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Differential response of groundnut genotypes for iron (Fe) deficiency chlorosis tolerance and productivity traits under Fe-supplemented and Fe-non-supplemented conditions

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Abstract

Groundnut is sensitive to Fe deficiency under alkaline and calcareous soils and exhibits iron deficiency chlorosis (IDC) causing significant reduction in growth and yield. Genotypes were assessed for IDC related traits such as visual chlorosis rating, SPAD chlorophyll meter reading, chlorophyll and active iron (Fe^{2+}) content across five growth stages and also for productivity traits *viz.*, plant height, number of primary branches, number of pods per plant, pod yield, shelling per cent, 100 seed weight and haulm yield. Comparison between Fe-supplemented and Fe-non-supplemented condition for IDC related traits showed not much difference among IDC tolerant genotypes across all five growth stages, while significant differences among IDC susceptible genotypes were observed. Maximum reduction in pod yield was observed among IDC susceptible genotypes compared to IDC tolerant and moderately tolerant genotypes. However, recently released variety G 2-52 with moderate tolerance to IDC and higher yield potential recorded higher pod yield both under Fe applied (1754 kgha^{-1}) and non-applied conditions (1544 kgha^{-1}).

Key words: Groundnut, iron deficiency chlorosis, productivity, tolerance

Introduction

Groundnut (*Arachis hypogaea* L.), an important food legume and oilseed crop is cultivated globally in an area of 28.5 million ha with production of 45.9 million tonnes (Faostat 2018, http://www.fao.org/faostat/en/#data/QC). India is a major producer of groundnut (6.69 million tonnes) with a cultivated area of 4.94 million ha, but productivity is low (1355 kg ha^{-1}) compared to USA (4473 kg ha^{-1}), China (3752 kg ha^{-1}), Argentina (2075 kg ha^{-1}) and world average (1611 kg ha^{-1}). Among the abiotic stresses, Fe deficiency is prevalent in alkaline and calcareous soils, wherein groundnut is found sensitive to Fe deficiency (Zuo and Zhang 2011; Sánchez-Alcalá et al. 2014). Several countries including China (Gao and Shi 2007), Cyprus (Papastylianou 1989), India (Potdar and Anders 1992), Indonesia (Field and Kameli 1987), Israel (Hartzook 1975), Pakistan (Imtiaz et al. 2010; Akhtar et al. 2013), Taiwan (Lee et al. 1983), Thailand (Ratanarat et al. 1987), and USA (Young 1967) have witnessed Fe deficiency in groundnut causing significant reduction in yield. In India, more than one-third of the soils are calcareous and spread mostly in the low rainfall areas of the western and central parts of the country, where groundnut is cultivated mainly as a rainfed crop. In India, IDC is prevalent in the states of Gujarat, Maharashtra, Rajasthan, Tamil Nadu and Karnataka showing considerable reduction (Singh 2001) in pod yield (16-32%). IDC severity will be high after excessive rainfall and under irrigated groundnut due to high bicarbonate ion concentration in the rhizosphere (Singh et al. 1995; Zuo et al. 2007).

To overcome IDC, application of Fe-containing fertilizers into soil or as foliar spray was suggested (Irmak et al. 2012) but it is ineffective due to conversion of Fe into unavailable form (Fe^{3+}) or poor translocation within the plant (Hüve et al. 2003). Application of

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chelated-Fe can overcome this problem but not viable economically since groundnut is mainly cultivated as a rainfed crop in the semi-arid tropics. Under such situations, development of IDC tolerant genotypes would overcome the Fe deficiency in soil and also contribute to improvement in human health (Imtiaz et al. 2010). The literature indicated existence of genetic variability for IDC response in groundnut (Samdur et al. 2000; Gao and Shi 2007; Akhtar et al. 2013; Su et al. 2015) which can be effectively utilized in cultivar development. Growing of IDC tolerant groundnut cultivars under calcareous soils have shown significantly higher pod yield compared to susceptible cultivars (Samdur et al. 1999; Prasad et al. 2000; Li and Yan-Xi 2007). Previous studies carried out by Boodi et al. (2015) have shown differential response in the form of tolerance (ICGV 86031), moderate tolerance (G 2-52, GPBD 5), and susceptible reaction (TMV 2, Dh 86) of different groundnut genotypes. Though many tolerant genotypes have been reported in groundnut for IDC but absolute resistance to any stress will have cost especially in the form of yield reduction. Information on assessment of amount of tolerance vis-à-vis productivity at field level is scarce and, therefore, the present study was conducted with a set of carefully chosen differentially IDC responsive (tolerant, moderately tolerant and susceptible) groundnut genotypes in Fe-supplemented and Fe-non-supplemented condition under calcareous soils in terms of IDC response and productivity traits.

Materials and methods

Eleven groundnut genotypes with differential response to IDC were selected for the study. Among them, ICGV 86031 and selected recombinant inbred lines (RIL 52, RIL 146 and RIL 307) from the cross, TAG 24 × ICGV 86031 were tolerant to IDC; the released cultivars, GPBD 5 and G 2-52, and advanced breeding lines ICGV 06146 and A 30b were moderately tolerant to IDC, and the popular released cultivars TAG 24, Dh 86 and TMV 2 were susceptible to IDC as evident from earlier studies (Boodi et al. 2015). All the genotypes were evaluated in a factorial design under Fe-deficient calcareous vertisol soils [DTPA extractable iron (Fe^{2+})< 4 mg kg^{-1}] (Table 1) at College of Agriculture, Vijayapur, Karnataka, India (16°49' N, 75°43' E, altitude, 593 m amsl and 597 mm average annual rainfall) during 2016 rainy season. First factor comprised of two conditions i.e., Fe-non-supplemented and Fe-supplemented through foliar application of 0.5% Fe-EDDHA (Chelated-Fe) at two stages i.e., 25 and 40 days after sowing. Second factor comprised of eleven genotypes wherein, each genotype was sown as five rows of 3 m length with a spacing of 30 × 10 cm in three replications. The recommended cultivation practices were followed to raise a good crop and protective irrigation was provided during moisture stress. All the major nutrients (N, P and K) were supplied in the form of urea, di-ammonium phosphate, and muriate of potash fertilizers as per recommended dose. Micronutrients like Zn, Mn and Mg were applied in the form of $ZnSO_4$, $MnSO_4$, and $MgSO_4$, respectively at 25 days after sowing to avoid the complexity of overlapping visual deficiency symptoms with Fe. Fe-containing fertilizers were not applied to maintain the iron deficiency status of the calcareous soil.

Table 1. Soil chemical properties in experimental site

Parameter	Values
pH	8.02
Electrical Conductivity (dSm^{-1})	0.53
Organic Carbon (%)	0.64
Available Nitrogen (kg ha^{-1})	294
Available P_2O_5 (kg ha^{-1})	48.75
Available K_2O (kg ha^{-1})	468
Available Ca (Cmol (p^+)kg^{-1})	19.25
Available Mg (Cmol (p^+)kg^{-1})	5.55
Available Sulphur (mg kg^{-1})	18.20
Free Lime (%)	8.93
Cation Exchange Capacity (Cmol (p^+)kg^{-1})	58
Base Saturation (%)	42.75
Zinc (mg kg^{-1})	2.09
Iron (mg kg^{-1})	3.12
Copper (mg kg^{-1})	2.24
Manganese (mg kg^{-1})	0.23

IDC response was assessed in terms of visual chlorosis rating (VCR), SPAD chlorophyll meter reading (SCMR), Chlorophyll 'a', Chlorophyll 'b', total chlorophyll and active iron (Fe^{2+}) content across five stages i.e., 30, 45, 60, 75 and 90d after sowing (d).

Visual chlorosis rating (VCR)

VCR scoring was done as per the scale proposed by Singh and Chaudhari (1993) [1-5 scale: 1 – normal green leaves with no chlorosis, 2 – green leaves but with slight chlorosis on some leaves, 3 – moderate chlorosis on several leaves, 4 – moderate chlorosis on most of the leaves, 5 – severe chlorosis on all the leaves] on five plants in each genotype and mean was calculated for each replication. Higher VCR score (>3) indicate IDC susceptibility, while lower score (<2) indicate IDC tolerance and intermediate score (2-3) indicates moderate tolerance.

SPAD chlorophyll meter reading (SCMR)

The chlorophyll meter SPAD 502 (Soil Plant Analysis Development meter, Konica Minolta, Japan) was used to measure the absorbance of the leaf in the red (at 650 nm) and near infrared region (at 940 nm). Using these two transmittances, numerical SPAD value was calculated which is proportional to the chlorophyll present in the leaf and is negatively related to chlorosis of the plants. The SPAD chlorophyll meter reading (SCMR) was recorded in the standard leaf (third fully expanded leaf from tip on the main stem) of five plants per genotype and mean was calculated. Higher SCMR (>25) indicates tolerance, while lower SCMR (<25) indicates susceptibility to IDC.

Chlorophyll content

The leaf chlorophyll content was estimated as per the procedure given by Shoaf and Lium (1976) in the standard leaf (third fully opened leaf from shoot tip on main stem). Hundred mg of fresh leaf tissue was cut into small pieces and incubated in 7 ml of dimethyl sulfoxide at 65°C for 30 minutes. At the end of incubation period, the supernatant was decanted and leaf tissue was discarded. The supernatant volume was made up to 10 ml and absorbance was recorded at 645, 652 and 663 nm in UV-VIS spectrophotometer (ELICO-159). The chlorophyll 'a' and chlorophyll 'b' and total chlorophyll contents were estimated using the following formulae given by Arnon (1949) and expressed as mg per g fresh weight of leaf.

$$\text{Chlorophyll 'a'} = (12.7 \times A_{663}) - (2.69 \times A_{645}) \times \frac{V}{1000 \times W \times a}$$

$$\text{Chlorophyll 'b'} = (22.9 \times A_{645}) - (4.68 \times A_{663}) \times \frac{V}{1000 \times W \times a}$$

where, A = Absorbance at specific wave length (645 and 663 nm)

V = Final volume of the chlorophyll extract (ml)

W = Fresh weight of the leaf sample (g)

a = Path length of light (1 cm)

12.7, 2.69, 22.9 and 4.68 are constants

Total Chlorophyll = Chlorophyll 'a' + Chlorophyll 'b'

Active Fe (Fe^{2+})

Active Fe (ferrous, Fe^{2+}) content was estimated as per the procedure of Katyal and Sharma (1980). The leaf samples were collected from standard leaf (third fully opened leaf from shoot tip on main stem) of five random plants and washed with tap water followed by 0.1 N HCl and then rinsed with double distilled water. Further, the fresh leaves were chopped with stainless steel knife and used for estimation of active iron content. Extracting solution of o-phenanthroline was prepared by adding 15 g of o-phenanthroline in 850 ml of distilled water. Upon continuously stirring the solution 1 N HCl was added drop wise. When the last traces of the salt were soluble, the pH was determined which was found to be around 3.5. The volume of the solution was made up to 1 litre. Two grams of chopped sample was weighed immediately and transferred to 100 ml glass bottles. Twenty ml of o-phenanthroline solution was added and the contents of the bottles were stirred gently in order to embathe the plant sample with the extractant. The bottles were stopped and allowed to stand for about 16 hours at room temperature. The contents were filtered through Whatman No. 1 filter paper. The active iron content was estimated directly in the filtrate by measuring the transmittance at 510 nm in UV-VIS spectrophotometer (ELICO-159). The absorbance value was converted to ppm by multiplying with factor 0.002.

Productivity traits and statistical analysis

The yield and yield related traits such as plant height (cm), number of primary branches, number of pods per plant, pod yield (kg ha^{-1}), shelling per cent, 100 seed weight (g) and haulm yield (kg ha^{-1}) were recorded before or after harvest for all the genotypes. Plant height (cm) was measured from base of the plant to the tip of the main stem prior to harvest in five randomly selected plants in each genotype and mean was recorded. The data was analysed as per factorial design using Genstat 19.1 release (http://vsni.co.uk). Analysis of variance resulted in mean squares for IDC tolerance related traits across five growth stages, yield and its related traits and their significance was tested by Fisher's test (p=0.05). Least significant difference (LSD) (p=0.05) for mean comparison among genotypes were estimated for within and between conditions. Student Knewman-Keuls' (SNK) test (p=0.05) was used for mean comparison between genotypes under

Fe-non-supplemented condition.

Results

Mean squares for IDC response traits such as VCR, SCMR, chlorophyll ‘a’, chlorophyll ‘b’, total chlorophyll and active-Fe content across all five growth stages (30, 45, 60, 75 and 90d) showed highly significant differences for condition (Fe-supplemented and Fe non-supplemented) and genotypes. The interaction between condition and genotypes was also highly significant for all the IDC response traits. All the productivity traits such as plant height, number of primary branches, number of pods, pod yield, shelling per cent and haulm yield shown significant differences for genotypes, while number of pods per plant, pod yield and hundred seed weight shown significant differences for condition. There was no significant interaction between condition and genotypes for the productivity traits.

IDC response traits

Visual chlorosis rating was carried out across the five growth stages. Highest VCR was observed at 60 d under Fe-non-supplemented condition wherein susceptible genotypes i.e., Dh 86 (4.33), TMV 2 (4.07), and TAG 24 (3.93) recorded highest VCR scores (Table 2a). Lowest VCR scores were observed among IDC tolerant genotypes (ICGV 86031, RIL 146, RIL 52 and RIL 307) followed by moderately tolerant genotypes (ICGV 06146, GPBD 5, G 2-52 and A 30b (Table 2a). However, under Fe-supplemented condition, VCR score was almost similar (close to 1.0) during all stages of crop growth among all tolerant, moderately tolerant, and susceptible genotypes. Between the Fe-supplemented and Fe-non-supplemented condition, not much difference in VCR was observed among IDC tolerant genotypes at all the growth stages, while it was maximum among IDC susceptible genotypes. For example, the susceptible genotype Dh 86 had higher VCR score at 60d under Fe-non-supplemented condition as compared to Fe-supplemented condition (1.0). For moderately tolerant genotypes, the difference was moderate between Fe-supplemented and Fe-non-supplemented condition. Under Fe-non-supplemented condition, VCR scores among susceptible genotypes increased up to 60d, however, there was gradual recovery up to 90d and maximum recovery being in susceptible genotype, TMV 2 (Fig. 1).

SPAD chlorophyll meter reading was recorded in Fe-non-supplemented condition; IDC tolerant and moderately tolerant genotypes recorded highest SCMR, while IDC susceptible genotypes recorded lowest SCMR at all five growth stages (Table 2a). There was significant reduction in SCMR in case of IDC susceptible genotypes followed by moderately tolerant genotypes and least in case of IDC tolerant genotypes at all the growth stages and more specifically at grand growth stages i.e., 45 to 60d. Under Fe-non-supplemented condition, there was gradual recovery in SCMR in both IDC tolerant and moderately tolerant genotypes, but among IDC susceptible genotypes, only TMV 2 recovered after 60d while TAG 24 and Dh 86 did not show much recovery (Fig. 1). Between Fe-supplemented and Fe-non-supplemented condition, there was not much reduction in SCMR among tolerant and moderately tolerant genotypes across all growth stages and specifically at 45 and 60 d, except in case of ‘A 30b’a moderately tolerant genotype which has shown maximum reduction under Fe-non-supplemented condition both at 45 and 60d. Among susceptible genotypes, there was maximum reduction in SCMR in all growth stages and specifically at grand growth stages, 45 and 60d.

Chlorophyll contents were measured in Fe-non-supplemented condition, IDC tolerant and moderately tolerant genotypes recorded highest chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll, while IDC susceptible genotypes recorded lowest at all growth stages (Table 2b and c). There was significant reduction in chlorophyll (‘a’, ‘b’ and total) in case of IDC susceptible genotypes followed by moderately tolerant genotypes and least in case of IDC tolerant genotypes at all the growth stages and more specifically at grand growth stages i.e., 45 to 75d under Fe-non-supplemented condition. For example, the genotype TAG 24 had higher chlorophyll ‘a’ (1.56) under Fe-supplemented condition as compared to Fe-non-supplemented condition (0.47) at 90d. Under Fe-non-supplemented condition, there was more recovery in total chlorophyll in both IDC tolerant and moderately tolerant genotypes during later stages of the crop growth (Fig. 1). But among IDC susceptible genotypes, significant recovery in total chlorophyll was observed in TMV 2 (0.11 to 1.10) at 90d, while TAG 24 and Dh 86 did not show much recovery.

Active Fe (Fe^{2+}) was estimated in Fe-non-supplemented condition, IDC tolerant and moderately tolerant genotypes recorded higher active-Fe content, while IDC susceptible genotypes recorded lower active-Fe content during 45 to 90d (Table 2c). There was maximum reduction in active-Fe content among IDC susceptible genotypes followed by moderately tolerant

Table 2a. Mean performance of groundnut genotypes for VCR and SCMR over five growth stages under Fe-supplemented (Fe+) and Fe-non-supplemented (Fe-) conditions

IDC response	Genotype	Visual chlorosis rating (VCR)											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	1.00	1.07^{a}	1.07	1.07^{a}	1.00	1.17^{a}	1.07	1.07^{a}	1.00	1.13^{a}	1.03	1.10
	RIL146	1.00	1.40^{ab}	1.00	1.13^{a}	1.00	1.23^{a}	1.00	1.17^{a}	1.01	1.13^{a}	1.00	1.21
	RIL52	1.00	1.53^{b}	1.00	1.53^{ab}	1.00	1.20^{a}	1.00	1.13^{a}	1.00	1.07^{a}	1.00	1.29
	RIL307	1.00	1.40^{ab}	1.00	1.60^{ab}	1.00	1.20^{a}	1.00	1.07^{a}	1.00	1.27^{a}	1.00	1.31
Mod. Tol.	ICGV06146	1.07	2.07^{c}	1.07	2.77^{de}	1.00	1.33^{a}	1.00	1.23^{a}	1.00	1.13^{a}	1.03	1.71
	GPBD5	1.07	2.00^{c}	1.20	2.00^{bc}	1.13	2.10^{b}	1.07	1.07^{a}	1.00	1.13^{a}	1.09	1.66
	G2-52	1.40	2.27^{c}	1.47	2.47^{cd}	1.00	1.70^{ab}	1.20	1.23^{a}	1.00	1.00^{a}	1.21	1.73
	A30b	1.13	1.63^{b}	1.00	2.93^{d-f}	1.00	3.17^{c}	1.00	1.53^{a}	1.00	1.23^{a}	1.03	2.10
Sus.	TMV2	1.60	2.27^{c}	1.33	3.60^{g}	1.13	4.07^{d}	1.27	2.33^{b}	1.08	1.20^{a}	1.28	2.69
	TAG24	1.07	2.33^{c}	1.07	3.27^{e-g}	1.00	3.93^{d}	1.00	3.50^{d}	1.02	3.10^{b}	1.03	3.23
	Dh86	1.20	2.20^{c}	1.00	3.43^{fg}	1.00	4.33^{d}	1.00	2.97^{c}	1.00	2.90^{b}	1.04	3.17
	Mean – Fe+/ Fe-	1.14	1.83	1.11	2.35	1.02	2.31	1.05	1.66	1.01	1.48	1.07	1.93
	LSD(C) / LSD(G)	0.31	0.19	0.27	0.25	0.11	0.26	0.24	0.21	0.14	0.21	-	-
	Grand mean / LSD	1.49	0.30	1.73	0.37	1.67	0.35	1.36	0.30	1.25	0.29	1.50	-
	CV (%)	11.1	-	12.7	-	13.3	-	13.0	-	14.2	-	-	-

IDC response	Genotype	SPAD chlorophyll meter reading (SCMR)											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	42.63	39.85^{a}	44.17	38.67^{a}	39.91	32.96^{a}	44.73	41.50^{ab}	49.18	45.87^{ab}	44.12	39.77
	RIL146	36.52	34.26^{b}	38.82	37.97^{a}	40.76	34.61^{a}	44.42	43.78^{a}	47.36	45.72^{ab}	41.58	39.27
	RIL52	42.72	31.74^{bc}	41.32	35.81^{ab}	39.16	34.51^{a}	42.38	40.27^{ab}	45.70	41.63^{bc}	42.26	36.79
	RIL307	41.61	33.72^{b}	37.37	31.85^{a-c}	38.70	34.84^{a}	44.23	39.43^{b}	46.94	43.70^{bc}	41.77	36.71
Mod.Tol.	ICGV06146	39.52	27.84^{de}	41.83	29.31^{bc}	42.35	34.73^{a}	39.77	38.66^{b}	47.78	45.07^{a-c}	42.25	33.12
	GPBD5	37.91	28.62^{c-e}	35.73	29.05^{bc}	34.55	27.25^{a}	38.05	37.63^{b}	43.84	42.21^{bc}	38.02	32.95
	G2-52	32.07	26.84^{e}	37.69	25.98^{cd}	40.57	34.43^{a}	39.57	38.59^{b}	44.12	43.85^{bc}	38.80	33.94
	A30b	45.41	31.19^{b-d}	44.57	21.38^{d}	42.63	16.43^{b}	44.30	34.51^{c}	50.89	48.50^{a}	45.56	30.40
Sus.	TMV2	30.69	27.94^{de}	32.52	13.42^{e}	32.87	11.41^{b}	40.74	27.22^{d}	43.15	40.35^{c}	35.99	24.07
	TAG24	44.09	25.90^{e}	36.43	12.23^{e}	39.69	11.55^{b}	43.68	13.05^{f}	46.24	15.99^{d}	42.03	15.74
	Dh86	39.64	26.11^{e}	37.47	13.15^{e}	39.25	8.66^{b}	41.17	16.79^{e}	43.73	16.79^{d}	40.25	16.30
	Mean – Fe+/ Fe-	39.35	30.36	38.9	25.35	39.13	25.58	42.09	33.77	46.27	39.06	41.15	30.82
	LSD(C) / LSD(G)	3.05	4.58	3.12	4.85	4.23	4.78	2.94	2.85	1.28	2.02	-	-
	Grand mean / LSD	34.86	6.33	32.13	6.69	32.35	6.75	37.93	4.09	42.66	2.78	35.99	-
	CV (%)	11.3	-	12.9	-	12.7	-	6.4	-	4.1	-	-	-

genotypes and least in case of IDC tolerant genotypes at all the growth stages and more specifically at grand growth stages i.e., 45 to 60d under Fe-non-supplemented condition. For example, the genotype TAG 24 had higher active-Fe content under Fe-supplemented condition (6.34) compared to Fe-non-supplemented condition (2.20) at 60d. Under Fe-non-supplemented condition, there was higher active-Fe

Table 2b. Mean performance of groundnut genotypes for Chlorophyll ‘a’ and Chlorophyll ‘b’ over five growth stages under Fe-supplemented (Fe+) and Fe-non-supplemented (Fe-) conditions

IDC response	Genotype	Chlorophyll ‘a’											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	1.48	1.31^{a}	1.20	0.75^{ab}	0.82	0.61^{ab}	1.20	1.08^{ab}	1.23	1.09^{ab}	1.19	0.97
	RIL146	1.56	0.87^{c}	1.14	0.83^{ab}	0.70	0.47^{ab}	1.20	0.89^{b}	1.46	1.16^{ab}	1.21	0.84
	RIL52	1.64	1.06^{bc}	1.23	0.92^{a}	0.64	0.59^{ab}	1.31	1.04^{ab}	1.50	1.11^{ab}	1.26	0.94
	RIL307	1.31	1.14^{ab}	1.17	1.00^{a}	0.80	0.76^{a}	0.89	0.83^{b}	1.46	1.38^{a}	1.13	1.02
Mod.Tol.	ICGV06146	1.42	0.87^{c}	1.17	0.53^{bc}	0.89	0.65^{ab}	1.08	0.92^{b}	1.16	1.04^{ab}	1.14	0.80
	GPBD5	1.29	0.92^{bc}	1.23	0.51^{bc}	0.74	0.53^{ab}	1.51	1.03^{b}	1.32	0.98^{b}	1.22	0.79
	G2-52	1.40	1.01^{bc}	1.19	0.56^{bc}	0.76	0.60^{ab}	0.86	0.79^{b}	1.24	1.13^{ab}	1.09	0.82
	A30b	1.33	0.96^{bc}	1.18	0.47^{bc}	0.96	0.38^{b}	1.37	1.33^{a}	1.36	1.28^{ab}	1.24	0.88
Sus.	TMV2	1.13	0.81^{c}	0.99	0.37^{c}	0.53	0.10^{c}	1.12	0.17^{c}	1.28	0.95^{b}	1.01	0.48
	TAG24	1.31	0.80^{c}	1.09	0.22^{c}	0.72	0.10^{c}	1.28	0.35^{c}	1.56	0.47^{c}	1.19	0.39
	Dh86	1.41	0.82^{c}	1.18	0.38^{c}	0.80	0.11^{c}	0.96	0.35^{c}	1.22	0.38^{c}	1.11	0.41
	Mean – Fe+/ Fe-	1.39	0.96	1.16	0.59	0.76	0.44	1.16	0.80	1.34	1.00	1.16	0.76
	LSD(C) / LSD(G)	0.31	0.15	0.05	0.15	0.02	0.15	0.11	0.14	0.10	0.17	-	-
	Grand mean / LSD	1.18	0.26	0.88	0.20	0.60	0.20	0.98	0.19	1.17	0.24	0.96	-
	CV (%)	10.8	-	14.4	-	21.2	-	12.0	-	12.6	-	-	-

IDC response	Genotype	Chlorophyll ‘b’											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	0.23	0.16^{a}	0.19	0.12^{ab}	0.15	0.11^{a}	0.15	0.16^{b}	0.17	0.17^{a}	0.18	0.14
	RIL146	0.29	0.13^{a}	0.19	0.13^{ab}	0.14	0.11^{a}	0.20	0.12^{d}	0.22	0.18^{a}	0.21	0.13
	RIL52	0.27	0.15^{a}	0.21	0.16^{a}	0.14	0.11^{a}	0.21	0.16^{bc}	0.20	0.19^{a}	0.21	0.15
	RIL307	0.16	0.16^{a}	0.15	0.14^{ab}	0.15	0.12^{a}	0.13	0.15^{b-d}	0.23	0.21^{a}	0.16	0.16
Mod.Tol.	ICGV06146	0.22	0.12^{a}	0.19	0.11^{ab}	0.14	0.12^{a}	0.17	0.14^{b-d}	0.16	0.15^{a}	0.18	0.13
	GPBD5	0.19	0.14^{a}	0.15	0.10^{a-c}	0.13	0.10^{a}	0.24	0.14^{b-d}	0.17	0.15^{a}	0.18	0.13
	G2-52	0.21	0.13^{a}	0.18	0.10^{a-c}	0.12	0.09^{a}	0.13	0.12^{cd}	0.18	0.15^{a}	0.16	0.12
	A30b	0.23	0.12^{a}	0.18	0.08^{b-d}	0.16	0.06^{b}	0.21	0.22^{a}	0.22	0.17^{a}	0.20	0.13
Sus.	TMV2	0.14	0.07^{a}	0.15	0.04^{d}	0.06	0.01^{c}	0.19	0.03^{e}	0.15	0.15^{a}	0.14	0.06
	TAG24	0.19	0.10^{a}	0.17	0.03^{d}	0.09	0.01^{c}	0.19	0.05^{e}	0.23	0.08^{b}	0.17	0.05
	Dh86	0.23	0.09^{a}	0.18	0.05^{cd}	0.07	0.01^{c}	0.18	0.05^{e}	0.17	0.05^{b}	0.17	0.05
	Mean – Fe+/ Fe-	0.21	0.12	0.18	0.10	0.12	0.08	0.18	0.12	0.19	0.15	0.18	0.11
	LSD(C) / LSD(G)	0.01	0.03	0.01	0.02	0.01	0.02	0.01	0.01	0.002	0.025	-	-
	Grand mean / LSD	0.17	0.05	0.14	0.03	0.10	0.03	0.15	0.02	0.17	0.03	0.15	-
	CV (%)	17.1	-	15.3	-	18.0	-	8.7	-	12.6	-	-	-

content in both IDC tolerant and moderately tolerant genotypes at 30d and then reduction at 45d and recovery during 60d (Fig. 1). However, among IDC susceptible genotypes there was significant recovery in active-Fe content only in case of TMV 2 at 90d, while in case of TAG 24 and Dh 86, there was less recovery.

Table 2c. Mean performance of groundnut genotypes for total chlorophyll and active Fe content over five growth stages under Fe-supplemented (Fe+) and Fe-non-supplemented (Fe-) conditions

IDC response	Genotype	Total chlorophyll											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	1.71	1.47a	1.38	0.87^{a-c}	0.97	0.71^{ab}	1.35	1.24^{b}	1.40	1.26^{ab}	1.36	1.11
	RIL146	1.86	1.00^{bc}	1.33	0.96^{ab}	0.84	0.58^{ab}	1.40	1.01^{b}	1.68	1.34^{ab}	1.42	0.98
	RIL52	1.91	1.21^{bc}	1.43	1.08^{a}	0.78	0.69^{ab}	1.52	1.21^{b}	1.70	1.30^{ab}	1.47	1.10
	RIL307	1.47	1.30^{ab}	1.32	1.14^{a}	0.95	0.87^{a}	1.02	0.99^{b}	1.69	1.59^{a}	1.29	1.18
Mod.Tol.	ICGV06146	1.64	0.99^{bc}	1.37	0.63^{b-e}	1.03	0.77^{ab}	1.25	1.06^{b}	1.37	1.19^{ab}	1.32	0.93
	GPBD5	1.48	1.06^{bc}	1.38	0.61^{b-e}	0.87	0.63^{ab}	1.75	1.18^{b}	1.49	1.13^{b}	1.39	0.92
	G2-52	1.61	1.14^{bc}	1.37	0.66^{b-d}	0.88	0.69^{ab}	0.99	0.92^{b}	1.42	1.28^{ab}	1.25	0.94
	A30b	1.56	1.09^{bc}	1.35	0.55^{c-e}	1.12	0.44^{b}	1.58	1.55^{a}	1.58	1.45^{ab}	1.44	1.02
Sus.	TMV2	1.27	0.89^{c}	1.14	0.41^{de}	0.59	0.11^{c}	1.31	0.19^{c}	1.43	1.10^{b}	1.15	0.54
	TAG24	1.50	0.89^{c}	1.26	0.25^{e}	0.81	0.11^{c}	1.47	0.40^{c}	1.79	0.55^{c}	1.37	0.44
	Dh86	1.64	0.91^{c}	1.35	0.43^{de}	0.87	0.12^{c}	1.14	0.40^{c}	1.39	0.43^{c}	1.28	0.46
	Mean – Fe+/ Fe-	1.60	1.08	1.34	0.69	0.88	0.52	1.34	0.92	1.55	1.15	1.34	0.87
	LSD(C) / LSD(G)	0.32	0.16	0.06	0.15	0.04	0.12	0.43	0.18	0.07	0.16	-	-
	Grand mean / LSD	1.34	0.28	1.01	0.21	0.99	0.16	1.26	0.34	1.24	0.22	1.17	-
	CV (%)	10.3	-	13.0	-	10.0	-	12.0	-	11.2	-	-	-

IDC response	Genotype	Active Fe											
		30d		45d		60d		75d		90d		Mean	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	5.98	5.31^{a}	4.15	3.21^{b}	4.71	4.19^{a}	4.22	3.11^{ab}	4.14	3.00^{ab}	4.64	3.76
	RIL146	5.03	4.22^{b}	3.54	3.21^{b}	5.07	3.75^{ab}	4.83	3.90^{a}	4.11	3.19^{a}	4.52	3.65
	RIL52	5.50	5.16^{a}	3.73	3.00^{b}	5.97	3.79^{ab}	4.12	3.49^{a}	4.42	3.09^{ab}	4.75	3.71
	RIL307	4.91	5.51^{a}	4.41	3.79^{a}	5.54	4.08^{a}	4.24	4.09^{a}	3.86	3.36^{a}	4.59	4.17
Mod.Tol.	ICGV06146	5.91	4.18^{b}	3.92	2.62^{bc}	5.99	3.86^{a}	4.37	3.80^{a}	3.40	3.10^{ab}	4.72	3.51
	GPBD5	6.87	4.29^{b}	3.46	2.91^{b}	6.33	3.57^{ab}	4.47	3.56^{a}	4.21	3.05^{ab}	5.07	3.48
	G2-52	5.69	4.37^{b}	3.15	2.88^{b}	5.75	3.12^{b}	4.07	3.28^{ab}	3.21	3.05^{ab}	4.37	3.34
	A30b	5.95	3.99^{b}	3.73	1.95^{d}	5.67	2.30^{c}	4.10	3.10^{ab}	3.77	2.56^{bc}	4.64	2.78
Sus.	TMV2	5.29	3.61^{b}	3.05	1.95^{d}	5.24	1.89^{c}	3.96	2.40^{b}	2.79	2.58^{bc}	4.07	2.49
	TAG24	5.19	3.60^{b}	4.33	2.24^{cd}	6.34	2.20^{c}	6.31	2.39^{b}	3.75	2.07^{d}	5.18	2.50
	Dh86	4.71	3.53^{b}	3.70	2.63^{bc}	5.30	2.09^{c}	5.20	2.33^{b}	4.63	2.33^{cd}	4.71	2.58
	Mean – Fe+/ Fe-	5.55	4.34	3.74	2.76	5.63	3.17	4.54	3.22	3.84	2.85	4.66	3.27
	LSD(C) / LSD(G)	0.59	0.68	0.92	0.39	0.42	0.62	0.77	0.50	0.48	0.23	-	-
	Grand mean / LSD	4.95	0.95	3.25	0.74	4.40	0.86	3.88	0.78	3.35	0.41	3.96	-
	CV (%)	11.7	-	10.3	-	12.2	-	11.0	-	6.0	-	-	-

Fe+ = Sprayed with Fe-EDDHA, Fe- = Fe unsprayed; Tol. = Tolerant, Mod. Tol.= Moderately tolerant, Sus.= Susceptible; CV = Coefficient of variation (%).

LSD = LSD at p=0.05 for mean comparison among treatments; LSD(C) = LSD at p=0.05 for mean comparison between Fe-supplemented and Fe-non-supplemented conditions (C); LSD(G)– LSD at p=0.05 for mean comparison between genotypes (G) under respective conditions; †Student Knewman-Keuls'(SNK) test for mean comparison between genotypes under Fe = non-supplemented condition.

Different alphabets suggest differential behaviour, while similar alphabets suggest similar behaviour of genotypes for the respective IDC related traits

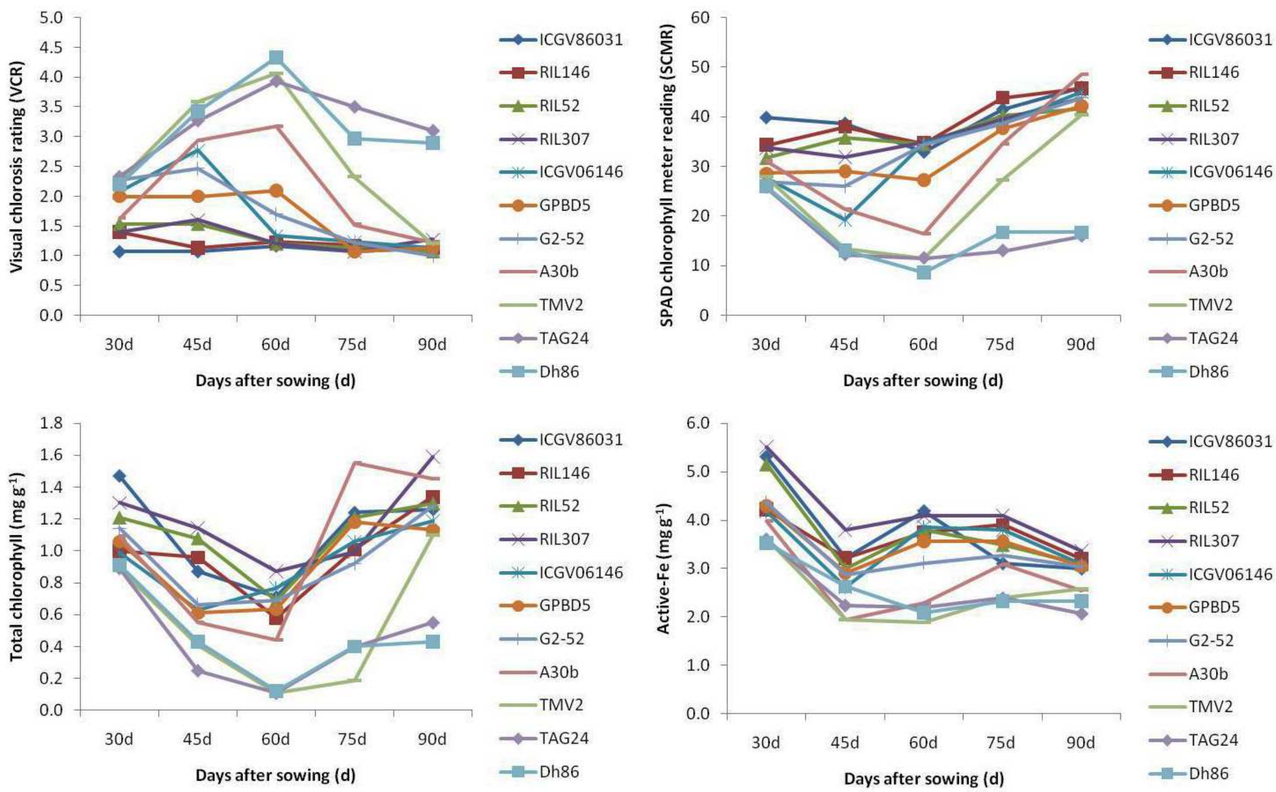

Fig. 1. Genotypic differences for IDC related traits across five growth stages under Fe-non-supplemented (Fe-) condition

Productivity traits

Significant difference were observed between Fe-supplemented and Fe-non-supplemented condition for productivity traits as evident from higher plant height, number of pods per plant, pod yield and haulm yield under Fe-supplemented condition. Reduction in Fe-non-supplemented condition was recorded over Fe-supplemented condition for all the productivity traits, except number of primary branches and hundred seed weight (Table 3). Shelling per cent was very less affected due to IDC among the genotypes. Pod yield and number of pods per plant were severely affected by IDC as evident from maximum reduction under Fe-non-supplemented condition.

Tolerant and moderately tolerant genotypes for IDC showed lesser reduction in terms of pod yield under Fe-non-supplemented compared to Fe-supplemented condition except A30 b, while highest reduction was observed among susceptible genotypes. For example, the maximum reduction in pod yield (33.24 %) was observed in susceptible genotype TMV 2, whereas lowest reduction in pod yield was observed in moderately tolerant genotype, GPBD 5 under Fe-non-supplemented condition (1378 kg ha^{-1}) as compared to Fe-supplemented condition (1493 kg ha^{-1}). It is interesting to note that moderately tolerant genotype G 2-52 had higher pod yield both under Fe-supplemented (1754 kg ha^{-1}) and Fe-non-supplemented conditions (1554 kg ha^{-1}). The IDC susceptible genotype TMV 2 had very less number of pods (10.20) and eventually lower pod yield (1358 kg ha^{-1}) under Fe-non-supplemented condition.

Maximum reduction of haulm yield was observed in susceptible genotype, Dh 86 under Fe-non-supplemented condition (1225 kg ha^{-1}) compared to Fe-supplemented condition (2207 kg ha^{-1}), while lowest reduction in moderately tolerant genotype, A 30b under Fe-non-supplemented condition (2195 kg ha^{-1}) compared to Fe-supplemented condition (2204 kg ha^{-1}).

Discussion

IDC is an important abiotic stress reducing the growth and yield of groundnut especially under calcareous soils (Singh et al. 1995; Naidu et al. 2017). Foliar application of Fe-chelates can overcome iron

Table 3. Mean performance of groundnut genotypes for yield and its related traits under Fe+ and Fe- conditions

IDC response	Genotype/parameters	PHT		NPB		NPP		PYLD		HSW		SH%		HYLD	
		Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†	Fe+	Fe-†
Tol.	ICGV86031	17.00	16.27^{a-c}	4.27	4.13^{a}	8.53	7.00^{bc}	884	747^{b}	32.54	33.65^{ab}	54.79	53.81^{e}	2636	2413^{d}
	RIL146	10.20	9.40^{cd}	4.00	3.80^{a}	10.60	9.53^{a-c}	1468	1263^{ab}	35.02	34.90^{a}	60.01	58.95^{cd}	2078	2026de
	RIL52	10.60	10.13^{cd}	3.87	3.93^{a}	12.67	11.33^{a-c}	1489	1340^{ab}	29.00	33.52^{ab}	62.78	62.60^{ab}	1658	1634^{ef}
	RIL307	11.97	11.60^{b-d}	4.07	4.73^{a}	12.13	10.20^{a-c}	1490	1274^{ab}	28.23	26.00^{c}	63.10	61.75^{bc}	2189	2118de
Mod.Tol.	ICGV06146	25.27	22.47^{a}	3.93	4.40^{a}	8.30	6.97^{bc}	1351	1237^{ab}	32.75	33.00^{ab}	59.78	56.23^{de}	4502	4405^{a}
	GPBD5	13.00	12.93^{b-d}	4.03	4.47^{a}	15.87	12.50^{ab}	1493	1378^{ab}	26.74	26.61^{c}	56.70	56.11^{de}	2783	2723^{cd}
	G2-52	22.60	22.27^{a}	4.37	4.03^{a}	15.87	15.07^{a}	1754	1544^{a}	30.01	30.99^{a-c}	59.95	55.25^{de}	4029	3836^{b}
	A30b	19.57	18.83^{ab}	4.13	3.53^{a}	13.60	11.10^{a-c}	1005	731^{b}	32.13	31.61^{a-c}	55.13	53.42^{e}	2204	2195de
Sus.	TMV2	22.03	15.80^{a-c}	4.07	4.27^{a}	14.33	10.20^{a-c}	2034	1358^{ab}	25.37	27.26^{bc}	70.51	65.46^{a}	4214	3055^{c}
	TAG24	9.40	7.00^{d}	3.77	4.13^{a}	12.27	8.47^{bc}	1490	1194^{ab}	32.37	33.88^{ab}	62.76	57.87^{de}	1578	1482^{ef}
	Dh86	9.37	7.00^{d}	3.63	3.80^{a}	15.53	12.20^{a-c}	1438	1145^{ab}	31.30	36.62^{a}	58.78	55.94^{de}	2207	1225^{f}
	Mean – Fe+/Fe-	15.5	14.0	4.0	4.1	12.7	10.3	1445	1201	30.50	31.64	60.39	57.94	2734	2465
	LSD(C)/LSD(G)	3.35	3.81	0.53	0.42	2.11	2.85	96	317	1.05	3.38	3.85	3.56	427	424
	Grand mean/LSD	14.8	5.37	4.1	0.63	11.5	3.97	1323	430	31.07	4.58	59.17	5.14	2600	607
	CV (%)	22.1	-	8.9	-	21.2	-	20.6	-	9.3	-	5.2	-	14.0	-

PHT= Plant height (cm), NPB= Number of primary branches per plant, NPP= Number of mature pods per plant, PYLD= Pod yield (kg ha^{-1}), HSW= Hundred seed weight (g), SH%= Shelling percent, HYLD= Haulm yield (kg ha^{-1}); Tol.= Tolerant, Mod. Tol.= Moderately tolerant, Sus= Susceptible, CV= Coefficient of variation (%), LSD= LSD at p=0.05 for mean comparison among treatments; LSD(C)= LSD at p=0.05 for mean comparison between Fe-supplemented and Fe-non-supplemented conditions (C); LSD(G)= LSD at p=0.05 for mean comparison between genotypes (G) under respective conditions

† Student Knewman-Keuls' (SNK) test for mean comparison between genotypes under Fe- condition; Different alphabets suggest differential behaviour, while similar alphabets suggest similar behaviour of genotypes for the respective yield related traits

deficiency but it is not economical. Under such situation, growing IDC resistant cultivars is an amenable approach. Absolute resistance to any stress will have cost especially in the form of yield reduction. In this regard, the present study was aimed at studying a set of carefully chosen differentially IDC responsive (tolerant, moderately tolerant and susceptible) groundnut genotypes in Fe-supplemented and Fe-non-supplemented condition under calcareous soils in terms of IDC response and productivity traits.

Highly significant differences for genotypes, condition and interaction between genotype and condition indicated existence of genotypic differences and their differential response to conditions for all the IDC response traits such as VCR, SCMR, chlorophyll 'a', 'b' and total chlorophyll and active-Fe content in leaf at all the growth stages (30, 45, 60, 75 and 90d). Though genotypic differen-ces existed for all the productivity traits individua-lly for the Fe-supplemented and Fe-non-supplemented conditions, there was significant effect of condition only for the economically important traits such as number of pods per plant, pod yield and hundred seed weight. This shows more pronounced effect of IDC on yield parameters thus reducing the yields.

The maximum severity

of IDC as seen in the form of higher VCR and lower SCMR was at 60 d indicating higher requirement of Fe at grand growth stages of the crop. However, Fe taken up by the plants was metabolized for other functions of plant decreasing the chlorophyll synthesis, thereby leading to IDC in groundnut. Severity also coincides with high soil moisture due to receipt of rainfall during the period (data not provided) converting Fe^2 to Fe^3 which may become unavailable to the plants. Severity of IDC usually coincides with often excessive rainfall and also for groundnut grown under irrigation due to excessive bicarbonate ion concentration in the rhizosphere (Singh et al. 1995; Zuo et al. 2007). Earlier, higher chlorosis in groundnut was reported at 60 days (Boodi et al. 2016) or 80-100 days (Pattanashetti et al. 2018). Similarly, Kulkarni et al. (1994) found higher visual chlorosis scores at 60 d and suggested screening at 60 days as more reliable for IDC in groundnut.

In Fe-supplemented condition, VCR score around 1.0 and SCMR value above 30 during all stages of crop growth irrespective of IDC tolerant, moderately tolerant and susceptible genotypes indicated effectiveness of Fe-EDDHA spray in controlling IDC. The effectiveness of chelated form of iron especially Fe-EDDHA has been reported earlier (Papastylianou 1990; Singh and Sahu 1993). The chelated form of Fe helps in correcting IDC through slow release of iron and thus helps in the immobilization of Fe in the plant tissue.

In Fe-non-supplemented condition, lowest VCR scores and highest SCMR values were observed among IDC tolerant genotypes followed by moderately tolerant genotypes, while highest VCR scores and lowest SCMR values among IDC susceptible genotypes at all growth stages indicating distinct differentiation between tolerance/moderate tolerance and susceptibility for IDC (Table 2a). Wide genotypic variation for IDC tolerance has been reported earlier in groundnut (Boodi et al. 2015; Li and Yan-Xi 2007; Omesh et al. 2019; Samdur et al. 1999, 2000; Sowrabha and Motagi 2020). There was gradual recovery in VCR score and SCMR values during later part of the growth stage i.e., after 60d, across all the genotypes. Among the IDC susceptible genotypes, TMV 2 recovered most from the IDC during the later stage of crop growth (at 75 and 90d) under Fe-non-supplemented condition. In groundnut, self-recovery of chlorosis as leaves becomes older has been noted but the newly emerging leaves still show chlorosis (Singh 1994a). Boodi et al. (2016) also noted gradual recovery of IDC among the groundnut genotypes under pot experiment as seen in the present study. In soybean also, there was report of severe iron chlorosis in the early growing season and gradual recovery in the later part of the growing season (Naeve and Rehm 2006).

Among the physiological parameters, chlorophyll 'a', 'b' and total chlorophyll recorded maximum reduction among all the genotypes at 60 d both under Fe-supplemented and Fe-non-supplemented condition, which is coinciding with higher moisture in the soil due to rain during that period. Excess irrigation exacerbates chlorosis, causing reductions in leaf chlorophyll contents, plant height, dry matter production, pod and haulm yields and nutrient uptake (Singh et al. 1995). Reduction in chlorophyll (a, b and total) was maximum in case of susceptible genotypes compared to tolerant and moderately tolerant genotypes at 60d. This is in close correspondence with the VCR rating and SCMR values in these genotypes. Reduced chlorophyll content in leaves is at least in part due to the involvement of Fe in the formation of precursors of chlorophyll molecule, β-aminolevulinic acid and proto-chlorophyllide (Marschner et al. 1986). Reduced chlorophyll content under IDC has been noted in field (Samdur et al. 2000), pot (Boodi et al. 2016) and hydroponic experimentation (Xiao-Ping et al. 2010; Akshay and Koti 2019) in groundnut.

Tolerant and moderately tolerant genotypes had higher active-Fe content compared to susceptible genotypes suggesting higher active-Fe uptake in tolerant and moderately tolerant genotypes through different mechanisms. Chlorotic plants in groundnut are known to have lower active-Fe content in their leaves (Singh 1994b). IDC tolerant or moderately tolerant genotypes under iron deficiency conditions are expected to display mechanisms such as increased reduction of Fe^{3+} to Fe^{2+} at the root cell plasma membrane, acidification of the rhizosphere (enhanced net exudation of protons), enhanced exudation of reducing and/or chelating compounds in the rhizosphere and changes of root histology and morphology. Higher plants have developed various specific and non-specific mechanisms to increase the solubility and uptake of Fe in the rhizosphere. Among the non-specific mechanisms, the so called 'acidic' (cations > anions) uptake is one of the most important factors inducing pH decrease in the rhizosphere (Romheld and Marschner 1986). Increased Fe-reduction capacity and release of hydrogen ions from roots under Fe-deficiency stress are evident among

IDC tolerant groundnut cultivars in an earlier study (Li and Yan-Xi 2007). Further, increased protonation in IDC tolerant groundnut genotype ICGV 86031 compared to susceptible genotypes TMV 2 and JL 24 have been established under hydroponic condition (Akshay and Koti 2019). Under Fe-non-supplemented condition, there was higher active-Fe content in both IDC tolerant and moderately tolerant genotypes at 30 d and then reduction at 45 d and recovery during 60d which could be attributed to acclimatization of tolerant and moderately tolerant groundnut genotypes to iron deficient conditions. TMV 2, a susceptible genotype had significant recovery in active-Fe content at 90d which was corresponding to its reaction for VCR, SCMR and chlorophyll (a, b and total) in comparison to other susceptible genotypes TAG 24 and Dh 86.

Significantly higher plant height, number of pods per plant, pod yield and haulm yield in Fe-supplemented condition over Fe-non-supplemented condition across genotypes indicated that Fe spray in the chelated form (Fe-EDDHA) has been effective in overcoming IDC and also resulted in increased pod yield through component traits in groundnut. Earlier, Fe-EDDHA spray has been shown to be correcting the IDC and concurrent increase in pod yield in groundnut (Hartzook et al. 1974). Among the various productivity traits, number of primary branches and shelling per cent were very less affected due to IDC among the diverse genotypes with differential IDC response.

Maximum reduction in number of pods, pod yield and haulm yield was noted in susceptible genotypes but lowest reduction in moderately tolerant genotypes revealing the necessity of cultivating moderately tolerant genotypes over susceptible genotypes in getting higher pod yield under calcareous soils. Among the moderately tolerant genotypes, G 2-52 had maintained its yielding ability even under Fe-non-supplemented condition. The known IDC resistant genotype, ICGV 86031 which is having resistance to multiple stresses (Dwivedi et al. 1993) though shown very less reduction in pod yield between Fe-supplemented and Fe-non-supplemented condition, had very less yielding ability and thus not suitable for cultivation under iron deficient calcareous soils. Iron chlorosis resulting in mild to severe yield losses (38 to 50 %) were noted in groundnut (Singh et al. 1995; Young 1967). Rao and Narayan (1990) noticed that groundnut cultivars TMV-3, K-3, JL-24 and TMV-7 grown in solution cultures with 0 to 5 ppm Fe, resulted in reduction of dry matter yield due to Fe deficiency and was greatest in cultivated varieties such as SE-24 and J-11. Significantly lower haulm and pod yield were recorded in susceptible compared to tolerant groundnut genotypes (Prasad et al. 2000). Thus, present study has revealed that genotype with high yielding potential and moderate tolerance to IDC is suitable for cultivation under iron deficient calcareous soils rather than low yielding tolerant genotypes.

Authors' contribution

Conceptualization of research (GKN, SKP, OS); Designing of the experiments (GKN, SKP, OS, BCP); Contribution of experimental material (GKN, SKP); Execution of field/lab experiments and data collection (OK); Analysis of data and interpretation (GKN, SKP); Preparation of manuscript (GKN and SKP).

Declaration

The authors declare no conflict of interest.

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