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Evaluation of Advanced F4 Groundnut Breeding Lines for Chlorosis Tolerance, Morphological and Yield Parameters under Lime-induced Iron Chlorosis Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Iron deficiency chlorosis, a major physiological disorder affecting the groundnut production worldwide and is prevalent in alkaline and calcareous soils with a pH of 7.5 to 8.5. Identifying and developing a chlorosis tolerant genotype is the best solution to overcome this major abiotic stress in calcareous soils. Therefore, a field experiment was conducted at University of Agricultural

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Sciences, Dharwad, in June, 2019 under rainfed conditions to evaluate a set of sixteen advanced breeding lines along with three parents of groundnut checks for chlorosis tolerance, morphological and yield parameters. Associated traits like SPAD chlorophyll meter reading (SCMR) and visual chlorotic rating (VCR) were assessed to evaluate the chlorosis tolerance. Among the parents, lime induced iron chlorosis (LIIC) tolerant parent, ICGV 86031 had recorded higher SCMR value and lower VCR (35.62 and 2.40, respectively) at 60 DAS with lower plant height, higher number of branches per plant, total dry matter production and pod yield (19.27cm, 5.20, 9.34g and 9.21g, respectively) at harvest compared to LIIC susceptible parents. However, among the derived breeding lines, TIP 16-5 recorded higher SCMR value and lower VCR (28.82 and 1.72, respectively) at 60 DAS with higher plant height, number of branches and total dry matter (26.29 cm, 5.33 and 12.80g, respectively) at harvest over the respective susceptible parent TMV 2. Further, TIP 16-5 and JIP 29-14 recorded about 50.47 and 31.46 per cent increased pod yield over their susceptible parents. These results indicate introgression of dry matter production, pod yield and chlorosis tolerance from the tolerant parent.

Keywords: Groundnut; lime induced iron chlorosis; SPAD chlorophyll meter reading; visual chlorotic rating; yield.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important cash crop and is a mighty source of proteins and oil [1] containing 22% to 30% protein and 35% to 60% oil in seeds. As a root nodule legume, it is also capable of fixing atmospheric nitrogen and thus increases soil fertility [2]. Groundnut oil even governs several cardiovascular defensive properties [3]. Indiaranks second in groundnut production with 10.24 million tonnes next to china accounting 19 percent of total world production of 53.97 million tonnes in 2020-21 [4].

Amidst all the essential micronutrients, a plant needs iron more than the others [5]. Even though iron is one of the most abundant micro-nutrients in the soils, it is very often unavailable for the plant uptake in the calcareous soils, since it produces insoluble ferric oxides, hydroxides and phosphate complexes at neutral or basic pH in presence of oxygen [6,7]. Iron (Fe) is essential for all the living organisms and is required for formation of chlorophyll, respiration, nitrogen fixation, DNA synthesis, hormone production and a major component of several redox and iron-sulphur enzymes [8].

Iron deficiency in groundnut exhibits a characteristic symptom *i.e.,* yellowish inter-veinal areas on the young leaves and turns completely into pale white (loss of chlorophyll) under severe deficiency [9] which is referred as iron chlorosis. Iron deficiency chlorosis (IDC) is wide-ranging and is estimated to appear in about 30 to 50% of the cultivated soils [10]. It was majorly exhibited in peanut, soybean, chickpea, cotton, citrus, ornamentals and many tree species [11]. Traditional strategies to alleviate mild chlorosis was to include soil amendments and foliar iron sprays [12], especially to correct yield loss. However, these are not economically feasible. The most effective, practically feasible approach is to grow and choose (iron) Fe efficient and high yielding varieties [13,14].

[15] reported a 12-24 per cent increase in pod yield when efficient cultivars (IDC tolerant) were grown in irrigated black soils. Efficient cultivars adopt strategy-I mechanism which includes the rhizospheric proton extrusion, reduction of Fe^{3+} to Fe^{2+} by ferric reductase activity and releasing several chelates [16]. These efficient cultivars have evolved and inherited adaptive or inducible mechanisms to resolve iron chlorosis under unavailable or low Fe conditions [17]. Groundnut adopts strategy-I mechanism and found to be IDC susceptible [18].

Identifying and developing a Fe efficient genotype is complex, but will be a successive tool to conquer the Fe deficiency in calcareous soils [11]. IDC response in groundnut is generally assessed by total chlorophyll content, visual chlorosis rating (VCR) and SPAD chlorophyll meter reading (SCMR) [9, 19, 20]. Growing IDC tolerant groundnut genotypes under calcareous soils had reported a significantly higher pod yield on comparison with susceptible genotypes [21, 19, 20]. Hence, the present investigation undertook to assess the advanced F_4 groundnut breeding lines for the chlorosis tolerance through screening the morphological and yield parameters which are correlated with the iron chlorosis tolerance. Moreover, these lines can be advanced in breeding programs intending to develop chlorosis tolerant genotypes.

2. MATERIALS AND METHODS

A field experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad in June, 2019 under rainfed condition to evaluate the advanced F_4 groundnut breeding lines for chlorosis tolerance, morphological and yield parameters under calcareous soils. The population consists of 16 breeding lines derived from two crosses TMV 2 × ICGV 86031 (TIP) and JL 24 × ICGV 86031 (JIP).

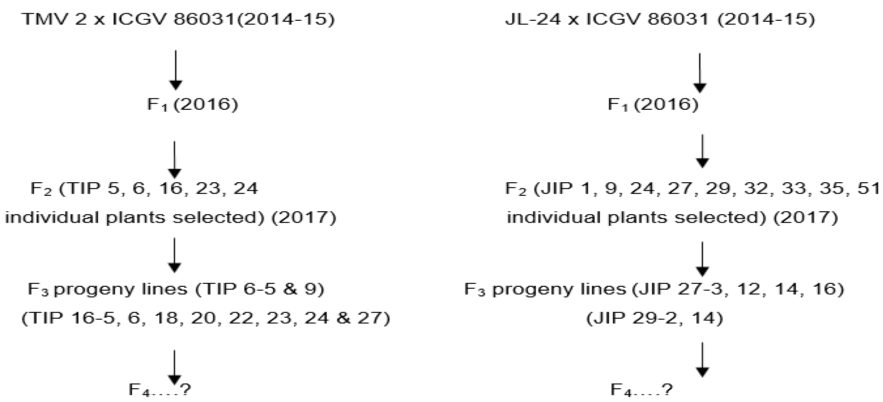
TIP 6-5,9 and TIP 16-5,6,18,20,22,23,24,27 breeding lines from the TIP cross and JIP 27-2,3,12,16 and JIP 29-2,14 breeding lines from the JIP cross were selected along with their parents (TMV 2, JL-24 and ICGV 86031) on the basis of yield (≥ 20gm) and VCR scores (1 and 2) from F_3 derived population. Each genotype was sown in a net plot of 2 rows, each with 1m length in a randomized complete block design with 3 replications and spacing adopted was 30 cm × 10 cm.

To evaluate the chlorosis tolerance along with the morphological and yield traits, a healthy crop is raised by following recommended package of practices like irrigation, fertilizer application, pest management. However, a heavy rainfall of 893.5 mm had recorded during the crop growth period and resulted in low yields. IDC associated traits like SCMR and VCR were assessed at five stages *i.e.,* 30, 45, 60, 75 and 90 DAS for obtaining a vibrant and accurately screened data on chlorosis tolerance. Higher VCR score indicates susceptibility and vice-versa indicates resistance to IDC. Based on VCR score, breeding lines are classified as resistant (VCR 1 to 2), moderately resistant (>2 to 3) or susceptible (>3 to 5). VCR score was allotted as per the scale [22] (Table 1. & Plate 1.).

The chlorophyll meter SPAD 502 (Single Photoelectric Analysing Device, Konica Minolta, Japan) is a simple diagnostic tool that gives the relative chlorophyll content and greenness in leaves in terms of SPAD values. The SCMR values were recorded in the standard leaf (third fully opened leaf from shoot tip on main stem) of all plants and mean was recorded. Such SCMR value was recorded in different stages *viz.,* 30, 45, 60, 75 and 90 DAS. Higher SCMR indicates more chlorophyll content and thereby resistance to IDC, while lower SCMR indicates susceptibility. Since SCMR is a continuous variable, it is quite difficult to make classes for IDC response. However, for a better understanding of SCMR values, we grouped the breeding lines into three categories, *i.e.,* ≤20, >20–25, >25–30, >30–35, >35–40 and >40.

Morphological parameters like plant height, number of branches and the total dry matter (a sum of stem, leaf and pod dry weights) per plant were collected at harvest. Yield parameters like number of pods and pod yield per plant, shelling percentage and the hundred kernel weight were also recorded. The data collected were subjected to statistical analysis under randomized complete block design (RCBD). The mean values of treatments were subjected to DMRT using the corresponding error mean sum of squares and degrees of freedom values at five per cent probability under WASP programme [23].

Flow diagram of populations developed for chlorosis tolerance



(Evaluated during *Kharif* 2019)

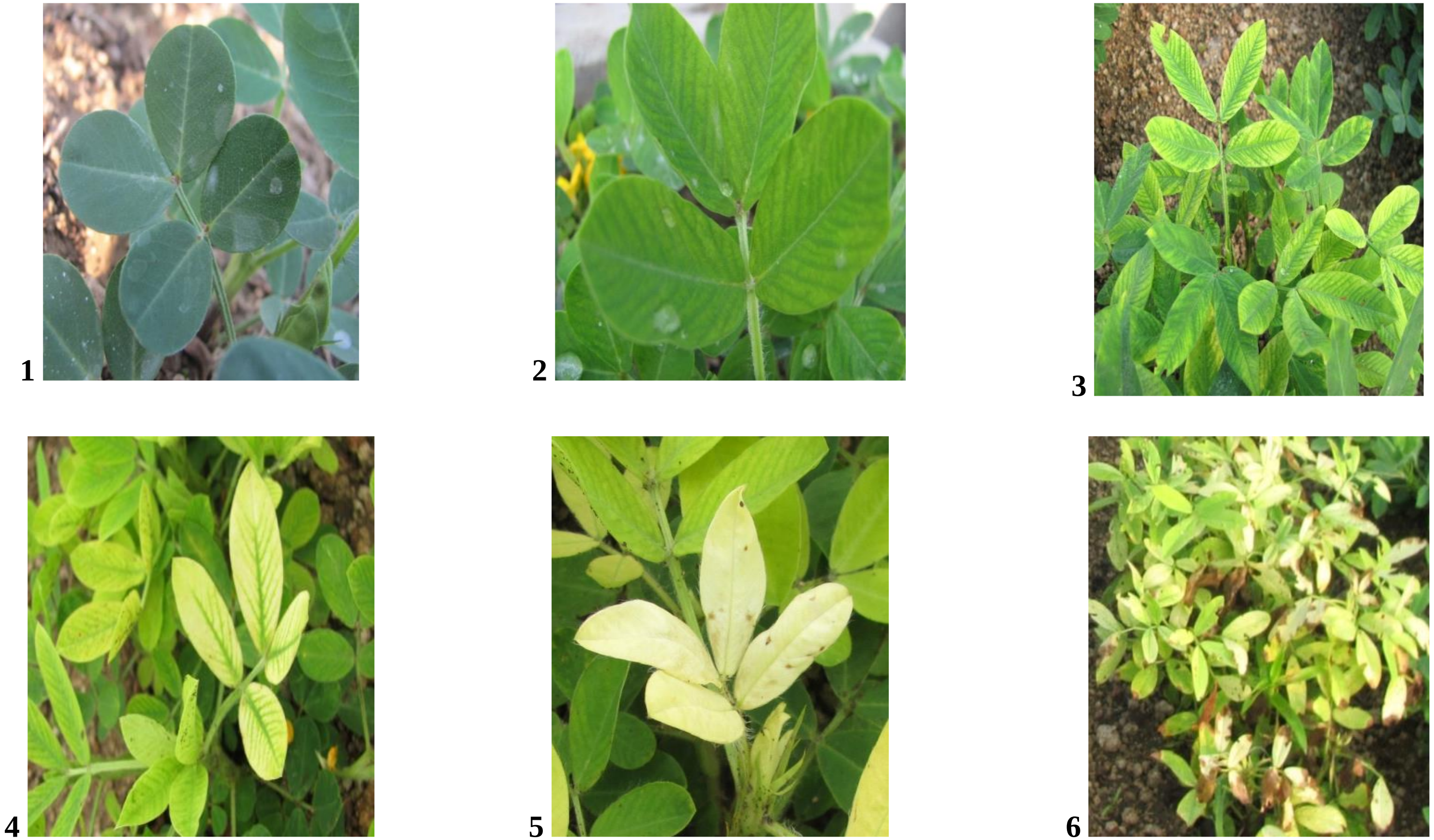


Plate 1. Visual Chlorosis Rating (VCR) (1 to 5 scale) for IDC response representation used for assessment of RILs

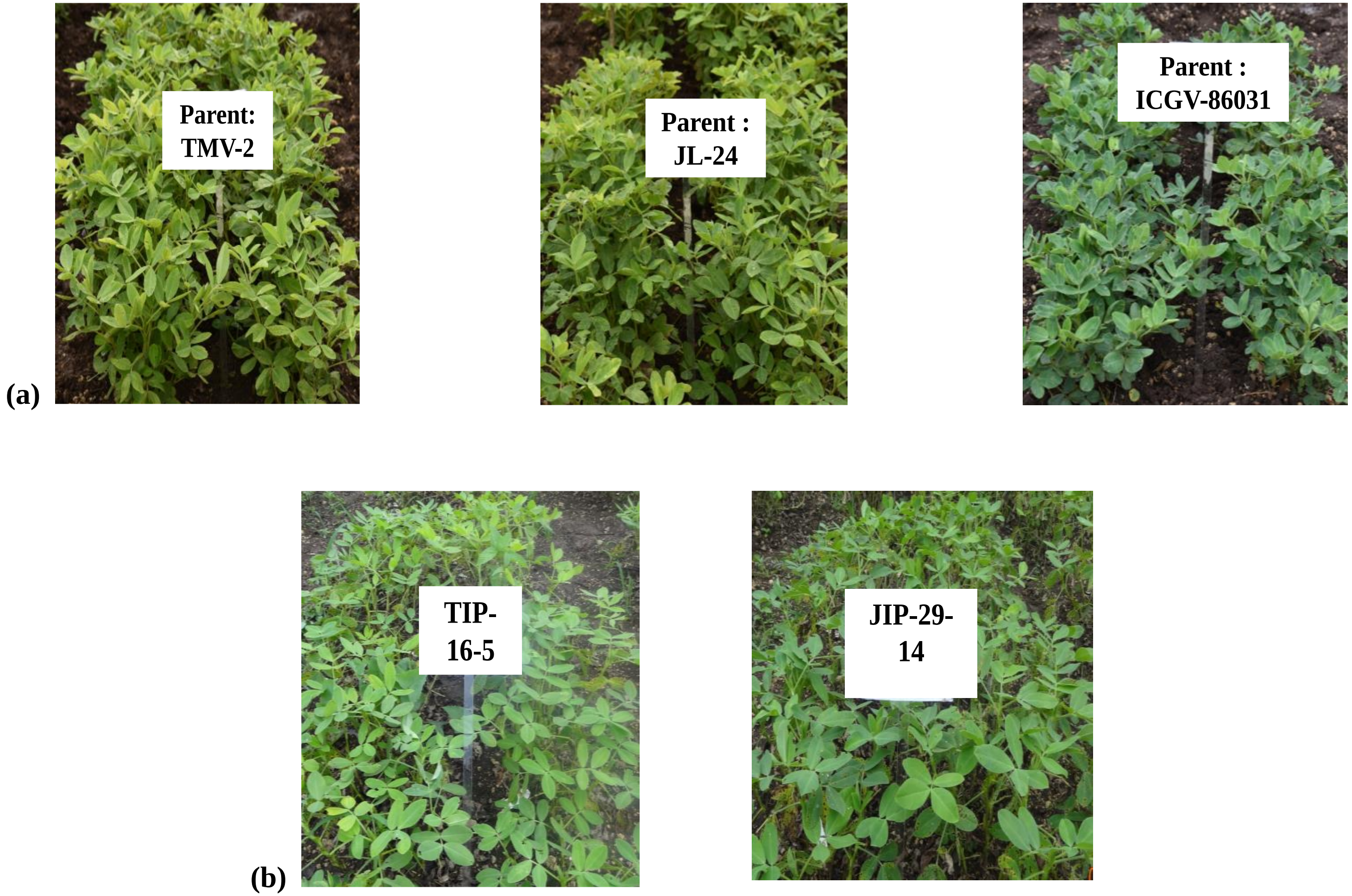


Plate 2. Phenotypic variability in parents and in the F_4 advanced lines. (a) IDC response of parents and (b) variability for IDC response among RILs

Table 1. Visual Chlorosis Rating (VCR) on a scale of 1 to 5 for IDC response representation

Ratings	Symptoms
1	Green leaves
2	Leaves with slightly yellow margins
3	Distinct yellowing over most of the leaf except in mid-vein
4	Completely bright yellow leaves
5	Largely necrotic leaves

3. RESULTS AND DISCUSSION

3.1 Visual Chlorotic Rating (VCR)

Significant difference was observed among the parents with respect to VCR. Among the parents, IDC tolerant parent, ICGV 86031 recorded significantly lower VCR (1.00, 1.33, 2.40, 1.00 and 1.00) over IDC susceptible parents TMV 2 (1.89, 2.35, 3.30, 1.54 and 1.50) and JL 24 (1.94, 2.37, 3.57, 1.65 and 1.59) at 30, 45, 60, 75 and 90 DAS, respectively.

VCR differed significantly among the TIP progeny lines. Whereas, JIP progeny lines did not vary significantly except at 45 DAS. However, both the progeny lines recorded lower VCR over their respective susceptible parents. Among the TIP cross, TIP 16-5 recorded significantly lower VCR (1.29, 1.35, 1.72, 1.05 and 1.00) over others and higher VCR was recorded by TIP 16-22 (1.84, 2.27, 2.38, 1.27 and 1.21). Further, it was on par with TIP 16-6 (1.37, 1.55, 1.82, 1.06 and 1.03) and TIP-6-5 (1.56, 1.63, 2.02, 1.15 and 1.09). Among the JIP cross, JIP 29-14 recorded numerically lower VCR (1.56, 1.52, 2.12, 1.05 and 1.07) and it was found to be on par with other lines at 30, 45, 60, 75 and 90 DAS, respectively. VCR at different stages of advanced F_4 groundnut breeding lines showed variation and indicated genetic variation existing among the progenies of both the crosses (Table 2.). Based on these results, it is confirmed that the trait of chlorosis tolerance has carried into these crossed breeding lines.

Among all the stages, higher VCR was recorded at 60 DAS and self-recovery has been observed at 75 and 90 DAS in both parents and progeny lines. [24] have reported that groundnut genotypes commenced showing chlorosis right from 30 DAS and became susceptible and later self-recovered during 60 -90 DAS. After 90 DAS again started showing more susceptibility to LIIC and continued till 120 DAS under calcareous soils. This susceptibility phenomenon is mainly because of higher iron requirement at initial stages and also at the pod development stage which indicates higher metabolic activities at these respective stages. ICGV 86031 had lower VCR as evident from the higher SCMR values over the susceptible genotypes, TMV-2 and JL-24 while studying the mini core germplasms under calcareous soils [25, 26]. A similar result was also reported while evaluating the F_2 and F_3 generations at Dharwad [27], at Vijayapura [28], respectively.

3.2 SCMR- SPAD Chlorophyll Meter Readings (Relative Chlorophyll Content)

SPAD has been used before as a good indicator of chlorophyll concentration and degree of chlorosis [29-31]. Among the parents, IDC tolerant parent, ICGV 86031 recorded significantly higher SCMR (37.21, 40.75, 35.62, 44.75 and 41.38) over IDC susceptible parents TMV 2 (28.74, 26.80, 25.29, 32.58 and 32.26) and JL 24 (27.11, 23.90, 23.63, 31.93 and 31.33) at 30, 45, 60, 75 and 90 DAS, respectively.

TIP progeny lines differed significantly with SCMR. While, JIP progeny lines did not show any significant variation except at 60 DAS (Table 2.). However, both breeding lines performed significantly superior over their respective susceptible parents. Among the TIP cross, TIP 16-5 recorded significantly higher SCMR (31.64, 31.31, 28.82, 36.06 and 36.07) over others and lower SCMR was recorded by TIP 16-22 (28.25, 26.31, 24.93, 32.66 and 32.49). Further, it was on par with TIP 16-6 (31.26, 31.76, 27.96, 35.11 and 34.99) and TIP 16-18 (30.45, 28.00, 27.89, 34.56 and 33.74). Among the JIP cross, JIP 29-14 recorded numerically higher SCMR (31.14, 29.47, 28.31, 34.74 and 34.76) and was on par with other breeding lines at 30, 45, 60, 75 and 90 DAS, respectively.

Among all the stages, lower SCMR was recorded at 60 DAS which was justified by higher VCR. Further, there was a gradual recovery of SCMR values at 75 and 90 DAS in both the parental and progeny lines. Similar results have been reported while evaluating the crosses of F_2 and F_3

generations respectively [27, 28]. On comparing the chlorosis tolerance and susceptibility traits of parents with the progenies, chlorosis tolerance trait appeared to be inherited into advanced F_4 breeding lines.

3.3 Morphological and Yield Traits of the Advanced F_4 Groundnut Breeding Lines

Yield of any crop is determined by the index of various morphological, physiological, growth parameters and yield attributed components such as number of pods, kernel weight and shelling percentage. Further, pod yield in groundnut is determined by three physiological attributes *viz.*, partitioning of assimilates between vegetative and reproductive parts, length of pod filling period and rate of pod establishment [32]. In the present investigation, genotypes with lower chlorotic values recorded higher morphological characters suggesting that iron is the most active element in determining overall growth of the plant. [33] reported the yield reduction to the extent of 13-50 per cent due to iron deficiency chlorosis.

Even-though, no significant difference was recorded in the number of pods per plant, pod yield varied significantly because of great differences in the hundred kernel weight and shelling percentage. Among the parents, the tolerant parent ICGV 86031 had recorded a higher pod yield (9.21 g) because of higher hundred kernel weight (47.33 g). However, a higher shelling percentage (78.83) was recorded in JL 24, but it has not attributed to higher pod yield due to very low number of pods per plant and hundred kernel weight. It further recorded lower plant height, higher number of branches per plant and total dry matter production (19.27cm, 5.20 and 9.34g, respectively) at harvest compared to LIIC susceptible parents. In this context, the current results match with the findings of earlier works who confirmed that, TMV 2 reported significantly higher plant height followed by JL 24 over ICGV 86031 [25, 27, 28]. However, the increased plant height in susceptible parents TMV 2 and JL 24 has not resulted in higher yields as they have suffered iron deficiency chlorosis.

Among the derived breeding lines, TIP 16-5 recorded lower plant height, higher number of branches and total dry matter (26.29 cm, 5.33 and 12.80g, respectively) at harvest over the respective susceptible parent TMV 2 (Table 3.). It also recorded higher yield (8.08 g) with higher shelling percentage (84.17) and hundred seed weight (30.68 g) whereas in case of JIP cross, JIP 29-14 recorded higher yield (6.77 g) with higher shelling percentage (78.01) and hundred seed weight (38.13 g) (Table 4.). TIP 16-5 of the TIP cross and JIP 29-14 of the JIP cross reported about 56.10 and 46.86 per cent increase in dry matter production over their susceptible parents respectively. The iron deficit chlorotic leaves (low chlorophyll content) intercept less light and a proportionate decrease in photosynthetic rate as well as nutrient acquisition and utilization efficiency is observed [34]. Hence, variations in the Fe content certainly influences the growth and yield. Thus, the breeding lines are superior over their respective parents with an increased total dry matter production and pod yield by acquiring chlorosis tolerance. These results were in conformity with [27, 28] while evaluating the F_2 and F_3 generation groundnut populations, respectively.

3.4 Correlation Analysis of VCC and SCMR of Advanced F_4 Groundnut Breeding Lines on Yield and Yield Traits

The correlation coefficient analysis was estimated between VCR, SCMR, yield and yield traits (Table 5.). VCR at 30 DAS had non-significant positive correlation with number of pods per plant (0.032). Further, VCR at 45, 60, 75 and 90 DAS had non-significant negative correlation with number of pods per plant (-0.211, -0.428, -0.150, -0.311)

VCR at all stages except for 60 DAS had non-significant negative correlation with hundred seed/ kernel weight (-0.430, -0.294, -0.243, -0.117, respectively). Whereas, at VCR at 60 DAS had non-significant positive correlation with hundred seed/ kernel weight (0.144).

VCR at all stages *i.e.,* 30, 45, 60, 75 and 90 DAS had non-significant negative correlation with pod yield per plant (-0.773, -0.689, -0.503, -0.605 and -0.673, respectively). In general, a negative correlation of VCR with parameters like number of pods per plant, hundred seed weight and pod yield per plant was observed. Similar results were reported by [28, 35, 36]. This is obvious due to the fact that there is a direct relation between the source (leaves) to sink (pods) in any crop in general and groundnut in particular.

Table 2. VCR and SCMR- SPAD chlorophyll meter reading of advanced F_4 groundnut breeding lines at different stages

Genotypes	Visual Chlorotic Rating (VCR)					SCMR- SPAD chlorophyll meter reading				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
TIP 6-5	1.56^{b-d}	1.63^{c-f}	2.02^{b-d}	1.15^{c-e}	1.09^{b}	29.65^{b-e}	28.37^{b-e}	27.36^{b-g}	32.73^{cd}	33.92^{b-e}
TIP 6-9	1.79^{ab}	1.85^{c-e}	2.30^{bc}	1.16^{c-e}	1.07^{b}	30.53^{b-d}	30.14^{b-d}	27.88^{b-e}	32.95^{cd}	33.24^{c-e}
TIP 16-5	1.29^{de}	1.35^{f}	1.72^{d}	1.05^{de}	1.00^{b}	31.64^{b}	31.76^{b}	28.82^{b}	36.06^{b}	36.07^{b}
TIP 16-6	1.37^{cd}	1.55^{d-f}	1.82^{cd}	1.06^{de}	1.03^{b}	31.26^{bc}	31.31^{bc}	27.96^{b-d}	35.11^{bc}	34.99^{bc}
TIP 16-18	1.71^{ab}	1.85^{c-e}	2.12^{b-d}	1.37^{bc}	1.14^{b}	30.45^{b-d}	28.00^{c-e}	27.89^{b-e}	34.56^{b-d}	33.74^{b-e}
TIP 16-20	1.77^{ab}	1.62^{d-f}	2.18^{b-d}	1.13^{c-e}	1.13^{b}	29.21^{b-e}	29.91^{b-e}	26.44^{c-h}	34.05^{b-d}	33.10^{c-e}
TIP 16-22	1.84^{ab}	2.27^{ab}	2.38^{b}	1.27^{cd}	1.21^{b}	28.25^{b-e}	26.31^{ef}	24.93^{hi}	32.66^{cd}	32.49^{c-e}
TIP 16-23	1.56^{b-d}	1.93^{b-d}	2.02^{b-d}	1.21^{c-e}	1.06^{b}	29.25^{b-e}	27.29^{d-f}	25.46^{g-i}	32.98^{cd}	33.08^{c-e}
TIP 16-24	1.71^{ab}	1.63^{c-f}	2.00^{b-d}	1.07^{de}	1.04^{b}	28.95^{b-e}	28.75^{b-e}	25.66^{e-i}	32.69^{cd}	33.27^{c-e}
TIP 16-27	1.71^{ab}	1.72^{c-f}	2.23^{b-d}	1.13^{c-e}	1.14^{b}	29.85^{b-e}	27.84^{c-e}	25.51^{g-i}	33.76^{b-d}	32.54^{c-e}
JIP 27-2	1.76^{ab}	2.03 $^{a-c}$	2.30^{bc}	1.23^{c-e}	1.15^{b}	28.66^{c-e}	27.29^{d-f}	25.59^{f-i}	32.91^{cd}	32.47^{c-e}
JIP 27-3	1.67^{a-c}	1.77^{c-e}	2.15^{b-d}	1.10^{de}	1.08^{b}	30.10^{b-d}	29.07^{b-e}	25.60^{g-i}	32.99^{cd}	33.66^{b-e}
JIP 27-12	1.62^{a-c}	1.68^{c-f}	2.13^{b-d}	1.13^{c-e}	1.08^{b}	30.62^{b-d}	28.54^{b-e}	27.85^{b-f}	34.12^{b-d}	33.57^{b-e}
JIP 27-16	1.62^{a-c}	1.90^{b-e}	2.15^{b-d}	1.08^{de}	1.10^{b}	29.01^{b-e}	27.97^{c-e}	27.29^{b-g}	33.04^{cd}	34.26^{b-d}
JIP 29-2	1.69^{a-c}	1.55^{c-e}	2.05^{b-d}	1.08^{de}	1.12^{b}	30.15^{b-d}	28.72^{b-e}	25.91^{d-h}	34.40^{b-d}	34.09^{b-d}
JIP 29-14	1.56^{b-d}	1.52^{ef}	2.12^{b-d}	1.05^{de}	1.07^{b}	31.14^{bc}	29.47^{b-e}	28.31^{bc}	34.74^{b-d}	34.76^{b-d}
TMV 2 (Parent)	1.89^{a}	2.35^{a}	3.30^{a}	1.54^{ab}	1.50^{a}	28.74^{c-e}	26.80^{d-f}	25.29^{g-i}	32.58^{cd}	32.26^{de}
JL 24 (Parent)	1.94^{a}	2.37^{a}	3.57^{a}	1.65^{a}	1.59^{a}	27.11^{e}	23.90^{f}	23.63^{i}	31.93^{d}	31.33^{e}
ICGV 86031 (Parent)	1.00^{e}	1.33^{f}	2.40^{b}	1.00^{e}	1.00^{b}	37.21^{a}	40.75^{a}	35.62^{a}	44.75^{a}	41.38^{a}
Mean	**1.63**	**1.78**	**2.26**	**1.18**	**1.14**	**30.09**	**29.06**	**27.00**	**34.16**	**33.91**
S. Em. ±	0.113	0.139	0.186	0.083	0.077	0.961	1.269	0.786	1.022	0.935
CD (P=0.05)	0.324	0.400	0.535	0.238	0.221	2.756	3.639	2.256	2.930	2.682

TIP- TMV 2 × ICGV 86031, JIP- JL 24 × ICGV 86031. DAS- Days After Sowing

Table 3. Morphological parameters of advanced F_4 groundnut breeding lines at harvest

Genotypes	Plant Height (cm)	Number of primary branches per plant	Total dry matter production (g plant^{-1})	Per cent increase of TDM over respective susceptible parent
TIP 6-5	24.26^{b-e}	4.93	9.40^{d-g}	14.63
TIP 6-9	22.64^{d-f}	5.20	10.74^{cd}	30.98

Genotypes	Plant Height (cm)	Number of primary branches per plant	Total dry matter production (g plant^{-1})	Per cent increase of TDM over respective susceptible parent
TIP 16-5	26.29^{ab}	5.33	12.80^{a}	56.10
TIP 16-6	25.70^{a-c}	5.33	12.21^{ab}	48.90
TIP 16-18	24.01^{b-e}	5.00	10.28^{c-e}	25.37
TIP 16-20	23.36^{c-f}	5.07	10.72^{cd}	30.73
TIP 16-22	21.16^{fg}	4.87	9.05^{e-g}	10.37
TIP 16-23	24.19^{b-e}	4.93	9.86^{c-f}	20.24
TIP 16-24	25.72^{a-c}	4.97	10.84^{bc}	32.20
TIP 16-27	21.49^{e-g}	5.00	9.96^{c-f}	21.46
JIP 27-2	21.49^{e-g}	5.07	8.60^{f-h}	17.49
JIP 27-3	21.62^{e-g}	4.73	9.62^{c-f}	31.42
JIP 27-12	24.49^{b-d}	4.93	9.89^{c-f}	35.11
JIP 27-16	21.67^{e-g}	4.87	9.81^{c-f}	34.02
JIP 29-2	22.32^{d-f}	5.13	9.58^{c-g}	30.87
JIP 29-14	25.09^{a-d}	5.00	10.75^{cd}	46.86
TMV 2 (Parent)	27.66^{a}	4.93	8.20^{gh}	-
JL 24 (Parent)	25.76^{abc}	4.87	7.32^{h}	-
ICGV 86031 (Parent)	19.27^{g}	5.20	9.34^{d-g}	-
Mean	**23.59**	**5.02**	**9.95**	
S. Em. ±	0.97	0.14	0.50	-
CD (P=0.05)	2.79	NS	1.42	

TIP- TMV 2 × ICGV 86031, JIP- JL 24 × ICGV 86031. DAS- Days After Sowing, TDM- Total Dry Matter

Table 4. Yield parameters of advanced F_4 groundnut breeding lines at harvest

Genotypes	Number of pods per plant	Pod yield per plant (g)	Per cent increase of pod yield over respective susceptible parent	Shelling percentage	Hundred kernel weight (g)
TIP 6-5	7.60^{c-h}	6.08^{c-f}	13.22	78.53^{bc}	32.59^{c-g}
TIP 6-9	9.40^{a-f}	7.44^{a-d}	38.55	77.16^{bc}	35.56^{b-e}
TIP 16-5	10.07^{a-c}	8.08^{ab}	50.47	84.17^{a}	30.68^{d-g}
TIP 16-6	9.20^{a-g}	7.92^{a-c}	47.49	80.92^{ab}	30.68^{d-g}
TIP 16-18	10.93^{a}	7.02^{b-f}	30.73	80.59^{ab}	29.40^{e-g}

Genotypes	**Number of pods per plant**	**Pod yield per plant (g)**	**Per cent increase of pod yield over respective susceptible parent**	**Shelling percentage**	**Hundred kernel weight (g)**
TIP 16-20	10.87^{a}	7.20^{b-e}	34.08	78.27^{bc}	28.22^{fg}
TIP 16-22	9.80^{a-d}	6.54^{b-f}	21.79	78.02^{bc}	28.93^{fg}
TIP 16-23	9.40^{a-f}	6.64^{b-f}	23.65	78.71^{bc}	27.79^{g}
TIP 16-24	9.73^{a-e}	7.29^{a-e}	35.75	78.30^{bc}	29.84^{e-g}
TIP 16-27	10.20^{ab}	6.83^{d-f}	27.19	77.03^{bc}	32.77^{c-g}
JIP 27-2	6.00^{h}	5.95^{b-f}	15.53	79.27^{ab}	36.49^{b-d}
JIP 27-3	7.20^{e-h}	6.15^{b-f}	19.42	77.52^{bc}	34.17^{c-f}
JIP 27-12	7.73^{b-h}	6.36^{b-f}	23.50	75.94^{bc}	41.58^{ab}
JIP 27-16	6.60^{h}	6.13^{b-f}	19.03	76.29^{bc}	34.35^{c-f}
JIP 29-2	7.27^{d-h}	5.65^{f}	9.71	73.65^{c}	36.42^{b-d}
JIP 29-14	7.73^{b-h}	6.77^{b-f}	31.46	78.01^{bc}	38.13^{bc}
TMV 2 (Parent)	7.13^{f-h}	5.37^{ef}	-	77.15^{bc}	32.52^{c-g}
JL 24 (Parent)	6.40^{h}	5.15^{f}	-	78.83^{bc}	34.48^{c-f}
ICGV 86031 (Parent)	6.73^{gh}	9.21^{a}	-	68.18^{d}	47.33^{a}
Mean	**8.42**	**6.70**		**77.71**	**33.79**
S. Em. ±	0.90	0.69	**-**	1.81	2.22
CD (P=0.05)	2.59	1.97		5.18	6.37

TIP- TMV 2 × ICGV 86031, JIP- JL 24 × ICGV 86031. DAS-Days After Sowing.

Table 5. Correlation analysis of VCC and SCMR of advanced F_4 groundnut breeding lines on yield and yield traits

Traits	VCR30	VCR 45	VCR60	VCR75	VCR90	SCMR30	SCMR45	SCMR60	SCMR75	SCMR 90	NPP	HSW	PYPP
VCR30	1.000												
VCR 45	0.770***	1.000											
VCR60	0.504*	0.746***	1.000										
VCR75	0.654**	0.857***	0.848***	1.000									
VCR90	0.657**	0.816***	0.936***	0.928***	1.000								
SCMR30	-0.882	-0.715	-0.324	-0.564	-0.560	1.000							
SCMR45	-0.870	-0.728	-0.343	-0.621	-0.586	0.960***	1.000						
SCMR60	-0.862	-0.664	-0.296	-0.523	-0.536	0.958***	0.938***	1.000					
SCMR75	-0.843	-0.602	-0.165	-0.431	-0.400	0.949***	0.935***	0.925***	1.000				
SCMR 90	-0.927	-0.702	-0.327	-0.578	-0.546	0.955***	0.954***	0.953***	0.951***	1.000			

Traits	**VCR30**	**VCR 45**	**VCR60**	**VCR75**	**VCR90**	**SCMR30**	**SCMR45**	**SCMR60**	**SCMR75**	**SCMR 90**	**NPP**	**HSW**	**PYPP**
NPP	0.032	-0.211	-0.428	-0.150	-0.311	-0.038	-0.006	-0.066	-0.084	-0.121	1.000		
HSW	-0.430	-0.294	0.144	-0.243	-0.117	0.636**	0.553**	0.633**	0.625**	0.587**	-0.644	1.000	
PYPP	-0.773	-0.689	-0.503	-0.605	-0.673	0.790***	0.846***	0.783***	0.751***	0.764***	0.441	0.175	1.000

VCR- Visual Chlorotic Rating, SCMR- SPAD chlorophyll meter reading, NPP - Number of Pods Per Plant, HSW-Hundred Seed Weight, PYPP - Pod Yield Per Plant
**Significant values (p<0.1), **Significant values (p=0.05-0.01), ***Significant values (p<0.01)*

SCMR at all stages *i.e.,* 30, 45, 60, 75 and 90 DAS had non-significant negative correlation with number of pods per plant (-0.038, -0.006, -0.066, -0.084 and -0.121, respectively). Further, SCMR at all stages had significant positive correlation with hundred seed/kernel weight (0.636, 0.553, 0.633, 0.625 and 0.587, respectively) and (0.790, 0.846, 0.783, 0.751 and 0.764, respectively). Overall, SCMR had a significant positive correlation with various yield parameters. Similar results were reported by [28, 35, 37].

4. CONCLUSION

The present evaluation of F_4 groundnut breeding lines by crossing TMV 2, JL 24 with ICGV 86031 separately under calcareous conditions, confirms that the traits of both the susceptible (plant height) and the tolerant parent (dry matter production, pod yield and chlorosis tolerance) has been introgressed. However, TIP 16-5, TIP 16-6 of the TIP cross and JIP 29-14 of the JIP cross were adjudged better breeding lines among all the progenies, since they have outperformed their parents.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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