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DISTRIBUTION OF DIFFERENT FRACTIONS OF FE AND THEIR ASSOCIATION WITH SOIL CHEMICAL PROPERTIES IN SOUTH SAURASHTRA AGRO-CLIMATIC ZONE OF GUJARAT, INDIA

D.V. Parakhia*, H.L. Sakarvadia, A.S. Jadeja, L.C. Vekaria and D.V. Hirapra

Department of Soil Science and Agricultural Chemistry, College of Agriculture, Junagadh Agricultural University, Junagadh - 362 001 (Gujarat), India.

*Corresponding author E-mail : dvparakhia@jau.in

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ABSTRACT

An attempt has been made in the present investigation to study the Dynamics of iron in the soils belong to South Saurashtra Agro-climatic Zone of Junagadh, Gir-Somnath, Amreli , Bhavnagar, Porbandar and Rajkot district and interrelations among the fractions from two hundred seventy samples (10 soil samples from each taluka) were collected based on survey of cultivated farmer's fields. The soil samples were analyzed for different fractions of iron *viz.*, Water Soluble, Exchangeable, DTPA Available, Reducible, Available Total, Total, Residual and Percent Available. On the basis of analyzed data of soil samples collected from different districts cover under South Saurashtra Agro-climatic Zone of Gujarat, it can be concluded that different factions of iron in soils were found between 0.133-2.101, 0.51-6.51,1.15-16.59, 0.080-0.932, 1.90-26.13, 11220-68628, 11213-68606 mg/kg and 0.007-0.051 % with mean value 0.689, 2.12, 6.28, 0.384, 9.45, 34415-34405 mg/kg and 0.026%, respectively.for above discused fraction. Soil fertility class based on nutrient index for available iron were calculated. In case of iron about 27.04 per cent samples were tested as low class (< 5 mg/kg), 61.11 per cent samples were under medium class (5-10 mg/kg) and 11.85 per cent samples were under falls in high class (> 10 mg/kg). Based on multiple correlations and regression analysis the prediction model for available Fe was represented, the available Fe was highly significantly positive correlated with towards all fractions. While, in case of soil chemical properties like soil $pH_{2.5}$ and $EC_{2.5}$ were non-significant for different fractions of iron in soils study area, due to at high range of pH (Alkaline) most of iron has less solubility and available. The path co-efficient analysis of available iron fractions with other fractions influenced by the direct positive effect on rediucible iron ascribed maximum, while other fractionalso direct positive effect on available iron.

Key words : Iron fractions, Nutrient index, Correlation, Regression and Path analysis.

Introduction

Micronutrients are present in soils mainly as their oxides, sulphides and silicates and are inherited from the soil-forming rocks and mineral through transformation during various stages of soil development. Micronutrients has been realized during the past three decades when widespread micronutrient deficiencies were observed in most of the soils in our country, where intensive agriculture is practiced with high analysis fertilizers and high yielding varieties. The efficient micronutrient management practices in soil–plant systems help in sustainable crop production, production of better-quality agricultural produce and in turn, improve animal and human health (Behera *et al.*, 2021).

Micronutrient cations are usually held very strongly by the organic legends; however, those exist in the soils in different pools. Viet (1962) postulated existence of five distinct pools of micronutrient cations in soil viz., (i) soil solution or water soluble, (ii) exchangeable, (iii) adsorbed, complexed and chelated, (iv) associated with secondary minerals and as insoluble metal oxides and hydroxides and (v) associated with primary minerals. First three pools exist in a state of dynamic equilibrium and constitute the labile pool from which the plants takeoff micronutrients. Consequently, a number of sequential fraction procedures have been developed for studying the relative abundance of different fractions in the soils and their relative importance in respect of soils for supplying power of micronutrients to the growing crops. The availability of the micronutrients in soil is also affected by the soil properties like pH, EC, content of organic matter, free lime, moisture, soil texture, type of clay, amount of clay and concentrations of interacting ions, etc.

Micronutrients has been realized during the past four decades, when widespread micronutrient deficiencies were observed in most of the soils in our country, where intensive agriculture is practiced with high analysis fertilizers and high yielding varieties. In Indian soilswere found to be revealed that on an average of 36.5, 12.8, 7.1 and 4.2 soils are deficient in Zn, Fe, Mn and Cu, respectively. While, overall percentage deficiency of micronutrients in Gujarat soils was found 36.56, 25.87, 0.46 and 0.38 for respective demand of Zn, Fe, Mn and Cu(Shukla *et al*., 2018).

Materials and Methods

Study area

The total geographical area of Saurashtra region is 6.43 million ha representing 32.82 per cent area of Gujarat (19.61 million ha). Of the total geographical area of Saurashtra, 3.95 million hectares (61%) is estimated to be net-sown area, while total geographical area of South Saurashtra Agro-climatic Zone (study area) is 24440 km^2.

Collection of soil samples

The ten surface soil samples were collected from each 27 each talukas of 6 districts belonging in South Saurashtra Agro-climatic Zone of Gujarat during summer season of 2021. On the basis of the information available from the departmental survey, 270 surface (0-20 cm) soil samples were collected from the tagged survey numbers of the South Saurashtra Agro-climatic Zone of Gujarat.

Soil sample analysis

The prepared soil samples were analysed for determining fractions of Fe, Mn, Zn and Cu by adopting standard methods. Exactly 20 gram processed air-dried soil were weighed accurately into conical flask of 150 ml capacity and to be kept ready for the sequentialfractions analysis of Fe, Mn, Zn and Cu as per procedure described by Jackson (1979) and Viet (1962) as follows:

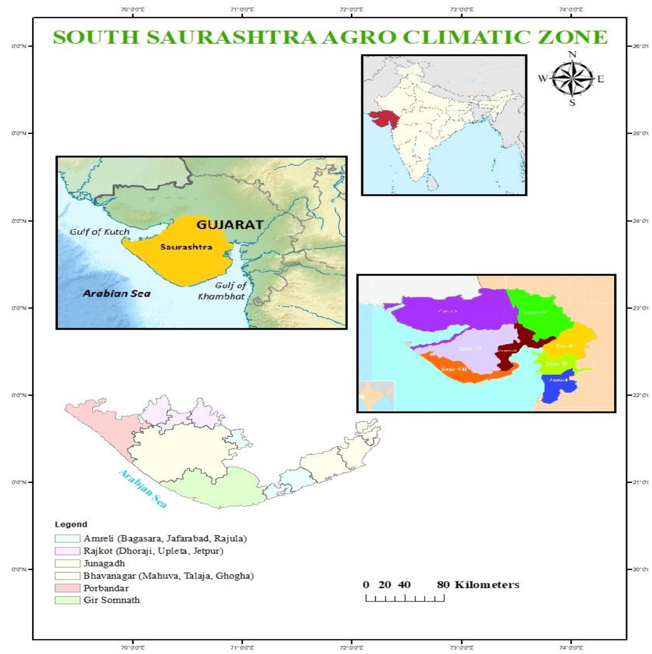

Fig. 1 : Sampling area (South Saurashtra Agro-climatic zone).

Water soluble fraction

About 40 ml distilled water add in the conical flask and shake for 2 hours on horizontal (mechanical) shaker. The soil suspension allows to settle down for one hour and supernatant liquid filter through using whatman filter paper number 42 for the analysis of water soluble Fe, Mn, Zn and Cu.

Water soluble fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Exchangeable fraction

Residual soil uses to determine the exchangeable Fe, Mn, Zn and Cu. Take exactly 40 ml of 1 N neutral ammonium acetate add in the same conical flask and shake for 2 hr. The soil suspension allows to settle down as mentioned above and supernatant liquid use for the estimation of above.

Exchangeable fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

DTPA available fraction

Residual soil use for the determination of DTPA available Fe, Mn, Zn and Cu by adding 40 ml DTPA-TEA-$CaCl_2$ (pH 7.3) in the same conical flask and shake for 2 hours. The soil suspension allows to settle down for one hr. The supernatant liquid use for the estimation of above said micronutrients.

DTPA available fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Reducible fraction

Residual soil use for the determination of reducible

Fe, Mn, Zn and Cu. Take exactly 40 ml 1 N neutral ammonium acetate containing 0.2% hydro quinon in the same conical flask and shake for one hour, put the suspension at list one hour for separation of soil and supernatant liquid. Use extract for the estimation of above micronutrients.

Reducible fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Total fraction

Total micronutrients *viz*., Fe, Mn, Zn and Cu to be determined by using HF: $HClO_4$ (5:1). The soil (1.0 g) take in a platinum crucible treated with 2 ml distilled water and 1 ml $HClO_4$ before 5 ml HF to be added. The contents evaporate to dryness. The residue was heated with 1 ml HCl and 5 ml water till it dissolved (discolour). After cooling, the 100 ml volume to be made before filtration and use for the estimation of total elements.

Total fraction (mg/kg) = Net reading (mg/kg) × 100

Residual fraction

Residual Fe, Mn, Zn and Cu were calculated by deducting water soluble + exchangeable + DTPA available + residual (*i.e.* available total) from total nutrients of Fe, Mn, Zn and Cu.

Residual fraction (mg/kg) = Total fraction – Available total

Percent available fraction

The percent available of Fe, Mn, Zn and Cu were calculated as percent available nutrients in the form of water soluble + exchangeable + DTPA available + reducible (*i.e.* available total) of the total nutrients content in the respective soils.

$$\text{Percent available fraction (\%)} = \frac{\text{Available total} \times 100}{\text{Total fraction}}$$

Available total fraction

Available total was the sum of water soluble, exchangeable, DTPA available and reducible form.

Available total (mg/kg) = Sum of Water soluble + Exchangeable + DTPA available + Reducible form

Nutrient index value was calculated by using following formula given by Parker *et al.* (1951).

$$\text{Nutrient index (NI)} = \frac{(\text{NL x 1}) + (\text{NM x 2}) + (\text{NH x 3})}{\text{Number of total sample}}$$

Where, NL, NM and NH are the number of soil samples falling in low, medium and high categories for nutrient status and are given weightage of 1, 2 and 3, respectively.

Keeping in view in Table 1, the soil analysed data were classified as available iron as low, medium and high categories (<5, 5-10, >10 - Low, Medium and High respectivly) as given by Dangarwala *et al.* (1983), Tandon (1995) and Patel *et al.* (1999).

Table 1 : Classification of nutrient index by Parker.

S. no.	Nutrient index class	Value	Interpretation
1.	Low	≤1.67	Low fertility status of area
2.	Medium	1.67-2.33	Medium fertility status of area
3.	High	≥2.33	High fertility status of area

Geo-statistics and interpolation delineating maps

Soil samples points marked using GPS were fed into the GIS environment. Values of available iron was tagged with corresponding points and interpolation of maps for each individual parameter was done using IDW technique in Arc GIS 10.0 software. Further, the maps of this buffered zone were generated for available iron (Trehan *et al*., 2008). GIS software was also used to estimate the area falling under different classes of respective chemical parameters (Gorasiya *et al*., 2024).

Results and Discussion

Different fractions of iron (mg/kg) in soils South Saurashtra Agro-climatic Zone

The overall range of water soluble iron in South Saurashtra Agro-climate was 0.133-2.101 mg/kg with mean value of 0.689 mg/kg. The data revealed that the lowest mean value of water soluble iron (0.260 mg/kg) was obtained from the samples of Bhavnagar district and the highest mean value of water soluble iron (0.990 mg/kg) was found in samples of Junagadh. Similar results was also reported Selvaraj and Basavaraj (2015) for Gangavati taluka of north Karnataka.

Generally, iron content is the highest in the top soils and declines with depth following the distribution of organic matter The overall range of exchangeable iron in soil was found 0.51-6.51 mg/kg with mean value of 2.12 mg/kg. The data revealed that the lowest mean value of exchangeable iron (1.71 mg/kg) was obtained from the samples of Rajkot district and the highest mean value of 3.09 mg/kg was found in samples of Junagadh district (Table 2). Naria *et al.* (2008) had similarly found exchangeable iron for cultivated farmers field of Saurashtra region and Selvaraj and Basavaraj (2015) showed exchangeable iron (0.22 to 3.93 mg/kg) in paddy growing soils of Gangavati taluka of north Karnataka.

The overall range of available iron in the soils was recorded as 1.15-16.59 mg/kg with mean value of 6.28

Table 2 : Range and mean of different fractions of Iron (mg/kg) in soils of different districts of South Saurashtra Agro-climatic Zone.

Name of Talukas	Water Soluble	Exchangeable	DTPA available	Reducible	Avail. Total	Total	Residual	Percent available
Junagadh	0.476-2.101 (0.990)	1.11-6.51 (3.09)	3.76-16.59 (8.17)	0.210-0.932 (0.458)	5.92-26.13 (12.50)	21948-68628 (42740)	21942-68606 (42728)	0.017-0.051 (0.029)
Gir-Somnath	0.311-1.676 (0.759)	0.92-4.97 (2.29)	3.00-16.19 (7.11)	0.162-0.872 (0.404)	4.40-23.71 (10.56)	18545-63192 (40554)	18541-63174 (40544)	0.015-0.038 (0.026)
Amreli	0.451-1.509 (0.818)	1.08-3.48 (1.84)	3.88-12.37 (6.69)	0.213-0.680 (0.396)	5.63-18.04 (9.75)	21575-68327 (37063)	21569-68309 (37053)	0.02-0.042 (0.027)
Bhavnagar	0.133-0.376 (0.260)	1.11-2.95 (1.99)	3.54-9.44 (6.02)	0.227-0.620 (0.422)	5.00-14.13 (8.75)	11220-37655 (22006)	11213-37641 (21995)	0.024-0.021 (0.026)
Porbandar	0.156-1.413 (0.594)	0.51-4.20 (1.80)	1.15-11.16 (4.57)	0.080-0.673 (0.293)	1.90-17.44 (7.26)	15350-64046 (29745)	15347-64029 (29737)	0.007-0.035 (0.025)
Rajkot	0.309-1.454 (0.715)	0.72-3.38 (1.71)	2.22-10.47 (5.14)	0.134-0.531 (0.329)	3.39-15.83 (7.90)	18260-57702 (34380)	18257-57689 (34372)	0.019-0.042 (0.023)
Overall SSAZ	**0.133-2.101 (0.689)**	**0.51-6.51 (2.12)**	**1.15-16.59 (6.28)**	**0.080-0.932 (0.384)**	**1.90-26.13 (9.45)**	**11220-68628 (34415)**	**11213-68606 (34405)**	**0.007-0.051 (0.026)**

mg/kg. The data revealed that lowest mean value of available iron (4.57 mg/kg) was recorded from the soils samples of Porbandar district and the highest mean value of 8.17mg/kg was recorded in soils samples of Junagadh district. The status of DTPA available iron highest noted in Junagadh district, it is due to high lime content in soils. The soils of Junagadh district are medium black *calcareous* in nature. That's way less iron removal from soils as compared to other districts. Similar findings were also recorded Singh and Athokpam (2018) in soil of Chandel district of Manipur, Thombe *et al.* (2020) also found the status of DTPA extractable iron (2.11 to 9.00 mg/kg) in Shemda and Umtha village of Narkhed tehsil and Durkheda village of Katol tehsil of Nagpur district of Maharastra.

The district wise mean and range value of reducible iron is designated in Table 2. The overall range of reducible iron in soil was 0.080-0.932 mg/kg with mean value of 0.384 mg/kg. The data revealed that lowest mean value (0.293 mg/kg) was obtained from the samples of Porbandar district and the highest mean value (0.458 mg/kg) was found in samples of Junagadh. This finding is in conformity with the findings of earlier work done by Naria *et al.* (2008) for soils of Saurashtra region of Gujarat.

Available total is the sum of water soluble, exchangeable, DTPA available and reducible fraction. Available total iron ranged from 1.90-26.13 mg/kg with a mean value of 9.45 mg/kg. The highest value of available total iron was recorded in Junagadh with a mean of 12.50 mg/kg, whereas the lowest value of 7.26 mg/kg was recorded in the soil sample collected from Porbandar district. Similar findings were also recorded by Naria *et al.* (2008) for coastal deep and river coastal deep soil group of Saurashtra region of Gujarat.

In the South Saurashtra Agro-Climatic region, the overall range of total iron was 11220-68628 mg/kg, with a mean value of 34415 mg/kg. The highest total iron value of 42740mg/kg was found in Junagadh, while the lowest of 22006 mg/kg was found in a soil sample collected from Bhavnagar soils. Naria*et al.* (2008) found similar range (10163-31930 mg/kg) of total iron in different soil group of Saurashtra.

Residual iron ranged from 11213-68606 mg/kg with a mean value of 34405 mg/kg. The highest value of residual ironwas recorded in Junagadh with a mean of 42728 mg/kg whereas the lowest value of 21995 mg/kg was recorded in the soil sample collected from Bhavnagar soils. The overall range of percent available iron in South Saurashtra Agro-climatic was 0.007-0.051% with mean value of 0.026%. The data revealed that the lowest mean

Table 3 : District wise percent distribution of soil samples in low, medium and high fertility classes for available iron.

S. no.	Name of districts	Low	Medium	High	Total sample	Nutrient index	Nutrient index class
1	**Junagadh**	10(09)	71(64)	19(17)	100(90)	2.09	Medium
2	**Gir-Somnath**	18(11)	64(38)	18(11)	100(60)	2.00	Medium
3	**Amareli**	27(08)	66(20)	07(02)	100(30)	1.80	Medium
4	**Bhavanagar**	17(05)	83(25)	0.0(00)	100(30)	1.83	Medium
5	**Porbandar**	80(24)	17(05)	03(01)	100(30)	1.23	Low
6	**Rajkot**	54(16)	43(13)	03(01)	100(30)	1.50	Low
7	**Overall SSAZ**	**27.04(73)**	**61.11(165)**	**11.85(32)**	**100(270)**	**1.85**	**Medium**

Note: Values in parenthesis are indicated number of soil samples.

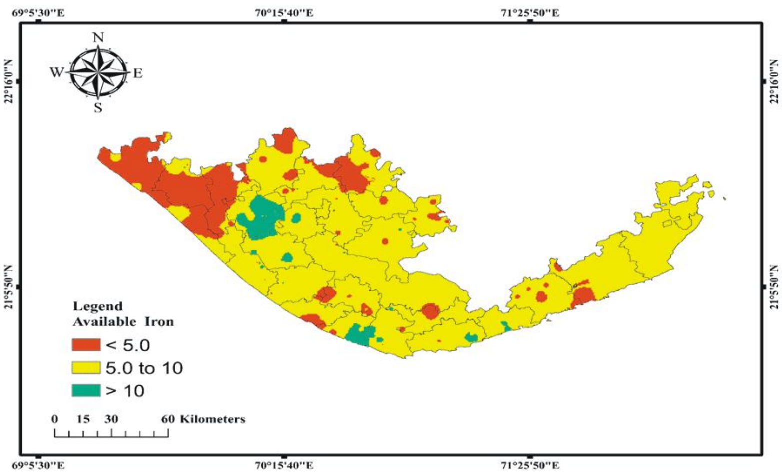

Fig. 2 : Status of available (DTPA extractable) iron in soil of South Saurashtra Agro-climatic zone.

value of percent available iron (0.023%) was obtained from the samples of Rajkot district and the highest mean value of percent available iron (0.029%) was found in samples of Junagadh district (Table 2).

Delineation of the extent of available iron status in soils of North Saurashtra Agro-climatic Zone of Gujarat through concept of nutrient index

Classification of samples and nutrient index values of different district falls in jurisdiction of North Saurashtra Agro-climatic Zone are given in Table 3 and also depicted graphically in Fig. 3 for available iron. Overall, the soils of Southern Saurashtra Agro-climatic Zone had nutrient index values of 1.85 for available iron. About 27.04 per cent samples were tested as low class (< 5 mg/kg), 61.11 per cent samples were under medium class (5-10 mg/kg) and 11.85 per cent sample falls in high available iron class (> 10 mg/kg). The high nutrient index values not found in Southern Saurashtra Agro-climatic districts, while in case of medium vale of nutrient index were found in Junagadh, Gir-Somnath, Amreli and Bhavnagar with value of 2.09, 2.00, 1.80 and 1.83, respectively. Low nutrient index values of 1.23 and 1.50 was recorded for available iron in the soils of Porbandar and Rajkot district.

Correlation between different fractious of iron and soil chemical properties

Iron transformation and its availability in the soils is dependent on its various forms and some soil chemical properties i.e. soil pH and EC, therefore, interrelationships among various forms of iron and soil chemical properties *i.e.*, water soluble iron, Exchangeable iron, Available iron, Reducible iron, Total iron, soil pH and soil EC were worked out. Thus, various soils exhibited varied relationship with available iron with respect to different forms might be depending on the nature of the soil chemical and physical properties.

The data on correlation values indicated highly significant positive relation between available iron with water soluble (r = 0.843**), exchangeable iron (r = 0.877**), reducible (r = 871**) and total (r = 0.834**). These indicated that availability iron increased with increasing the value of water soluble iron, exchangeable iron, reducible iron and total iron, while in case of soil chemical properties like soil $pH_{2.5}$ and $EC_{2.5}$ on different fractions of iron, majorly negative non-significant correlation might be due to at high range of soil pH (Alkaline) cationic micronutrients has less solubility and availability. The availability of iron was also affected by lime and soil EC. The available iron was highly significant with exchangeable iron and water soluble iron. The percent investigations find supports from the works reported earlier by Pati and Mukhopadhyay (2011), Adhikari and Yang (2015) and Joshi *et al.* (2017).

Regression analysis and multiple regression co-efficient of available iron with different fractions of iron and soil chemical properties

Many workers have tried to correlated water soluble, exchangeable, reducible and total fractions with available fractions of iron and if this association is significant then regression equation is worked out. Such equations are

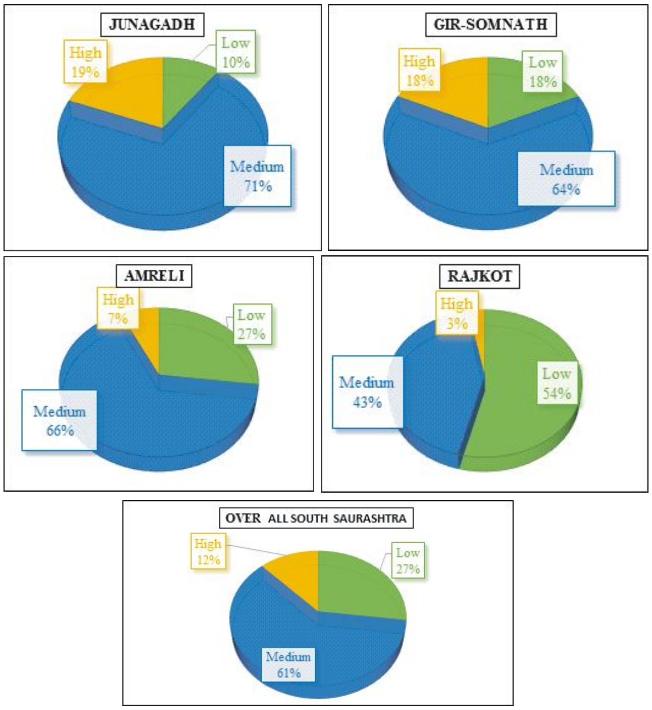

Fig. 3 : District wise percentage of soil samples falling in low, medium and high fertility classes for available iron.

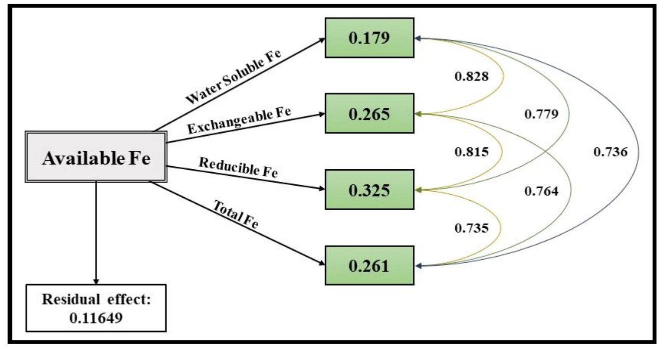

Fig. 4 : Path diagram depicting correlation and direct effects of various fractions of micronutrients on available iron.

Path co-efficient analysis between different fractions of ironin soils

From the path analysis of different fractions of iron in soils of South Saurashtra Agro-climatic Zone presented in Fig. 4, it can conclude that reducible iron ascribed maximum direct positive effect on available iron followed by reducible iron (0.325), exchangeable (0.265) total iron (0.261) and water soluble iron (0.179).

Table 4 : Correlation matrix among different fractions of iron and soil chemical properties.

Iron	AF-Fe	WSF-Fe	EF-Fe	RF- Fe	Total-Fe	$pH_{2.5}$	$EC_{2.5}$
AF-Fe	1.00						
WSF-Fe	0.843**						
EF-Fe	0.877**	0.828**					
RF- Fe	0.871**	0.779**	0.815**				
Total Fe	0.834**	0.736**	0.764**	0.735**			
$pH_{2.5}$	0.002^{NS}	-0.063^{NS}	-0.115^{NS}	-0.009^{NS}	0.026^{NS}		
$EC_{2.5}$	-0.039^{NS}	0.022^{NS}	0.033^{NS}	-0.053^{NS}	0.039^{NS}	-0.220**	1.00

*= 5 % level of significance ** = 1 % level of significance.

very useful in characterization of a large number of samples. The highly significant correlation coefficient (r) value were obtained between available iron with water soluble, exchangeable, reducible as well as total of micronutrients. The available iron regression with other fractions explained up to 86.32 of the variation in soils of South Saurashtra Agro-climatic Zone. The result also supported by Yasrebi *et al.* (1994), Prasad *et al.* (1995) and Ramzan *et al.* (2014).

Regression equations for available of iron based on different fractions and soil chemical properties

Dependent variables	Regression Equation ($Y= a +b_1x_1 +b_2x_2$…)	R square
Av Fe (Y)	Y= -2.693+ 1.44 (Water Soluble Fe) + 0.744 (Exchangeable Fe) + 5.34 (Reducible Fe) + 0.0 (Total Fe) + 0.301 (Soil pH) - 0.198 (Soil EC)	0.886

Conclusion

Based on analysis data of collected 270 soil samples, soil fertility status of available iron was medium (61.11%). Further, analysed data of iron factions like water soluble, exchangeable, available, reducible, available total, total, residual and percent available were noted in mean value of 0.689, 2.12, 6.28, 0.384, 9.45, 34415-34405 mg/kg and 0.026%, respectively. The available Fe was highly significantly positive correlated towards to their respective fractions, but those were remain unaffected by soil chemical properties like $pH_{2.5}$ and $EC_{2.5}$. Based on multiple correlations and regression analysis, the percent variance (R_2) of available Fe was note in value of 0.886. As per the path analysis of available iron with their fractions, the direct positive effects were found on the availability of iron by their respective fractions. Among the different fractions of iron, relatively higher direct positive effects was found on availability of iron by their reduciblefraction.

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