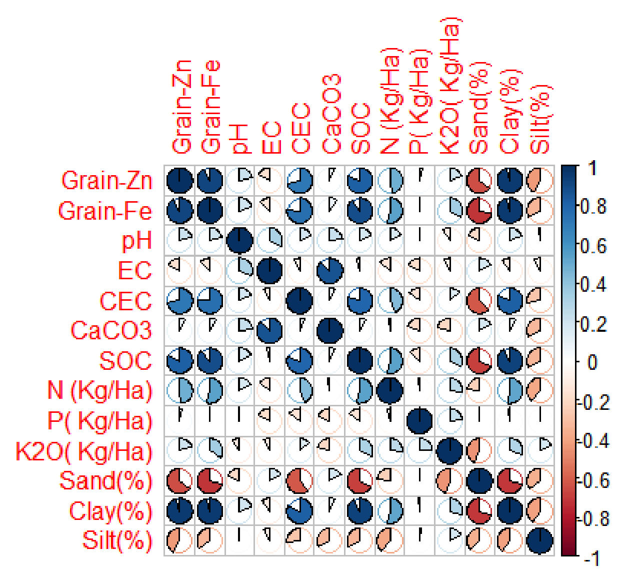

Figure 11 Correlation matrix using correlogram of soil properties with relation to grain Zn and Fe

4 Conclusion

North western India was found to have significantly different soil properties among rice wheat cropping systems (RWCS). There are essentially differences in the mean and median values of soil properties measured in the study area, which indicates dominant measures of central tendency in the soil properties. In view of this, the following outlines are drawn from the present study:

1. The DTPA-extractable Zn concentration gradually decreased from the first day of incubation up to 60 days as Zn does not have redox potential.
2. The DTPA-extractable Fe generally increased initially up to 30 days after incubation and then reduced throughout incubation up to 60 days due to its redox potential. Also, the rate and extent of release were greater for Fe than Zn.
3. The release of both Fe (17.98–18.03 mg/kg) and Zn (1.03–1.14 mg/kg) was higher in clayey soils (Panchkula, Yamuna Nagar) compared to sandy soils (Jind). Hence, Zn (29.71–30.57 mg/kg) and Fe (59.74–60.41 mg/kg) concentration were also higher in grains of rice grown under clayey soils.
4. Principal component analysis (PCA) confirmed that soil extractable Zn and Fe were controlled by the clay (%) and SOC content of the soil, which accounts for 79.09% and 78.21% of the variance explanation soil properties in relation to soil extractable Zn and Fe concentration, respectively. Correlogram's correlation test showed that significant positive correlation (Grain Zn & Fe ~ clay (%), CEC, SOC, extractable soil Zn; p <0.005) and negative correlation (Grain Zn & Fe ~ sand (%), EC, pH; p <0.005).

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