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Components of resistance to late leaf spot and rust among interspecific derivatives and their significance in a foliar disease resistance breeding in groundnut (*Arachis hypogaea* L.)

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Summary

Late leaf spot (LLS) and rust cause substantial yield losses and reduce the fodder and seed quality in groundnut (*Arachis hypogaea* L.). Adoption of resistant cultivars by the semi-arid tropic farmers is the best option to overcome yield losses. Knowledge on components of resistance to these diseases should facilitate the development of groundnut cultivars with enhanced resistance to LLS and rust. The objectives of the experiments were to study the genetic variability and relationships among components of resistance to LLS and rust, and assess their significance in disease resistance breeding. Fifteen interspecific derivatives for LLS and 14 for rust and a susceptible control, TMV 2, were evaluated in a randomised complete block design with two or three replications under greenhouse conditions. The experiments were repeated twice. Genotypic differences were highly significant for all the traits studied. Resistance to LLS is due to longer incubation and latent periods, lesser lesions per leaf, smaller lesion diameter, lower sporulation index, and lesser leaf area damage and disease score. Selection based on components of resistance to LLS may not lead to plants with higher retained green leaf area. The remaining green leaf area on the plant should, therefore, be the major selection criteria for resistance to LLS in breeding programs. Resistance to rust is due to longer incubation and latent periods, fewer pustules per leaf, smaller pustule diameter, lower sporulation index, and lesser leaf area damage and disease score. Rust resistant components appear to work additively, therefore, selection based on resistance components together with green leaf area retained on the plant should be the basis of selecting for resistance to rust in breeding programs. ICGV# 99005, 99003, 99012, and 99015 for rust and ICGV# 99006, 99013, 99004, 99003, and 99001 for LLS are the better parents for use in resistance breeding programs.

Introduction

Late leaf spot (LLS) caused by *Phaeoisariopsis personata* (Berk. & Curt.) Van Arx, early leaf spot (ELS) (caused by *Cercospora arachidicola* Hori), and rust (caused by *Puccinia arachidis* Speg.) are the three most important leaf diseases in groundnut (*Arachis hypogaea* L.) causing yield losses in excess of 50% in semi-arid tropic regions (Subrahamanyam et al., 1984; Subrahmanyam et al., 1985a; Waliyar, 1991). Although the diseases can be controlled by fungicides, adoption of resistant cultivars by semi-arid tropic farmers is the best option to minimize losses at farm level and maintain good product quality (Dwivedi et al., 1993). Identification of resistant sources and knowledge of components and mechanism of resistance are the pre-requisite for the success of disease resistance breeding programs. Several sources of resistance to LLS and rust have been reported in *A. hypogaea* (Waliyar et al., 1993; Anderson et al., 1993; Mehan et al., 1996; Singh et al., 1997). A majority of the resistant germplasm belong to subsp. *fastigiata*, and are land races from south America (Subrahmanyam et al., 1989). They possess a high degree of resistance to rust but show only low to moderate resistance to LLS. Resistant sources in wild *Arachis* species show immune reaction to rust (Subrahmanyam et al., 1983b) and from immune to highly resistant reaction to LLS (Abdou et al., 1974; Subrahmanyam et al., 1985b).

There are only few studies dealing with components of resistance to rust and LLS and their associations among themselves in groundnuts. Resistance to rust in *A. hypogaea* is attributed to longer incubation period, less number of pustules, smaller pustules, and less ruptured pustules and leaf area damage (Subrahmanyam et al., 1983a; Reddy & Khare, 1988; Mehan et al., 1994). Infection frequency, pustule diameter, percent ruptured pustules, and leaf area damage are correlated with each other and with mean field rust score. The incubation period is negatively correlated with other components. Most of the wild *Arachis* species in sections *Erectoides*, *Triseminale*, *Extranervosae*, and *Rhizomatosae* show immunity to rust with no recognizable symptoms of the disease appearing even after an incubation period of 40 days (Subrahmanyam et al., 1983b). Resistance to LLS in *A. hypogaea* is due to longer latent period, reduced sporulation, and less defoliation (Nevill, 1981). Sporulation, lesion size, and latent period are the important components of resistance to LLS and are highly correlated with each other and with percentage of leaf necrotic area (Chiteka et al., 1988). Lesion diameter, defoliation, and sporulation from glasshouse study are correlated with field disease score (Subrahmanyam et al., 1982). Wild *Arachis* species resistant to LLS in sections *Erectoides*, *Triseminalae*, *Extranervosae*, *Rhizomatosae*, and *Caulorhize* have small and nonsporulating lesions whereas species in section *Arachis* have accessions either with nonsporulating lesions or with variably sporulating lesions. Frequency of infection (number of lesions per square centimeter of leaf area) and defoliation vary greatly within each section and species (Subrahmanyam et al., 1985b). Although several interspecific derivatives resistant to LLS and rust have been developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the genetic variability for components of resistance to LLS and rust have not been investigated.

The present investigation was initiated to study (i) the genetic variability for components of resistance to LLS and rust among interspecific derivatives, (ii) the associations among components of resistance to LLS and rust, and (iii) assess the significance of resistance components in foliar diseases resistance breeding in groundnut.

Materials and methods

Fifteen phenotypically uniform and stable interspecific derivatives with varying degree of resistance to rust and LLS and a susceptible control, TMV 2, were selected for the greenhouse study. They were produced from crosses between *A. hypogaea* germplasm and wild *Arachis* species following hexaploid or amphidiploid routes followed by intermitant backcrossing with a recurrent *A. hypogaea* parent. Prior to the greenhouse study, they were evaluated (in nonreplicated trials) for resistance to LLS and rust on a 1 to 9 scale (where 1 = no disease and 9 = 81 to 100% diseases severity) one week before harvest under field conditions using the infector row technique (Subrahmanyam et al., 1995) for two rainy seasons at Patancheru. The average field scores ranged from 3 to 6 for LLS and from 3 to 5.5 for rust. The TMV 2 showed an average score of 9 for both rust and LLS (Table 1).

Production of LLS and rust inoculums

The LLS and rust inoculums were produced and maintained separately on incubated, inoculated detached leaves of the susceptible groundnut cultivar, TMV 2, in a Percival Plant Growth Chamber using a temperature of 23 °C and 12 h photoperiod. The LLS conidia and rust urediniospores were harvested with a cyclone spore collector, and used for inoculation of experimental materials separately.

Components of resistance to LLS

The 15 interspecific derivatives were then examined in greenhouse studies. Two separate experiments were conducted using a randomised complete block design (RCBD) with two replications in experiment 1, and three replications in experiment 2. Five seeds of each genotype were sown in 15 cm diameter plastic pots containing autoclaved alfisol and farmyard manure (v/v 4:1 ratio). After germination, three healthy plants were retained in each pot. Thirty-five day old plants were inoculated uniformly in the evening with LLS inoculum, containing 20.000 conidia ml^{-1}, with an automizer. Immediately after inoculation, the pots were shifted into dew chambers (Clifford, 1973) at

Table 1. Pedigree, botanical type, and disease's scores of interspecific derivatives and a susceptible control, TMV 2, in groundnuts

Identity	Pedigree	Botanical type	Disease's score[1]	
			Rust	Late leaf spot
ICGV 99001	Robust 33-1 × *A. villosa*	SB	4.0	3.0
ICGV 99002	(Chico × Shulamith) × (*A. corretina* × *A. batizocoii*)	VB	3.0	5.5
ICGV 99003	*A. hypogaea* × *(A. duranensis* × *A. stenosperma)*	VB	3.0	5.0
ICGV 99004	TMV 2 × (*A. hypogaea* × *A. cardenasii*)	SB	4.0	3.0
ICGV 99005	TMV 2 × (*A. hypogaea* × *A. batizocoii* × *A. duranensis*)	VB	3.0	4.5
ICGV 99006	*A. hypogaea* × *A. cardenasii*	SB	3.5	3.0
ICGV 99007	*A. hypogaea* × *A. cardenasii*	VB	3.0	5.0
ICGV 99008	Robut 33-1 × *A. villosa*	VB	4.0	4.5
ICGV 99009	(*A. hypogaea* × *A. cardenasii*) × T 900	VB	4.0	4.5
ICGV 99010	(*A. hypogaea* × *A. cardenasii*) × T 900	VB	5.5	3.0
ICGV 99011	ICGMS 42 × (*A. hypogaea* × *A. cardinasii*)	VB	5.0	3.0
ICGV 99012	ICGMS 42 × (*A. hypogaea* × *A. cardinasii*)	VB	3.0	6.0
ICGV 99013	*A. hypogaea* × *A. cardenasii*	SB	3.5	3.5
ICGV 99014	*A. hypogaea* × *A. cardenasii*	SB	4.0	4.0
ICGV 99015	TMV 2 × *A. hypogaea* × (*A. batizocoii* × *A. duranensis*)	VB	3.0	4.5
TMV 2	–	SB	9.0	9.0

VB = Virginia bunch, *A. hypogaea* subsp *hypogaea*; SB = Spanish bunch, *A. hypogaea* subsp *fastigiata*.
[1] Average of two rainy season evaluations (non replicated) under field conditions following an infector-row technique. Scored on a 1–9 scale where 1 = no disease and 9 = 81 to 100% disease severity.

23 °C to ensure wetness of the leaf surface during the night. The pots were removed from the dew chambers on the morning of the following day and returned to the greenhouse to maintain a dry period during the day. This alternate wet (16 h) and dry (8 h) period treatments (Butler et al., 1994) were repeated for 10 days. The pots were then kept permanently in the greenhouse till the completion of the experiment. The experiments were terminated at 45 days after inoculation (DAI) as the leaves of many genotypes were completely defoliated due to LLS.

Two undamaged fully expanded quadrifoliate leaves of the main axis of two plants per pot were tagged for each genotype to study the components of resistance to LLS. Observations on incubation (defined as days from inoculation to appearance of the first symptom) and latent (defined as days from inoculation to appearance of the sporulating lesion) periods, lesions per leaf (on 20 DAI), lesion diameter (mm) (on 35 DAI), sporulation index (defined as intensity of sporulation) (on 35 DAI), percentage leaf area damaged (on 20 DAI), percentage leaf defoliation (on 45 DAI), and disease score (on 45 DAI) due to LLS were recorded. Incubation and latent periods were observed everyday beginning 6 DAI. These measurements were taken on whole plants for all the leaves. Latent period was identified by observing the leaves every day with the aid of 20 × magnifying lense. Lesions per leaf, percentage leaf area damaged, and percentage leaf defoliation were recorded only on the tagged leaves. Lesion diameter and sporulation index were recorded on non-tagged leaves. Ten random lesions on two leaflets per replication were selected to measure lesion diameter and estimate sporulation index. Lesion diameter was measured by using a measuring scale. For sporulation index, the leaf with lesions was kept in the moist chamber (9 cm diameter petri dish with moist filter paper) and incubated at 25 °C with 12 h light and 12 h dark periods for 72 h to enhance sporulation. Sporulation index was recorded using Stereobinocular, on 1 to 9 scale, where 1 = no sporulation and 9 = dense sporulation (91–100% lesion area covered with fascicles with conidia). The percentage leaf area damaged was assessed by comparing the leaves with diagrams depicting leaves with known percentage of their areas affected (Hassan & Beute, 1977). Percent leaf defoliation and disease scores were recorded between 20 to 45 DAI at 5 day intervals. The number of defoliated leaflets of the tagged leaves of both plants were counted at each assessment and percent defoliation was calculated based on the total number of leaves and number of leaves defoliated.

Table 2. Mean incubation and latent periods, lesion per leaf, lesion diameter, sporulation index, % leaf area damage, % leaf defoliation, and disease score due to late leaf spot in groundnuts

Genotype	Incubation period (in days)	Latent period		Lesion per leaf (20 DAI)[1]	Lesion diameter (35 DAI)	Sporulation index (35 DAI)	% leaf area damage (20 DAI)	% leaf defoliation (45 DAI)	Disease score[2] (45 DAI)
		1st lesion sporulated (in days)	50% lesions sporulated						
ICGV 99001	9.50	25.92	30.50	115.59	2.483	1.833	1.960 (7.342)[3]	66.81 (77.62)[3]	5.75
ICGV 99002	11.08	17.33	25.33	65.88	1.983	1.567	0.907 (3.217)	86.55 (97.92)	7.25
ICGV 99003	11.25	27.17	20.00	52.70	2.667	3.383	1.705 (9.325)	63.75 (76.57)	5.87
ICGV 99004	10.00	15.92	20.92	83.25	2.800	2.583	1.668 (6.408)	54.91 (61.99)	6.04
ICGV 99005	10.92	22.92	30.50	91.64	1.908	1.350	0.616 (2.475)	86.55 (97.92)	5.71
ICGV 99006	9.58	20.33	24.83	59.43	1.658	1.533	0.295 (1.683)	30.71 (27.62)	5.50
ICGV 99007	9.00	19.42	27.83	69.22	2.433	1.567	1.837 (6.442)	80.00 (91.67)	6.33
ICGV 99008	9.00	14.33	21.92	66.60	3.700	3.200	2.554 (13.225)	86.55 (97.92)	7.33
ICGV 99009	10.00	21.92	30.58	72.28	2.325	1.650	1.565 (10.175)	71.70 (86.99)	6.25
ICGV 99010	11.00	28.33	35.83	49.53	1.158	1.400	1.131 (4.400)	65.37 (77.58)	6.42
ICGV 99011	10.00	20.67	28.25	62.11	2.017	1.000	1.732 (6.175)	79.01 (91.08)	6.50
ICGV 99012	10.25	28.92	19.83	23.64	2.200	1.933	1.867 (9.033)	86.55 (97.92)	7.08
ICGV 99013	8.92	23.92	30.83	97.76	1.542	1.283	0.882 (2.925)	61.51 (72.92)	5.38
ICGV 99014	8.42	14.50	20.17	142.07	4.175	7.100	2.880 (18.417)	86.55 (97.92)	7.67
ICGV 99015	10.08	23.58	29.33	98.37	2.025	1.500	0.701 (2.750)	77.65 (92.13)	6.12
TMV 2	8.00	13.17	19.67	244.39	6.617	8.033	3.631 (39.050)	90.00 (100.00)	8.50
LSD (5%)	0.647	1.117	1.404	34.318	0.774	0.7005	0.7130	16.879	0.624

[1] Days after inoculation (DAI).
[2] 1 = No disease and 9 = 81–100% leaf area damaged by LLS.
[3] Figures in the parentheses are nontransformed values. Log transformation for % leaf area damaged and angular transformation for % leaf defoliation were adopted.

Components of resistance to rust

Two experiments were conducted with 14 interspecific derivatives and TMV 2 in greenhouse conditions. Both experiments were conducted in RCBD with three replications. All the experimental protocols were the same as for LLS except that the plants were inoculated uniformly with rust inoculum, containing 20.000 uredospore ml^{-1}. Observation on incubation and latent periods, pustules per leaf (on 20 DAI), pustule diameter (mm) (on 35 DAI), sporulation index (on 35 DAI), percentage leaf area damaged (on 45 DAI), and disease scores (on 45 DAI) due to rust were recorded. Sporulation index was recorded on a 1 to 9 scale where 1 = no sporulation and 9 = dense sporulation (91–100% of the uredium full with urediniospores and ruptured). The experiments were terminated at 45 DAI as the leaves of many genotypes were completely weathered due to rust.

Statistical analysis

Plot means were used for statistical analysis. Rust data were analysed using ANOVA. The LLS data, due to unequal replications in two experiments, were analysed using residual maximum Likelihood (REML) method (Thomson & Welham, 1993). Appropriate transformation, where necessary, was applied to data to meet the assumption of ANOVA and REML. Phenotypic and genotypic correlations among components of resistance to LLS and rust were determined following the method of Falconer (1981).

Results and discussion

Genotypic differences were significant ($p < 0.01$) for all the components of resistance to LLS and rust. For LLS, experiment (E) × genotype (G) interaction was significant for incubation and latent periods, lesion diameter, sporulation index, and percentage leaf area damaged. For rust, E × G interaction was significant

Table 3. Mean incubation and latent periods, pustule per leaf, pustule diameter, sporulation index,% leaf area damage, and disease score due to rust in groundnuts

Genotype	Incubation period (in days)	Latent period 1st postules sporulated (in days)	50% postules sporulated	Pustule per leaf (20 DAI)[1]	Pustule diameter (35 DAI)	Sporulation index (35 DAI)	% leaf area damage (45 DAI)	Disease score[2] (45 DAI)
ICGV 99001	9.67	12.83	1.14 (17.33)[3]	4.64 (112.40)[3]	0.95	8.13	2.93 (8.85)[3]	5.50
ICGV 99002	12.50	23.17	1.38 (0.00)	4.14 (66.30)	0.61	1.62	1.93 (3.75)	4.17
ICGV 99003	10.50	14.50	1.19 (0.00)	4.01 (64.90)	0.55	1.13	1.73 (3.19)	3.33
ICGV 99004	10.50	12.50	1.13 (18.00)	5.02 (162.90)	0.98	8.48	4.60 (21.98)	6.17
ICGV 99005	12.33	23.33	1.38 (0.00)	2.34 (11.30)	0.50	1.57	1.17 (1.43)	2.33
ICGV 99006	9.67	12.83	1.14 (16.00)	4.91 (145.80)	0.93	6.97	3.79 (15.17)	5.50
ICGV 99007	12.33	16.17	1.24 (26.33)	4.48 (91.70)	0.74	2.23	1.99 (4.05)	4.83
ICGV 99009	12.67	20.67	1.34 (0.00)	3.70 (40.70)	0.56	1.05	2.01 (4.10)	4.50
ICGV 99010	9.50	12.33	1.12 (16.83)	4.93 (151.20)	1.00	8.80	5.34 (28.73)	6.50
ICGV 99011	11.83	17.67	1.27 (35.17)	3.53 (37.70)	0.77	2.83	2.10 (4.68)	3.83
ICGV 99012	12.67	20.00	1.32 (0.00)	3.30 (34.10)	0.59	1.27	1.42 (2.17)	3.33
ICGV 99013	9.67	12.33	1.12 (17.33)	4.14 (79.10)	0.97	8.83	2.59 (7.63)	5.33
ICGV 99014	9.67	12.17	1.12 (16.83)	4.63 (128.60)	0.97	8.83	3.12 (11.68)	6.67
ICGV 99015	12.67	19.83	1.32 (0.00)	3.71 (44.20)	0.55	1.15	1.61 (2.62)	3.33
TMV 2	7.00	9.83	1.03 (14.00)	5.29 (204.90)	0.98	9.00	7.10 (50.73)	8.17
LSD (5%)	0.546	0.942	0.021	0.524		0.084	0.753	0.718 0.593

[1] Days after inoculation (DAI).
[2] 1 = No disease and 9 = 81–100% leaf area damaged by rust.
[3] Figures in the parentheses are nontransformed values. Log transformation for % leaf area damaged and angular transformation for % leaf defoliation were adopted.

Table 4. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between incubation period, latent period, lesion per leaf, lesion diameter, sporulation index, % leaf area damage, % leaf defoliation, and disease score due to late leaf spot in groundnut

	Incubation period	Latent period (1st lesion sporulated)	Latent period (50% lesion sporulated)	Lesion per leaf	Lesion diameter	Sporulation index	Leaf area damage (%) (%)	Defoliation (%)	Disease score
Incubation period	–	–0.616	0.554	–0.691	–0.667	–0.578	–0.669	–0.035	–0.439
Latent period (1st lesion sporulated)	0.470**	–	0.748	–0.582	–0.690	–0.580	–0.586	–0.155	–0.618
Latent period (50% lesion sporulated)	0.021	0.399**	–	–0.412	–0.818	–0.811	–0.684	–0.107	–0.701
Lesion per leaf	–0.391**	–0.469**	–0.167	–	0.83	0.781	0.891	0.245	0.606
Lesion diameter	–0.516**	–0.570**	–0.287	0.674**	–	0.923	0.999	0.402	0.862
Sporulation index	–0.476**	–0.520**	–0.210	0.649**	0.844**	–	0.952	0.284	0.801
Leaf area damage (%)	–0.363*	–0.481**	–0.415**	0.666**	0.768**	0.731**	–	0.382	0.898
Defoliation (%)	–0.030	–0.095	–0.034	0.235	0.262	0.203	0.322*	–	0.602
Disease score	–0.341*	–0.458**	–0.284	0.415**	0.549**	0.523**	0.591**	0.530**	–

*, ** = Significant 0.05 and 0.01 probability levels, respectively.

Table 5. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between incubation period, latent period, pustule per leaf, pustule diameter, sporulation index, % leaf area damage and disease score due to rust in groundnut

	Incubation period	Latent period (1st lesion sporulated)	Latent period (50% lesion sporulated)	Postule per leaf	Pustule diameter	Sporulation index	Leaf area damage (%) (%)	Disease score
Incubation period	–	0.911	–0.365	–0.871	–0.841	–0.874	–0.832	–0.849
Latent period (1st lesion sporulated)	0.833**	–	–0.563	–0.856	–0.903	–0.873	–0.684	–0.842
Latent period (50% lesion sporulated)	–0.336*	–0.542**	–	0.418	0.694	0.522	0.277	0.497
Pustule per leaf	–0.619**	–0.650**	0.326*	–	0.846	0.803	0.908	0.910
Pustule diameter	–0.707**	–0.818**	0.644**	0.629**	–	0.981	0.682	0.913
Sporulation index	–0.800**	–0.840**	0.505**	0.615**	0.903**	–	0.697	0.880
Leaf area damage (%)	–0.707**	–0.613**	0.265*	0.805**	0.584**	0.621**	–	0.930
Disease score	–0.761**	–0.772**	0.463**	0.762**	0.803**	0.820**	0.793**	–

*, ** = Significant 0.05 and 0.01 probability levels, respectively.

for latent period, pustules per leaf, and percentage leaf area damaged.

Late leaf spot

All interspecific derivatives recorded longer incubation period (except for ICGV 99014), longer latent period when first lesion sporulated, longer latent period when 50% lesions sporulated (except for ICGV# 99003, 99004, 99012, and 99014), lesser lesions per leaf, smaller lesion diameter, lower sporulation index, lesser percentage leaf area damaged, and lower disease scores than TMV 2 (Table 2). In spite of their superiority in other components of resistance, many interspecific derivatives (ICGV# 99002, 99005, 99007, 99008, 99011, 99012, 99014, and 99015) had similar percent defoliation as that of TMV 2. Except for percentage leaf area damaged, percentage defoliation was not correlated with other components of resistance (Table 4). However, it is the percentage defoliation which has a most direct bearing on photosynthesis in a plant. On the other hand, percentage defoliation had a highly significant positive association with field disease score. The latter was highly significantly associated (positively or negatively) with all other components of resistance except for latent period when 50% lesions sporulated. This indicates that percentage defoliation under artificial inoculation may be influenced by factors other than components of resistance. Some genotypes, particularly in interspecific derivatives, have high sensitivity to LLS. Even a few lesions on a leaflet would cause it to defoliate. Latent period when 50% lesions sporulated was associated only with latent period at first lesion sporulation and percentage leaf area damaged. It had no association with percentage defoliation. It does not appear to be a useful characteristic.

The differences between minimum and maximum values of different components of resistance in interspecific genotypes varied from 1.34 times for incubation period to 9.76 times for percentage leaf area damaged (Table 2). An analysis of interspecific derivatives falling in the first significant group of the components of resistance in desirable direction brings out an interesting picture. ICGV 99010 appeared in the first significant group for six components of resistance and ICGV# 99005 and 99006 for five components each. But it was only ICGV 99006 which had the lowest leaf area damage and percent leaf defoliation, and a low disease score. The lowest disease score was observed in ICGV 99013 which had smaller lesion diameter, and lower sporulation index and leaf area damage. It appears that an optimum balance of various components of resistance is required to have a low disease score. The disease score, which is primarily based on percentage defoliation, integrates all components of resistance and their optimum combination brings out the lower score. This has significant implication in a breeding program. The choice of the parents will still be guided by the desirable direction of components of resistance. The best genotypes for different resistance components should be intercrossed to generate progenies with higher resistance. Selection in the segregating generations, however, should be based on percentage defoliation in the field.

Rust

Most of the interspecific derivatives had longer incubation period, longer latent period when first pustule and 50% pustules sporulated, fewer pustules per leaf, smaller pustule diameter, smaller sporulation index, lesser percentage leaf area damaged, and lesser disease score than TMV 2 (Table 3). In the case of rust, all the components of resistance were correlated (positively or negatively) with each other and also with disease score (Table 5). Unlike LLS, the rust does not cause defoliation. The difference between minimum and maximum values of different components of resistance in interspecific derivatives varied from 1.23 times for latent period when 50% pustules sporulated to 8.4 times for sporulation index (Table 3). ICGV 99005 had the lowest disease score (2.33) and it was significantly superior to the remaining interspecific derivatives. It appeared in the first significant group for seven components of resistance. In the next group, ICGV# 99003, 99012, and 99015 were included and they all had a score of 3.33.They were included in the first significant group of either three or four components of resistance. Incubation period was the most frequent component of resistance involved in resistant genotypes. It was followed by pustule diameter, sporulation index, and percentage leaf area damaged. Unlike LLS, in the case of rust various components of resistance appear to work additively. Therefore in a breeding program, not only the use of parents with desirable components of resistance but also selection for them in the segregating generations should lead to the plants with low field disease scores.

Selection based on components of resistance together with green leaf area retained on the plant should be the strategy to select for high degree of resistance to rust. The remaining green leaf area on the plant should be the major selection criteria for resistance to LLS. ICGV# 99005, 99003, 99012, and 99015 for rust and ICGV# 99006, 99013, 99004, 99003, and 99001 for LLS are better parents for use in resistance breeding programs.

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