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Genetic Variability for Iron Deficiency Chlorosis Resistance in Groundnut (*Arachis hypogaea* L.) under Calcareous Soil

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Abstract The present study was undertaken to know the variability for IDC resistance response of 43 groundnut genotypes in a replicated field experiment under iron deficient calcareous soil (confirmed through soil analysis). Genotypes were assessed for IDC related traits like visual chlorotic rating (VCR) and SPAD chlorophyll meter reading (SCMR) at four different stages of crop growth (30, 60, 90 and 120 days after sowing) and also impact of IDC on yield and yield components. Among the 43 genotypes tested, ICGV 86031, A30b and ICGV 06146 with significantly lower VCR scores and higher SCMR values were found as highly resistant for IDC. Among the released varieties, ICGV 86031, ICGV 87846, GPBD 5, Dh 101,and TG 26 were found to be resistant/moderately resistant with lower VCR (≤ 2.0) and higher SCMR mean values across four stages. Seed iron content was found to be generally higher in resistant/moderately resistant lines compared to susceptible lines. The estimates of PCV and GCV were high for pod yield/plant, main stem height, haulm yield/plant, no. of pods/plant, VCR and SCMR. High heritability coupled with high genetic advance as percent of mean was recorded for all the traits under study except no. of primaries/plant, shelling % and seed iron (low GAm %). Iron chlorosis did not cause significant reduction in yield and yield components in resistant genotypes. Identified IDC resistant genotypes can be used directly as variety or in crop improvement program to develop high yielding varieties to grow under iron deficient calcareous, alkaline and black soils.

Keywords Iron deficiency chlorosis, Groundnut, Calcareous soil, Visual chlorotic rating, SPAD chlorophyll meter reading.

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Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important food crops of the world. It is the world's fourth most important source of edible oil and third most important source of vegetable protein [1]. In India, groundnut is the major oilseed crop grown over an area of 4.90 million ha with a production of 5.77 million tonnes and average productivity of 1179 kg/ ha [2]. The major groundnut growing states are Gujarat, Andhra Pradesh, Karnataka,Tamil Nadu and Maharashtra which account for more than 80 % of the total area and production.

In India, more than one-third of the soil is calcareous and spread mostly in the low rainfall areas of the western (Gujarat, Maharashtra, Rajasthan and Karnataka) and central (MP, UP) parts of the country where groundnut is a major crop. Therefore, iron chlorosis is more prevalent in Saurashtra region of Gujarat, Marathwada region of Maharashtra and parts of Rajasthan, Tamil Nadu and Karnataka, causing considerable yield reductions. Groundnut is susceptible to iron (Fe) deficiency chlorosis and can cause yield losses upto 16-40% [3].

Deficiency of Fe manifest into yellowish interveinal paling of younger leaves (commonly referred as iron deficiency chlorosis). In general, the plants are prone to iron deficiency in alkaline, calcareous, coarse textured, eroded and low organic matter containing and cold region soils. The application of iron to soil in the form of ferrous sulfate (Fe_2SO_4) has often been recommended to alleviate the problem of iron chlorosis and concomitant loss in yield. But this is often of little benefit to the crop as iron ionizes and gets converted into insoluble ferric compounds which are unavailable to plants. A major problem with foliar application is poor translocation of applied iron within the plant. Though, the use of iron chelates provides iron in available form, their use is not popular and not feasible from the economic point of view. In order to increase production of groundnut in calcareous soils, the most effective, economical and practically feasible approach is growing Fe resistant and high yielding varieties [4, 5].

Most of the popular groundnut bunch cultivars of Karnataka are susceptible for IDC. Growing iron-resistant cultivars in irrigated black soils could be economically preferable as it does not need application of any iron compounds. An increase in 12-24% of pod yield has been observed when efficient cultivars were grown in irrigated black soils [5, 6]. The present study was planned to identify the IDC resistant, most suitable and promising groundnut genotypes to overcome Fe deficiency chlorosis in calcareous soil.

Materials and Methods

Field experiment was conducted during *kharif* of 2013 in iron-deficient calcareous soils [Soil pH (1 : 2.5) 8.12; exchangeable calcium 21.10c mol (P^+)kg/l; Ca_2CO_3 9.5% ; DTPA extractable iron (ppm) 3.96] at Regional Agricultural Research Station, Vijayapura, Karnataka. Seeds of groundnut genotypes were collected from different institutions like

Table 1. Mean squares for IDC related, yield and yield components traits of groundnut genotypes grown in iron-deficient calcareous soil. df- Degrees of freedom; DAS – Days after sowing; *, ** Significant at 5% and1% level of probability respectively.

Source of variation	df	VCR 30 DAS	VCR 60 DAS	VCR 90 DAS	VCR 120 DAS	SCMR 30 DAS	SCMR 60 DAS	SCMR 90 DAS	SCMR 120 DAS
Replication	1	1.41	0.1	0.01	0.02	1.88	15.07	18.98	0.84
Genotypes	42	1.22**	0.70**	1.08**	1.14**	73.27**	83.98**	155.54**	194.69**
Error	42	0.41	0.08	0.08	0.13	3.42	10.91	34.21	8.7

Table 1. Continued.

Source of variation	df	MSH	NPR	NPP	NPP	HY	SP	TW	SI
Replication	1	5.68	0.42	1.38	0.6	0.56	35.38	18.58	0.82
Genotypes	42	46.57**	1.57**	22.24**	11.15**	26.23**	50.38**	38.59**	37.34**
Error	42	4.61	0.71	1.69	1.08	2.38	19.53	7.99	7.7

AICRP on Groundnut, University of Agricultural sciences, Dharwad (21); University of Agricultural Sciences, Raichur (2); International Crops Research Institute for the semi-arid tropics (ICRISAT), Patancheru (11) and Bhabha Atomic Research Center (BARC), Mumbai (9). The plot size was 1.8 m^2 and recommended package of the practices were followed with respect to application of fertilizers (except iron containing fertilizers), pest management and other agronomic practices to raise a healthy crop.

Genotypes were assessed for IDC related traits like visual chlorotic rating (VCR) on line-basis using 1 to 5 scale proposed by Singh and Chaudhari [7] (VCR score : 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 and 5 - Severe chlorosis on all the leaves and SPAD chlorophyll meter reading (SCMR) at four different stages of crop growth [30, 60, 90 and 120 days after sowing (DAS)] . The chlorophyll meter SPAD 502 (Soil plant analysis development meter, Konica Minolta) was used to record SCMR on standard leaf (third leaf from the top on main stem) at four different stages viz., 30,60, 90 and 120 DAS. Iron content in seeds was estimated at soil and plant analysis laboratory, ICRISAT, Patancheru. Seed samples were digested by using the triacid and concentrations were measured by AAS (atomic absorption spectrometer), varian spectra AA 20 and results were expressed in mg kg^{-1} as per the method of Sahrawat et al. [6].

Yield and yield components like main stem height (cm), number of primaries/plant , number of pods/plant, pod yield/plant (g), haulm yield/plant (g) (dried) were recorded as mean of five randomly selected plants; 100 g of dried pods were shelled, weight of kernels was obtained and shelling % was calculated as the ratio of kernel weight to pod weight multiplied by 100; test weight (g) was recorded as weight of 100 randomly chosen kernels.

Results and Discussion

The estimates of mean sum of squares for VCR, SPAD SCMR and iron content in seed showed highly significant differences (Table 1). Similarly for yield and yield components like main stem height, no. primaries/plant, no. of pods/plant, pod yield/plant, haulm yield/plant, shelling % and test weight,highly significant differences were observed.

The phenotypic coefficients of variation (Table 2) were higher than genotypic coefficient of variation suggesting the influence of environment on traits under study. Less difference was observed between phenotypic coefficient of variation and genotypic coefficient of variation for the traits VCR, SCMR, no. of pods/plant and shelling % indicating lower influence of environment on these traits. In the present investigation, pod yield/plant (40.6 and 36.8), main stem height (39.5 and 35.8), haulm yield/

Table 2. Components of variation for iron deficiency related, yield and yield parameters in groundnut genotypes. VCR : Visual chlorotic rating. SCMR : SPAD chlorophyll meter reading. PCV : Phenotypic coefficient of variation. GCV : Genotypic coefficient of variation. h^2 : Heritability in broad sense. GA : Genetic advance. GAM : Genetic advance over mean.

Components	VCR	SCMR	Main stem height (cm)	No. of primaries/ plant	No. of pods/ plant	Pod yield/plant (g)	Haulm yield/plant (g)	Shelling percent-age	Test weight (g)	Seed iron content (ppm)
Maximum	3.8	39.0	24.3	6.8	18.9	13.8	16.8	70.6	38.5	34.4
Minimum	1.0	14.6	5.6	3.4	4.6	2.4	3.6	50.5	16.9	19.0
Mean	2.3	27.2	12.8	4.8	11.0	6.1	9.8	61.2	25.2	25.3
GCV (%)	25.6	22.1	35.8	13.6	29.2	36.8	35.4	7.1	17.2	14.8
PCV (%)	27.1	23.1	39.5	22.1	31.5	40.6	38.8	8.7	20.1	19.3
h^2 (%)	89.4	91.8	82.0	37.8	85.9	82.4	83.4	66.2	73.2	59.2
GA	1.2	11.9	8.5	0.8	6.1	4.2	6.5	7.3	7.7	6.0
GAM (@ 5%)	50.0	43.6	66.7	17.2	55.7	68.8	66.6	11.9	30.4	23.5

plant (38.8 and 35.4), no. of pods/plant (31.5 and 29.2) recorded higher PCV and GCV values indicating substantial variability and scope for improvement. Higher PCV and moderate GCV values noticed for no. of primaries/plant and test weight. Low PCV and GCV values were recorded for seed iron con-

Table 3. Mean values for IDC related traits, yield and yield components of groundnut genotypes in iron-deficient calcareous soil. DAS - Days after sowing, R — Resistant, S—Susceptible, MR— Moderately resistant.

		VCR				SCMR				
Sl. No.	Genotypes	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	Mean
1	TMV 2	3	2	3	3	21.00	28.80	18.80	17.10	21.40
2	JL 24	3	2	3	3	13.80	31.30	18.40	12.80	19.10
3	GPBD 4	3	2	3	3	13.70	37.80	20.90	11.60	21.00
4	GPBD 5	1	1	2	2	25.60	39.10	31.40	13.10	27.30
5	G-2-52	3	2	3	2	17.80	37.00	24.40	31.80	27.70
6	Dh 86	3	2	2	2	17.10	41.50	35.10	33.50	31.80
7	Dh 40	3	2	3	3	19.60	29.70	18.70	13.60	20.40
8	Mutant III	4	4	3	3	11.80	13.80	21.80	12.00	14.90
9	TGLPS 3	3	2	2	3	18.20	27.30	35.90	20.40	30.50
10	Dh-3-30	3	2	3	3	20.30	29.30	22.90	17.40	22.50
11	DSG 1	2	2	3	2	20.30	34.30	29.30	27.60	27.90
12	S 230	2	3	3	3	20.00	40.00	31.80	14.30	26.50
13	JSP 39	3	3	3	3	23.60	24.30	28.70	21.00	24.40
14	Dh 8	2	2	3	3	14.00	31.10	18.40	22.00	21.40
15	Dh 216	2	2	3	3	21.30	30.90	30.80	13.10	24.00
16	Dh 101	2	2	2	2	25.60	41.40	39.50	30.30	34.20
17	Dh 2000-1	4	3	3	3	14.30	27.30	23.90	13.20	19.70
18	ICGV 06040	3	3	3	3	21.40	25.40	25.10	15.60	21.80
19	ICGV 06099	2	3	3	3	17.30	26.30	19.20	17.50	20.10
20	ICGV 06420	2	1	2	3	25.70	40.30	32.70	20.70	29.80
21	ICGV 05155	2	1	1	2	24.10	41.40	41.70	34.10	35.30
22	ICGV 02266	3	3	2	3	16.60	33.00	27.90	30.80	27.00
23	ICGV 06146	1	1	1	1	23.10	41.50	41.60	39.40	36.40
24	ICGV 91114	3	2	3	3	16.90	32.50	20.90	20.70	22.70
25	ICGV 00350	3	2	2	3	20.20	42.10	33.50	19.10	28.70
26	ICGV 87846	1	2	2	1	13.90	41.40	38.40	41.20	33.70
27	ICGV 93468	3	2	2	2	18.80	41.40	35.50	34.30	32.50
28	ICGV 86031	1	1	1	1	33.50	39.40	41.30	41.80	39.00
29	TAG 24	3	2	2	3	18.60	40.60	31.40	34.90	31.30
30	TG 26	2	2	2	3	30.80	39.00	30.10	21.50	30.30
31	TG 37A	3	2	3	3	27.30	37.40	29.50	17.50	27.90
32	TG 38	1	2	3	3	21.80	38.10	28.30	17.00	26.30
33	TG 51	3	2	3	4	24.90	35.10	32.60	13.00	26.40
34	TG 67	3	2	2	3	31.00	30.10	32.00	17.40	27.60
35	TG 68	2	2	3	3	26.20	33.70	28.30	19.80	27.00
36	TG 69	2	1	2	2	28.80	41.20	35.70	30.80	34.10
37	TG 72	2	1	2	2	32.10	39.80	41.30	36.80	37.50
38	A30b	1	1	1	1	35.10	32.30	41.40	41.20	37.50
39	JG (Thin shell)	3	2	3	3	16.40	40.30	21.70	14.60	23.20
40	MG 8 (Dwarf)	2	1	1	1	23.20	40.30	40.90	39.90	36.10
41	GBFDS 272	3	2	3	2	12.20	33.00	22.10	33.00	25.00
42	R 8808	4	2	3	4	17.50	36.30	20.10	17.30	22.80
43	R 9227	4	3	4	4	11.70	22.90	13.30	10.80	14.60
	SE m ±	0.36	0.23	0.24	0.30	1.51	2.70	2.05	2.41	1.46
	CD (5%)	0.72	0.47	0.47	0.60	3.05	5.44	4.13	4.86	2.95
	CD (1%)	0.97	0.63	0.63	0.80	4.08	7.28	5.52	6.50	3.95
	CV (%)	18.8	14.47	11.97	14.20	8.78	9.54	8.57	12.62	6.59

Table 3. Continued.

Sl. No.	Genotypes	MSH	NPR	NPP	NPP	HY	SP	TW	SI	IDCR
1	TMV 2	10.5	4.1	8.5	6.48	4.54	60.56	22.99	27.95	S
2	JL 24	9.6	4.1	8.3	6.19	4.42	67.75	21.95	30.45	S
3	GPBD 4	12.1	4.5	10.8	8.77	5.47	56.08	23.51	24.90	S
4	GPBD 5	17.2	5.6	14.2	13.38	7.46	62.56	28.42	26.45	MR
5	G-2-52	12.9	4.8	11.3	10.01	6.01	61.28	24.22	23.15	S
6	Dh 86	15.1	5.5	12.8	12.48	7.17	64.61	25.93	19.90	S
7	Dh 40	9.2	4.1	8.2	6.15	4.37	52.73	21.56	23.15	S
8	Mutant III	5.6	3.6	5.9	4.51	2.90	61.04	17.40	24.60	S
9	TGLPS 3	12.8	4.7	11.3	9.39	5.88	63.63	23.91	21.55	S
10	Dh-3-30	8.7	4.1	8.1	6.14	4.19	65.37	20.78	31.40	S
11	DSG1	13.8	5.0	11.8	11.10	6.64	59.55	24.56	23.25	S
12	S 230	11.5	4.2	9.6	7.48	5.17	57.35	23.22	25.25	S
13	JSP 39	8.0	4.1	8.0	6.13	4.06	61.15	20.76	19.45	S
14	Dh 8	13.2	5.0	11.7	10.85	6.58	61.18	24.42	31.25	S
15	Dh 216	13.1	4.8	11.7	10.77	6.23	66.51	24.40	22.20	S
16	Dh 101	15.9	5.5	13.1	13.08	7.21	61.28	26.15	23.80	MR
17	Dh 2000-1	5.6	3.8	5.9	5.40	2.93	60.78	17.58	21.50	S
18	ICGV 06040	6.3	3.8	6.9	5.75	3.51	65.22	18.71	25.24	S
19	ICGV 06099	6.7	4.0	7.9	6.02	3.85	68.59	20.12	21.85	S
20	ICGV 06420	15.5	5.5	12.9	13.00	7.21	59.72	25.94	22.90	MR
21	ICGV 05155	19.9	5.8	14.8	13.72	7.94	62.81	29.60	20.30	MR
22	ICGV 02266	11.8	4.4	10.2	8.00	5.43	52.55	23.46	19.70	S
23	ICGV 06146	21.1	6.6	17.7	16.71	10.93	61.46	32.23	29.95	R
24	ICGV 91114	11.3	4.2	8.8	7.43	4.95	70.44	23.12	29.85	S
25	ICGV 00350	12.5	4.7	11.2	9.04	5.78	64.71	23.86	24.70	S
26	ICGV 87846	20.2	6.2	15.0	14.57	8.94	58.75	29.65	28.05	MR
27	ICGV 93468	15.0	5.3	12.7	12.29	7.16	59.94	25.90	20.55	S
28	ICGV 86031	24.3	6.8	18.9	16.83	13.84	57.81	38.52	25.82	R
29	TAG 24	12.9	4.8	11.3	10.10	6.18	68.26	24.32	22.86	S
30	TG 26	14.8	5.2	12.3	11.54	6.83	61.08	25.74	33.39	MR
31	TG 37A	10.9	4.1	8.6	7.34	4.58	57.79	23.06	26.03	S
32	TG 38	14.7	5.2	11.9	11.39	6.79	57.46	25.50	22.80	S
33	TG 51	6.5	3.9	7.6	6.00	3.74	64.07	20.04	19.55	S
34	TG 67	14.3	5.2	11.9	11.29	6.76	56.41	24.81	32.95	S
35	TG 68	12.1	4.6	10.9	8.84	5.62	63.88	23.64	31.55	S
36	TG 69	16.3	5.5	13.6	13.29	7.37	59.10	26.28	21.20	MR
37	TG 72	19.3	5.8	14.6	13.64	7.92	55.78	29.31	25.85	MR
38	A30b	20.4	6.5	17.3	15.95	10.81	63.90	32.12	34.40	R
39	JG (Thin shell)	6.5	3.9	7.3	5.83	3.62	65.55	19.89	23.15	S
40	MG 8 (Dwarf)	20.4	6.4	16.0	15.72	10.09	50.79	31.25	33.55	MR
41	GBFDS 272	11.7	4.3	9.8	7.87	5.33	56.08	23.26	26.80	S
42	R 8808	5.8	3.8	6.8	5.42	3.25	63.76	18.24	27.00	S
43	R 9227	5.6	3.4	4.6	3.60	2.42	51.74	16.86	19.00	S
	SEm ±	2.27	1.8	0.7	1.1	0.87	1.26	3.87	2.31	
	CD (5%)	4.58	3.5	1.4	2.1	1.71	2.54	7.81	4.66	
	CD (1%)	6.12	4.7	1.9	2.9	2.29	3.40	10.45	6.23	
	CV (%)	11.01	16.8	17.4	11.8	17.04	15.81	7.79	11.61	

tent (19.3 and 14.8) and shelling % (8.7 and 7.1). Genetic contribution to phenotypic expression of traits is better reflected by the estimates of heritability. A high estimate of heritability indicates the presence of more fixable variability. In this study, high heritability coupled with high genetic advance as percent of mean was recorded for all the traits under study except no. of primaries /plant , shelling % and seed iron (low GAM %). The current conclusions are supported earlier [4,8].

Table 4. Phenotypic correlation (*r*) among iron absorption efficiency related traits, yield and yield components of groundnut genotypes. VCR—Visual chlorotic rating (1 to 5 scale), SCMR—SPAD chlorophyll meter reading, DAS — Days after sowing. Table '*r*' value at (N-2) df, where N= 86 : 0.211 (5%) and 0.260 (1%) *,** Significant at 5% and 1% level of probability respectively. 1. VCR at 30 DAS; 2. VCR at 60 DAS; 3. VCR at 90 DAS; 4. VCR at 120 DAS; 5. SCMR at 30 DAs; ^. SCMR at 60 DAS; 7. SCMR at 90 DAS; 8. SCMR at 120 DAS; 9. Main stem height (cm) 10. No of primaries/plant 11. No of pods/plant; 12. Pod yield (g) plant; 13. Haulm yield (g) plant; 14. Shelling%; 15. Test weight (g); 16. Iron content in seed (ppm)

	1	2	3	4	5	6	7	8
1	1.000	0.564**	0.630**	0.542**	-0.566**	-0.463**	-0.526**	-0.429**
2		1.000	0.746**	0.577**	-0.616**	-0.699**	-0.599**	-0.603**
3			1.000	0.717**	-0.569**	-0.559**	-0.840**	-0.756**
4				1.000	-0.294**	-0.448**	-0.556**	-0.900**
5					1.000	0.338	0.550**	0.320
6						1.000	0.469**	0.513**
7							1.000	0.612**
8								1.000
9								
10								
11								
12								
13								
14								
15								
16								

Table 4. Continued.

	9	10	11	12	13	14	15	16
1	0.115	0.090	-0.346	-0.069	-0.428**	0.032	-0.043	-0.402**
2	-0.176	0.138	-0.601**	-0.284	-0.632**	0.090	0.072	-0.304
3	0.026	-0.019	-0.521**	-0.239*	-0.657**	0.093	-0.149	-0.182
4	-0.200	-0.093	-0.473**	-0.387**	-0.590**	0.236*	-0.112	-0.262
5	-0.196	-0.205	0.343	0.036	0.479**	-0.027	-0.003	0.261
6	-0.044	-0.170	0.533**	0.189	0.430**	-0.087	-0.100	0.048
7	-0.231*	0.140	0429**	0.186	0.614**	-0.083	0.341**	-0.007
8	0.101	0.074	0.454**	0.391**	0.559**	-0.201	0.217	0.131
9	1.000	-0.019	0.400**	0.493**	0.304	-0.172	-0.183	0.281
10		1.000	0.234*	0.266	0.241	-0.011	0.209**	0.276
11			1.000	0.482**	0.853**	-0.132	-0.128	-0.141
12				1.000	0.490**	0.307	0.032	0.078
13					1.000	-0.100	0.170	-0.076
14						1.000	0.012	0.063
15							1.000	-0.169
16								1.000

Visual chlorotic rating score across different stages of crop growth ranged from 1.0 to 4.0 indicating the variability and severity of iron deficiency chlorosis (Table 3). Genotypes like ICGV 86031 (1.0, 39.0), ICGV 06146 (1.0, 36.4), A30b (1.0, 37.5), MG 8 (Dwarf) (1.1, 36.1) followed by TG 26 (2.0, 30.3) had significantly lower VCR score and higher SCMR values respectively throughout their crop growth period, exhibiting higher resistance to IDC [4,5].

The iron content in seed was ranged from 19.00 to 34.40 ppm. Significantly higher iron content in seed was observed in A 30b (34.40 ppm), MG 8

(Dwarf) (33.55 ppm), TG 26 (33.39 ppm), TG 67 (32.95 ppm), TG 68 (31.55 ppm), ICGV 06146 (29.95 ppm) except ICGV 86031 (25.82 ppm) which recorded lesser seed iron, it may be due to the poor translocation of absorbed ferrous iron into the seed.

The mean values for yield and its component traits of groundnut genotypes are presented in Table 3. Among the 43 genotypes evaluated, the significant superiority for the traits main stem height, no of primaries, no. of pods/plant, pod yield/plant, haulm yield/plant, shelling % and test weight was recorded for the gentypes ICGV 86031, ICGV 06146, A30b and TG 26 Li and YanXi [8] reported similar genotypic differences for these traits Boodi et al [3] while comparing to IDC resistant and susceptible genotypes noted that there was drastic decrease in number of pods per plant in iron absorption inefficient genotypes when grown in calcareous soil due to the iron deficiency chlorosis.

The correlation co-efficient ('r' value) among various parameters are presented in Table 4. There is a negative correlation between VCR and SCMR, yield and yield parameters like number of pods per plant, haulm yield per plant and iron content in seed whereas, positive correlation between SCMR and yield and yield parameters like number of pods per plant and haulm yield per plant. Similar results were reported earlier [4, 9, 10].

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