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RESEARCH PAPER

Screening of F_3 population for iron chlorosis tolerance in groundnut under calcareous soils

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Abstract: Iron is an important nutrient required for the synthesis of chlorophyll, photosynthesis, respiration and assimilation of nitrogen and sulphur. Iron is present in large quantities in the soil but mainly in the forms that are not available to plants. Iron deficiency is an important abiotic constraint reducing growth and yield of groundnut especially under calcareous soils. One of the ways to address the issue is breeding for genotypes tolerant to iron chlorosis. Keeping this in view breeding was initiated and advanced. In this context, F_3 populations of two crosses TMV 2 × ICGV 86031 (TIP) and JL 24 × ICGV 86031 (JIP) were screened for chlorosis tolerance along with parents during *kharif*-2018. Among F_3 populations, the progenies TIP 6, TIP 16 of TMV 2 × ICGV 86031 (TIP) and the progenies JIP 27 and JIP 29 of JL 24 × ICGV 86031 (JIP) were found superior as compared to susceptible parents TMV 2 and JL 24, respectively for visual chlorotic ratings (VCR), SPAD chlorophyll meter readings (SCMR) and morphological traits. The estimates of variance components revealed predominance of additive component of variance for the characters studied. The progenies TIP 6, TIP 16, JIP 27 and JIP 29 also recorded more number of pods per plant, total dry matter and pod weight compared to tolerant variety, ICGV 86031 and their susceptible parents, TMV 2 and JL 24. The chlorosis tolerance in the selected progenies might be due to higher acquisition of iron in calcareous soils mainly indicated by higher greenness leading to increase in photosynthesis, growth and yield.

Key words: Groundnut, Iron chlorosis, Population, Progeny

Introduction

Groundnut (*Arachis hypogaea* L.) is grown as commercial crop throughout the tropical and subtropical areas of the world (Akshay, 2018). It is considered as "King of oilseed crops" by virtue of its higher oil content and maximum consumption (Kavita et. al., 2015). It is one of the most important oilseed crops in India, grown on an area of 5.80 m ha with a production of 6.85 m t and productivity of 1675 kg ha^{-1} (Indiastat, 2018). The productivity needs to be increased for an ever increasing demand for growing population. The lower productivity in India is mainly attributed to various biotic and abiotic stresses affecting the crop growth and yield (Naidu *et al*., 2017). Among the abiotic stresses, iron deficiency is one which reduces growth and yield in groundnut. Iron is an essential micronutrient and has a significant role in various physiological and biochemical processes in plants like in the synthesis of chlorophyll, carbohydrate production, cell respiration, nitrogen assimilation and reduction of nitrate and sulphate. In India one-third of the soils are calcareous and mostly spread in the low rainfall areas of the western and central parts of the country. Calcareous soils are deficient in available iron (Fe^{2+}) because, iron forms insoluble ferric hydroxide complexes in the presence of oxygen at neutral or basic pH in calcareous soils (Guerinot and Yi, 1994).

Groundnut adopts strategy-I mechanism of acquiring iron from calcareous soils and overcome the iron chlorosis (Fageria *et al*., 1994). Pujar (2016) screened groundnut genotypes for iron chlorosis tolerance and found variability among the genotypes. She reported TMV 2 and JL 24 are susceptible, whereas ICGV 86031 is tolerant. Akshay (2018) confirmed the variability existing in strategy I mechanism in both tolerant and susceptible groundnut genotypes. Hence, to develop a genotype tolerant to iron chlorosis, the susceptible genotypes JL 24 and TMV 2 were crossed with resistant genotype ICGV 86031 during *kharif* 2016 and advanced to F_3 generation. With this background, the F_3 generation of groundnut has been screened for iron chlorosis tolerance and yield potential.

Material and methods

Experimental material consisted of selected F_3 population as mentioned below in the table and parents were used as checks.

Populations developed for chlorosis tolerance

TMV 2 x ICGV 86031(TIP, 2014 -15)
↓
F_1 (2016)
↓
F_2 (TIP 5, 6, 16, 23, 24 individual plant selected) (2017)
↓
F_3..... (2018)

JL 24 x ICGV 86031(JIP, 2014-15)
↓
F_1 (2016)
↓
F_2 (JIP 1, 9, 24, 27, 29, 32, 33, 35, 51 individual plant selected) (2017)
↓
F_3..... (2018)

Note: TIP: TMV 2 cross ICGV 86031 population, JIP: JL 24 cross ICGV 86031 population

The field experiment was conducted during *kharif*-2018 at College of Agriculture, Vijayapur, (16°49' N, 75°43' E and 593 m above mean sea level) in the calcareous soil with 24.8 per cent $CaCO_3$ and pH 8.44 and the soil was deficient in available Fe

Table 1. List of F_3 population used for screening

TMV 2 X ICGV 86031 (TIP)		JL 24 X ICGV 28031 (JIP)	
TIP 5	23 plants	JIP 1	17 plants
TIP 6	11 plants	JIP 9	59 plants
TIP 16	30 plants	JIP 24	24 plants
TIP 23	26 plants	JIP 27	19 plants
TIP 24	51 plants	JIP 29	32 plants
Checks		JIP 32	20 plants
ICGV 86031		JIP 33	8 plants
TMV 2		JIP 35	43 plants
JL 24		JIP 51	11 plants

Table 2. Soil properties of experimental site

Sl. No.	Particulars	Value
I	Chemical properties	
1	Soil reaction – pH	
	(1:2.5 soil : water suspension)	8.44
2	Electrical conductivity (dS m^{-1})	
	(1:2.5 soil : water supernatant)	0.23
3	Organic carbon (%)	0.31
4	Free $CaCO_3$ (%)	24.8
II	Available macronutrients	
5	Nitrogen (N) (kg ha^{-1})	175.73
6	Phosphorus (P_2O_5) (kg ha^{-1})	22
7	Potassiun (K_2O) (kg ha^{-1})	204
8	Sulphur (S) (mg kg^{-1})	16
III	Available macronutrients	
9	Iron (Fe)(ppm)	3.54
10	Zinc (Zn)(ppm)	0.32
11	Manganese (Mn)(ppm)	5.94
12	Copper (Cu)(ppm)	0.75

(DTPA extractable Fe < 4 ppm) (Table 2). The seeds of F_3 population (Table 1) were sown in an augmented design without replications. Each cross had six equal sized blocks. Where F_2 derived F_3 progeny families were planted as one row of 2 m length with spacing of 30 and 10 cm. The recommended package of practises was followed to raise the crop. To screen for iron chlorosis tolerance, visual chlorotic rating (VCR) 1 to 5 scale proposed by Singh and Chaudhari (1993) and SPAD chlorophyll meter reading (SCMR) for measuring chlorophyll content was adopted. These observations were recorded at 30, 45, 60, 75 and 90 days after sowing (DAS). The morphological, yield related traits *viz*., plant height, number of primary branches per plant, number of pods per plant, plant dry weight and pod weight per plant were recorded at the time of harvesting. The data was analysed using WINDOSTAT statistical package. Significance of variance was tested using 'F' value at $p<0.05$ (Fischer 1963). To assess variability in the population, genetic parameters like genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV) (Burton and Devane 1953), broad sense heritability (Hbs) (Hanson *et al*., 1956) and genetic advance as per cent of mean (GAM) (Johnson *et al*., 1955) were estimated.

Results and discussion

Variance components

Analysis of variance (ANOVA) showed significant variation among the entries for most of the traits except for pod weight, pod yield for TIP progenies and total dry matter for both (Tables

Table 3. Analysis of variance for VCR, SCMR and yield related traits of TMV 2 X ICGV 86031 (TIP) groundnut population

Source of Variance	df	VCR 30 DAS	VCR 45 DAS	VCR 60 DAS	VCR 75 DAS	VCR 90 DAS	SCMR 30 DAS	SCMR 45 DAS	SCMR 60 DAS	SCMR 75 DAS	SCMR 90 DAS	Plant height (cm)	Primary branches /plant	Pods / plant	Total dry matter (g/plant)	Pod weight (g/plant)
Block	5	0.15	0.12**	0.20**	0.03**	0.05**	12.12	6.27	11.74	1.99	3.57	7.97**	0.17*	14.12	7.6	22.52
Entries	141	0.19**	0.51**	1.00**	1.33**	1.78**	26.85	47.75**	137.19**	117.63**	114.09**	5.82**	0.93**	14.75	12.65	21.75
Checks	3	2.17**	5.34**	9.17**	12.50**	16.37**	225.22**	532.58**	1078.85**	1070.98**	1034.65**	35.10**	1.73**	1.97	48.84	5.37
Lines	137	0.13*	0.40**	0.81**	1.07**	1.44**	14.75	29.28**	112.74**	87.50**	86.47**	5.10**	0.92**	14.96	10.59	21.54
Checks v/s Lines	1	2.27**	1.77**	1.90**	2.26**	3.42**	1089.90**	1123.21**	662.64**	1384.72**	1136.97**	16.59**	0.22*	24.12	186.74**	100.10*
Error	15	0.05	0.05	0.09	0.03	0.03	13.95	5.13	14.39	2.58	1.82	1.33	0.04	13.89	15.72	14.53
S.E.D.		0.33	0.32	0.42	0.24	0.27	5.28	3.2	5.36	2.27	1.91	1.63	0.3	5.27	5.6	5.39

df: degrees of freedom, VCR: visual chlorotic ratings, SCMR: SPAD chlorophyll meter reading, DAS: days after sowing,

Table 4. Analysis of variance for VCR, SCMR and yield related traits of JL 24 X ICGV 86031 (JIP) groundnut population

Source of Variance	df	VCR					SCMR					Plant height (cm)	Primary branches /plant	Pods / plant	Total dry matter (g/plant)	Pod weight (g/plant)
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS					
Block	5	0.004	0.003	0.003	0.004	0.003	16.43	3.64	0.86	2.38	0.45	1.07	0.18	12.22**	25.89	5.78
Entries	237	0.19**	0.39**	0.87**	1.02**	1.27**	30.66	31.38**	119.48**	79.38**	77.65**	11.55**	0.58**	10.01**	13.64	14.77**
Checks	3	2.35**	6.08**	11.36**	13.46**	17.77**	216.65**	583.14**	1323.50**	1038.72**	958.23**	68.33**	1.16**	32.59**	47.76	38.38**
Lines	233	0.14**	0.29**	0.69**	0.80**	0.99**	21.09	17.74**	94.85**	56.54**	56.11**	10.81**	0.58**	9.75**	12.85	14.39**
Ch v/s L	1	5.15**	6.23**	11.74**	14.18**	17.26**	1702.85**	1552.78**	2244.46**	2521.56**	2455.12**	13.53**	0.04	1.03	95.33*	32.76*
Error	15	0.04	0.003	0.01	0.004	0.006	29.12	2.98	0.52	2.24	2.73	0.728	0.09	2.53	16.44	4.8
S.E.D.		0.3	0.08	0.15	0.09	0.11	3.11	2.44	1.02	2.11	2.33	1.2	0.43	2.25	5.73	3.1

Table 5. Mean performance for VCR, SCMR and yield related traits of TMV 2 X ICGV 86031 (TIP) groundnut population

Population	VCR										SCMR									
	30 DAS		45 DAS		60 DAS		75 DAS		90 DAS		30 DAS		45 DAS		60 DAS		75 DAS		90 DAS	
	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±
TIP 5	1.75	0.41	2.52	0.67	3.25	0.94	3.94	1.07	4.28	1.24	30.23	3.95	23.06	4.18	14.05	4.57	9.4	3.35	8.29	2.87
TIP 6	1.88	0.15	1.75	0.13	1.54	0.14	1.83	0.12	1.89	0.11	23.06	1.29	25.65	2.32	33.4	3.17	23.18	1.5	22.08	1.11
TIP 16	1.73	0.19	1.56	0.23	1.39	0.29	1.72	0.23	1.83	0.17	22.87	1.8	25.54	3.32	34.52	3.88	23.37	2.01	22.23	2.01
TIP 23	2.17	0.23	2.93	0.38	2.93	0.68	3.24	0.93	3.55	1.17	25.37	3.02	15.66	4.64	16.62	7.92	12.91	11.8	12.69	12.6
TIP 24	2.37	0.21	2.95	0.15	3.42	0.1	3.94	0.13	4.4	0.1	22.61	2.58	16.23	2.56	10.95	1.58	4.06	0.21	3.66	0.22
Mean	1.98	-	2.34	-	2.51	-	2.94	-	3.19	-	24.8	-	21.2	-	21.91	-	14.58	-	13.8	-
ICGV 86031	1	-	1	-	1	-	1	-	1	-	40.17	-	39.96	-	41.33	-	37.55	-	35.61	-
TMV 2	2.05	-	2.88	-	3.35	-	3.97	-	4.36	-	30.02	-	20.78	-	15.24	-	10.12	-	8.94	-

Plant Height (cm)		Primary branches plant^{-1}		Pods /plant		Total dry matter (g/plant)		Pod weight (g/plant)	
Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±
14.14	2.79	4.51	0.72	12.02	3.71	12.98	3.32	14.45	3.41
12.18	2.3	5.35	1.22	15.24	2.25	15.03	3.05	17.67	2.9
11.54	2.52	4.95	1.29	14.88	2.47	14.94	3.1	17.11	2.92
13.34	1.87	4.32	0.5	11.03	4.68	12.15	1.74	11.17	3.12
12.94	1.3	4.56	0.79	11.97	3.58	14.4	3.37	13.74	3.9
12.83	-	4.74	-	13	-	13.9	-	14.85	-
9.59	-	5.21	-	10.9	-	15.03	-	13.7	-
13.27	-	4.7	-	12.27	-	8.63	-	12.14	-

VCR: visual chlorotic ratings, SCMR: SPAD chlorophyll meter reading, DAS: days after sowing

3 & 4). This indicates that the lines under study were genetically diverse.

Mean performance

The parents and the F_3 cross population showed iron chlorosis which was measured in terms of VCR and SCMR at different stages of crop growth (Table 5 & 6). The appearance of chlorosis in the leaves commenced around 30 DAS since the soil was alkaline with high lime content. Maximum chlorosis in susceptible parents, TMV 2, JL 24 and very less chlorosis was seen in ICGV 86031 at 60 DAS, suggesting that screening of F_3 cross population for iron chlorosis at 60 DAS is effective. The severity of chlorosis coincided with high soil moisture. Similarly, Boodi (2014) reported higher chlorosis at 60 and 90 DAS, while Singh (2015) and Kulkarni *et al.* (1994) reported higher visual chlorosis scores at 60 DAS as was observed in the present investigation also.

In the present study, the parent ICGV 86031 was tolerant as evident from lower VCR and higher SCMR values, while TMV 2 and JL 24 were susceptible as they showed higher VCR and lower SCMR values. In F_3 cross population, range of variation for VCR and SCMR was much more than that of the parents at all the stages indicating the presence of segregates and variability for chlorosis. Among the progenies of cross TIP, TIP 6 showed lower VCR

Table 6. Mean performance for VCR, SCMR and yield related traits of JL 24 X ICGV 86031 (JIP) groundnut population

Population	VCR										SCMR									
	30 DAS		4 5 DAS		60 DAS		75 DAS		90 DAS		30 DAS		45 DAS		60 DAS		75 DAS		90 DAS	
	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±
JIP 1	2.23	0.21	2.85	0.14	3.34	0.15	3.86	0.18	4.25	0.14	25.66	3.32	18.28	2.12	13.47	1.55	8.7	1.64	7.26	1.07
JIP 9	2.55	0.28	2.99	0.21	3.62	0.29	3.91	0.21	4.29	0.23	19.94	3.54	16.34	3.07	9.45	2.6	5.21	2.59	4.36	2.25
JIP 24	2.07	0.43	2.9	0.2	3.38	0.12	3.95	0.12	4.35	0.09	27.6	4.72	18.49	2.91	11.9	1.94	4.36	0.33	3.8	0.25
JIP 27	1.93	0.11	1.79	0.11	1.68	0.12	1.83	0.11	1.96	0.1	22.78	1.36	25.1	1.94	33.7	2.11	23.23	1.33	22.2	1.33
JIP 29	1.8	0.19	1.71	0.16	1.59	0.17	1.78	0.13	1.91	0.12	23.11	1.64	25.29	2.25	33.24	3.04	23.42	1.58	22.14	1.41
JIP 32	2.31	0.23	3.06	0.15	3.72	0.18	4.03	0.1	4.38	0.23	22.75	2.09	15.64	1.72	10.25	1.24	7.36	1.79	4.04	0.69
JIP 33	2.35	0.23	2.89	0.17	3.53	0.24	4.06	0.13	4.38	0.14	23.19	2.34	17.98	1.71	13.72	2.56	8.98	2.04	4.91	0.96
JIP 38	2.21	0.25	2.91	0.23	3.55	0.2	3.94	0.12	4.31	0.14	25.61	6.29	18.51	2.33	10.87	2.85	6.03	2.54	4.31	0.93
JIP 51	2.89	0.24	3.1	0.24	3.43	0.31	3.88	0.2	4.2	0.23	20.38	1.96	16.7	1.44	11.41	2.59	7.52	1.38	4.21	0.25
Mean	2.26	-	2.69	-	3.09	-	3.47	-	3.78	-	23.5	-	19.2	-	16.45	-	10.53	-	8.58	-
ICGV 86031	1	-	1	-	1	-	1	-	1	-	41	-	41.21	-	42.52	-	37.49	-	35.3	-
JL 24	2.42	-	3.13	-	3.74	-	4	-	4.4	-	28.34	-	19.69	-	12.15	-	9.85	-	8.61	-

Plant Height (cm)		Primary branches plant-1		Pods /plant		Total dry matter (g/plant)		Pod weight (g/plant)	
Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±	Mean	S.D±
14.17	2.7	4.2	0.67	11.81	2.4	13.17	2.05	13.37	3.54
14.13	1.85	4.27	0.6	11.06	3.06	15.24	3.96	14.53	4.08
16.55	2	4.09	0.5	8.8	2.64	14.66	4	13.67	3.53
12.33	2.05	4.86	0.81	14.96	1.12	16.73	1.05	17.44	1.62
12.41	1.45	4.9	1.08	14.43	1.06	16.6	1.03	16.37	1.33
16.72	1.84	4.46	0.6	9.98	2.21	15.18	2.75	13.93	3.33
16.77	0.97	4.1	0.54	9.16	2.17	13.2	5	12.1	2.43
18.38	4.15	4.08	0.56	11.46	2.85	14.93	4.08	13.46	4.26
17.2	2.01	4.49	0.69	10.23	3.33	13.17	4.29	12.68	4.77
15.41	-	4.38	-	11.3	-	14.76	-	14.17	-

(< 2) with higher SCMR values (22- 33) followed by TIP 16 (Table 5).

Similarly, among the progenies of cross JIP, JIP 27 showed lower VCR (< 2) with higher SCMR values (22-34) followed by JIP 29 (Table 6). Such a large variation has been noticed among parents and RIL populations for iron deficiency chlorosis tolerance in groundnut (Naidu *et al*., 2017). It has been seen the trait of chlorosis tolerance of ICGV 86031 has been introgressed into these lines susceptible

The visual scoring is fast and convenient method to evaluate iron chlorosis in groundnut. However, scoring differs from person to person and there is possibility of more variation during field observations. Hence, iron chlorosis has been measured as quantitative means using SPAD chlorophyll meter also. Boodi *et al*. (2015), Pujar (2016) and Akshay (2018) also established the usefulness of SPAD chlorophyll meter reading for rapid screening of groundnut genotypes for chlorosis tolerance.

Effect of iron chlorosis on productivity traits like pod yield, number of pods, total dry matter (TDM) and plant height was evident from variation between parents (Akshay, 2018). Wider range of variation was observed among F_3 progeny families for all the productivity traits indicating scope for selection of chlorosis tolerance with higher productivity under calcareous soils. Among TIP series, TIP 6 and TIP 16 had the lowest mean plant height of 12.18 and 11.54 cm, respectively, than the rest of the progenies. Among the checks, the lowest mean plant height was recorded in ICGV 86031 (9.59 cm), while the highest was in TMV 2 (13.27 cm). The number of primary branches per plant was maximum in TIP 6 (5.35) followed by TIP 16 (4.95). Among the checks, ICGV 86031(5.21) showed the highest number of primary branches per plant. The number of pods per plant differed among the progenies and TIP 6 (15.24) showed the highest followed by TIP 16 (14.88). Among the checks, ICGV 86031 (10.9) had the lowest, while TMV 2 (12.27) had the highest number of pods per plant. Total dry matter was highest in TIP 6 (15.03 g plant^{-1}) followed by TIP 16 (14.94 g plant^{-1}) and among the checks, the highest total dry matter was recorded in ICGV 86031 (15.03 g plant^{-1}), while lowest was noticed in TMV 2 (8.63 g plant^{-1}). Pod weight was maximum in TIP 6 (17.67 g plant^{-1}) followed by TIP 16

Table 6. Genetic variation of different traits in F_3 groundnut cross population of TMV 2 × ICGV 86031 (TIP) along with checks

Trait & stage	Range	Mean	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
VCR 30	1.00 - 2.79	2.02	12.55	16.93	54.97	19.17
VCR 45	1.00 - 3.52	2.45	22.23	24.06	85.41	42.33
VCR 60	1.00 - 3.86	2.68	29.21	31.25	87.37	56.24
VCR 75	1.00 - 4.11	3.13	30.17	30.67	96.77	61.15
VCR 90	1.00 - 4.64	3.42	31.94	32.43	96.97	64.79
SCMR 30	17.61 - 42.68	24.44	12.27	15.71	61.01	19.75
SCMR 45	9.59 - 41.17	21.02	23.11	25.76	80.51	42.72
SCMR 60	7.13 - 40.88	19.26	40.96	45.26	81.92	76.38
SCMR 75	6.15 - 29.91	12.16	56.95	69.04	68.03	96.77
SCMR 90	5.20 - 32.39	11.48	59.59	74.10	64.67	98.72
Plant height (cm)	8.06 - 21.34	12.75	14.11	16.72	71.30	24.55
Primary branches plant^{-1}	3.02 - 7.70	4.64	18.87	19.44	94.28	37.75
Pods plant^{-1}	5.80 - 23.40	12.45	28.20	30.55	85.90	55.70
Total dry matter (g plant^{-1})	5.20 - 22	13.50	15.22	24.01	40.20	19.88
Pod weight (g plant^{-1})	5.16 - 25.16	14.46	16.77	30.76	29.75	18.85

Where GCV-Genetic co-efficient of variance, PCV-Phenotypic co-efficient of variance, h^2–Heritability, GA-Genetic advance, GAM- Genetic advance over mean, VCR-visual chlorotic ratings, SCMR- SPAD Chlorophyll metre rate (Relative chlorophyll content)

(17.11 g plant^{-1}). Among the checks, the highest pod weight was recorded for ICGV 86031 (13.70 g plant^{-1}), while the lowest was noticed in TMV 2 (12.14 g plant^{-1}) (Table 5).

Among the progenies of JIP, JIP 27 and JIP 29 had the lowest mean plant height of 12.33 and 12.41 cm respectively. Among the checks, the lowest mean plant height was recorded in ICGV 86031 (11.05 cm), while the highest was recorded in JL 24 (18.20 cm). The number of primary branches per plant, number of pods per plant, total dry matter and pod weight were maximum in JIP 27 (4.86, 14.96, 16.73 g plant^{-1} and 17.44 g plant^{-1}, respectively) followed by JIP 29 (4.90, 14.43, 16.60 g plant^{-1} and 16.37 g plant^{-1}, respectively). Among checks, ICGV 86031 had highest number of primary branches per plant (4.93) and number of pods per plant (13.38), total dry matter (14.80 g plant^{-1}) and pod weight (16.51 g plant^{-1}) but total dry matter, pod weight was recorded least in JL 24 (9.86 and 10.81 g plant^{-1}, respectively) (Table 6).

The selected F_3 progenies TIP 6, TIP 16, JIP 27 and JIP 29 recorded more number of pods per plant, total dry matter and pod weight along with lower VCR and high SCMR values compared to susceptible checks TMV 2 and JL 24. These progenies of both the crosses might have acquired the trait of higher acquisition of iron from the soils. (Strategy I mechanism). It has helped to accumulate higher total dry matter and thereby increase in yield. Akshay (2018) in hydroponics has reported that root protonation and ferric reductase activity were higher in selected F2 lines of the present crosses and was of the opinion that these are the part of strategy I mechanism of acquiring the difficultly available iron from the rhizospere, which was higher in the tolerant genotype ICGV 86031 than susceptible parents. The activity of strategy I mechanism was found higher in these selected lines than their susceptible parents (TMV 2 and JL 24). Thus, it is reported that chlorosis in susceptible genotypes can be reduced by breeding and increase in yield to some extent in calcareous soils.

Table 7. Genetic variation of different traits in F_3 groundnut cross population of JL 24 × ICGV 86031(JIP) along with checks

Trait & stage	Range	Mean	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
VCR 30	1.00 - 3.72	2.22	13.57	16.66	66.32	22.77
VCR 45	1.00 - 3.78	2.65	19.28	19.40	98.80	39.49
VCR 60	1.00 - 4.40	3.06	25.33	25.56	98.20	51.72
VCR 75	1.00 - 4.38	3.40	24.79	24.86	99.45	50.93
VCR 90	1.00 - 4.73	3.71	25.24	25.33	99.31	51.82
SCMR 30	13.14 - 58.12	23.17	17.37	19.82	76.83	31.37
SCMR 45	9.38 - 29.64	19.04	20.06	22.12	82.26	37.49
SCMR 60	7.55 - 35.65	15.78	42.78	44.91	90.72	83.94
SCMR 75	5.66 - 27.36	11.55	53.60	60.94	77.35	97.11
SCMR 90	4.58 - 24.99	10.25	56.41	65.92	73.23	99.45
Plant height (cm)	8.52 - 38.90	15.17	20.03	20.80	92.75	39.75
Primary branches plant^{-1}	3.00 - 7.60	4.37	15.37	16.89	82.87	28.83
Pods plant^{-1}	5.33 - 19.60	11.59	22.33	26.22	72.52	39.17
Total dry matter (g plant^{-1})	5.20 – 24.00	14.93	12.05	23.96	25.31	12.49
Pod weight (g plant^{-1})	5.46 - 14.57	14.33	20.61	25.59	64.85	34.18

Where GCV-Genetic co-efficient of variance, PCV-Phenotypic co-efficient of variance, h^2_{bs} - Heritability, GA-Genetic advance, GAM- Genetic advance over mean, VCR-visual chlorotic ratings, SCMR- SPAD chlorophyll meter readings (Relative chlorophyll content)

Genetic variability

Analysis of genetic variance for iron absorption efficiency related traits (VCR and SCMR) showed the presence of significant genetic variability among progeny lines across different stages of plant growth indicating the scope for selection for low VCR and high chlorophyll efficiency. There was a difference between PCV and GCV and is minimal for both VCR and SCMR at all stages indicating limited influence of environment on the expression of these traits and reliability of selection based on VCR and SCMR in assessing iron chlorosis tolerance. High heritability combined with high genetic advance was observed for the traits VCR and SCMR suggesting the scope for effective selection of superior lines.

Among the productivity traits, pod yield (g plant^{-1}) and number of pods had higher PCV and GCV (Table 6 & 7) compared to plant height, number of primary branches and TDM indicating relatively more pronounced effect of iron chlorosis in F_3 cross population. Less difference between PCV and GCV for all the productivity traits indicated the reliability of phenotypic observation in measuring the genetic components. The heritability and GAM was high for number of pods indicating scope for selection of better productive lines under iron deficient conditions. The iron chlorosis parameter VCR had significant negative correlation with SCMR at all stages. With respect to productivity traits, VCR had significant negative correlation with pod yield. This shows the effect of iron chlorosis in reducing pod yield.

In conclusion, extensive phenotyping of genetic material for iron chlorosis tolerance traits under calcareous soils can be employed for identification of productive lines with iron chlorosis tolerance. In the present study based on the phenotypical observations, TIP 6, TIP 16, JIP 27 and JIP 29 were found to be superior as compared to susceptible parents TMV 2 and JL 24 for chlorosis and yield. Further, the superior iron chlorosis tolerant lines with higher productivity are to be advanced for their performance. The stable superior lines can be further released for commercial cultivation upon multi location evaluation for yield traits. The lines can also be utilized in the iron chlorosis tolerance breeding programme.

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