Groundnut Rust Disease: Epidemiology and Control
P. Subrahmanyan and D. McDonald

Abstract

Research on rust disease of groundnut at ICRISAT Center from 1976 to 1984 is briefly reviewed. Spread of the disease in India is documented, and the role of continuous cultivation of groundnut in perpetuating the disease emphasized. Data on yield losses from rust are presented. Methods of screening germplasm and breeding lines for resistance to rust are described, and the identified sources of resistance are listed. Components of resistance to rust and their possible use in greenhouse evaluation of rust resistance are discussed. The results of multilocation testing of rust-resistant germplasm lines are considered. The effects of different agronomic systems on epidemics of rust are discussed.


The rust disease of groundnut (Arachis hypogaea L.) caused by Puccinia arachidica Specklini has increased in importance in recent years. Prior to 1969, the disease was largely confined to South and Central America, with occasional outbreaks occurring in the southernmost groundnut producing areas of the USA. The disease was also recorded in the USSR (Jaczewski 1910), Mauritius (Stockdale 1914), and the People's Republic of China (Tai 1937), but did not become permanently established in these countries (Bromfield 1971). In recent years groundnut rust has spread to, and became established in, many countries in Asia, Australasia, Oceania, and Africa (Hammons 1977, Subrahmanyan et al. 1979, and Subrahmanyan and McDonald 1983) (Fig. 1). Rust is now of economic importance in almost all groundnut-growing areas of the world.

Yield losses from rust are substantial, damage being particularly severe if the crop is also attacked by the two leaf-spot fungi (Cercospora arachidicola Hori and Phaeoisariopsis personata (Berk. & Curt.) v. Arx). Rust epidemics are regular and severe on susceptible groundnut genotypes at ICRISAT Center. This paper briefly reviews research on the disease carried out in the Groundnut Pathology Subprogram from 1976 to the present time.

Biology of Groundnut Rust

The life cycle and taxonomy of P. arachidica are described in detail by Hennen et al. (these Proceedings). Investigations were carried out on the biology of the rust disease.
of *P. arachidis* to determine what factors influenced its perpetuation and spread. Biological data were also needed for the development of resistance-screening methods. Laboratory experiments showed thaturediniospores could be stored for long periods at low temperatures without loss of viability, but that at high temperatures they lost viability within 5 days (Table 1). Temperatures in the range of 20-25°C were optimum for urediniospore germination (Fig. 2). Light

<table>
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<th>40</th>
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</table>

1. 1000 spores per sample. Figures to nearest whole number.

**Table 1. Effects of storage temperature on viability of urediniospores.**

Figure 3. Effect of light intensity on urediniospore germination. Arrow indicates germination percentage of the same spores in dark.

Table 2. Viability of urediniospores after various periods of exposure to weather on infected crop debris (from Subrahmanyan and McDonald 1982).

<table>
<thead>
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<td>74</td>
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<tr>
<td>26</td>
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1. 1000 spores per sample. Figures to nearest whole number.

**Table 2. Viability of urediniospores.**

(5000 lux and above) was found to inhibit urediniospore germination (Fig. 3). Urediniospores on exposed infected crop debris lost viability within 4 weeks under postharvest conditions at ICRISAT Center (Table 2). Pods and seeds from rust-affected crops are commonly surface-contaminated with urediniospores at harvest. Tests on urediniospores taken from surface-contaminated seeds stored at room temperature showed viability to decrease from an initial 95% to zero after 45 days. Incubation of two-day-old seedlings of a rust-susceptible cultivar grown in petri dishes showed that urediniospores

**Figure 1. Geographical distribution of *Puccinia arachidis*** (top) prior to 1969 (based on Commonwealth Mycological Institute map 16, issued 30 June 1966) and (bottom) in 1983 (based on Commonwealth Mycological Institute map 160, issued 1 Apr 1980).

**Figure 2. Effect of temperature on urediniospore germination.**

**Figure 3. Effect of light intensity on urediniospore germination.**

**Figure 1. Geographical distribution of *Puccinia arachidis*** (top) prior to 1969 (based on Commonwealth Mycological Institute map 16, issued 30 June 1966) and (bottom) in 1983 (based on Commonwealth Mycological Institute map 160, issued 1 Apr 1980).
would germinate on the surfaces of hypocotyls and cotyledons but no infection developed. Plants grown in sterilized soil from seeds heavily contaminated withuredinia spores, did not become infected with rust disease (Subrahmanyan and McDonald 1982).

There is no record of the occurrence of any collateral hosts of groundnut rust outside the genus Arachis. The possible occurrence of other hosts was considered, and various crop and weed plants growing in or near rust-affected groundnut crops on the ICRISAT farm and in farmers’ fields were examined for rust. Some were also inoculated with uredinia spores in the greenhouse. No infection was recorded on any of the plant species examined (Subrahmanyan and McDonald 1982).

The possible occurrence of other hosts was recorded for the resulting losses in crop yield. During the 1979, 1980, and 1981 rainy seasons, yield losses were estimated by applying selective fungicides on a wide range of susceptible and resistant genotypes; chlorbacanil to control both rust and leaf spots, carbendazim to control only leaf spots, and thiadiazol to control only rust. Loss estimates are presented in Table 3. In general, yield losses were less in the resistant than in the susceptible genotypes (Subrahmanyan et al. 1984).

Assessment of yield losses

Rust and leaf-spot diseases normally occur together and it is difficult to allocate individual responsibility for the resulting losses in crop yield. During the 1979, 1980, and 1981 rainy seasons, yield losses were estimated by applying selective fungicides on a wide range of susceptible and resistant genotypes; chlorbacanil to control both rust and leaf spots, carbendazim to control only leaf spots, and thiadiazol to control only rust. Loss estimates are presented in Table 3. In general, yield losses were less in the resistant than in the susceptible genotypes (Subrahmanyan et al. 1984).

Figure 5. Groundnut cropping seasons in India. Overlapping of these seasons helps to perpetuate rust disease attack.

P. arachidis is known almost exclusively by its uredinial stage. There are a few records of the occurrence of the telial stage on cultivated groundnut (Fig.4a) and on wild Arachis species (Hennen et al.—these Proceedings). Only the uredinial stage (Fig.4b) of the rust has been found despite constant examination of many groundnut germplasm lines and wild Arachis species at ICRISAT and of rust-infected groundnut plants from various parts of India. Attempts to induce telial formation by modification of environmental factors failed. It was concluded that uredinia spores were the main, if not the only, means of rust carry-over and dissemination in India. The practice of continuous cultivation of groundnut in southern India (Fig.5) appears to be an important factor in the perpetuation of groundnut rust in the country (Subrahmanyan and McDonald 1982, 1983).

Survey of groundnut rust in India

From 1971 to 1981 surveys were made in all major groundnut-growing states in India to obtain information on rust and other diseases of groundnut, and to assess their relative importance in different regions. Rust and late leaf spot were the most common and severe diseases in all major groundnut-growing areas of India. Rust was particularly serious in Tamil Nadu, Andhra Pradesh, Karnataka, and Maharashtra States, probably because of extensive and continuous cropping (Subrahmanyan et al. 1979). During the disease survey in Gujarat State in the 1977 rainy season, rust was not observed in the main groundnut-growing tract (Sourashtra region), but a survey in the 1976 rainy season showed rust to be present and causing serious damage to groundnut crops throughout the state. Rust is now a well established and destructive disease of groundnut in all major groundnut-growing states in India.

Figure 4. (a) Teliospores (~ 800) and (b) Uredinia spores (~ 800) of Puccinia arachidis.

Table 3. Yield losses from rust and leaf spots, ICRISAT Center, rainy seasons, 1979, 1980, and 1981.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Rust</th>
<th>Leaf spots</th>
<th>Rust and leaf spots</th>
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<td>55</td>
<td>68</td>
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<td>40</td>
<td>37</td>
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<td>PI 2597475</td>
<td>31</td>
<td>27</td>
<td>29</td>
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<td>EC 764462925</td>
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<td>17</td>
</tr>
<tr>
<td>NC 170905</td>
<td>6</td>
<td>13</td>
<td>26</td>
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</table>

2. Standard susceptible cultivars.
3. Resistant genotypes.

Assessment of yield losses

Rust and leaf-spot diseases normally occur together and it is difficult to allocate individual responsibility for the resulting losses in crop yield. During the 1979, 1980, and 1981 rainy seasons, yield losses were estimated by applying selective fungicides on a wide range of susceptible and resistant genotypes; chlorbacanil to control both rust and leaf spots, carbendazim to control only leaf spots, and thiadiazol to control only rust. Loss estimates are presented in Table 3. In general, yield losses were less in the resistant than in the susceptible genotypes (Subrahmanyan et al. 1984).

Resistance to groundnut rust

Screening of germplasm

Screening of the world collection of groundnut germplasm for resistance to rust was started at ICRISAT Center in the 1977 rainy season, and a total of 8000 genotypes were screened in the period 1977-83.

Preliminary screening was done on germplasm multiplication material in the rainy seasons. Genotypes were grown in unreplicated, single-row plots. Rows of the cultivars TMV 2 and Robust 33-1, known to be highly susceptible to groundnut rust, were arranged throughout the germplasm fields with 1 to every 10 test genotypes. One week before harvest each genotype was scored for the development of rust using a 9-point scale in which 1 = no disease, and 9 = 50-100% foliage destroyed. Genotypes with scores of 5 or less were selected for advanced screening.

Advanced screening was done in both rainy and postrainy seasons. Genotypes were grown in replicated plots. Test plots were separated by single infector rows of a mixture of the cultivars TMV 2 and Robust 33-1 sown 14 days before the test material. Cultivars TMV 2 and Robust 33-1 were also sown on test plots to monitor disease spread from infector rows. Due to the dry atmosphere, rust development is not usually high during the postrainy season at ICRISAT Center. Therefore, a field-inoculation technique was developed. Infector rows were sown as described above were inoculated with a uredinio-pore suspension at the time of peak flowering. The suspension (50000–100000 spores ml⁻¹) was made up in tap water to which a small amount of the wetting agent Tween 80 had been added. Inoculation was done in the evening following furrow irrigation. Potted "spreader plants" heavily infested with rust were placed systematically throughout the field to serve as additional sources of inoculum (Fig.6). Following inoculation, the fields were irrigated using overhead sprinklers, on alternate days initially, and then as required by climatic conditions until harvest.

The genotypes were scored for rust development just before harvest using the 9-point scale. Genotypes found resistant to rust at ICRISAT Center are listed in Table 4, together with their mean rust scores on the 9-point scale. Some of these genotypes are also resistant to late leaf spot disease (Subrahmanyan et al. 1980 a, 1980 b, and 1983 a). It is interesting that most of the rust-resistant genotypes listed in Table 4 originated in Peru, which is believed to be one of the secondary “gene centers” of cultivated groundnut (Gregory et al. 1980, Ramanatha Rao—these Proceedings).

Pod and haulm yields, and shelling percentages of all resistant genotypes were estimated in almost all the seasons, results of the 1982-83 postrainy season trials are presented in Table 5.
Figure 6. Inoculation of infector rows with urediniospores. Note the potted "Spreader plants" placed in infector rows to serve as additional sources of inoculum.

Table 4. Genotypes resistant to rust at ICRISAT Center.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>ICG No.</th>
<th>Seed color</th>
<th>Country of origin</th>
<th>Rust score</th>
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<tr>
<td>TMV 2&lt;sup&gt;3&lt;/sup&gt;</td>
<td>221</td>
<td>Tan</td>
<td>India&lt;sup&gt;3&lt;/sup&gt;</td>
<td>9.0</td>
</tr>
<tr>
<td>Robust 33-1&lt;sup&gt;4&lt;/sup&gt;</td>
<td>791</td>
<td>Tan</td>
<td>India&lt;sup&gt;3&lt;/sup&gt;</td>
<td>9.0</td>
</tr>
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<td>NC Ac 17090</td>
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<td>Peru</td>
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RHS colour chart. The Royal Horticultural Society, London, 1966. Rust scores on a 9-point scale, mean scores of 1977-1983 field trials. Standard susceptible cultivars. Also resistant to late leaf spot (Phaeosporangium personae) at ICRISAT.

Table 5. Pod and haulm yields and shelling percentages of some groundnut genotypes resistant or susceptible to rust and late leaf spot diseases at ICRISAT Center.

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<td></td>
<td>Yield (kg ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>Shelling (%)</td>
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<tr>
<td>pods</td>
<td>Haulms</td>
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Continued...
Table 5. Continued.

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<tr>
<th>Genotype</th>
<th>Yield (kg ha⁻¹)</th>
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Table 6. The FESR (Federal Experiment Research Station Puerto Rico) breeding lines resist rust and late leaf spot at ICRISAT Center.

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<tr>
<td>FESR 9-P9-B1</td>
<td>2.7</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>FESR 9-P12-B1</td>
<td>2.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>FESR 11-P11-B1</td>
<td>2.7</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>FESR 12-P4-B1</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>FESR 12-P5-B1</td>
<td>2.0</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>FESR 12-P6-B1</td>
<td>2.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>FESR 12-P14-B1</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>FESR 13-P12-B1</td>
<td>2.7</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

1. On a 9-point scale, with 1 = susceptible, 9 = resistant.
2. Standard susceptible cultivar.
3. Standard disease susceptible Indian cultivars for comparison. Several of the resistant genotypes outyielded the established Indian cultivars.
4. In addition to the sources of rust resistance, promising selections were backcrossed with the cultivated groundnut cultivars to produce the F₁ hybrid plants (Nigam et al. 1980).
5. The F₁ hybrid plants were normally grown in the greenhouse. Subsequent generations were grown in the field and screened for rust resistance using the "infector-row" method. The populations were classified as resistant (2 and 3 on the 9-point scale), moderately resistant (4, 5, and 6 on the 9-point scale), and susceptible (7, 8, and 9 on the 9-point scale).

Screening of wild Arachis species

Sixty-one accessions of wild species, representing five sections of the genus Arachis, were evaluated for resistance to rust during the 1980 and 1981 rainy seasons at ICRISAT Center. They were further tested in the laboratory by inoculation of rooted detached leaves (Fig. 7). Most of the species were immune, 6 were highly resistant, and 2 were susceptible (Subrahmanyam et al. 1983). The reactions of selected wild Arachis species to rust disease are presented in Table 7.

Several diploid wild Arachis species resistant to rust and/or late spot leaf were crossed with high-yielding but susceptible groundnut cultivars, and the resulting sterile or fertile tetraploids were treated with colchicine to produce fertile hexaploids. Following field evaluation of hexaploids for disease resistance, promising selections were backcrossed with the cultivated groundnut cultivars to produce resistant hexaploids.
breeders’ lines with 40 chromosomes. These tetraploid, or near-tetraploid, lines were evaluated in field-screening trials for rust and late-leaf spot resistance, using the “infector-row” method, and several field-screening trials for rust and breeders’ lines with rust resistance and several lines with rust resistance and high yield were selected (Singh et al.—these Proceedings).

Components of rust resistance

In studies of components of resistance to groundnut rust, it was found that neither the size nor the frequency of stomata were correlated with resistance. Urediniospores germinated on leaf surfaces and the fungus entered through stomata irrespective of whether a genotype was immune, resistant or susceptible to rust. However, in immune genotypes the fungus died shortly after entering the substomatal cavity (Subrahmanyam et al. 1980 b). Differences in resistance were associated with differences in rate and extent of mycelial development within the cavity and within leaf tissues. The rust resistance at present available in the cultivated groundnut is of the “slow rusting” type i.e., resistant genotypes have increased incubation period, decreased infection frequency, and reduced pustule size, spore production (Fig.8), and spore germinability (Table 8 (Subrahmanyam et al. 1983 b, 1983 c)).

The possible use of the resistance components in greenhouse screening of germplasm has been studied. All the components were significantly correlated with mean field rust scores. Resistant and susceptible genotypes were readily separated on the basis of resistance components measured in the greenhouse, but classification of moderately resistant genotypes in this way was less effective than by use of field scores (Subrahmanyam et al. 1983b).

The extent of rust damage to foliage is dependent on the physiological age of the plant. Young plants are most susceptible to rust attack and the susceptibility declines with age (Table 9 (Subrahmanyam et al. 1980a)).

Stability of rust resistance

The International Groundnut Foliar Diseases Nursery (IGFDN), a cooperative international program, was initiated in 1980. Through the assistance of cooperators in locations throughout the SAT, the

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Table 7. Reaction of some wild Arachis species to Puccinia arachidis (from Subrahmanyam et al. 1983 d).

<table>
<thead>
<tr>
<th>Section, series and species</th>
<th>USDA plant inventory (PI) number</th>
<th>ICRISAT groundnut accession number (ICG)</th>
<th>Rust reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. batizocoi</td>
<td>298639</td>
<td>8124</td>
<td>Immune</td>
</tr>
<tr>
<td>A. duranensis</td>
<td>219823</td>
<td>8123</td>
<td>Immune</td>
</tr>
<tr>
<td>A. spezzatii</td>
<td>262133</td>
<td>8138</td>
<td>Immune</td>
</tr>
<tr>
<td>A. correntina</td>
<td>321194</td>
<td>4984</td>
<td>Immune</td>
</tr>
<tr>
<td>A. seropentia</td>
<td>326260</td>
<td>8126</td>
<td>Highly resistant</td>
</tr>
<tr>
<td>A. cardenasi</td>
<td>262141</td>
<td>8216</td>
<td>Immune</td>
</tr>
<tr>
<td>A. chacconse</td>
<td>276235</td>
<td>4983</td>
<td>Immune</td>
</tr>
<tr>
<td>A. villon</td>
<td>210554</td>
<td>8144</td>
<td>Immune</td>
</tr>
</tbody>
</table>

---

Table 8. Components of resistance to rust in groundnut genotypes (after Subrahmanyam et al. 1983b, 1983c).

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Rust field score</th>
<th>Incubation period (days)</th>
<th>Infection frequency (lesions cm²)</th>
<th>Pustule diameter (mm)</th>
<th>Pustules ruptured (%)</th>
<th>Spores 1 mm² pustule area</th>
<th>Urediniospore germination (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMV 2 (Check)</td>
<td>9.0</td>
<td>9.3</td>
<td>13.5</td>
<td>1.12</td>
<td>100.0</td>
<td>855</td>
<td>75.1</td>
</tr>
<tr>
<td>NC 17090</td>
<td>2.2</td>
<td>19.3</td>
<td>5.9</td>
<td>0.68</td>
<td>0.5</td>
<td>121</td>
<td>37.2</td>
</tr>
<tr>
<td>EC 76444(292)</td>
<td>2.8</td>
<td>17.5</td>
<td>6.2</td>
<td>0.59</td>
<td>13.5</td>
<td>61</td>
<td>48.1</td>
</tr>
<tr>
<td>PI 405132</td>
<td>2.4</td>
<td>18.3</td>
<td>8.1</td>
<td>0.63</td>
<td>5.6</td>
<td>127</td>
<td>48.1</td>
</tr>
<tr>
<td>PI 407444</td>
<td>2.8</td>
<td>18.5</td>
<td>4.7</td>
<td>0.58</td>
<td>4.7</td>
<td>139</td>
<td>42.6</td>
</tr>
<tr>
<td>PI 393643</td>
<td>3.0</td>
<td>14.7</td>
<td>5.5</td>
<td>0.73</td>
<td>9.2</td>
<td>121</td>
<td>43.3</td>
</tr>
</tbody>
</table>

1. Mean rust scores recorded at the ICRISAT Center over the years 1979-82, using a 9-point disease scale, where 1 = no disease, and 9 = 50-100% foliage destroyed.

Table 9. Rust reactions of four groundnut genotypes 30 days after inoculation at three physiological stages of development in the greenhouse (after Subrahmanyam et al. 1980a).

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Percent leaf area damaged by rust (%)</th>
<th>Plant stage at inoculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMV 2</td>
<td>2597471</td>
<td>100.0</td>
</tr>
<tr>
<td>NC 17090</td>
<td>2679471</td>
<td>40.0</td>
</tr>
<tr>
<td>NC 17129</td>
<td>2501471</td>
<td>60.0</td>
</tr>
<tr>
<td>PI 2597471</td>
<td>1392471</td>
<td>80.0</td>
</tr>
</tbody>
</table>

1. Cultivar susceptible to rust. 2. Cultivar resistant to rust.
Table 10. Effect of the hyperparasite Verticillium lecanii on groundnut rust development

<table>
<thead>
<tr>
<th>Inoculation treatment</th>
<th>Infection frequency (lesions cm⁻²)</th>
<th>Leaf area damaged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rust pathogen alone</td>
<td>12.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Rust + hyperparasite</td>
<td>7.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Preinoculation with the hyperparasite</td>
<td>5.3</td>
<td>7.4</td>
</tr>
<tr>
<td>SE</td>
<td>±1.27</td>
<td>±1.95</td>
</tr>
<tr>
<td>CV (%)</td>
<td>33.7</td>
<td>36.4</td>
</tr>
</tbody>
</table>

Biological control of groundnut rust

The fungi, Verticillium lecanii (Zimm.) Viegas (Fig.9) Penicillium islandicum Sopp., Eudarluca carici (Fr.) O. Ericks, and Acrotrichum persicinum (Nicol.) W. Gams have been found growing on P. arachidis and their pathogenicity has been confirmed in laboratory inoculation tests. Preliminary investigations on the biological control of rust with V. lecanii in the laboratory using detached leaves showed considerable reduction in rust development (Table 10).

Epiphytotypes of groundnut rust in different agronomic systems

Many small-scale farmers in the SAT intercrop groundnut, traditional combinations often involving up to 5 or 6 crops. Although information is available on crop combination, genotype interaction, proportion of each crop in the intercropping system, land equivalent ratio, etc., very little is known of how intercropping affects foliar diseases of groundnut. Trials were carried out at ICRISAT Center during the 1980, 1981, and 1982 rainy seasons to investigate the effect of intercropping groundnut with cereals on the development of rust and leaf-spot diseases. In the 1980 rainy season, there were statistically significant differences in percentage defoliation and percentage leaf area damaged from rust and leaf spots between sole-crop and intercrop systems. Rust and leaf spot severity was higher on groundnut grown as a sole crop than in intercrop situations. Results obtained from the 1981 rainy season were largely in agreement. In the 1982 rainy season there were no significant differences in percentage defoliation or percentage leaf area damaged from leaf spots between sole and intercrop systems, but the percentage leaf area damaged from rust was higher in the intercrop situation.

Investigations on the effects of blending rust and late leaf-spot resistant and susceptible genotypes on the development of these diseases, and on yields were conducted during the 1981-82 postrainy, 1982 rainy, and 1982/83 postrainy seasons. Two trials were conducted in each season, with two sets of resistant and susceptible genotypes physically mixed in different ratios. In general, the resistant genotypes grown in mixed crops showed higher percentage defoliation than those grown as pure crops. There were no significant yield advantages from blending resistant and susceptible genotypes.

References


