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Resistance in groundnut to *Sclerotium rolfsii*-caused stem and pod rot†

(*Keywords: Arachis hypogaea*, resistance, *Sclerotium rolfsii*, India)

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Abstract. Eight hundred and fifty-nine groundnut germplasm accessions and breeding lines were screened in field trials for resistance to stem and pod rot caused by *Sclerotium rolfsii* during the 1985–88 post-rainy seasons at the ICRISAT Asia Center, Patancheru, India. Lines that showed low susceptibility to stem and pod rot (< 10%) were further evaluated at the Marathwada Agricultural University farm, Parbhani, India, during 1987–91 in the rainy and summer seasons. Of the 20 selected genotypes seven interspecific hybrid derivatives (326, 988, 1019, 1024, 1065, 1267, and 1364) consistently exhibited stable resistance to both stem and pod rot. Nine breeding lines (ICGV 86034, 86124, 86252, 86388, 86590, 86606, 86635, 87160, and 87359) showed low susceptibility to stem and/or pod rot. Effective screening for stem and pod rot resistance was possible in the post-rainy and summer seasons. Several lines with low susceptibility to *S. rolfsii* also possess resistance to rust (*Puccinia arachidis*) and moderate resistance/tolerance to late leaf spot (*Phaeoisariopsis personata*). Useful features of these lines are discussed.

1. Introduction

Stem and pod rots of groundnut (*Arachis hypogaea* L.) caused by *Sclerotium rolfsii* Sacc. commonly occur in many groundnut-growing areas of the world, and are reported to cause extensive damage in the USA and in parts of India, China, Taiwan, Indonesia, Thailand, and the Philippines (Porter *et al.*, 1982). Yield losses usually range from 10 to 25%, but may reach 80% in severely infested fields (Mayee and Datar, 1988; Bowen *et al.*, 1992). Irrigated groundnuts grown in the post-rainy (post-monsoon, lasting from November to March) or summer (hot, dry season lasting from January to May) seasons in India are often attacked by the pathogen. We found these diseases severely affected groundnuts grown in Vertisol fields at the ICRISAT Asia Center during post-rainy seasons. High incidences of stem and pod rot were observed in the 1983/84 and subsequent post-rainy seasons' irrigated groundnut crop at ICRISAT Asia Center and in farmers' fields in Maharashtra State, India (Asghari and Mayee, 1991).

The persistence of the pathogen in soil, and its wide host range often limit the effectiveness of chemical and cultural control practices that can provide only partial control of stem and pod rot (Hagan *et al.*, 1986; Shew *et al.*, 1987). Control with fungicides/insecticides has proved to be inconsistent, and costs may be prohibitive (Csinos, 1984; Hagan *et al.*, 1986). There are only a few reports of significant varietal differences in resistance to stem rot and practically no reports of resistance to *S. rolfsii*-caused pod rot. Only limited germplasm screening has been attempted to find resistance to these diseases (Garren, 1964; Muheet *et al.*, 1975; Branch and Csinos, 1987; Shew *et al.*, 1987). Some varieties with moderate resistance to stem rot have been bred and are grown by farmers in the USA (Branch and Csinos, 1987; Shew *et al.*, 1987; Branch and Brenneman, 1993). The use of resistant varieties is a practical approach to the control of these diseases for small-scale farmers of the semi-arid tropics. This paper reports field screening in India of groundnut germplasm accessions and breeding lines for resistance to *S. rolfsii* stem and pod rot.

2. Materials and methods

Preliminary screening trials were conducted at the ICRISAT Asia Center (17° 3'N lat.; 78° 16'E long.), Patancheru, India. Advanced screening trials were carried out at ICRISAT Asia Center and at the Marathwada Agricultural University farm, Parbhani (19° 08'N lat.; 76° 50'E long.), India.

2.1. *Production of inoculum*

Two highly virulent isolates (SR4 and SR5) of *S. rolfsii* isolated from diseased groundnut cultivar JL 24, grown on a Vertisol field at ICRISAT Asia Center in 1985, were selected for inoculum production. To raise mass inoculum, the isolates were grown separately on rehydrated, autoclaved groundnut shells (cv. TMV 2; partially broken, dry shells rehydrated to around 15% moisture content by soaking for a few hours in water) in autoclavable polyethylene bags at 28 ± 2°C for 15–17 days. The isolates produced profuse mycelial growth and substantial sclerotia on the rehydrated groundnut shells. Inoculum (mycelium and sclerotia) of the two isolates was mixed in equal proportions.

2.2. *Application of inoculum*

To enhance the inoculum potential of *S. rolfsii*, mixed inoculum of the two isolates was applied to the soil surface around the base of groundnut plants at approximately 200 g per 4-m row, 50–60 days after sowing. Sorghum stubble (3–4 cm pieces) was also scattered along the rows to enhance fungal growth. Immediately after soil inoculation, perfo irrigation (irrigation through perforated pipes) was given for half an hour to create moist conditions conducive to fungal growth and infection.

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Table 1. Distribution of groundnut genotypes in four arbitrary categories of percentage stem and pod rot caused by Sclerotium rolfsii

Year/ season	Number of genotypes tested	Pod rot (%)	Stem rot (%)			
			1–10	11–30	31–50	> 50
ICRISAT Asia Center						
1985/86	309	1–10	2	3	2	1
post-rainy		11–30	5	26	134	91
		31–50	0	4	16	25
		> 50	0	0	0	0
1986/87	450	1–10	14	8	2	0
post-rainy		11–30	0	27	121	23
		31–50	0	1	104	114
		> 50	0	0	2	34
1987/88	100	1–10	12	15	2	0
post-rainy		11–30	8	26	18	2
		31–50	0	7	6	4
		> 50	0	0	0	0
	64	1–10	9	16	11	6
		11–30	2	1	12	7
		31–50	0	0	0	0
		> 50	0	0	0	0
Parbhani						
1987	100	1–10	18	20	6	1
rainy		11–30	2	21	18	2
		31–50	0	3	6	3
		> 50	0	0	0	0
1988[a]	64	1–10	–	–	–	–
rainy		11–30	–	–	–	–
		31–50	–	–	–	–
		> 50	–	–	–	–

[a]Data from the 1988 rainy season are not indicated as the levels of stem rot were too low even in the susceptible check cultivars. The trial in the 1988 rainy season was conducted both at ICRISAT Asia Center and at Parbhani. Data from the 1989 rainy season are also not shown as the levels of stem and pod rot were low.

2.3. *Assessment of stem and pod rot*

Stem rot incidence was assessed both 15 days before harvest and at harvest itself by counting dead or wilted plants showing *S. rolfsii* sclerotia and/or mycelial growth. The percentage stem rot incidence in each plot was computed.

All genotypes were harvested at maturity, and pods from all plants in each plot were scored for incidence and severity of pod rot. Incidence was measured as the proportion of rotted to healthy pods, and expressed as a percentage. Disease severity was scored as slight (< 25% surface area of pods damaged), moderate (26–50% surface area of pods damaged) or severe (51–100% surface area of pods damaged). Slightly damaged pods were excluded, as there was difficulty in relating this damage exclusively to *S. rolfsii*, therefore only moderately and severely damaged pods were used to calculate percentage pod rot incidence.

2.4. *Preliminary screening*

Screening of groundnut germplasm accessions and breeding lines for resistance to stem rot and pod rot was started in the 1984/85 post-rainy season (November–April) and continued in the subsequent rainy (1985) and post-rainy seasons (1985/86, 1986/87, and 1987/88). In the 1984/85 post-rainy and the 1985 rainy seasons, 198 lines (including 64 breeding lines and 134 rust and/or late leaf spot resistant interspecific hybrid derivatives) were screened for stem and pod rot incidence.

From 1985/86 onwards replicated trials were carried out in Vertisol fields using triple lattice designs or complete randomized block designs with three replications; trials were carried out in different fields with previous histories of high stem and pod rot incidence. The crops were grown on raised beds. Superphosphate (60 kg P_2O_5 ha^{-1}) was applied once during land preparation. No fungicides or insecticides were applied to the trial plots. Plots were 4-m long × 30-cm wide. One row of seeds was sown in each plot at 10-cm spacing. Plots of a highly susceptible check cultivar, Kadiri 3 or Gangapuri, were sown after every 10 plots of test genotypes. The trials were irrigated, using the perfo irrigation system (see above) to promote stem rot development. Water was applied to field capacity at 10-day intervals until pegging, when the interval was reduced to 7 days. From 80 days after sowing the irrigation interval was increased to 15 days to reduce soil moisture levels and improve aeration in the pod zone, and encourage the development of pod rot disease.

Details of seasons, and number of genotypes tested in replicated trials each season are given in Table 1.

2.5. *Advanced screening*

Advanced screening trials were carried out at Parbhani in the 1987, 1988, and 1989 rainy seasons (July–November) and 1990 and 1991 summer seasons (January–May). The trials were conducted in different fields on a medium black soil with a known history of stem and pod rot problems, and crops were grown on the flat. Single superphosphate (40 kg P_2O_5 ha^{-1}) was applied at land preparation. Soil inoculations and disease assessments were performed as described for ICRISAT Asia Center. Genotypes were grown in replicated plots of two rows 30-cm apart and 4-m long, with seeds sown singly at 10-cm spacing along the rows. Plots of highly susceptible check cultivars Kadiri 3 and Gangapuri were sown after every eight or five plots of test genotypes. Timings of irrigation were also the same as described for preliminary screening, except that flood irrigation was used. In the 1987 rainy season 100 genotypes were screened; in the 1988 and 1989 rainy seasons 64 genotypes were evaluated. Triple lattice designs were used for these trials. Twenty selected genotypes were further evaluated in complete randomized block designs in the 1990 and 1991 summer seasons.

3. Results

All 64 breeding lines evaluated in the 1984/85 post-rainy season at ICRISAT were susceptible to stem and pod rot. Of 134 interspecific hybrid derivatives screened in the 1985 rainy season, nine lines showed less susceptibility to stem and pod rot than the controls.

In the 1985/86 and 1986/87 post-rainy seasons, the test lines had stem rot levels ranging from 3·4 to 47·8% and 1 to 68%, and pod rot levels from 7·2 to 81·4% and 2 to 78%, respectively. The ranges of stem rot and pod rot incidences in the susceptible check cultivar Kadiri 3 were 27–50% and 46–85%.

Genotypes were placed in four arbitrarily fixed categories of stem and pod rot levels (Table 1). Two lines (799 and 820/1) in the 1985/86 post-rainy season, and 14 lines [two breeding lines (ICGV 87359 and ICGV 87180) and 12 interspecific hybrid derivatives (326, 820/1, 988, 1019, 1024, 1065, 1072, 1084-2, 1267, 1269, 1364, and 1747)] in the 1986/87 season showed low ($\leq$ 10%) susceptibility to stem and pod rot. Seven of these lines (799, 1019, 1024, 1072, 1267, 1364, and 820/1) had also shown low susceptibility in the 1984/85 post-rainy season. Two lines (1268 and 83/151-146) earlier selected from the 1985 rainy season showed susceptibility to both stem and pod rot in the 1986/87 post-rainy season.

Of the 759 lines screened in the 1985/86 and 1986/87 post-rainy seasons, 16 genotypes exhibited < 10% stem and pod rot (Table 1).

In the 1987 rainy season screening trial at Parbhani, the incidence of stem rot ranged from 1 to 46%, and of pod rot from 3 to 71% in the genotypes tested. The susceptible check cultivars, Kadiri 3 had 40% stem and 44% pod rot, and Gangapuri had 58% stem and 59% pod rot. Of the 100 genotypes screened, 18 lines showed < 10% stem and pod rots.

In the 1987/88 post-rainy season, 17 of the 164 genotypes screened showed < 10% stem and pod rots. These were: ICGVs 87176, 87184, 87351, 86606, 86388, 86422, 86124, 87264, 86635, 86590, 86699, 86034, 86022, and 86600, 144, 246-1, and 1093-2. Fourteen lines previously showing resistance (< 10% stem and pod rot) in the 1986/87 post-rainy season again exhibited low levels of stem rot (4·1–11·7%) and pod rot (1–12%). The incidence of stem rot ranged from 1 to 46%, and of pod rot from 1 to 64% in the genotypes tested. The mean stem rot and pod rot levels in the two susceptible check cultivars were Kadiri 3 18% and 56%, and Gangapuri 26% and 63%.

In the 1988 rainy season stem and pod rot levels were too low to permit effective screening. This was attributed to waterlogging caused by excessive rainfall (1650 mm) at both ICRISAT and Parbhani. In the 1989 rainy season at Parbhani, incidence of stem rot ranged from 0·5 to 19%, and of pod rot from 0·2 to 15% in the genotypes tested. The disease incidences were generally low in the susceptible check cultivars and much lower in the selected lines (0·2–3·9% stem rot; 0·2–7·7% pod rot).

Levels of stem rot and pod rot in 20 selected genotypes tested in the 1990 and 1991 summer seasons are given in Table 2. This table also presents the levels of stem and pod rot of some of these genotypes evaluated in earlier seasons. Significant differences occurred between genotypes for both stem rot and pod rot in both summer seasons. The lines 326, 1019, 1024, 1065, 1267, and 1364 consistently showed low incidence of stem and pod rot across seasons (Table 2), the best lines being 1364, 1019, and 1065. The breeding lines (ICGV 87359 and ICGV 86606) that had shown low incidence of stem and pod rot in post-rainy seasons were moderately resistant in summer season trials. The breeding line ICGV 86590 showed lower incidences of stem and pod rot than other breeding lines. Pod rot incidence was slightly higher in all the genotypes tested in the 1991 summer season as compared with post-rainy seasons. The susceptible check cultivars consistently exhibited more than 45% stem and pod rot across the seasons.

4. Discussion

The present studies clearly demonstrated genotypic differences in crop susceptibility to stem and pod rot. These results support the earlier findings of significant genotypic differences in susceptibility to stem rot in limited screening of cultivars and breeding lines in the USA and India (Muheet *et al.*, 1975; Branch and Csinos, 1987; Shew *et al.*, 1987; Brenneman *et al.*, 1990). It is noteworthy that in the present studies several interspecific hybrid derivatives (1019, 1024, 1065, 1267, and 1364) consistently showed low incidence of both stem and pod rot over seasons and locations. Clear genotypic differences in susceptibility to stem rot have been reported in some other studies (Branch and Csinos, 1987; Shew *et al.*, 1987; Smith *et al.*, 1989). However, few studies have highlighted resistance to both stem and pod rot caused by *S. rolfsii*. Some workers have reported resistance to *P. myriotylum*-caused pod rot in some stem rot-resistant lines (Smith *et al.*, 1989; Grichar and Smith, 1992). Resistances to both stem and pod rot diseases caused by *S. rolfsii* are important as both types of diseases often occur, and this is particularly true of crops grown in Vertisols in India. The interspecific hybrid derivative

Table 2. Incidence of stem rot (SR) and pod rot (PR) in selected groundnut genotypes in different seasons and locations

Genotype ICGV Number[a]	Other identity	ICRISAT Asia Center Post-rainy seasons 1986/87 %SR[b]	1986/87 %PR[c]	1987/88 %SR	1987/88 %PR	Parbhani Rainy season 1987 %SR	1987 %PR	Summer seasons 1990 %SR	1990 %PR	1991 %SR	1991 %PR
—	326	11	16	22	13	16	16	15	16	14	16
—	988	—	—	—	—	11	20	18	16	16	17
—	1019	11	9	16	13	11	13	16	17	11	17
—	1024	17	20	12	9	15	18	17	15	14	16
—	1065	8	13	12	12	9	16	16	17	17	15
—	1084-2	6	11	26	15	25	15	20	17	12	18
—	1267	16	11	18	13	16	14	12	14	14	17
—	1364	13	6	11	9	11	9	17	18	14	15
86022	ICG (FDRS) 36	21	25	11	16	20	22	24	20	24	26
86029	—	24	24	12	18	20	23	21	22	19	28
86034	—	—	—	6	15	16	20	20	23	21	22
86124	—	—	—	17	17	—	—	23	27	19	26
86252	—	—	—	12	21	13	16	30	26	24	27
86388	—	—	—	11	15	12	15	26	24	20	27
86590	ICG (FDRS) 246	—	—	6	12	20	25	17	21	20	23
86606	ICG (FDRS) 68	—	—	16	12	16	18	19	20	19	29
86635	ICG (FDRS) 55	—	—	11	18	15	19	20	23	19	24
87160	ICG (FDRS) 10	—	—	19	16	21	23	25	23	17	21
87264	ICG (FDRS) 149	—	—	8	16	20	19	22	23	18	26
87359	ICG (FDRS) 65	16	11	16	17	12	17	25	26	19	25
Susceptible checks											
Kadiri 3		49	57	31	49	40	48	50	41	43	44
Gangapuri		40	50	29	54	41	50	52	49	49	43
SE ±						2·57	2·99	2·63	2·48	1·52	1·61
CV (%)						24·30	24·80	19·80	18·90	13·1	11·8

[a]ICRISAT Groundnut Variety Number.
[b]%SR = % stem rot; [c]%PR = % pod rot; values of percent stem rot and pod rot are arc sine transformations.

lines found with resistance to both diseases in the trials at ICRISAT Asia Center and Parbhani are late-maturing, semi-spreading Virginia bunch types with low yield potential. However, they have the advantage of possessing resistance to rust and late leaf spot diseases. They should be valuable for use in breeding programmes to develop agronomically-acceptable varieties with multiple disease resistance. Most of these lines appear to have non-succulent stems, and smooth and hard pod shells, indicating that these morphological characters of stem and pod are probably associated with resistance. It would be useful to study the static defence mechanism of resistance to *S. rolfsii* in groundnut.

In general, bunch-type groundnut lines (Spanish and Valencia types) tended to show more susceptibility than Virginia bunch and runner types. Most of the Spanish and Valencia genotypes tested had a high percentage of both stem and pod rots. These observations support the findings of previous studies (Cooper, 1961; Grichar and Smith, 1992). However, two Spanish bunch lines (ICGV 87160 and ICGV 86590) showed moderate resistance to stem and pod rot. These varieties with resistance to rust and tolerance to late leaf spot have recently been released for cultivation in India and should prove useful where both foliar fungal diseases and *S. rolfsii* stem rot/pod rot are serious problems.

None of the lines tested was found to be completely resistant to stem or pod rot. It is unlikely that it will be possible to locate a very high degree of resistance to a highly necrotrophic pathogen such as *S. rolfsii*. It would be desirable to select or develop lines that possess moderate resistance to *S. rolfsii* and resistance to other economically important diseases of groundnut.

Variations in performance of genotypes against stem and pod rot were noted in different seasons, emphasizing the need to evaluate genotypes for stability of resistance over several seasons under high disease pressure. Screening for resistance to stem and pod rot was found to be successful in the post-rainy and summer seasons where high temperatures (30–38°C) during the crop season, particularly from pegging until harvest, favour *S. rolfsii* infection and disease development (Punja, 1985), and where soil moisture can be manipulated by irrigation. Continuous, heavy rainfall and associated relatively low temperatures (< 25°C) are not conducive to disease development, as was demonstrated in the 1988 rainy season trial.

The availability of partial genetic resistance to stem and pod rot, and of effective cultural measures such as crop rotation and deep ploughing, could provide a sound basis for integrated disease management. This may be further improved by the application of fungicides that are effective against both foliar fungal diseases and *S. rolfsii*.

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