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ORIGINAL PAPER

Resistance to late leaf spot and rust diseases in ICRISAT's mini core collection of peanut (*Arachis hypogaea* L.)

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Abstract Late leaf spot (LLS) (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*) are major foliar diseases of peanut causing significant losses worldwide. Identification and infusion of resistance into peanut cultivars is important in the management of these diseases. The present study therefore aimed at screening the peanut mini core collection to identify potential sources of resistance to these diseases. Two separate field experiments were conducted for screening LLS and rust under artificial epiphytotic conditions during rainy seasons of 2012 and 2013 at ICRISAT, Patancheru, India. The trials were laid in a randomized complete block design on beds with three replications. Data on LLS and rust disease severities were collected using 1 to 9 scales at 75, 90 and 105 days after sowing (DAS), and pod yields were recorded at harvest. Results indicate significant variations among accessions for LLS and rust resistance. Mean of 2 years study revealed that 53 accessions were moderately resistant (MR), 86 accessions were susceptible (S) and 45 accessions were highly susceptible (HS) to LLS. For rust disease, 10 accessions were resistant (R), 115 accessions were with 'MR' reaction and 59 accessions with susceptible (S) reaction. Six superior accessions in terms of combined disease resistance and yield (ICGs 4389, 6993, 11426, 4746, 6022, 11088) were selected and the disease progress curves, for each, were generated. Highest yields were recorded with ICG 11426 in LLS and rust plots. Overall, our results indicate that these six accessions can be potential sources of LLS and rust resistance.

Keywords Peanut · Mini core collection · Host plant resistance · Late leaf spot · Rust

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Introduction

Peanut (Groundnut; *Arachis hypogaea* L.) is an important annual food legume crop grown in many tropical and subtropical countries of the world. Of various biotic stresses affecting peanut production, foliar diseases such as late leaf spot (LLS) caused by *Phaeoisariopsis personata* (Berk. & M.A. Curtis) Van Arx and rust, caused by *Puccinia arachidis* Speg. are economically significant (Grichar et al. 1998; Subrahmanyam et al. 1980). Significant pod yield losses have been reported for each of these diseases especially under favorable conditions. For example, up to 80 % of the pod losses are reported due to LLS (Grichar et al. 1998; Miller et al. 1990; McDonald et al. 1985). However, yield losses vary with the type of cultivar and management practices followed (Kornegay et al. 1980; Smith and Littrell 1980). Besides direct seed losses, seed size and seed weight are also reduced thereby affecting the seed quality (Souta 1912; Arthur 1929) and oil content (Gupta et al. 1988). Initially, LLS produces small chlorotic lesions, which later turn dark brown or black. The conidiophores and conidia are produced in concentric rings on the lower surface of the leaf. Severe LLS infection results in considerable defoliation (Harrison 1969). Rust disease outbreaks have previously been reported from Asia and Africa (Mehan et al. 1994) with substantial yield losses (Felix and Ricaud 1977; Subrahmanyam et al. 1980, 1985). On an average, the losses due to peanut rust alone are estimated to be in the range of 50 to 70 % (Subrahmanyam et al. 1985). Time of incidence of rust has a direct bearing on yield losses. It is estimated that rust infestation on the crop at flowering, pegging, pre-pod-forming, and mid-pod-forming stages resulted in yield losses of 49, 41, 31 and 18 % respectively (Zhou et al. 1980). Previous research at ICRISAT, India indicated that rust disease causes yield losses to a tune of 50 % (Subrahmanyam and McDonald 1983). The rust pathogen produces orange uredinial pustules on the lower leaf surfaces that rupture to expose the reddish brown urediniospores. Rust infection also results in leaf necrosis and total leaf drying (Mehan et al. 1994). Both LLS and rust together usually account for more than 50 % yield losses (Subrahmanyam et al. 1989; Waliyar 1991; Savary and Van Santen 1992). These diseases collectively reduce the green leaf area available for photosynthesis and stimulate leaflet abscission leading to extensive defoliation (McDonald et al. 1985). They also affect the seed quality and fodder value of the plants (Gupta et al. 1987).

Often, these foliar diseases are managed through use of chemical fungicides as sprays (Natrajan 1984; Biswas and Singh 2005). Other management practices in the developing countries include seed treatment with non-conventional chemicals (Maiti et al. 2005), cultural practices by adjusting sowing times (Naidu and Vasanthi 1995), and through use of biological control agents (Kishore and Pande 2005) and botanicals (Hossain and Hossain 2013). Multiple applications of chemical fungicides offer quick and effective remedy for these diseases. For example, in developed countries like USA, fungicidal sprays every 2 weeks, beginning at 30 to 35 days after sowing (DAS) and continuing throughout the crop season for LLS and rust diseases is practiced for disease control (Shokes et al. 1982; Culbreath et al. 2002; Augusto and Brenneman 2011). However, under rainfed conditions, application of fungicides is not economical especially in the semi-arid tropics where crop yields are uncertain, farmers are resource poor and the crop productivity is low (Gibbons 1980). Besides, their use has several concerns such as environmental safety and scope for development of fungicide-tolerant strains of pathogen (Clark et al. 1974; Littrell 1974).

Identification of resistance to both LLS and rust, and incorporation of resistance into adapted cultivars, is a viable option without any additional input cost for managing these foliar diseases (Pensuk et al. 2003). The most recent reports on rust and LLS resistant genotypes date back to Cook (1972), Porter et al. (1982); Subrahmanyam et al. (1980, 1989). Similarly, several studies reported the rate-reducing resistance as a viable strategy for identifying improved resistance to LLS (Aquino et al. 1995; Abdou et al. 1974; Chiteka et al. 1988; Gorbet et al. 1990; Kornegay et al. 1980; Pixeley et al. 1990). However, for precise identification of resistant sources, knowledge on components and mechanisms of resistance are the prerequisites for successful breeding programs. Though earlier studies have identified several genotypes for foliar disease resistance (Waliyar et al. 1993; Anderson et al. 1993; Mehan et al. 1996; Singh et al. 1997), high degree of resistance to these diseases are not available. Moreover, differential field reaction of recently released peanut cultivars to these diseases is another problem. For example, the peanut cultivar "Southern Runner", released by the University of Florida, USA; is found to be promising and with improved resistance to LLS (Gorbet et al. 1987). On the other hand, highly susceptible reaction is observed in the recently released Thai cultivars, "Tainan 9" and "Lampang" for both LLS and rust diseases (Pensuk et al. 2003).

Plant genetic resources are being used in breeding programs, mainly as sources of resistance to pests and diseases (Knauft and Gorbet 1989). Screening of peanut mini core lines is an important aspect for identifying promising donors to biotic and abiotic stresses. These mini core collections with diverse agronomic characters are widely used for infusing genetic diversity in plant breeding programs (Upadhyaya et al. 2010). Holbrook and Dong (2005) demonstrated that the developed peanut mini core from US germplasm collection could be used for enhancing the efficiency in identifying desirable traits in the larger core and entire collection. For example, molecular characterization studies of US peanut mini core collection indicated that 39 accessions from spanish, valencia, runner market types were potentially resistant to *Sclerotinia* blight disease (Chamberlin et al. 2010). Similarly, partial resistance to tomato spotted wilt virus (TSWV) was identified in peanut by screening core collection (Anderson et al. 1996). In view of the frequent breakdown of foliar disease resistance as in wheat rust, our studies on identification of resistance sources to these LLS and rust diseases assume significance. For example, in wheat, the breakdown of the *Yr17* resistance gene was reported in cultivars to yellow rust disease caused by *Puccinia striiformis* f.sp. *tritici* (Bayles et al. 2000; El-Jarroudi et al. 2011). Therefore, our objective was to evaluate the peanut mini core collection for resistance to LLS and rust diseases and identify new sources of resistance. Our present studies form the first comprehensive report on field evaluation and resistance levels among ICRISAT's mini core collection against LLS and rust diseases.

Materials and Methods

Genotypes

The peanut mini core collection consisting of 184 accessions (Upadhyaya et al. 2002) was developed based on morphological and agronomic traits from 1,704 entries of the core collection of peanut, representing 14,310 accessions available in the ICRISAT gene bank (Upadhyaya et al. 2003). These accessions are comprised of 37 *fastigiata*, 58 *vulgaris*, 85 *hypogaea*, two *peruviana*, and one each of *aequitoriana*,

Table 1 Variance components due to genotypes (σ^2 g) and genotype x environment (σ^2 g.e) for late leaf spot (LLS) and rust severity in the peanut mini core collection evaluated at ICRISAT, Patancheru, India during rainy seasons of 2012 and 2013

Covariance Parameter	Late Leaf Spot			Rust		
	2012	2013	Pooled	2012	2013	Pooled
Environment (σ^2 e)	–	–	0.12 ^{NS}	–	–	0.002 ^{NS}
Genotype (σ^2 g)	1.47**	1.13**	1.24**	0.84**	0.67**	0.7**
Genotype×Environment (σ^2 g*e)	–	–	0.05**	–	–	0.06**

** Significant at Prob < 0.01

NS Non-significant at Prob >= 0.05

and *hirsuta*. The trial also included four released cultivars Gangapuri (*fastigiata*), ICGS 44 (*vulgaris*), ICGS 76 (*hypogaea*) and M 13 (*hypogaea*) for comparison. Gangapuri and M 13 are Indian cultivars, whereas ICGS 44 (ICGV 87128, PI 537112) (Nigam et al. 1990) and ICGS 76 (ICGV 87141, PI 546372) (Nigam et al. 1991) are ICRISAT-bred high-yielding cultivars released in India (Upadhyaya 2005). Three cultivars were used as standard checks: ICGV 00068 for LLS resistance, ICGV 00064 for rust resistance, and TMV 2 as susceptible check for both LLS and rust.

Field evaluation of genotypes against late leaf spot (LLS) and rust diseases

Two individual experiments on LLS and rust were laid out in two separate fields during rainy seasons of 2012 and 2013 at ICRISAT, Patancheru, India. A total of 186 accessions (184 mini core plus two standard checks) were screened for the LLS and rust experiments. The trials were laid out in a randomized complete block design (RCBD) on 20 June during both years with three replications on broad bed furrows. The size of the beds was 4.0 m×1.5 m and the mean planting density was 26.7 plants/m^2. Altogether, there were 80 plants/replication for each accession, spread in two rows, and there were four rows for each bed. Precaution was taken to ensure uniform and proper depth of planting (5 cm). Standard agronomic and cultural practices were followed during the cropping season. Infector row method was followed by sowing one bed (4 rows) of TMV 2 (susceptible to LLS and rust) for every four beds of test materials. In LLS experimental plots, a preventative spray with tridemorph 80 % EC (Calixin) at 1.0 ml per liter of water was given from 50 DAS at fortnight intervals on need basis to prevent rust infection. Similarly, in rust experimental plots, carbendazim 50 % WP (Bavistin) at 1.5 g per liter of water was sprayed as a preventative measure from 50 DAS at 15 days interval to prevent LLS incidence.

For artificial inoculation of these foliar pathogens, urediniospores of rust and conidia of LLS pathogens were collected separately using a cyclone spore collector (Fischer scientific co., USA) from naturally infected leaf lesions of the susceptible cultivar TMV 2 and inocula were stored at -20C. Ten days before planting of the test material in the field, the peanut cultivar TMV 2, susceptible to both diseases, were planted in poly bags in the greenhouse to multiply the inoculum. Thirty five

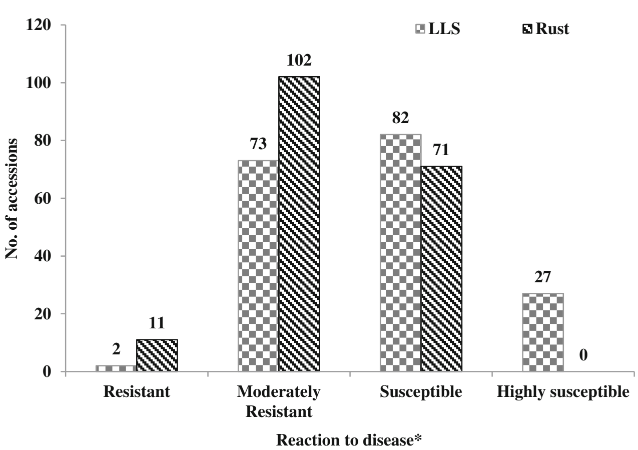


Fig. 1 Differential reaction of peanut mini core accessions to late leaf spot (LLS) and rust diseases during rainy season of 2012 at ICRISAT, Patancheru, India

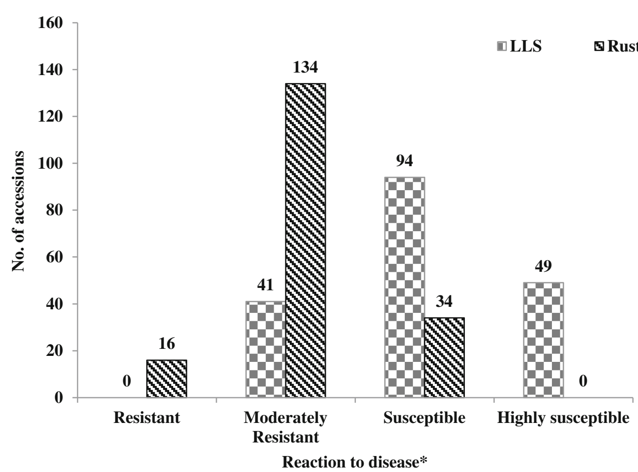


Fig. 2 Differential reaction of peanut mini core accessions to late leaf spot (LLS) and rust diseases during rainy season of 2013 at ICRISAT, Patancheru, India

Table 2 Performance of peanut mini core collection against rust and LLS diseases based on field studies during rainy season of 2012 and 2013 at ICRISAT, Patancheru, India

Reaction	Disease	No. of Accessions & Details*
Resistant	Rust	10 accessions (ICGs 11426, 11088, 4389, 6022, 6993, 2857, 4746, 15419, 6402, 6766)
	LLS	Nil
	Rust and LLS	Nil
Moderately Resistant	Rust	115 accessions (ICG's 14127, 5051, 6646, 7153, 12276, 12625, 2925, 9961, 10036, 111, 2381, 4343, 4527, 10479, 12000, 14466, 3053, 5891, 6813, 862, 928, 11457, 163, 2772, 2773, 2777, 4412, 4538, 513, 76, 8285, 8490, 9037, 9666, 9842, 11109, 13723, 13787, 1668, 2511, 3027, 7243, 875, 9777, 5827, 12370, 4156, 5663, 721, 13099, 14008, 14475, 6913, 9905, 10185, 12672, 15042, 15190, 3992, 5286, 5662, 6667, 14523, 188, 5745, 8760, 11862, 14482, 14705, 4598, 4998, 6892, 334, 118, 5016, 5327, 6057, 12189, 12682, 6703, 7000, 7969, 13856, 3343, 3673, 3681, 5494, 6263, 8106, 1137, 1274, 3102, 10566, 11651, 14118, 15287, 15309, 5475, 6201, 7190, 10384, 10554, 11219, 11855, 12921, 13982, 14106, 14985, 442, 7181, 8083, 9157, 9418, 9809)
	LLS	53 accessions (ICG's 11426, 12625, 13787, 4412, 513, 9842,11109, 8760, 10479, 11457, 12000, 12370, 2772, 6022, 6993, 928, 10185, 14008, 163, 2777, 2857, 4343, 4389, 4527, 5051, 532, 6913, 721, 76, 8490, 9037, 9905, 9961, 111, 12276, 12672, 13723, 14475, 2773, 5286, 875, 9777, 14466, 3053, 5663, 5891,7243, 15419, 11219, 3992, 4598, 6813, 7153)
	Rust and LLS	47 accessions (ICG's 12625, 13787, 4412, 513, 9842,11109, 8760, 10479, 11457, 12000, 12370, 2772, 928, 10185, 14008, 163, 2777, 4343, 4527, 5051, 532, 6913, 721,76, 8490, 9037, 9905, 9961, 111, 1227, 12672, 13723, 14475, 2773, 5286, 875, 9777, 14466, 3053, 5663, 5891, 7243, 11219, 3992, 4598, 6813, 7153)
Susceptible	Rust	59 accessions (ICG's 10474, 10566, 1142, 115, 11651, 13982, 14630, 1973, 332, 5221, 6201, 6263, 6375, 8083, 8517, 9809, 11249, 1711, 2019, 3421, 36, 3746, 4684, 6888, 1137, 7963, 10890, 11687, 12879, 15287, 2106, 4543, 5195, 5236, 5494, 5779, 6654, 7906, 9507, 12988, 1519, 3584, 4729, 4729, 81, 8567)
	LLS	86 accessions (ICG's 14482, 1668, 2925, 4156, 4746, 5016, 6057, 6667,6766, 8285, 862, 9666, 2511, 3027, 4538, 4998, 7000, 15190, 2381, 11862, 14705, 5662, 6892, 13099, 5745, 6646, 5327, 10036, 14523, 14127, 15042, 5475, 5827, 6402, 11088, 11515, 442, 9249, 11855, 12682, 3102, 334, 4955, 10384, 188, 7190, 11144, 4750, 118, 12189, 14106, 14118, 1415, 15309, 3343, 3673, 434, 10554, 13491, 14710, 297, 397, 6703, 8106, 10092, 11322, 13603, 1399, 14985, 3240, 7181, 9157, 9315, 3775, 5609, 6407, 1274, 12921, 13856, 13858, 9418, 12697, 3681, 4670, 4911, 7969)
	Rust and LLS	25 accessions (ICG's 13491, 13858, 1399, 3240, 36, 3775, 434, 4750, 4911, 4955, 9315, 11144, 11322, 14710, 297, 4670, 5609, 10092, 11515, 397, 6407, 9249, 13603, 1415, 12697)
Highly susceptible	Rust	Nil
	LLS	45 accessions (ICG's 10474, 10566, 1142, 115, 11651, 13982, 14630, 1973, 332, 5221, 6201, 6263, 6375, 8083, 8517, 9809, 11249, 1711, 2019, 3421, 36, 3746, 4684, 6888, 1137, 7963, 10890, 11687, 12879, 15287, 2106, 4543, 5195, 5236, 5494, 5779, 6654, 7906, 9507, 12988, 1519, 3584, 4729, 81, 8567)
	Rust and LLS	Nil

*Six accessions (ICG's 11426, 2857, 4389, 6022, 6993 and 15419) showed resistant to rust and moderately resistant to LLS

*Accessions are categorized based on the mean resistance/susceptible reaction to rust and LLS diseases on a 1–9 scale where Resistant (R)= 1–3; Moderately resistant (MR)= 4–5; Susceptible (S)= 6–7; Highly susceptible (HS)= 8–9 disease severity rating scale

days-old "TMV 2" seedlings raised in the greenhouse were inoculated separately by spraying with urediniospores of rust and conidia of LLS at 5×10^4 ml^{-1}. The non-ionic detergent, Tween 20 was added to the spore solution as a surfactant at the rate of 0.05 % of the spore solution. Water was sprinkled in and around the inoculated plants in the polybags and the plants were covered with polyethylene sheet during the nights for 7 days to maintain high humidity (95 %). Severe rust and LLS developed in 2 weeks and the plants were transplanted as infector rows in respective experimental fields. When the test materials were around 50-days-old, rust and LLS infected plants in polybags were transplanted in the infector and spreader rows in the two separate trials. At 50 DAS, both conidia of LLS and urediniospores of rust were sprayed at a concentration of 5×10^4 spores ml^{-1} in the respective trials. To promote disease development, sprinkler

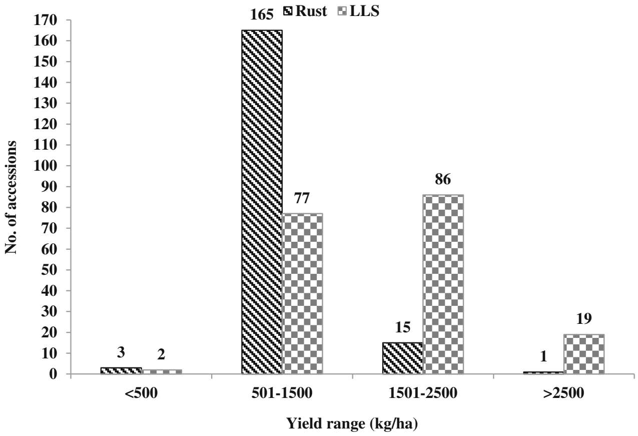


Fig. 3 Frequency distribution of peanut mini core accessions showing mean differential yields during rainy seasons of 2012 and 2013 in late leaf spot and rust infested fields at ICRISAT, Patancheru, India

irrigation was provided to the trials daily on rain free days for 30 min/day for 1 month from the day of field inoculation with the pathogen.

Data collection

Data on disease severity (LLS and rust) were collected from each plot, per replication, separately in the randomized experimental blocks during 2012 and 2013. Observations on rust and LLS severity were recorded at 75, 90 and 105 DAS. For recording disease severities, 10 plants from each row were selected at random and a total of 20 plants were assessed per accession. Pod yields were recorded for each of the accessions per replication.

The disease severities for LLS and rust were measured on a 1 to 9 point field scale (Subrahmanyam et al. 1995). The disease severities corresponding to the rust and LLS scores are 1=0 %; 2=1–5 %; 3=6–10; 4=11–20 %; 5=21–30 %; 6=31–40 %; 6=31–40 %; 7=41–60 %; 8=61–80 % and 9=81–100 %. Based on the severities, the accessions were differentiated as resistant (score of <3); moderately resistant (score of 4 and 5); susceptible (score of 6 and 7); and highly susceptible (score of 8 and 9).

Accessions with lowest severity ratings for LLS and rust during 2012 and 2013 were selected for evaluating the disease progress at 75, 90 and 105 DAS were compared with that of resistant and susceptible checks. Pod yields were recorded by harvesting each accession per replication. For harvesting, plants from the entire plot were uprooted by hand and brought to the threshing floor, stripped off, and then dried prior to yield assessment. Pod yields for the selected accessions were compared with that of resistant and susceptible checks in respective experimental plots.

Statistical analysis

For each LLS and rust diseases scores, combined and year wise analysis of variance was carried out by using SAS Mixed procedure (SAS V9.3) and variance components were estimated for year (environment), genotype and genotype*environment (g*e) effects (SAS Institute Inc 2013). Best Linear Unbiased Predictors were estimated for genotypes. The performance of mini core accessions in terms of yield was analyzed and categorized. The influence of these foliar disease severities on yield was determined by comparing the yields of moderately resistant (LLS) and resistant accessions (rust) with that of resistant cultivars, ICGV 00068 and ICGV 00064 respectively.

Table 3 Field reaction of six selected peanut mini core accessions against late leaf spot (LLS) and rust diseases during rainy seasons of 2012 and 2013 at ICRISAT, Patancheru, India

Genotype	Late leaf spot disease severity*			Rust disease severity*		
	2012	2013	Pooled	2012	2013	Pooled
ICG 4389	4.7	5.3	5.0	3.0	3.0	3.0
ICG 4746	5.0	6.0	5.5	3.3	3.0	3.2
ICG 6022	5.0	4.7	4.8	2.7	3.3	3.0
ICG 6993	4.7	5.0	4.8	3.3	2.7	3.0
ICG 11088	6.3	6.7	6.5	2.3	2.3	2.3
ICG 11426	3.0	4.0	3.5	2.0	2.0	2.0
Resistant check***	3.0	2.3	2.7	2.0	1.3	1.7
TMV 2	7.0	8.0	7.5	6.0	7.0	6.5

*Accessions are categorized based on the mean resistance/susceptible reaction to rust and LLS diseases on a 1–9 scale

Resistant (R)= 1–3; Moderately resistant (MR)= 4–5; Susceptible (S)= 6–7; Highly susceptible (HS)= 8–9 disease severity rating scale

*** ICGV 00068 for LLS and ICGV 00064 for rust are the resistant checks

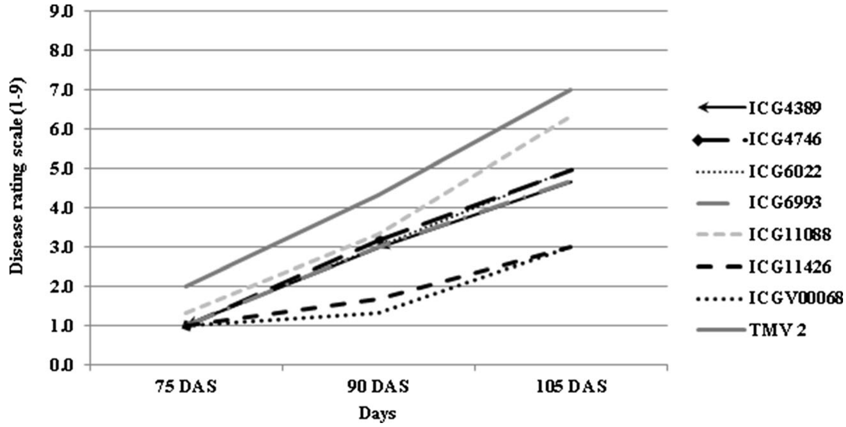


Fig. 4 Late leaf spot progress in selected peanut mini core accessions during 2012 rainy season at ICRISAT, Patancheru, India

Results

Data analysis indicated no significant differences for pooled data with respect to year for both LLS and rust diseases. Significant genotypic variances for both LLS and rust diseases were observed during individual years as well as for pooled data ($p<0.01$). Similarly, the variance due to genotype*environment interaction (σ^2 ge) was significant for both LLS and rust diseases ($p<0.01$). However, variance components due to genotypes (σ^2 g) were high compared to the genotype*environment interaction for both LLS and rust diseases (Table 1).

Field evaluation of genotypes against late leaf spot (LLS) and rust diseases

Late leaf spot

During 2012, out of 184 mini core accessions, two accessions (ICG 11426 and ICG 12625) showed resistance reaction. Further, 73 accessions were moderately resistant; 82 accessions were susceptible. About 27 accessions have shown highly susceptible reaction (Fig. 1). During 2013, a total of 41 accessions have shown moderately resistant reaction, whereas 94 accessions were susceptible and 49 accessions were highly susceptible (Fig. 2).

Analysis of pooled data for 2012 and 2013 experiments indicated that 53 accessions were moderately resistant (MR) to LLS (Table 2). The majority of accessions were susceptible (S) (n=86), whereas 45 accessions were highly susceptible (HS). However, none of the accessions were completely resistant (R) to LLS. The control, TMV 2 was rated 8, with a highly susceptible reaction. In LLS plots, 19 accessions yielded >2500 kg ha^{-1} and only two genotypes had < 500 kg ha^{-1}. Further, 86 accessions yielded between 1501 and 2000 kg ha^{-1}, whereas 77 yielded between 501 and 1500 kg ha^{-1} (Fig. 3).

Rust

During 2012, out of 184 mini core accessions, eleven accessions (ICGs 11426, 11088, 6022, 12625, 15419, 4389, 111, 4343, 4527, 4746, and 6993) have shown resistance reaction. Further, 102 accessions were MR; 71 accessions were susceptible. None of the accessions have shown highly S reaction (Fig. 1). During 2013, a total of 16 accessions (ICGs 11426,

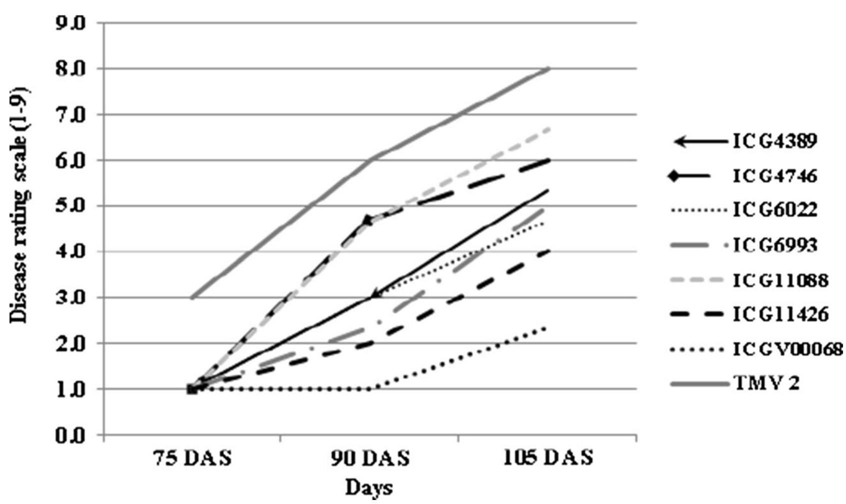


Fig. 5 Late leaf spot progress in selected peanut mini core accessions during 2013 rainy season at ICRISAT, Patancheru, India

11088, 2857, 6402, 6993, 2925, 4389, 4746, 5051, 6646, 6766, 10036, 14127, 2381, 6022, 7153) showed resistance reaction, 134 were moderately resistant, 34 accessions were susceptible. None of the accessions showed highly susceptible reaction (Fig. 2).

Analysis of pooled data for 2012 and 2013 experiments indicated that 10 accessions showed R reaction to rust. The majority of the accessions showed MR reaction (n=115). Further, 59 lines were in the S category (Table 2). A disease severity scale of 8.0 (HS) was recorded for the susceptible cultivar TMV 2. In rust plots, only one accession (ICG 11426) has recorded a yield of >2500 kg ha^{-1} (2661 kg ha^{-1}). The majority of the accessions (n=165) have recorded yields in the range of 501–1500 kg ha^{-1}. Only 15 accessions showed a yield level ranging from 1501 to 2500 kg ha^{-1}, whereas three accessions showed pod yields of <500 kg ha^{-1} (Fig. 3).

A few lines (six accessions: ICG 4389, ICG 6993, ICG 11426, ICG 4746, ICG 6022 and ICG 11088) with the lowest disease severity scores (for rust and LLS) were selected and their disease progress over time was plotted from the existing data. All these six accessions showed R reaction to rust in individual years. Of these, four accessions (ICGs' 4389, 6993, 11426 and 6022) showed MR reaction to LLS during individual years of assessment and their pooled mean (Table 3). Though, the other two accessions ICG 4746 and ICG 11088 showed S reaction to LLS, but exhibited superior yields (mean of 2012 and 2013 experiments) performance over other 'MR' accessions in LLS plots (data not shown), and hence were selected for further studies.

Late leaf spot

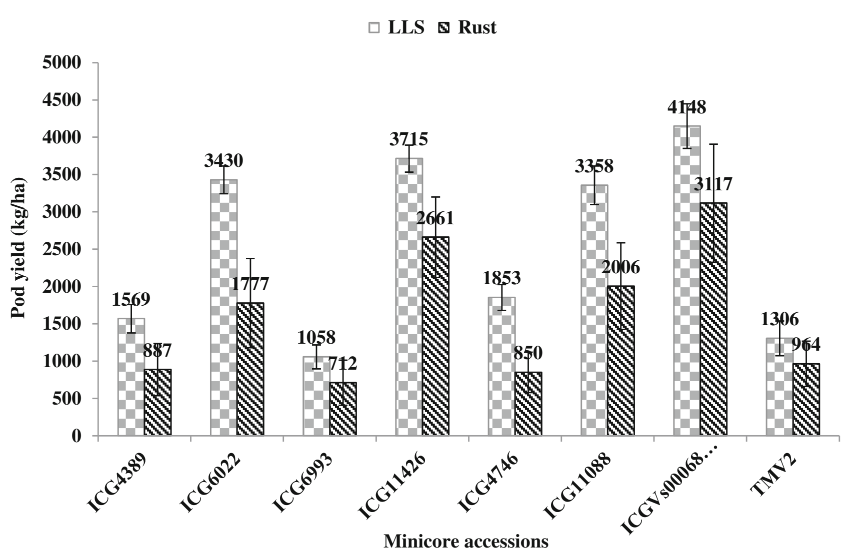
During both 2012 and 2013, the LLS disease severity was lowest with ICG 11426 and highest with ICG 11088 at 105 DAS (Table 3). All the remaining accessions were within the limits of resistant and susceptible controls that showed lowest and highest LLS progression respectively during both the years. There was more disease as the plants grew older, but this has more to do with the disease progress due to increase of inoculum rather than age of the plants (Figs. 4 and 5).

The yield levels varied among the selected accessions in LLS plots. The mean yields for 2012 and 2013 were highest with ICG 11426 (3715 kg ha^{-1}), followed by ICG 6022 (3430 kg ha^{-1}) and ICG 11088 (3358 kg ha^{-1}). No significant differences in yield were observed for ICG 11426 with that of resistant control ICGV 00068 (4148 kg ha^{-1}). However, the remaining five accessions produced significantly lower yield than the resistant control. The two susceptible accessions in LLS plots, ICG 6022 and ICG 11088 have also recorded higher yields (3430 and 3358 kg ha^{-1}, respectively) over the susceptible check (TMV 2). Lower yields were recorded with ICG 6993 (1058 kg ha^{-1}) and ICG 4389 (1569 kg ha^{-1}) and were comparable to those of the susceptible control TMV 2 (1306 kg ha^{-1}) (Fig. 6).

Rust

During 2012 and 2013, the rust disease severity was lowest for ICG 11426 and ICG 11088 (Table 3). The disease progression was lowest with ICG 11426 and ICG 11088 at 75, 90 and 105 DAS, whereas it was highest in ICG 4746 and ICG 6993 during 2012 (Fig. 7). During 2013, it was highest in ICG 6022 at 105 DAS (Table 3 and Fig. 8). All the remaining accessions were within the limits of resistant and susceptible controls that showed lowest and highest LLS progression respectively. As the plants grew older, there was more disease, due to the increase in inoculum rather than the plant age (Figs. 7 and 8).

Fig. 6 Mean pod yield of selected peanut mini core accessions in late leaf spot (LLS) and rust screening plots calculated during 2012 and 2013 rainy seasons



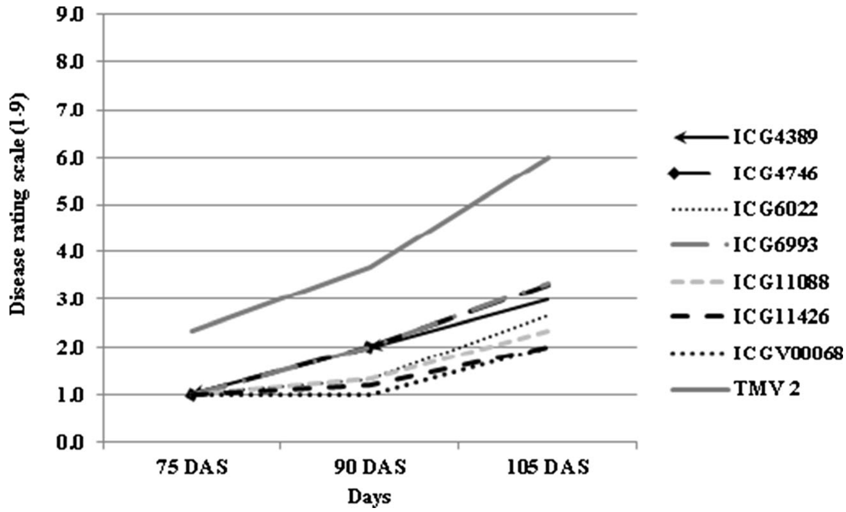


Fig. 7 Progress of rust disease in peanut fields during 2012 rainy season in selected peanut mini core accessions at ICRISAT, Patancheru, India

The mean yields for 2012 and 2013 also varied among the selected accessions in rust plots. Highest yield among accessions was recorded for ICG 11426 (2661 kg ha^{-1}), followed by ICG 11088 (2006 kg ha^{-1}) and ICG 6022 (1777 kg ha^{-1}). No significant differences in yield were observed for ICG 11426 with that of resistant control, ICGV 00064 (3117 kg ha^{-1}). The remaining five accessions however produced significantly lower yields than the resistant control. Lower yields were recorded for ICG 6993 (712 kg ha^{-1}), ICG 4746 (850 kg ha^{-1}) and ICG 4389 (887 kg ha^{-1}) with no significant differences with the susceptible control. TMV 2 had a yield of 964 kg ha^{-1} (Fig. 6).

Reaction of released cultivars to late leaf spot and rust

All the cultivars (Gangapuri, ICGS 44, ICGS 76 and M 13) were found to be susceptible to LLS disease. For rust screening, ICGS 44, ICGS 76 and M 13 exhibited MR reaction, whereas Gangapuri recorded susceptible (S) reaction.

Discussion

Selection of resistant sources by thorough screening of mini core collection accessions is in practice for infusing genetic diversity in plant breeding programs (Upadhyaya et al. 2010). Mini core germplasm screening for identifying promising resistant sources for biotic and abiotic stresses (Vadez et al. 2007; Kashiwagi et al. 2007) has also been done in other crops. One of the advantages with mini core collection is its reduced size over core collection, and this provides more scope for systematic evaluation, for traits useful in crop improvement (Upadhyaya et al. 2010). Mini core collections of ICRISAT mandate crops such as peanut, pigeonpea and chickpea have become international public goods (IPGs) and are now being used by National Agricultural Research System (NARS) researchers in 20 countries. For example, in pigeonpea, sources of combined resistance to *Fusarium* wilt and sterility mosaic diseases (ICPs 6739, 8860, 11015, 13304 and 14819) were identified from the mini core collection (Sharma et al. 2012). Earlier studies indicated useful variation

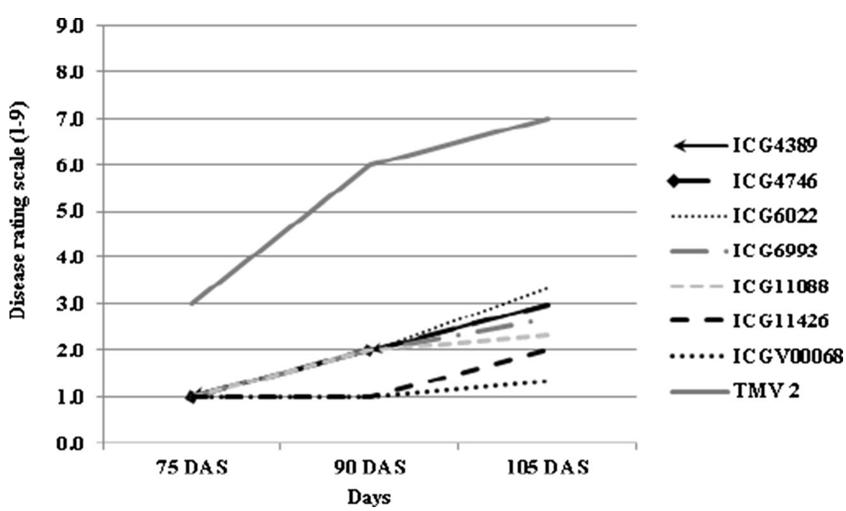


Fig. 8 Progress of rust disease in peanut fields during 2013 rainy season in selected peanut mini core accessions at ICRISAT, Patancheru, India

in mini core to various biotic and abiotic stresses as in chickpea (Kaul et al. 2005; Johnson et al. 2007).

In the present study, the selected peanut accessions (all are *Arachis hypogaea*) ICGs 4389 (Origin: India), 6993 (Origin: Brazil), 11426 (Origin: India), 6022 (Origin: Sudan), 4746 (Origin: Israel) and 11088 (Origin: Peru) showed superior reactions in terms of resistance, lower rates of LLS and rust disease progress and also good pod yields. These six mini core accessions can therefore be considered for infusing resistance for LLS and rust diseases in peanut. Detailed investigations should also be further carried out to determine the resistance levels of these accessions towards different components such as incubation period, latent period, sporulation, lesion size, plant appearance score and per cent necrotic area (Aquino et al. 1995). It has been reported that several components have been shown to negatively impact the rate of disease progression under field conditions (Foster et al. 1980; Ricker et al. 1985). For example, in case of early leaf spot (ELS) of peanut induced by *Cercospora arachidicola*, latent period (Foster et al. 1980) and the maximum percentage of sporulating lesions (Ricker et al. 1985) are the critical components for selecting the rate reducing resistance of ELS. For LLS, components of resistance have been investigated earlier (Nevill 1981; Pixeley et al. 1990; Shew et al. 1988; Subrahmanyam et al. 1982; Watson 1987). However, evaluating multiple components for these foliar diseases can be a tedious task due to various reasons (Aquino et al. 1995). Since, sporulation, latent period and lesion size are most critical components that determine the resistance of accessions to these diseases, critical investigations in these lines will be useful before recommending these selected accessions for resistance breeding programs on LLS and rust.

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