RESEARCH ARTICLE

DISTRIBUTION OF IRON FRACTIONS AND THEIR RELATIONSHIP WITH SOIL PROPERTIES IN DIFFERENT SOIL SERIES OF HARYANA

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Abstract: A laboratory experiment was conducted to determine the distribution of iron fractions and their relationship with soil properties in different soil series of Haryana. Surface soil samples (0-15 cm) were collected from each soil series using Global Positioning System (GPS). The soil samples were processed and analyzed for the determination of total Fe and Fe fractions (exchangeable, organic bound, calcium carbonate bound and residual). Iron fractions were analyzed by sequential extraction procedure. Results showed that total amount of the Fe ranged from 689.47 to 913.50 mg kg^{-1} with a mean value of 813.74 mg kg^{-1} in soil series of Aeolian Plain while it ranged from 979.18 to 1560.56 mg kg^{-1} with an average value of 1133.00 mg kg^{-1} in soil series of Alluvial Plain. In soil series of Aravali Hills, the total Fe content was 972.44 mg kg^{-1}. Iron associated with Ex- and $CaCO_3$- fractions was found to represent a minor fraction (< 0.40%) of total soil Fe. On an average OM-Fe was less than 0.74%. The majority of the soil Fe was found to be associated with residual fraction which was nearly 98% of total soil Fe. Iron as percentage of total soil Fe in different fractions was in the order: Res- > OM- > $CaCO_3$- ~ Ex- in Aeolian Plain, Alluvial Plain and Aravali Hills soils. Ex-Fe fraction was positively and significantly correlated with soil organic carbon. OM-Fe fraction showed positive and significantly correlation with EC, OC, CEC and clay. Results reflected that soil properties influence the distribution of different Fe fractions in soils.

Keywords: Sequential extraction, Organic bound, Calcium carbonate bound, Residual

INTRODUCTION

Iron is an essential element that is required for various cellular events in plants, including respiration, chlorophyll biosynthesis, and photosynthetic electron transport. Iron is also a component of the Fe-S cluster, which is present in numerous enzymes (Bashir *et al.*, 2006). Fe deficiency significantly affects plant growth and development. In spite of high total iron in soils, its availability to crops is a major problem in many soils. The total content of metals in soil is generally not a suitable index for estimating their availability in soils, because only part of them is mobile in the soil profile and is available for absorption by the roots of plants. These metals can accumulate in the soil in different forms such as water-soluble, exchangeable, bound to oxides, bound to carbonates, and bound to organic and residual matter in the structure of minerals. Water-soluble and exchangeable fractions are considered readily mobile and available; fractions associated to oxides, carbonates, and organic matter may be potentially available, depending on the combination of chemical and physical properties of the soil, while the residual fraction is not available to plants and microorganisms.

Thus, a proper understanding of the fractions which control the distribution of micronutrients between active soil constituents and soil solution is fundamental to understanding of the chemistry of micronutrients in soil (Viets, 1962). The extent to which each fraction of micronutrients is present and the transformations in equilibrium between various fractions is influenced by soil properties such as pH, cation exchange capacity, texture and soil organic matter. The available Fe status in soils of Haryana has been reported by many workers. However, the data available is hardly sufficient to bring out the variability inherent in soils, it is only possible to draw conclusion if the sampling with soil series as the basis is considered. Understanding the distribution of Fe in different fractions helps to know its retention in soil and release to plants. The study of various fractions of Fe present in surface soils of different series of Haryana and conditions under which they become available to plants is pre-requisite in assessing its availability to plants. Knowledge on distribution of Iron fractions in soils and various soil properties influencing its availability might prove to be the best approach for obtaining reliable information about the need of Iron. Therefore, the major objective of this study was to determine Iron fractionation of soils from different soil series and their relationships with some soil properties.

MATERIAL AND METHODS

Location

The study area under different soil series of Haryana state is located between 27° 39’ to 30º 35’ N latitudes and between 74º 28’ to 77 º 36’ E longitudes with an altitude ranging between 200 meters to 1200 meters above sea level covering a total geographical area of 4.42 million hectare. The area under various soil series in Haryana is characterized by light in texture, moderate to high in pH and low to medium in organic content. These soils were also studied in the field in detailed description and classified using soil

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taxonomical classification procedure. Majority of the soils of eighteen soil series fall under alluvial plain followed by Aeolian plain and only one type of soil series falls under Aravali hills soil. These soil series were selected based on the physical and chemical properties of the soils. The details on location of soil samples collected from different soil series of Haryana are given in Table 1.

Table 1. Details of location of soil samples collected from different soil series of Haryana

Sr. No.	Name of Soil Series	Latitude	Longitude	Details
Soils of Aeolian Plain				
1.	Balsamand	29°05'293" N	74°44'560" E	Near Rajasthan border on Balsamand-Bhadra road, district Hisar
2.	Isarwal	29°06'393" N	75°46'436" E	CCS HAU Dry Land Research Farm, Balsamand, district Hisar
3.	Rawalwas	29°08'716" N	75°58'162" E	1 km before village Rawalwas on Hisar-Balsamand road, district Hisar
4.	Nimriwali	28°89'029" N	75°89'545" E	Near Tosham by pass, district Bhiwani
5.	Atela	28°59'239" N	76°11'575" E	1 km from Barsana towards Loharu on Dadri-Loharu road, district Bhiwani
6.	Khoh	28°35'453" N	76°89'525" E	After crossing Manesar village, left towards Kasan village, district Gurugaon
Soils of Alluvial Plain				
7.	Barwala	29°33'389" N	75°90'884" E	3 km from Barwala towards south on Barwala-Hansi road, district Hisar
8.	Ladwa	29°15'036" N	75°67'844" E	Field No.63/16, CCS HAU Research Farm, district Hisar
9.	Lukhi	28°32'010" N	76°79'572" E	East of Pataudi-Gurgaon road, village Uncha Majra, district Gurugaon
10.	Nai	27°84'770" N	77°26'318" E	2 km from village Singar near Punhana block, district Mewat
11.	Uchani	29°72'991" N	76°98'333" E	Field No. 67, CCS HAU Research Farm, Uchani, district Karnal
12.	Kaul	29°85'756" N	76°65'667" E	Field No. 3, Block-B, CCS HAU Research Farm, Kaul, district Kaithal
13.	Ujina	28°04'991" N	77°08'187" E	Nuh to Hodal road, village Ujina, district Gurugaon
14.	Narnaund	29°20'993" N	76°10'750" E	4 km from Narnaund on Narnaund-Hansi road, district Hisar
15.	Berpura	30°43'978" N	76°98'413" E	Shahzadpur-Ambala road, left towards Berpura village, district Ambala
16.	ZarifaViran	29°70'926" N	76°94'584" E	After crossing CSSRI, about 1.5 km from village Gudha, district Karnal
17.	Shahzadpur	30°49'729" N	77°14'342" E	After crossing village Kularpur , 0.5 km towards Tokkas-Gurudawara road, district Ambala
Soils of Aravali Hills				
18.	Sohna	28°22'823" N	77°01'715" E	About 10 km from Sohna town on Sohna–Rewari road, district Gurugaon

Soil series and characteristics: It was found that there are 18 soil series in Haryana. The name of the 18 soil series and their characteristics are mentioned below:

Balsamand Series:

The Balsamand series is a member of mixed, hyperthermic family of Typic Torripsamments. Balsamand soils have yellowish brown, mildly alkaline sandy A horizon and dark yellowish brown to brown, mildly alkaline sandy C horizon.

Isarwal Series:

The Isarwal series is a member of mixed, hyperthermic family of Typic Torripsamments. Isarawal soils have yellowish brown, loamy sand, moderately alkaline A horizon and brown, loamy fine sand, moderately alkaline C horizon.

Rawalwas Series:

The Rawalwas series is a member of coarse loamy, mixed, hyperthermic family of Typic Paleorthids. Rawalwas soils have brown, mildly alkaline, loamy sand A horizon; dark yellowish brown to yellowish brown, mildly alkaline; loamy sand to sandy loam B horizon and yellowish brown to light olive brown loamy C horizon. The B2 horizon has hard calcic layer.

Nimriwali Series:

The Nimriwali series is a member of coarse loamy, mixed, hyperthermic family of Typic Camborthids. Soils have yellowish brown mildly alkaline, loamy sand A horizon, brown to dark brown, moderately alkaline, sandy loam, B horizon, ‘C’ horizon are dark yellowish brown, moderately alkaline, sandy loam and calcareous.

Atela Series:

The Atela series is a member of mixed, hyperthermic family of Aridic Ustipsamments. Atela soils have dark yellowish brown to yellowish brown, loamy sand and mildly alkaline A horizon and dark yellowish brown, loamy sand and mildly alkaline C horizon.

Khoh Series:

The Khoh series is a member of mixed, hyperthermic family of Typic Ustipsamments. Typically, Khoh soils have brownish yellow to yellowish brown, moderately alkaline, loamy sand A horizon and brownish yellow to yellowish brown, moderately alkaline, loamy sand C horizon.

Barwala Series:

The Barwala series is a member of mixed, hyperthermic, coarse loamy, non-calcareous family of Aridic Ustochrepts. These soils have yellowish brown, loamy fine sand, moderately alkaline A horizon and dark yellowish brown, sandy loam to loam moderately alkaline B horizon.

Ladwa Series:

The Ladwa series is a member of fine loamy, mixed, hyperthermic family of Aridic Ustochrepts. Ladwa soils have yellowish brown, mildly alkaline, sandy loam to loam A horizon, yellowish brown to dark yellowish brown, mildly alkaline clay loam B horizon.

Lukhi Series:

The Lukhi series is a member of coarse loamy, mixed, hyperthermic, family of Typic Ustochrepts. Typically, Lukhi soils have dark yellowish brown to dark brown, moderately alkaline, sandy loam A horizon and dark brown, moderately to strongly alkaline, sandy loam B horizon.

Nai Series:

The Nai series is a member of coarse loamy, mixed, hyperthermic, family of Typic Ustorthents. Typically, Nai soils are brown to yellowish brown, moderately alkaline, loamy fine sand A horizon and grayish brown to light yellowish brown, moderately alkaline, sandy loam C horizon.

Uchani Series:

The Uchani series is a member of fine loamy, mixed, hyperthermic, and family of Typic Ustochrepts. These soils have dark brown, mildly alkaline, loam A horizon, dark brown, mildly alkaline, loam to clay loam B horizon and dark yellowish brown, mildly alkaline, silty clay loam C horizon.

Kaul Series:

The Kaul series is a member of fine, mixed, hyperthermic, family of Aquic-Vertic Ustochrepts. These soils have dark brown, loam, moderately alkaline A horizon and dark gray brown to very dark gray brown, clay loam, moderately alkaline B horizon.

Ujina Series:

The Ujina series is a member of fine, calcareous, mixed, hyperthermic, family of Aeric Haplaquepts. These soils have grayish brown to dark grayish brown, moderately alkaline, clay loam A horizon and dark gray to very dark gray with dark brown mottles, alkaline, clay loam B horizon. The lithlogically separate C horizon is light yellowish brown with dark brown mottles, strongly alkaline, loam and soft Fe-Mn concretions.

Narnaund Series:

The Narnaund series is a member of coarse loamy (saline-alkali), mixed, hyperthermic, family of Natric Ustochrepts. Narnaund soils have light olive brown to light yellowish brown, very strongly saline-alkali, sandy loam A horizon and yellowish brown, very strongly alkali and moderately saline, loam to silt loam B horizon. The C horizon is brown, strongly alkali, silt loam.

Berpura Series:

The Berpura series is a member of fine loamy, mixed, hyperthermic, family of Udic Ustochrepts. Typically, Berpura soils have pale brown to dark yellowish brown, moderately alkaline, loam A horizon and dark yellowish brown to brown, mildly to moderately alkaline, clay loam B horizon.

Zarifa Viran series:

The Zarifa Viran series is a member of fine silty, mixed, hyperthermic, family of Typic Natrustalfs. Typically, Zarifa Viran soils have pale yellow to yellowish brown, very strongly alkaline, loam to clay loam A horizon, olive brown to light olive brown, very strongly alkaline, loam to clay loam B horizon and light olive brown, very strongly alkaline, loam C horizon.

Shahzadapur Series:

The Shahzadapur series is a member of fine loamy, mixed, hyperthermic, family of Udic Ustochrepts. Typically, Shahzadpur soils have yellowish brown to dark yellowish brown, neutral, loamy fine sand A horizon and yellowish brown to dark brown, slightly acidic to neutral, sandy loam to sandy clay loam B horizon underlain by brown to dark brown, slightly acidic, sandy loan C horizon.

Sohna Series:

The Sohna series is a member of loamy skeletal, mixed, hyperthermic, cancerous family of Ruptic-Lithic Ustorthents. Sohna soils have known to yellowish brown, mildly alkaline, loamy sand A horizon; brown to dark brown, mildly alkaline loam AC horizon and dark brown bed rock (Aravali hill) C horizon.

Collection and processing of soil samples

In order to assess the Iron fractions, surface soil samples (0-15 cm) representing all the eighteen soil series of Haryana were collected using Global Positioning System (GPS). Location of the soil sample sites (X, Y coordinates) was recorded. In the laboratory, the soils were processed by drying at ambient temperature and sieving through 2mm aperture stainless sieve. Air-dried samples <2 mm were stored in polythene bags for subsequent analysis.

Soil analysis

These processed soil samples were used for the determination of total Fe and Fe fractions (exchangeable, organic bound, calcium carbonate bound and residual) in the soil. Iron fractions were analyzed by sequential extraction procedure out lined by Tessier *et al.* (1979). Total Fe (%) was analyzed by Hydrofluoric-perchloric acid mixture as prescribed by Page *et al.* (1982). Fe content in the extract was estimated using Atomic Absorption Spectrophotometer (Varian-Spectra AA-240 FS).

Statistical analysis

Data obtained from all the observation were statistically analyzed. The relationship between relevant soil properties and Fe fractions was carried out and the correlation coefficients were computed as per Snedecor and Cochran (1967) by using the formula:

$$r = \sqrt{\frac{SP(xy)}{SS(x), SS(y)}}$$

Where,
r = Correlation coefficient
SP (xy) = Sum product of x, y variables
SS (x) = Sum of square of x variable
SS (y) = Sum of square of y variable.

RESULTS AND DISCUSSION

In the studied soil profiles (Aeolian, Alluvial and Aravali Hills), the results of the fractions of iron in the surface soils (0-15 cm) is presented in Table 2 and their mean percent distribution is shown in Fig. 4.12.

Distribution of iron fractions

The total Fe in the soils ranged from 689.47 to 913.50 mg kg^{-1} with a mean value of 813.74 mg kg^{-1} in soil series of Aeolian Plain while it ranged from 979.18 to 1560.56 mg kg^{-1} with an average value of 1133.00 mg kg^{-1} in soil series of Alluvial Plain (Table 2). In soil series of Aravali Hills, the total Fe content was 972.44 mg kg^{-1}. Soils of Alluvial Plain were rich in total Fe as compared to soils of Aeolian Plain. These compared fairly well with the values reported by Sharma *et al*. (2016). The concentration of Fe in Ex-, OM- and $CaCO_3$- fractions were found to be very small in all the soils under study. Soils of Aravali Hills had 972.44, 2.70, 4.98, 3.01 and 951.48 mg kg^{-1} concentration of total Fe, Ex-, OM-, $CaCO_3$- and Res-, respectively.

Iron associated with Ex- and $CaCO_3$- fractions was found to represent a minor fraction (< 0.40%) of total soil Fe. On an average OM-Fe was less than 0.74%. The majority of the soil Fe was found to be associated with residual fraction which was nearly 98% of total soil Fe. Iron as percentage of total soil Fe in different fractions was in the order: Res- > OM- > $CaCO_3$- ~ Ex- in Aeolian Plain, Alluvial Plain and Aravali Hills soils as also confirmed in research by Jaloud *et al.* (2013), they concluded that considering the total amount of the four micronutrients (Zn, Fe, Mn and Cu) within each fraction, the five fractions followed the order: Residual>oxide bound> organic bound> CO_3 bound >exchangeable.

Relationship between Fe fractions and soil properties

A perusal of data presented in Table 3 revealed that Ex-Fe fraction was positively and significantly correlated with OC while it was positively and non-significantly correlated with pH, EC, $CaCO_3$, CEC and clay. The results were in close agreement with findings of Murthy and Murthy (2005) and the negative correlation of available Fe with soil pH and $CaCO_3$ indicated that there is precipitation of available iron in to insoluble products which supports the classical phenomenon of lime induced iron deficiency. OM-Fe fraction showed positive non-significant correlation with pH, and $CaCO_3$ while it was positively and significantly correlated with EC, OC, CEC and clay. The high content of OM-Fe in the surface layers may be due to an increased amount of organic carbon. $CaCO_3$-Fe was positively and significantly correlated with OC and $CaCO_3$ while it was positively and non-significantly correlated with pH, EC, CEC and clay. Res-Fe showed positive non-significant correlation with pH and negative non-significant correlation with $CaCO_3$ while it was positively and significantly correlated with EC, OC, CEC and clay. Similar conclusions were made by Ibrahim *et al.* (2011). They observed that Ex-Fe fraction was positively and significantly correlated with soil organic carbon. Ex-Fe fraction was positively and significantly correlated with soil organic carbon these results were reported earlier by Sharma *et al*. (2008). They stated that besides organic matter, the content of clay and silt fractions also had a strong bearing on the distribution of forms of Fe.

CONCLUSION

The results revealed that soil properties influence the distribution of different Fe fractions in soils. Soils of Alluvial Plain were rich in total Fe as compared to soils of Aeolian Plain. The concentration of Fe in Ex-, OM- and $CaCO_3$- fractions were found to be very small in all the soils under study. The majority of the soil Fe was found to be associated with residual fraction which was nearly 98% of total soil Fe. Iron as percentage of total soil Fe in different fractions was in the order: Res- > OM- > $CaCO_3$- ~ Ex- in Aeolian Plain, Alluvial Plain and Aravali Hills soils. Ex-Fe fraction was positively and significantly correlated with soil organic carbon. OM-Fe fraction showed positive and significantly correlation with EC, OC, CEC and clay. $CaCO_3$-Fe was positively and significantly correlated with OC and $CaCO_3$.

Table 2. Iron fractions expressed as amount extracted and percentage of total Fe for Aeolian Plain, Alluvial Plain and Aravali soils

Location/Soil series	Total-Fe	Ex-Fe *		OM-Fe		$CaCO_3$-Fe		Res-Fe	
	(mg kg^{-1})	(mg kg^{-1})	(%)**	(mg kg^{-1})	(%)	(mg kg^{-1})	(%)	(mg kg^{-1})	(%)
Soil of Aeolian Plain									
1. Balsamand	689.47	0.48	0.07	2.13	0.31	1.53	0.22	682.35	98.97

2. Isarwal	891.75	2.64	0.30	3.44	0.39	2.38	0.27	880.34	98.72
3. Rawalwas	787.13	2.60	0.33	6.08	0.77	2.61	0.33	772.84	98.18
4. Nimriwali	913.50	2.25	0.25	3.38	0.37	2.06	0.23	901.56	98.69
5. Atela	783.00	2.60	0.33	3.90	0.50	2.52	0.32	770.54	98.41
6. Khoh	817.58	2.51	0.31	4.36	0.53	2.52	0.31	806.89	98.69
Range	689.47- 913.50	0.48- 2.64	0.07-0.33	2.13- 6.08	0.31- 0.77	1.53- 2.61	0.22-0.33	682.35- 901.56	98.18- 98.97
Mean	813.74	2.18	0.27	3.88	0.48	2.27	0.28	802.42	98.61
Soil of Alluvial Plain									
7. Barwala	983.31	3.54	0.36	12.88	1.31	2.72	0.28	968.98	98.54
8. Ladwa	1049.22	3.00	0.29	13.34	1.27	2.72	0.26	1024.32	97.63
9. Lukhi	1044.00	2.43	0.23	4.72	0.45	2.39	0.23	1029.89	98.65
10. Nai	979.18	2.84	0.29	6.20	0.63	2.66	0.27	955.12	97.54
11. Uchani	1087.50	2.85	0.26	7.38	0.68	2.66	0.24	1066.79	98.10
12. Kaul	1272.37	2.93	0.23	16.90	1.33	2.80	0.22	1253.47	98.51
13. Ujina	1560.56	2.78	0.18	13.38	0.86	2.65	0.17	1546.32	99.09
14. Narnaund	1021.38	2.76	0.27	11.14	1.09	3.04	0.30	1007.99	98.69
15. Berpura	1300.32	2.90	0.22	8.88	0.68	2.66	0.20	1286.92	98.97
16. Zarifa Viran	1070.10	2.60	0.24	10.64	0.99	2.95	0.28	1047.89	97.92
17. Shahzadpur	1095.11	2.91	0.27	6.68	0.61	2.68	0.24	1076.85	98.33
Range	979.18- 1560.56	2.43- 3.54	0.18-0.36	4.72- 16.90	0.45- 1.33	2.39- 3.04	0.17-0.30	955.12- 1546.32	97.54- 99.09
Mean	1133.00	2.87	0.26	10.19	0.90	2.72	0.24	1114.96	98.36
Soil of Aravali Hills									
18. Sohna	972.44	2.70	0.28	4.98	0.51	3.01	0.31	951.48	97.84

*Ex-Fe: Exchangeable + water soluble; OM-Fe: Organically bound; $CaCO_3$-Fe: Calcium carbonated bound; Res-Fe: Residual

**Expressed as a percentage of total

Table 3. Simple linear correlation coefficient (r) between forms of Fe and soil properties

Fe	**pH**	**EC**	**OC**	**$CaCO_3$**	**CEC**	**Clay**
Total-Fe	0.446^{NS}	0.721^{**}	0.770^{**}	-0.001^{NS}	0.906^{**}	0.949^{**}
Ex-Fe	0.093^{NS}	0.341^{NS}	0.772^{**}	0.059^{NS}	0.243^{NS}	0.378^{NS}
OM-Fe	0.412^{NS}	0.563^{*}	0.913^{**}	0.158^{NS}	0.631^{**}	0.657^{**}
$CaCO_3$-Fe	0.251^{NS}	0.462^{NS}	0.763^{**}	0.484^{*}	0.223^{NS}	0.351^{NS}
Res-Fe	0.447^{NS}	0.716^{**}	0.763^{**}	-0.002^{NS}	0.909^{**}	0.949^{**}

* Significant at p<0.05; ** Significant at p<0.01; NS: Non-significant

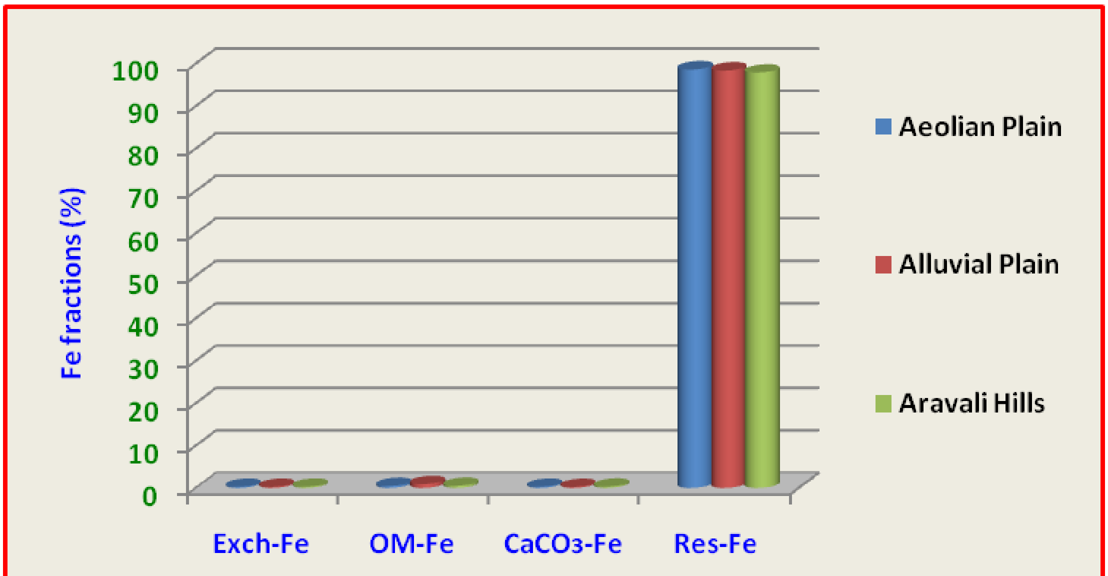

Fig. 4.12: Average percent Fe fractions in the surface soils

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