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Genetic diversity studies for yield attributing traits, oil content and late leaf spot disease in advanced backcross lines of groundnut (*Arachis hypogea* L.)

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Abstract

Groundnut is currently a major industrial oilseed crop with good commercial significance. 20 advanced Groundnut lines were planted in Randomized Complete Block Design along with parental lines and two checks and they were evaluated for 13 traits. The analysis of variance showed significant differences among all the traits studied. The genotypes were grouped into five clusters. Among the clusters, cluster I had 14 lines (PP-19, PP-12, PP-6, PP-13, PP-14, PP-11, PP-18, PP-20, PP-17, PP-5, PP-8, PP-10, PP-9, PP-4) followed by cluster II had one line (PP-2), cluster III had one line (PP-16) and cluster IV had one lines (PP-1) and cluster V had three lines (PP-7, PP-15, PP-3). Clusters II and V had the long stand best inter-cluster distance (635.60), followed by clusters II and III (367.54), clusters IV and V (304.12), clusters I and V (302.11) and clusters I and III (235.79) indicating that these cluster pairs were most divergent. The relative contribution of individual character towards the divergence revealed that Protein content (5098.81%), was the highest contributor to the total genetic divergence followed by Oil content (2055.34%) (7.35%) and pod yield per plant (1976.28%). Thus, on the basis of inter-cluster distance, cluster means, characters with high contribution to D^2 values and by comparing the mean values of the all the genotypes, this study revealed that the genotypes, belong to the cluster II, V and III will be used for further breeding programme. In the present study, four lines *viz.*, PP-1, PP-2, PP-5 and PP-14 developed through marker assisted backcross breeding programme showed resistance to late leaf spot, improved oil quality features like high oil and oleic acid content and were also superior or equivalent in yield compared with the recurrent parent, K6, further forward to yield evaluation trails and promising lines with LLS resistance and high yield will be released as superior variety/varieties.

Keywords: Groundnut, genetic divergence, randomized complete block design, cluster analysis

Introduction

Groundnut (*Arachis hypogea* L.) (2n=4x=40) is one of the important oilseed crops of India and World. It is a herbaceous legume that is native to South America (Brazil) and belongs to the Fabaceae family. The crop consists edible oil (40-56%), protein (20-30%), carbohydrate (10-20%) and various nutritious components such as vitamin E, niacin, calcium, magnesium, phosphorus, zinc, iron, riboflavin, thiamine and potassium in its seeds. Groundnut fat consists of mono unsaturated fatty acid, oleic acid (36-81.3%) poly unsaturated fatty acid, linoleic acid (3.9-40.2%) (Janila *et al*., 2016) [9].

In semi-arid regions of the world including India the productivity and quality are likely to be impaired in coming years owing to fluctuating climatic conditions. The incidence of fungal disease like late leaf spot have increased in the recent years due to continuous cultivation of K6 and TAG24 varieties. The occurrence of late leaf spot is common in rainfed ecologies world over and studies showed that in India they cause 50 per cent reduction in pod yield (Pande *et al*., 2003 and Singh *et al*., 2011) [14, 20]. The fungal pathogen (*Phaeoisariopsis personata*) causes late leaf spot disease in groundnut.

Materials and Methods

The experiment was carried out at the AICRP on Groundnut Supporting Centre, Regional Agricultural Research Station, Palem, Nagarkurnool, Telangana state during the *Rabi* season 2021-22.

The experimentation site has a semi-arid climate and is located at 16º351 latitude, 78º11 longitude and 642 m above mean sea level in the Southern Telangana Zone. Twenty advanced backcross progenies (10 $BC1F_6$ and 10 $BC2F_5$) were raised in a randomised block design with two replications with spacing of 30 cm between rows and 10 cm between the plants, together with parental lines and checks (K6, ICGV 13193, ICGV 15033, GPBD 4 and TMV 2).

The observations of Days to 50 per cent flowering, Plant height (cm), Number of primary branches per plant, number of secondary branches per plant, number of pods per plant, seed yield (gm), pod yield (gm), shelling outturn, pod length (mm), pod width (mm), 100 seed weight, pod constriction, pod beak, pod ridge, pod reticulation, oil content (%), protein content (%) were recorded in five plants of each backcross line and the mean values were considered for analysis.

Analysis of variance for Randomized Complete Block Design was done initially to find out the genotypic differences between the lines based on the method given by Panse and Sukhatme (1964) [15] (Table 1). The calculation of genotypic (σ^2 g) and phenotypic (σ^2p) variances was carried out based on the formula given by Burton (1952) [4]. Following this the range of variation was categorized according to Subramanian and Menon's (1973) [22] recommendations. All the mentioned analyses were performed using the INDOSTAT software.

D^2 statistics were first introduced by P.C. Mahalanobis in 1928. In an effort to reduce variability within clusters while enhancing diversity among clusters, the D^2 analysis divides genotypes into nearly uniform groupings. Genotypes from different clusters may be used in the breeding programme, depending on the breeding objectives. The genetic divergence among all the groundnut lines was studied in the current study for thirteen characters by using Mahalanobis D^2 statistics.

The artificial epiphytotic conditions for rust and LLS were created in the field using the 'Spreader Row Technique' (Subrahmanyam *et al*., 1995) [23], which involved planting disease spreader plants (TMV 2) every 10th row in the experimental plot. Tween 80 (0.2 ml/1,000 ml water) was added to the inoculum, which contained 5 × 104 conidia/urediniospores per ml (source: Groundnut Pathology Division, ICRISAT). The artificial inoculum was applied to the 35 to 40 day old crop in the evening using a Knapsack sprayer. Infected leaf samples from susceptible plants were collected and immersed in water overnight and conidia spores from LLS and uredia spores were collected by rubbing leaf samples in water and inoculum was sprayed in the field. To achieve uniform disease pressure, additional infected leaves and plant debris were dispersed over the field. A perfo-irrigation by sprinkler was given 15 minutes every day in the evening hours for 25 days to promote disease growth, followed by furrow irrigation during the night to maintain high humidity. For scoring rust and LLS disease at different stages of growth, a modified 9-point scale (1-9 score) (Subrahmanyam *et al*., 1995) [23] was utilised (70, 80 and 90 DAS). Furthermore, based on disease scores, the Sudini *et al*. (2015) [24] method was used for classification into disease reaction groups.

Near Infrared Spectroscopy (NIRS) (model XDS RCA, FOSS Analytical AB, Sweden, Denmark) was used at ICRISAT, Patancheru, Hyderabad, to evaluate oil, fatty acid composition and protein level. Near Infrared Spectroscopy (NIRS) or Near Infrared Transmittance Spectroscopy (NITS) is a multi-trait technique used to analyse quality features in food and agricultural commodities (Kavera, 2008) [12]. In NIRS, the vibrational reactions of chemical bonds to NIR radiations are used to identify and evaluate the chemical composition of biological material. The calibration equation's regression coefficient (R2) value for predicting oleic and linoleic acid was 0.96, while 0.89 for oil content and 0.80 for palmitic acid.

Results and Discussion

The 20 advanced back cross lines, along with parents K6, ICGV15033 and ICGV 13193 were evaluated for 13 quantitative characters (yield, its contributing characters and quality traits) in two replications and the data was subjected to analysis of variance. The analysis of variance showed significant difference among all traits such as days to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, pod yield per plant, seed yield per plant, shelling outturn, pod length, pod width, 100 seed weight, oil content and protein content. It indicates presence of substantial amount of variation in experimental material under investigation.

Tocher's method, which is based on D^2 values, is used to group all of the groundnut lines into different clusters. A total of five clusters are formed in which cluster I had 14 lines (PP-19, PP-12, PP-6, PP-13, PP-14, PP-11, PP-18, PP-20, PP-17, PP-5, PP-8, PP-10, PP-9, PP-4) followedby clusterII had one line (PP-2), cluster III had one line (PP-16) and cluster IV had one lines (PP-1) and cluster V had three lines (PP-7, PP-15, PP-3).

The average inter and intra clusters distances were depicted in Table 2. The intra cluster distances were less than the inter cluster distances which represents presence of narrow diversity among the lines of same clusters and existence of genetic diversity of genotypes of different groups than those of the same cluster. The intra-cluster D^2 values were ranged between zero and 139.52. Cluster V (139.52) had the greatest intra-cluster distance among the 5 clusters, followed by Cluster I (92.60), indicating the presence of some amount of genetic divergence in the lines belonging to these clusters. The remaining three clusters had zero intra-cluster distance as they each had a single line. The lines carefully selected from clusters I and V may be used in future recombination breeding programmes. The inter-cluster distance ranged from 111.15 to 635.60. Clusters II and V had the long stand best inter-cluster distance (635.60), followed by clusters II and III (367.54), clusters IV and V (304.12), clusters I and V (302.11), and clusters I and III (235.79). Similarly, the relatively short inter-cluster distance was observed between clusters III and IV (111.75), followed by clusters III and V (144.58) and clusters II and IV (147.19).

A considerable difference was noticed among the cluster means for all the characters. The minimum mean performance for days to 50% flowering was observed in cluster II (34.16) and maximum recorded in cluster III (37.08). The plant height recorded minimum mean performance in cluster III (13.67) and maximum in cluster I

(21.17). Number of primary branches per plant showed minimum mean performance in cluster II (7.11) and maximum in cluster V (7.40). Number of secondary branches per plant recorded minimum in Cluster III (39.04) and maximum in cluster I (41.41). Number of pods per plant showed minimum mean performance in cluster III (14.35) and maximum in cluster IV (15.05). Seed yield per plant showed minimum mean performance in cluster III (7.95) and maximum mean performance in cluster I (9.21). Shelling outturn showed minimum mean performance in cluster II (69.70) and maximum mean performance in cluster V (71.58). Pod length recorded minimum mean performance in cluster III (25.16) and maximum in cluster II (27.35). Pod width showed minimum mean performance in cluster III (11.45) and maximum in cluster I (12.83). 100 seed weight recorded minimum mean performance in cluster I (40.39) and maximum in cluster V (42.61). Pod yield per plant showed minimum mean performance in cluster V (12.27) and maximum in cluster I (13.66). Oil content showed minimum mean performance in cluster IV (51.23) and recorded maximum in cluster II (59.63). Protein content recorded minimum mean performance in cluster II (22.48) and maximum in cluster IV (27.23).

Groundnut oil, fatty acids of are essential factors in the food, seed and trade industries. The relative proportions of oleic, linoleic and palmitic acid play a major role in nutritional quality of groundnut kernels, oil and its storage Among them, oleic acid (mono unsaturated fatty acid), linoleic acid (poly unsaturated fatty acid) and palmitic acid together constitute approximately 90% of the total oil composition in groundnut seed (Janila *et al*., 2016a) [9]. Oil quality in groundnut determined by the oleic and linoleic acid(O/L) ratio and a high oleic to linoleic acid ratio (O/L ratio) in groundnut is the most desirable quality for health and improves shelf life of oil.

The primary objectives of groundnut breeders are to improve quality and oil content because about 80% of groundnut crop in India is used to extract oil (Sarvamangala *et al*., 2011) [17]. In the current study, a set of 20 advanced backcross groundnut lines of BC1F6 and BC2F5 generations were assessed for oil content along with parents (Table 3). The oil content in backcross lines was varied from 49.97 to 60.78% with an average of 55.19% while the recurrent parent K6 recorded 53.77% oil. A total of 14 lines recorded oil content more than recurrent parent, K6 that includes eight lines from BC_1F_6 generation PP-1 (57.28), PP-2 (60.78), PP-4 (57.29), PP-5 (55.92), PP-6 (55.87), PP-8 (58.28), PP-9 (59.85), PP-10 (54.31) and six lines from BC2F5 generation PP-14(54.35), PP-16(57.13), PP-17(56.32), PP-18(54), PP-19 (54.45), PP-20 (54.67).The higher oil content of 60.78% found in PP-2 which is 7.01% higher than K6. The high oil content lines, PP-2 and PP-9 lines recorded statistically significant difference over recurrent parent K6.

Groundnut breeders are currently focusing on introducing the high O/L trait into groundnut cultivars and selecting genotypes with lower levels of unfavourable fatty acids, such as linoleic and palmitic acid. Peanut oil has a high ratio of UFAs to SFAs when compared to coconut and palm oil thus considered as healthy cooking oil. Additionally it contains significant amount of vitamin E, antioxidants and plant sterols like β-sitosterol, which has anti-cancer property and can lower cholesterol levels up to 15% (Shashidar *et al*., 2017) [19].

In the present study, a continuous variation was recorded for oil content (49.97 to 60.78%) showing the polygenic nature like the other significant oil seed crops like soybean, rapeseed and mustard (Singh *et al*., 2013 and Wang *et al*., 2013) [12]. The amount of oil that accumulates in peanuts is influenced directly or indirectly by environmental factors like temperature, moisture, and light. In previous studies, RILs showed that the oil content is polygenic nature. (Sarvamangala *et al*., 2011) [17]. Similar to the earlier study, Shasidar *et al*. (2020) [18], Janila *et al*., (2016a) [9] and Bera *et al*. (2018) [3] also recorded genetic variation in oil content of groundnut.

NIRS was used in the present work to estimate the composition of fatty acids (oleic, linoleic, palmitic and stearic acid content). Fatty acid composition, which makes up the majority of peanut oil, has a significant impact on the oil's quality and other related factors including nutrition and shelf life Reddy *et al*. (2017) [16] found that frequency of distribution of oleic, linoleic and palmitic acids was found to be influenced by a single factor, ah FAD alleles.The oleic acid content of backcross lines (BC1F6 and BC2F5) was recorded in the range 45.82% (PP-11) to 87.02% (PP-1) with a mean value of 64.02% compared to the K6 with 42.29% of oleic acid content. The oleic acid content of donor parent (ICGV 15033) was recorded to be 81.66%. Groundnut varieties having oleic acid concentration >78±2 % were considered as high oleic line. A total of six progenies recorded >78% oleic acid content, while other remaining lines recorded low oleic acid content. Four BC1F6 lines *viz*., PP-1(87.02), PP-2 (86.46), PP-3(77.89), PP-5 (82.14) and two BC2F5 lines *viz*., PP-13 (81.98), PP-14 (79.49) showed high oleic content.

Advanced Backcross lines were ranged between 1.14 (PP-2) and 34.07% (PP-11) for linoleic acid content with a mean value of 18.68% when compared to the recurrent parent K6 with 36.84%. Most consumers prefer groundnut cooking oil with a high proportion of oleic acid and a low proportion of linoleic acid because it reduces the low-density lipoproteins (LDL) thus by reducing the risk of cardiovascular disease (CVD) (Wang *et al*., 2015) [27]. Additionally, having a high amount of oleic acid increases the shelf life of peanut oil and provides consumers health benefits. (Janila *et al*., 2016a) [9].

(Barkely *et al*., 2013) [2] observed two loci were responsible for the oleic acid content, however other epistatic interactions and modifiers cause variations in oleic acid content. This might be the cause of variation (45.82 to 87.02%) for oleic acid content in advanced backcross lines of current study. Similar studies were reported by Janila *et al*. (2016a) [9], Shashidar *et al*. (2017) [19], Bera *et al*. (2018) [18], Wang *et al.* (2015) [27] and linoleic acid content was recorded by Wang *et al.* (2015) [27]. Recently, two groundnut varieties, Girnar4 (ICGV15083) and Girnar 5 (ICGV 15090) with >78% high oleic acid content were released for *kharif* cultivation in India during AICRP-G workshop-2019.

The oleic and linoleic acid ratio (O/L) was showed in the range of 1.5 (PP-20) to 75.84 (PP-2) with an average of 14.31 when compared to the K6 with 1.14. A total of 6 backcross progenies have reported >10 O/L ratio among them, four BC1F6 lines *viz*., PP-1 (46.04), PP-2 (75.84), PP-

3 (21.81), PP-5 (43.92) and two BC2F5 line PP-13 (44.31), PP-14 (20.97) showed high oleic to linoleic ratio (O/L) and these lines recorded statistical significance over the recurrent parent K6. In comparison to linoleic acid, oleic acid has ten times higher auto-oxidative stability. High O/L ratio peanuts and their derivatives will therefore have a longer shelf life than normal groundnuts (Bera *et al*., 2018) [18]. High O/L ratio groundnut kernels are preferred by the majority of the food-processing industry because they provide the high oil oxidative stability (Chu *et al*., 2011) [5]. In current study, results are similar with the reports of Bera *et al*. (2018) [18].

Among, advanced backcross lines palmitic acid ranged from 5.66%(PP-2) to 12.09% (PP-11) with an average value of 9.05% compared to K6 with 12.64 % whereas, stearic acid was varied between 2.27% (PP-12) and 3.55%(PP-2) with an average of 2.87% compared to K6 with 2.91%. Shashidar *et al*. (2017) [19] recorded that the majority of consumers prefer peanut oil with lower levels of palmitic acid since groundnut oil's high levels of palmitic acid have a negative impact on human health by increasing several life-threatening diseases like cardiovascular diseases (CVD) and atrial fibrillation. Stearic acid is a neutral fatty acid that lowers the risk of atrial fibrillation and has no effect on low density lipoproteins in blood level (Wang *et al*., 2015) [27]. Similar reports were showed in Bera *et al*. (2018) [18], Wang *et al*. (2015) [27] and Shashidar *et al*. (2020) [18].

Based on the prior research, the influence of right proportions of different fatty acids on the shelf life of peanut products and human health were reported. Therefore, breeding groundnut lines with high oleic acid and low palmitic and linoleic acids are mostly preferred by consumers for oil consumption. Hence, a high oil content combined with high oleic, low linoleic and palmitic acid is preferred for improvement in groundnut oil quality. The present investigation identified three lines of BC1F6 and two $BC_2F_5$with high oil content (>54%) and high oleic content (>78%) with a low level of palmitic and linoleic acid content are currently under multiplication, and promising lines with superior yield trials may eventually replace the existing lines.

Modified 9-point scale (Subrahmanyam *et al*., 1995) [23] was used for disease scoring and disease reaction classification was done according to Sudini *et al*. (2015) [24] (Table 4). In the current study, 20 backcross lines were scored at 70 DAS, 90 DAS and 105 DAS showed a mean disease score of 1.25(1-5), 2.65 (1 to 7) and 4.25 (2-9) respectively. The susceptible check (TMV-2) exhibited a highly susceptible reaction with a mean score of 6 at 90 DAS and 7 at 105 DAS. Six lines recorded resistance with score of ‘3’ against late leaf spot, whereas eleven genotypes showed moderate resistance (score: 4 to 5) and three genotypes recorded susceptible reaction (score: 6 to 7) to late leaf spot disease. GPBD 4 (resistant check) and ICGV 13193 (donor parent for LLS and rust resistance) exhibited resistance reaction with a mean disease score of 2. While K6 recurrent parent showed a susceptible reaction of score 6. six lines *viz.*, PP-1, PP-2, PP-3, PP-5, PP-14 and PP-16 were showed to be resistant with a score of 1-3, while moderate resistance with a score of 4-5 was found in eleven lines (PP-4, PP-6, PP-7, PP-9, PP-10, PP-11, PP-12, PP-13, PP-15, PP-17 and PP-20).Three susceptible lines found with mean disease score ranged between 6 (PP-8, PP-18 and PP-19).In the current study highly susceptible disease reaction was not found in any of the backcross lines.

In the present study, four backcross lines *viz*., PP-1, PP-2, PP-3, PP-5, PP-14 and PP-16 recorded superiority or on par performance with K6, the recurrent parent in terms of LLS resistance, morpho-agronomic traits, pod characteristics and improved oil quality features (Table 5). These superior lines (PP-1, PP-2, PP-3, PP-5, PP-14 and PP-16) showed resistance against LLS (3.0) when compared to K6 (highly susceptible) with 6.0 score. The days to 50% flowering was observed between 33and 38 compared to K6 with 35 days. Plant height was ranged from 11.33 to 22.99 cm, while it was 21.10 cm in K6. The number of primary branches per plant ranged from 6.20 to 8.59 in superior lines, while it was7.19 in K6. Among superior lines, number of secondary branches per plant ranged from 37.03 to 44.1 compared to K6 (41.05). The selected lines ranged between 13.14 and 16.26 for number of pods per plant while, it was 14.39 in K6. Seed yield per plant was ranged from 7.16 to10.63 g when compared to K6 with 7.99 g. Shelling outturn in superior lines, varied between 65.37 to 74.88%, against K6 with 69.39%. The100 seed weight in superior progenies were ranged from 39.5 to 44.8 g compared to K6 with 40.8 g. For pod yield per plant these lines, ranged between 10.28 and 14.8 g, while K6 recorded 11.5 g (Table 6).

Among superior lines, pod length was varied from 23.78 to 30.08 mm compared with K6 as 26.2 mm whereas, pod width was ranged between10.55 to13.76 mm while it was 12.17 mm in K6. Slight pod constriction and pod beak traits were observed in PP-1, PP-3 and PP-14. All the superior lines showed moderate for pod reticulation and pod ridges, like K6. The oil content in superior lines was high and ranged between 49.57 and 60.78% compared with K6 (53.77%). All the selected lines showed higher oleic content (>78%), low level of palmitic and linoleic acid content compared with K6. While the O/L ratio was ranged between 1.5 and 75.84 against K6 with 1.14. Leaf color showed light green in three lines, PP-12, PP-15 and PP-18 and green in one line, PP-4. Further more, these three lines *viz*., PP-12, PP-15 and PP-18 showed oblong elliptic leaf shape similar with K6 and PP-4 showed Lanceolate shape. All the selected lines, showed ligh tan seed color as with K6, but seed shape in three lines, PP-12, PP-15 and PP-18 showed round shape likeK6.

Table 1: Analysis of variance for yield contributing traits and oil traits

Source of variation	df	Traits												
		DFF	PH (cm)	NPB/P	NSB/P	NPP	PY/P (g)	SY/P (g)	SH (%)	100 SW	PL (mm)	PW (mm)	Oil content	Protein content
Replication MSS	1	2.630	1.737	0.146	0.039	0.302	0.011	0.032	4.445	6.327	0.283	0.660	1.256	2.480*
Treatment MSS	22	5.994***	26.140***	0.704**	6.752***	1.543***	3.570***	1.440***	12.897***	20.058	5.378***	1.330***	13.786***	5.616***
Error MSS	22	0.721	1.200	0.219	1.276	0.372	0.294	0.271	3.130	19.279	0.728	0.262	0.634	0.327
CV(%)		2.410	6.273	6.401	2.791	4.130	4.332	6.080	2.503	10.665	3.229	4.173	1.446	2.357
S.Em		0.84	1.09	0.46	1.12	0.61	0.54	0.52	1.76	4.39	0.85	0.51	0.76	0.57
CD (P=0.05%)		1.761	2.272	0.969	2.343	1.265	1.125	1.080	3.669	9.106	1.770	1.061	1.651	1.185

DFF: Days to 50% Flowering, PH: Plant Height (cm), NPB/P: Number of primary branches per plant, NSB/P: Number of secondary branches per plant, NPP: Number of pods per plant, PY/P: Pod yield per plant (g), SY/P: Seed yield per plant (g), SH (%): Shelling outturn (%), PL: Pod length (mm); PW: Pod width(mm), 100 SW :100 seed weight (g), MSS: Mean sum of squares, CV (%): Coefficient of variation, S. Em: Standard error of mean, CD: Critical Difference

Table 2: Average inter and intra-cluster (bold values) distances ($D^{2)}$ values for 13 traits.

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
Cluster 1	92.60	191.77	235.79	166.20	302.11
Cluster 2		0.00	367.54	147.19	635.60
Cluster 3			0.00	111.75	144.58
Cluster 4				0.00	304.12
Cluster 5					139.52

Table 3: Oil content and fatty acid composition of backcross lines estimated by using Near-Infrared Reflectance Spectroscopy (NIRS)

S. No	Backcross line	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	O/L ratio	Palmitic acid (%)	Stearic acid (%)	Protein content (%)
1	PP-1	57.28	87.02	1.89	46.04	5.83	2.83	22.93
2	PP-2	60.78	86.46	1.14	75.84	5.66	3.55	21.80
3	PP-3	53.15	77.89	3.57	21.81	6.88	2.95	28.01
4	PP-4	57.29	62.25	20.50	3.03	9.75	3.06	25.34
5	PP-5	55.92	82.14	1.87	43.92	6.24	2.85	24.07
6	PP-6	55.87	69.02	14.63	4.71	8.85	2.62	22.09
7	PP-7	49.57	50.14	29.62	1.69	11.19	2.58	26.89
8	PP-8	58.28	52.35	30.39	1.72	10.66	3.09	22.60
9	PP-9	59.85	63.68	21.42	2.97	9.04	3.07	23.05
10	PP-10	54.31	46.56	33.62	1.38	11.92	2.88	22.92
11	PP-11	52.35	45.82	34.07	1.34	12.09	2.60	23.15
12	PP-12	53.02	56.76	24.85	2.28	10.42	2.27	22.63
13	PP-13	53.76	81.98	1.85	44.31	5.94	2.51	24.97
14	PP-14	54.35	79.49	3.79	20.97	5.94	2.87	25.90
15	PP-15	50.97	58.23	22.69	2.56	10.11	2.75	26.79
16	PP-16	57.13	63.63	20.79	3.30	9.00	3.22	25.06
17	PP-17	56.32	63.46	19.73	3.21	9.04	3.24	24.98
18	PP-18	54.00	56.04	25.71	2.17	10.57	3.16	25.93
19	PP-19	54.45	53.03	29.12	1.82	9.4	2.80	23.32
20	PP-20	54.67	48.47	32.27	1.50	5.9	2.55	23.10
31	K6(RP)	53.77	42.29	36.84	1.14	12.64	2.91	24.84
32	ICGV13193 (DP for FDR)	54.12	45.2	32.0	1.41	10.7	2.7	20.7
33	ICGV15033 (DP for high oleic trait)	55.32	81.66	1.17	1.17	6.77	2.76	23.30
	Mean	55.11	64.02	18.71	38.4	9.26	2.87	24.26
	Range	49.5-60.7	45.8-87.0	1.1-36.8	1.1-75.8	5.6-12.0	2.2-3.2	21.8-28.0

O/L ratio: oleic acid/linoleic acid, RP: Recipient parent, DP: Donor Parent, FDR: Foliar disease resistant

Table 4: Mean disease score and reaction of groundnut genotypes to late leaf spot disease during *rabi* 2020-21

S. No	Generation	Genotype	Late leaf spot score			Disease reaction
			MDS 70 DAS	MDS 90 DAS	MDS 105 DAS	
1	BC1F6	PP-1	1	2	3	R
2	BC1F6	PP-2	1	2	3	R
3	BC1F6	PP-3	1	2	3	R
4	BC1F6	PP-4	2	3	4	MR
5	BC1F6	PP-5	2	4	3	R
6	BC1F6	PP-6	1	2	4	MR
7	BC1F6	PP-7	1	3	5	MR
8	BC1F6	PP-8	2	4	6	S
9	BC1F6	PP-9	2	4	5	MR
10	BC1F6	PP-10	1	2	4	MR
11	BC2F5	PP-11	1	2	4	MR
12	BC2F5	PP-12	1	3	4	MR
13	BC2F5	PP-13	1	2	5	MR
14	BC2F5	PP-14	1	2	3	R
15	BC2F5	PP-15	1	2	4	MR
16	BC2F5	PP-16	1	2	3	R
17	BC2F5	PP-17	2	4	5	MR
18	BC2F5	PP-18	1	3	6	S
19	BC2F5	PP-19	1	3	6	S
20	BC2F5	PP-20	1	2	4	MR
		Mean	1.25	2.65	4.25	
		Range	1-5	1-7	2-9	
	Parents	K6(RP)	4	5	6	S
		ICGV 13193(DP for FDR)	1	1	2	R
		ICGV15033 (DP for high oleic trait)	1	3	4	MR
	Checks	GPBD4 (RC)	1	1	2	R
		TMV2 (SC)	4	6	7	HS

Note: MDS: Mean disease score, RP: Recurrent parent, DP: Donor parent, DAS: Days after sowing, MR: Moderate resistant, R: Resistant, S: Susceptible, HS: Highly susceptible FDR: Foliar disease resistant

Table 4.1: Disease reaction and categorization of backcross lines into different disease reaction groups for late leafspot disease at 105 DAS

S. No	Disease reaction	Disease scale	Disease severity (%) at 105 DAS	Backcross lines
1	Resistant	1	0	-
		2	1-5	-
		3	6-10	PP-1, PP-2, PP-3, PP-5, PP-14, PP-16
2	Moderately resistant	4	11-20	PP-4, PP-6, PP-10, PP-11, PP-12, PP-15, PP-20
		5	21-30	PP-7, PP-9, PP-13, PP-17
3	Susceptible	6	31-40	PP-8, PP-18, PP-19,
		7	41-60	-
4	Highly susceptible	8	61-80	-
		9	81-100	-

DAS: Days after sowing

Table 5: Performance of selected superior backcross lines for LLS disease, agronomic, yield related traits and pod characteristics

S. No	Backcross lines	LLS Score	Agronomic and yield related Traits									Pod characteristics					
			DFF	PH	NPB/P	NSB/P	NPP	PY/P	SY/P	SH (%)	100 SW	PL	PW	PB	PC	PR	PRG
1	PP-1	3	34.0	20.7	6.9	40.7	14.9	14.8	9.0	72.0	42.8	29.1	13	S	S	M	M
2	PP-2	3	35.0	21.3	8.0	43.4	15.7	14.1	9.4	72.5	41.1	30	13	M	S	M	M
3	PP-5	3	34.0	21.3	7.8	40.7	15.6	14.0	9.9	73.8	41.9	27.8	11.8	M	M	M	M
4	PP-14	3	36.0	18.4	7.3	40	15.1	11.9	8.7	73.5	42.7	28.7	13.2	S	S	M	M
5	K6	6	35.0	21.1	7.1	41.0	14.3	11.5	7.9	69.3	40.8	26.5	12.1	P	M	M	M
6	ICGV13193	2	40.0	12.9	7.7	41.1	15.3	10.9	7.5	70.7	42	26.1	12.1	S	S	S	M
7	ICGV15033	4	39.0	11.3	8.4	38.9	14.8	11.9	8.3	69.7	39.9	24.2	11.9	S	S	S	A
8	GPBD 4 (RC)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	TMV 2 (SC)	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C.D	-	1.7	2.2	0.9	2.3	1.2	1.1	1.0	3.6	2.2	1.7	1.0	-	-	-	-

DFF: Days to 50% Flowering, PH: Plant Height (cm), NPB/P: Number of Primary Branches per Plant, NSB/P: Number of Secondary Branches per Plant, NPP:Number of Pods per Plant, PY/P: Pod Yield per Plant (g), SY/P: Seed Yield per Plant (g), SH (%): Shelling outturn (%), PL: Pod Length (mm); PW: Pod Width(mm), PC: Pod Constriction, PR: Pod Reticulation, PB: Pod Beak, PRG: Pod Ridges, S: Slight, M: Medium, P: Prominent, A: Absent, RC: Resistant check, SC: Susceptible check.

Table 6: Mean performances of advanced backcross lines and parents

S. No	Genotype	DFF	PH	NPB/P	NSB/P	NPP	PY/P	SY/P	SH (%)	100 SW	PL	PW	PC	PR	PB	PRG	Oil	Protein
1	PP-1	34.0	20.7	6.9	40.7	14.9	14.8	9.0	72.0	42.7	29.1	13.0	S	M	S	M	57.2	22.9
2	PP-2	34.5	21.3	8.0	43.4	15.7	14.1	9.4	72.5	41.1	30.0	13.0	S	M	M	M	60.7	21.8
3	PP-3	33.5	19.7	7.3	42.5	15.4	14.7	9.6	70.2	40.7	26.0	12.2	M	M	S	M	53.1	28.0
4	PP-4	35.5	22.9	8.5	44.4	16.2	14.1	10.6	74.8	44.7	28.0	13.7	S	M	M	M	57.2	25.3
5	PP-5	34.0	21.3	7.8	40.7	15.6	14.0	9.9	73.8	41.9	27.8	11.8	M	M	M	M	55.9	24.0
6	PP-6	35.0	16.6	7.4	39.1	14.6	12.5	8.6	68.7	39.5	25.4	10.7	VD	M	M	M	55.8	22.0
7	PP-7	35.5	20.2	7.2	37.0	14.1	11.5	8.0	69.1	42.1	27.2	12.7	M	M	P	M	49.5	26.8
8	PP-8	33.0	20.3	7.0	39.8	14.2	12.1	8.1	69.0	40.5	25.8	11.6	M	p	P	M	58.2	22.6
9	PP-9	35.0	15.1	6.3	39.4	14.0	11.6	7.8	67.5	41.0	26.1	12.4	S	M	M	M	59.8	23.0
10	PP-10	33.5	18.8	6.7	40.0	15.0	13.0	8.0	65.3	28.3	25.1	13.0	M	M	M	P	54.3	22.9
11	PP-11	36.5	15.8	7.2	39.2	14.2	11.8	7.9	67.1	42.2	24.0	12.2	M	M	M	M	52.3	23.1
12	PP-12	37.5	11.3	6.2	37.9	13.1	11.2	7.7	68.3	39.6	23.7	10.5	D	M	P	M	53.0	22.6
13	PP-13	34.0	14.6	6.5	38.9	14.3	11.0	8.1	73.2	43.8	27.1	12.0	D	M	M	P	53.7	24.9
14	PP-14	35.5	18.4	7.3	40.0	15.1	11.9	8.7	73.5	42.6	28.7	13.2	S	M	S	M	54.3	25.9
15	PP-15	34.5	15.7	7.4	41.7	15.5	12.3	8.7	70.6	40.7	25.8	10.9	M	M	M	M	50.9	26.7
16	PP-16	34.0	22.0	7.1	41.5	13.6	14.2	9.6	72.5	43.7	27.1	13.1	D	M	P	M	57.1	25.0
17	PP-17	34.0	12.1	7.3	39.8	13.3	11.9	7.8	69.6	40.8	25.5	12.5	VD	M	M	M	56.3	24.9
18	PP-18	34.5	14.8	7.3	42.7	15.6	11.8	8.7	73.4	43.2	26.9	12.5	M	M	S	M	54.0	25.9
19	PP-19	37.5	15.0	6.8	38.1	13.7	10.2	7.1	69.6	40.1	24.2	11.3	M	p	M	M	54.8	23.3
20	PP-20	35.5	18.7	7.7	42.1	16.1	13.7	8.9	74.2	43.9	26.4	12.5	S	M	M	M	54.6	23.1
21	K6	35.0	21.1	7.1	41.0	11.5	11.5	7.9	69.3	26.5	12.1	40.7	M	M	P	M	53.7	24.8
22	ICGV13193	40.0	12.9	7.7	41.1	10.9	10.9	7.7	70.7	26.1	12.1	42.0	S	S	S	M	54.2	23.8
23	ICGV15033	38.5	11.3	8.3	38.9	11.9	11.9	8.3	69.7	24.2	11.8	39.8	S	S	S	A	55.3	23.3
	Mean	35.2	17.4	7.3	40.4	14.7	12.5	8.5	70.6	26.4	12.2	41.1	-	-	-	-	**55**	24.2
	Range	33.0-40.0	11.3-22.9	6.2-8.5	37-44.4	13.1-16.2	10.2-14.8	7.1-10.6	65.3-74.8	23.7-30.0	10.5-13.7	28.3-44.7					59.5-60.7	21.8-28
	C.V (%)	2.40	6.27	6.40	2.79	4.13	4.33	6.07	2.50	6.07	2.50	6.07	-	-	-	-	1.44	2.35
	CD (P=0.05%)	1.76	2.27	0.96	2.34	1.26	1.12	1.08	3.66	6.07	2.50	6.07	--	-	-	-	1.44	2.35
	S.Em	0.60	0.77	0.33	0.79	0.43	0.38	0.36	1.25	0.60	0.36	3.10	-	-	-	-	0.56	0.40

DFF: Days to 50% Flowering, PH: Plant Height (cm), NPB/P: Number of Primary Branches per Plant, NSB/P: Number of Secondary Branches per Plant, NPP: Number of Pods per Plant, PY/P: Pod Yield per Plant (g), SY/P: Seed Yield per Plant (g), SH (%): Shelling outturn (%), PL: Pod Length (mm), PW: Pod Width, (mm),100 SW :100 seed weight (g), PB: Pod Beak, PC: Pod Constriction, PR: Pod Reticulation, PRG: Pod Ridges, S: Slight, M: Medium, P:Prominent, A: Absent, D: Deep, VD: Very deep, CV (%): Coefficient of variation, CD: Critical Difference, S. Em: Standard error of mean

Conclusion

In the present study, four lines *viz.*, PP-1, PP-2, PP-5 and PP-14 developed through marker assisted backcross breeding programme showed resistance to late leaf spot, improved oil quality features like high oil and oleic acid content and were also superior or equivalent in yield compared with the recurrent parent K6. Pod characteristics showed superior over the recurrent parent in terms of pod beak and pod constriction, while pod reticulation, pod ridges and seed color are similar to K6.These superior backcross lines (PP-1, PP-2, PP-5 and PP-14) which have LLS resistance, high oil content and desirable pod features are currently under seed multiplication, further forward to yield evaluation trails and promising lines with LLS resistance and high yield will be released as superior variety/varieties.

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