Original Research Article

Evaluation of advanced F_4groundnut lines for chlorosis tolerance, morphological and yield parameters under lime-induced iron chlorosis condition

ABSTRACT

Iron deficiency chlorosis, a major physiological disorder affecting the groundnut production worldwide 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 Sciences, Dharwad during *kharif* 2019 under rainfed conditions to evaluate a set of sixteen advanced breeding lines along with three parents of groundnut 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 lines, TIP 16-5 recorded higher SCMR value and lower VCR (28.82 and 1.72, respectively) at 60DAS 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 TMV2. 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 and proteins [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]. It is grown on a global scale of 29.59 million ha area with 48.75 million metric tons of in-shell production of [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 productionand 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 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 cultivarsadopt 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 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. MATERIAL AND METHODS

A field experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad during *kharif* 2019 under rainfed condition to evaluate the advanced F_4 groundnut lines for chlorosis tolerance, morphological and yield parameters under calcareous soils.The population consists of 16 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 lines from the TIP cross and JIP 27-2,3,12,16 and JIP 29-2,14 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 andspacing adopted was 30 cm × 10 cm.

Flow diagram of populations developed for chlorosis tolerance

TMV 2 x ICGV 86031(2014-15) JL-24 x ICGV 86031 (2014-15)

↓ ↓

F_1 (2016)F_1 (2016)

↓ ↓

F_2 (TIP 5, 6, 16, 23, 24 individual plants selected) (2017) F_2 (JIP 1, 9, 24, 27, 29, 32, 33, 35, 51 individual plants selected) (2017)

↓ ↓

F_3 progeny lines (TIP 6-5 & 9)F_3 progeny lines(JIP 27-3, 12, 14, 16)
(TIP 16-5, 6, 18, 20, 22, 23, 24 & 27) (JIP 29-2, 14)

↓ ↓

F_4….? F_4….?

(Evaluated during *Kharif* 2019)

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, 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. &Plate1.).

The chlorophyll meter SPAD 502 (Single PhotoelectricAnalysing 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 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].

3. RESULTS AND DISCUSSION

3.1Visual 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 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 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, 30, 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 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 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 lines.

3.3 Morphological and yieldtraits of the advanced F_4 groundnut lines

Yield ofany 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 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 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.

4. CONCLUSION

The present evaluation of F_4 groundnut 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 linesamong all the progenies, since they have outperformed their parents.

REFERENCES

1. Tang R, Gao G, He L, Han Z, Shan S, Zhong R, Zhou C, Jiang J, Li Y, Zhuang W. Genetic diversity in cultivated groundnut based on SSR markers. J. Genet. Genomics.2007; 34(5): 449-459.

2. Jasani H. Groundnut (*Arachis hypogaea* L.) varieties. 2009; Accessed 21 November 2019. Available: http://agropedia.iitk.ac.in/ content/economic-importance-groundnut-oilseed-crop

3. Stephens AM, Dean LL, Davis JP, Osborne JA, Sanders TH. Peanuts, peanut oil, and fat free peanut flour reduced cardiovascular disease risk factors and the development of atherosclerosis in Syrian golden hamsters. J. Food Sci.2010; 75: 116-122.

4. FAO STAT, 2019. *Food and Agriculture Organization (FAO): Food and Agricultural Organization of the United Nations,* FAO Statistical Database. Available: http://www.fao.org/faostat/en/#data/QC data [15 June 2021].

5. Taiz L, Zeiger E. Plant physiology, Sinauer Associates, Inc. Sunderland, Massachusetts; 2002.

6. Guerinot ML, Yi Y.Iron: Nutritious, noxious, and not readily available. Plant Physiol. 1994; 104(3): 815-820.

7. Graziano M, Lamattina, L. Nitric oxide and iron in Plants: An emerging and converging story. Trends Plant Sci. 2005; 10(1): 4-8.

8. Zheng SJ. Iron homeostasis and iron acquisition in plants: Maintenance, functions and consequences. Ann. Bot.2010; 105: 799-800.

9. Samdur MY, Singh AL, Mathur RK, Manivel P, Chikani BM, Gor HK, Khan MA. Field evaluation of chlorophyll meter for screening groundnut (*Arachis hypogaea* L.) genotypes tolerant to iron deficiency chlorosis. Indian J. Agric. Sci.2000; 79(2): 211-214.

10. Cakmak I, Plant nutrition research: Priorities to meet human needs for food in sustainable way. Plant and Soil.2002;247: 3-24.

11. Imtiaz M, Rashid A, Khan P, Memon MY, Aslam M. The role of micronutrients in crop production and human health. Pak. J. Bot. 2010;42(4): 2565-2578.

12. Schenkeveld WD, Reichwein AM, Bugter MH, TemminghoffEJ, Van Riemsdijk WH. Performance of soil-applied FeEDDHA isomers in delivering Fe to soybean plants in relation to the moment of application.J. Agric. Food Chem. 2010; 58: 12833-12839.

13.Habib AF, Joshi MS. Combating iron chlorosis in black soils of Malaprabha and Ghataprabha project area. Curr. Sci.1982;11: 51-54.

14. Vasconcelos MW, Grusak MA. Morpho-physiological parameters affecting iron deficiency chlorosis in soybean (*Glycine max* L.). Plant and Soil.2013; 374: 161-172.

15. Panchaksharaiah S.*Investigations on the effect of nitrogen, iron, gypsum, sulphur and calcium on growth and yield of groundnut (Arachis hypogaea L.) and iron efficiency of genotypes on black soil under irrigation.* Ph.D. Thesis, University of Agricultural Sciences, Bangalore; 1982.

16. Romheld V, Marschner H. Mechanism of iron uptake by peanut plants. Plant Physiol.1983; 71(4)d: 949-954.

17. Marschner H. Mineral Nutrition of Higher Plants. *Academic Press Inc (London) Ltd.* (pp. 112-116). *England;*1986.

18.Gholizadeh H, Kohnehrouz BB, Hekmatshoar H. Step-by-step morpho physiological responses of *Arachis hypogaea* L. cv. NC 2 to iron deficiency. Plant Soil Environ.2007;53(7): 290-298.

19. Li G, Yanxi S. Genetic differences in resistance to iron deficiency chlorosis in peanut. J. Plant Nutr. 2007; 30(1): 37-52.

20. Mann A, Singh AL, Oza S, Goswami N, Mehta D, Chaudhari V. Effect of iron source on iron deficiency induced chlorosis in groundnut. Legume Res. 2017; 40(2): 241-249.

21. Prasad PV, Satyanarayana V, Potdar MV, Craufurd, PQ. On-farm diagnosis and management of iron chlorosis in groundnut. J. Plant Nutr. 2000; 23(10): 1471-1483.

22. Singh AL, Chaudhari V. Screening of groundnut germplasm collection and selection of genotypes tolerant to lime-induced iron chlorosis. Indian J. Agric Sci. 1993; 121: 205-211.

23. Gomez AK, Gomez AA. Statistical Procedures for Agriculture Research, A Wiley Inheritance Publication, (2nd ed., pp. 187-241). New York; 1984.

24. Boodi IH, Pattanashetti SK, Biradar BD. Identification of groundnut genotypes resistant to iron deficiency chlorosis. Karnataka J. Agric. Sci. 2015;28(3): 406-408.

25. Pujar A, Koti RV. Variation in morphological traits in lime induced iron chlorosis resistant and susceptible groundnut genotypes. J. Farm Sci. 2016;29(3): 401-404.

26. Naidu GK, Pattanashetti SK, Boodi IH, Singh OK, Kumar PKV, Biradar BD, Wali CM. Genetic analysis of recombinant inbred lines for iron deficiency chlorosis and productivity traits in groundnut. Indian J. Genet Plant Breed. 2017; 77(3): 414-421.

27. Akshay. Physiological characterization of groundnut (Arachis hypogaea L.) for lime induced iron chlorosis. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad; 2018.

28. Chethana MV.Physiological evaluation of F_3 groundnut populations for iron chlorosis tolerance in calcareous soils. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad; 2019.

29. Markwell J, Osterman J, Mitchell J. Calibration of the Minolta SPAD-502 leaf chlorophyll meter. *Photosynth. Res.* 1995; 46: 467-472.

30. Richardson AD, Duigan SP, Berlyn GP. An evaluation of non-invasive methods to estimate foliar chlorophyll content. New Phytol.2002; 153:185-194.

31. Uddling J, Gelang-Alfredsson J, Piikki K and Pleijel H. Evaluating the relationship between leaf chlorophyll concentration and SPAD-502 chlorophyll meter readings.Photosynth. Res. 2007; 91: 37-46.

32. Duncan WG, Mccloud DE, Mcgraw IG, Boote KG. Physiological aspects of peanut yield improvements. Crop Sci. 1978;18: 1015-1020.

33. Kulkarni VN, Gowda MVC, Panchal YC, Nadaf HL. Evaluation of groundnut cultivars for iron absorption efficiency. Crop Res.1994; 7(1): 8492.

34. Su Y, Zhang Z, Su G, Liu C, Shi G. Genotypic differences in spectral and photosynthetic response of peanut to iron deficiency. J. Plant Nutr. 2015;38(1): 145-160.

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

Table 2. VCR and SCMR- SPAD chlorophyll meter reading of advanced F_4 groundnut 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

Note: TIP- TMV 2 × ICGV 86031, JIP- JL 24 × ICGV 86031. DAS- Days after sowing.

Table 3. Morphological parameters of advanced F_4 groundnut 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
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	

Note: 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 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}
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

Note: TIP- TMV 2 × ICGV 86031, JIP- JL 24 × ICGV 86031. DAS-Days after sowing.

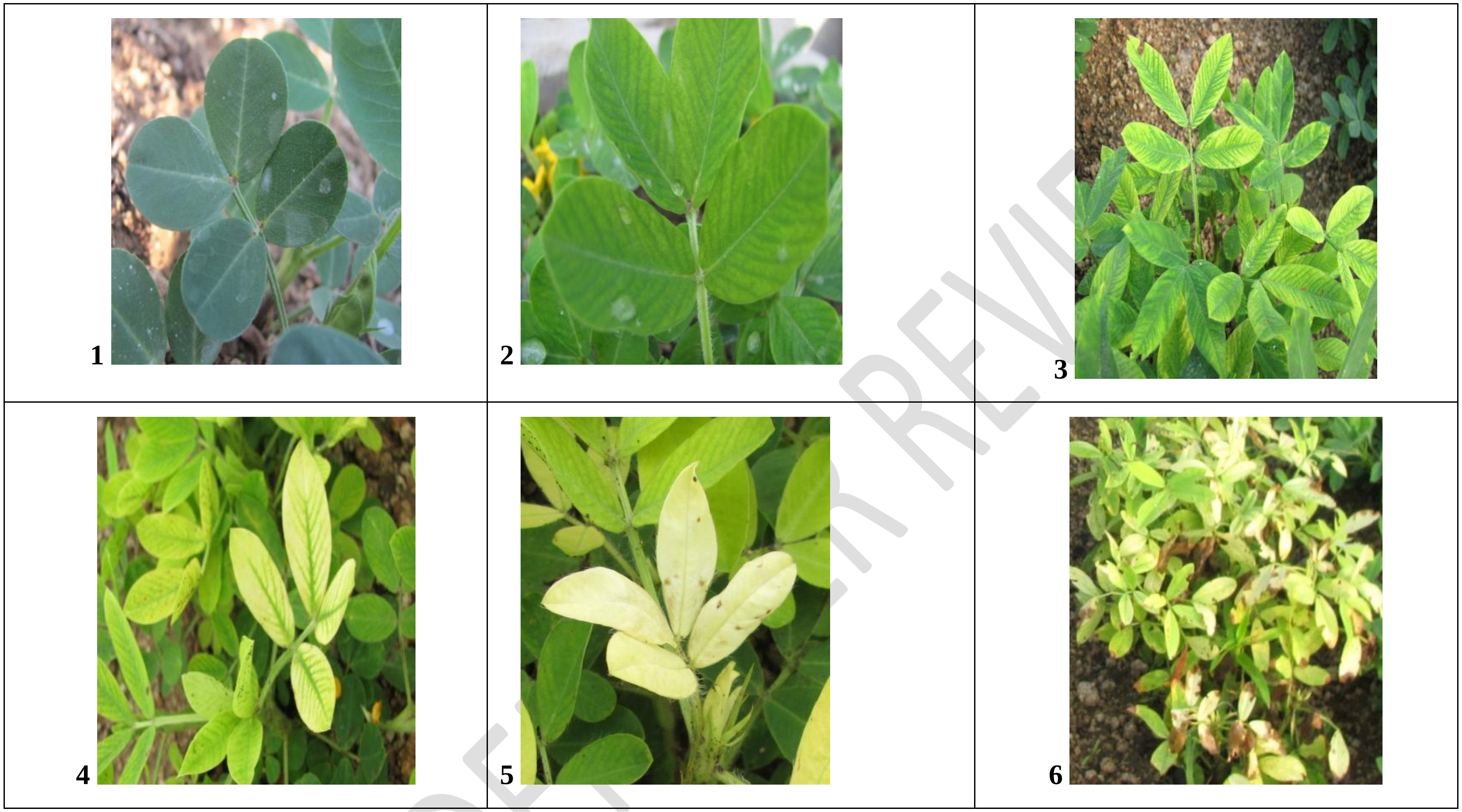

Plate 1. Visual chlorosis rating (VCR) (1 to 5 scale) for IDC response representation used for assessment of RILs

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