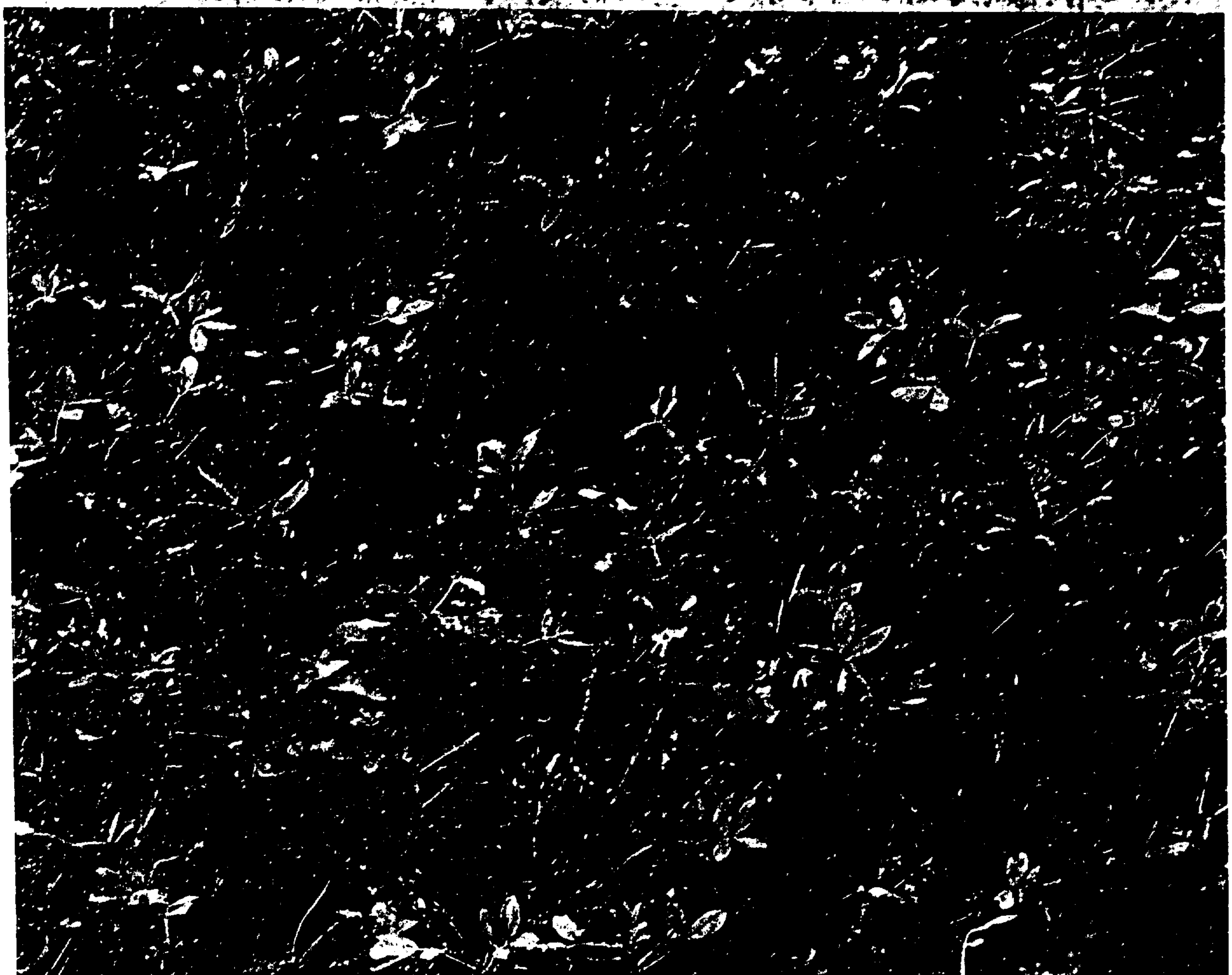
Information Bulletin no. 47

Screening Methods and Sources of Resistance to

Rust and Late Leaf Spot of Groundnut



International Crops Research Institute for the Semi-Arid Tropics

Abstract

Citation: Subrahmanyam, P., McDonald, D., Waliyar, F., Reddy, L.J., Nigam, S.N., Gibbons, R.W., Ramanatha Rao, V., Singh, A.K., Pande, S., Reddy, P.M., and Subba Rao, P.V. 1995. Screening methods and sources of resistance to rust and late leaf spot of groundnut. (In En. Summaries in En, Fr, Sp, and Pt.) Information Bulletin no. 47. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 24 pp. ISBN 92-9066-319-7. Order code IBE 047.

Rust and late leaf spot are the most serious fungal diseases of groundnut worldwide, and can cause severe yield losses, particularly when they occur together. This Bulletin describes simple and effective field screening methods to identify genotypes with resistance to these diseases. Production of inoculum, sowing and inoculation of test genotypes, and disease assessment in the field, using a 1–9 scale, are discussed. These methods were used during 1977–89 to evaluate ICRISAT's world collection of over 12 000 groundnut accessions. Several reliable sources of resistance to rust and/or late leaf spot were identified, and are listed here—124 lines resistant to rust, 54 lines resistant to late leaf spot, and 29 lines with combined resistance. An extensive bibliography is also presented, for those who require more detailed information on specific aspects of the diseases.

Résumé

La rouille et la cercosporiose tardive de l'arachide: méthodes de criblage et sources de résistance. La rouille et la cercosporiose tardive sont les plus importantes maladies fongiques de l'arachide dans le monde. Les deux maladies peuvent causer de graves pertes de rendement, surtout lorsqu'elles sévissent ensemble dans une région. Cet ouvrage décrit des méthodes de criblage simples et efficaces susceptibles d'être utilisées en champs pour identifier des génotypes résistants. La production de l'inoculum, le semis et l'inoculation des génotypes ainsi que l'évaluation de ces maladies à l'aide d'une échelle de pointage (1–9) sont exposés. On s'est servi de ces méthodes en 1977–89 pour évaluer la collection des ressources génétiques de l'arachide de l'ICRISAT (plus de 12 000 entrées). Plusieurs sources de résistance fiables à la rouille et/ou à la cercosporiose tardive ont été identifiées. Un tableau de ces sources est dressé ici—124 lignées résistantes à la rouille, 54 lignées résistantes à la cercosporiose tardive et 29 lignées à résistance conjuguée. Est aussi présentée, une bibliographie destinée aux lecteurs désireux d'avoir de plus amples informations sur des aspects spécifiques de ces maladies.

Resumen

Roya y mancha foliar tardía de maní: métodos de aislación y fuentes de resistencia. Roya y mancha foliar tardía son las enfermedades más serias causadas por hongos en maní por todas partes del mundo y pueden resultar en graves pérdidas de rendimiento, en particular, cuando ocurren al mismo tiempo. Este boletín describe métodos eficaces de aislación en campo para identificar genotipos con resistencia a estas enfermedades. Trata de la producción de inoculum, siembra e inoculación de los genotipos de prueba, evaluación de la enfermedad en campo usando la escala 1–9. Estos métodos fueron usados durante 1977–89 para evaluar la colección global de ICRISAT de más de 12 000 adquisciones de maní. Se identificaron muchas fuentes de resistencia confiables a roya y/o a mancha foliar tardía y se alistan aquí: 124 líneas resistentes a roya, 54 líneas resistentes a mancha foliar tardía y 29 líneas con resistencia combinada. También se presenta una bibliografía para los que quieran información más detallada sobre aspectos específicos de las enfermedades.

Sumário

Ferrugem e mancha foliar tardia do amendoim: métodos da avaliação e fontes da resistência. Ferrugem e mancha foliar tardia são as doenças mais serias do amendoim pelo mundo inteiro, e podem causar severas perdas no rendimento, especialmente quando ocorrem juntamente. Esse boletim descreve métodos da avaliação simples e efetivos para identificar genótipos com resistência a essas doenças. Foram discutidos usando a escala 1–9, produção do inoculo, sementeira e inoculação dos genótipos, avaliação das doenças no campo. Esses métodos foram utilisados durante 1977–89 para avaliar mais de 12 000 genotipos de amendoim que pertencem a ICRISAT de varias partes do mundo. Seguras fontes da resistência a ferrugem e mancha foliar tardia foram identificadas e estão àqui catálogadas—124 linhas resistentes a ferrugem, 54 linhas resistentes a mancha foliar tardia e 29 linhas com uma resistência combinada. Para os que necessitam uma mais detalhada informacão sobre es especificos aspetos das doenças, uma extensiva bibliografia esta tambem introduzida.

Cover: Groundnut crop in a farmer's field in India showing severe rust and late leaf spot attack.

Screening Methods and Sources of Resistance to Rust and Late Leaf Spot of Groundnut

P Subrahmanyam, D McDonald, F Waliyar, L J Reddy, S N Nigam,
R W Gibbons, V Ramanatha Rao, A K Singh, S Pande,
P M Reddy, and P V Subba Rao

Information Bulletin no. 47

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

1995

Contents

Preface

Rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) are the most serious fungal diseases of groundnut worldwide. They are widely distributed throughout groundnut production areas and cause considerable yield losses, especially if the crop is attacked simultaneously by both diseases. Breeding for resistance is the most economical approach to managing these diseases in smallholder systems, common in the semi-arid tropics.

ICRISAT has devoted considerable efforts over the past 20 years to developing simple and effective field screening methods for rust and late leaf spot which can be readily adopted by groundnut breeding programs. These methods have been used to screen the entire ICRISAT groundnut germplasm collection for resistance to the two diseases. Valuable sources of resistance to both diseases have been identified for use by national and regional programs.

This Information Bulletin provides a comprehensive, well-illustrated guide to resistance screening, including screening methodologies, inoculum production, field layout, field inoculation, and disease assessment. The best sources of resistance presently available have been clearly tabulated. This publication is a most appropriate and practical way to disseminate the information to groundnut researchers, especially in developing countries, where access to scientific journals is often difficult.

This bulletin complements previous ICRISAT Information Bulletins 13 (published in 1983) and 21 (1985), which provide basic information on rust and late leaf spot.

J M Lenné
Director, Crop Protection Division, ICRISAT

Figure 1. Groundnut rust disease caused by *Puccinia arachidis*.

Figure 2. Late leaf spot caused by *Phaeoisariopsis personata*.

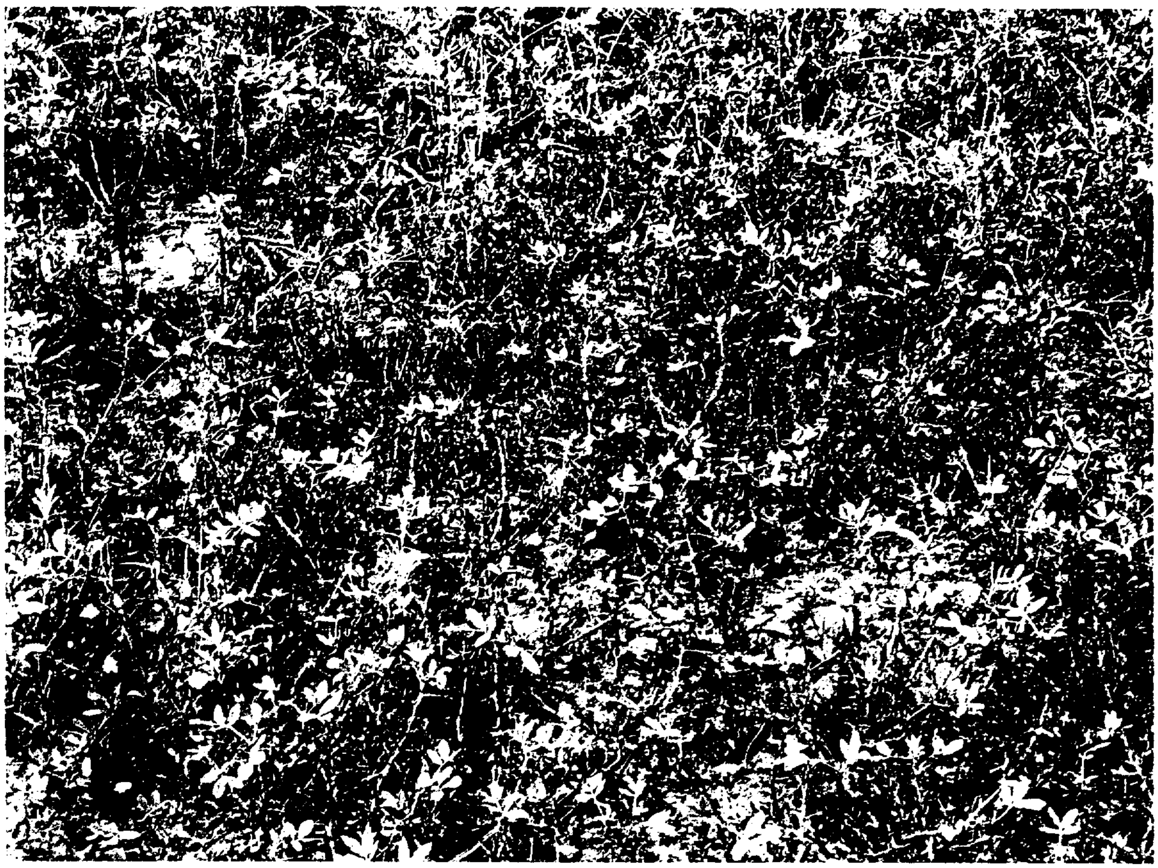


Figure 3. Severe rust and late leaf spot attack on a farmer's groundnut crop in India.

Introduction

Rust (*Puccinia arachidis* Speg.) and late leaf spot (*Phaeoisariopsis personata* (Berk. & Curt.) v. Arx = *Cercosporidium personatum* (Berk. & Curt.) Deighton) are the most serious fungal diseases of groundnut (*Arachis hypogaea* L.) worldwide (Subrahmanyam et al. 1985, McDonald et al. 1985). Both diseases occur commonly throughout the world wherever groundnut is grown; however, the incidence and severity of each disease varies between locations and seasons. Yield losses are generally substantial when the crop is attacked by rust and late leaf spot together (Subrahmanyam et al. 1984). Although these diseases can be controlled very effectively by certain fungicides (Smith and Littrell 1980), these are costly and are not readily available to smallholder farmers in the semi-arid tropics (SAT), who generally lack the resources and technical expertise to effectively use chemical control methods. Breeding for resistance is therefore one of the best means of reducing disease-related yield losses. In recent years, there has been an increased effort in many countries to exploit genetic resistance to groundnut rust and late leaf spot.

At ICRISAT Asia Center (IAC) near Hyderabad, Andhra Pradesh, simple and effective field screening methods for resistance to rust and late leaf spot have been developed for use in areas where natural disease pressure is high, or where such pressure can be artificially induced. A world collection of over 12 000 groundnut accessions from 87 countries was systematically evaluated for resistance to rust and late leaf spot between 1977 and 1989, and several reliable sources of resistance to rust and/or late leaf spot have been identified (Subrahmanyam et al. 1989, Waliyar and McDonald 1988).

The objectives of this Bulletin are to provide research workers with information on methods of field screening of groundnut germplasm lines for resistance to rust and late leaf spot, and to provide a comprehensive list of the resistance sources available at IAC.

Production of inoculum

Rust and late leaf spot inocula may be required for field inoculations in areas where the disease pressure is not adequate for a meaningful evaluation of groundnut genotypes for their reactions to these diseases. Field inoculation is also a useful way to achieve uniform disease pressure across the field. The following methods can be used to collect and maintain inoculum.

1. The late leaf spot pathogen can survive from season to season in infected leaves. Collect infected leaf debris from the fields at harvest and store it in jute/cloth bags in farm sheds for use in the following season. Five bags (75 × 100 cm in size) of infected leaf debris are required to inoculate 1 ha of groundnut. The rust pathogen survives in infected leaf debris for only a short period (Subrahmanyam and McDonald 1983), and cannot be maintained in infected leaf debris from one season to the next.
2. Collect spores of rust or late leaf spot pathogens from severely infected groundnut crops with a low-power vacuum cleaner (12 V) and store them in airtight plastic bags in a deep freezer at –15°C. These spores can retain their viability long enough for use in field inoculation in the following season.
3. Rust and late leaf spot pathogens can be multiplied on potted groundnut plants

grown in plastic pots or nursery bags in the greenhouse. Inoculate 40-day old plants of a cultivar susceptible to both rust and late leaf spot by spraying the leaves uniformly with spore suspension (50 000 spores mL^{-1}), using an atomizer (Fig. 4) or a knapsack sprayer. Irrigate the pots, place them side by side, and cover them with a thin plastic sheet to maintain high humidity for 24 hours at 25° C. Inoculation is most successful when done in the evening. If greenhouse facilities are not available, plants can be raised and inoculated outdoors, preferably in the shade (Fig. 5). Ensure high humidity by flooding the pot-culture area with water. If only rust is to be multiplied, spray rust-inoculated plants with carbendazim (0.05%) 2 days after inoculation to suppress the development of late leaf spot. Rust can be suppressed by spraying tridemorph (0.05%) on plants where late leaf spot is to be multiplied. Severe rust or late leaf spot develops approximately 15 days after inoculation, after which the diseased plants can be placed in the field as spreader plants.

Sowing test genotypes

1. Infector rows of a highly susceptible cultivar(s) should be arranged systematically throughout the trial. The ratio of infector rows to rows of test genotypes depends on the disease situation at a particular location; at IAC, a ratio of one infector row to every four rows of test genotypes is generally adequate.
2. Treat the seed of test entries with a suitable seed-protectant chemical just before sowing to avoid mortality due to seedling diseases. Sow the seeds in field rows 4 to 9 m long, 60 to 75 cm apart, preferably on ridges. Preliminary screening can be carried out in nonreplicated single-row field plots; advanced screening requires replicated (3–5 replications) field plots. A spacing of 10–15 cm between plants within a row is normally sufficient, depending on plant growth habit. Close spacing should be avoided. Include some known susceptible cultivars along with the test entries to serve as controls.
3. Spray insecticides as required to control foliage damage by insect pests. Keep the field weed-free, and avoid drought stress.

Field inoculation

Inoculate infector rows 15 days after sowing, preferably after rain. If the soil is dry, use perfo or sprinkler irrigation to wet the foliage and soil surface and increase relative humidity.

Rust

1. Prepare the urediniospore suspension (approximately 100 000 spores mL^{-1}) in tap water containing a small quantity (10 drops L^{-1}) of Tween 80 or any other mild surfactant. Approximately 80 L of spore suspension is required to inoculate the infector rows in a 1 ha field (1:4 ratio of infector:test rows, 4 m long, 75 cm apart, 1 m alleyway).
2. Inoculate plants in the infector rows by spraying them with the urediniospore suspension, using a knapsack sprayer, as shown in Figure 6. Inoculation is most successful if it is caried out in the evening, because strong sunlight inhibits urediniospore germination.

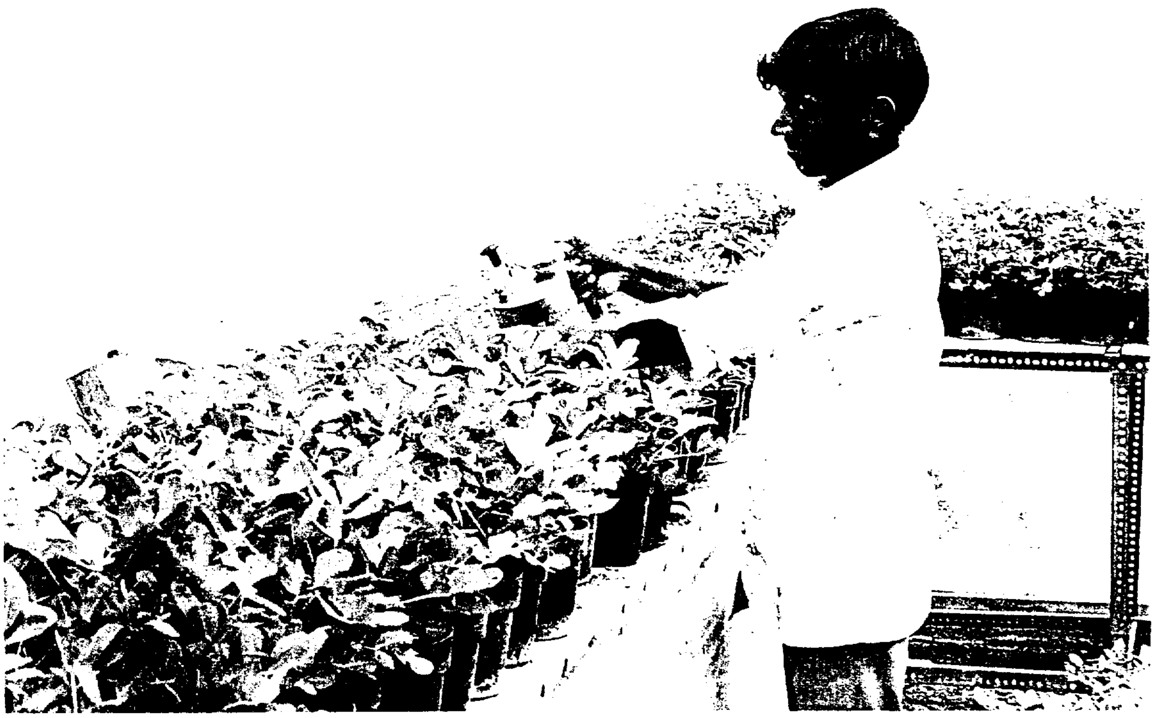


Figure 4. Greenhouse inoculation of groundnut plants with spore suspensions.

Figure 5. Inoculation of groundnut plants raised outdoors.

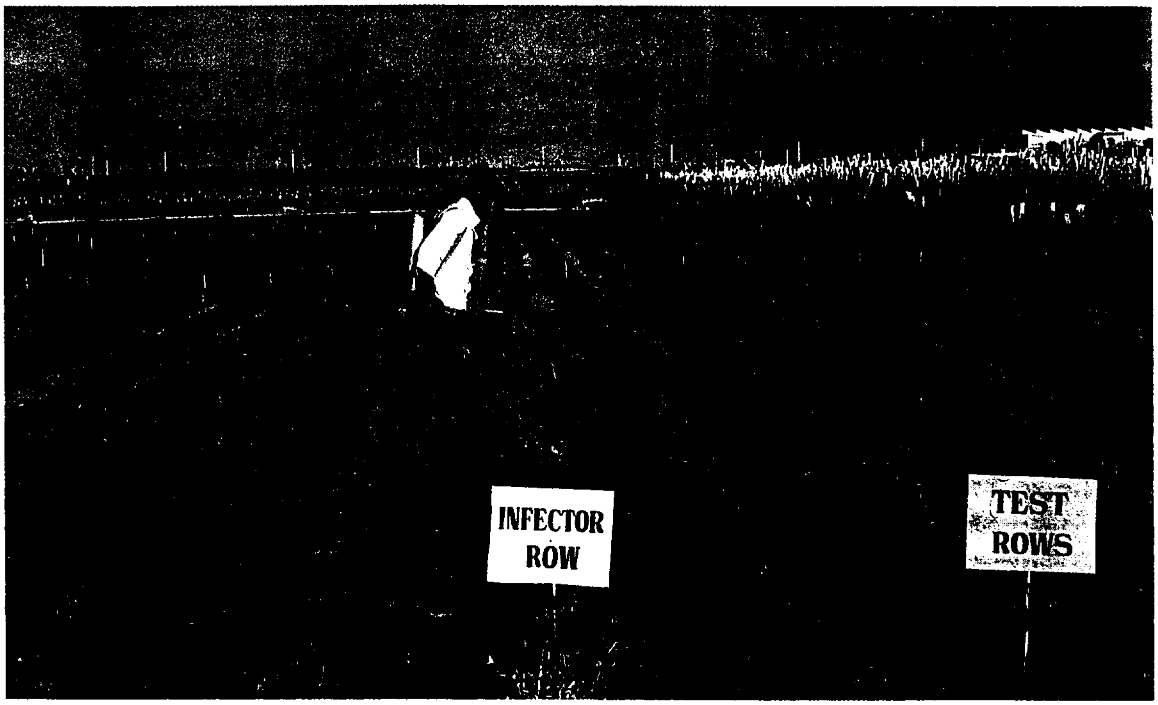


Figure 6. Field inoculation of infector rows with rust or late leaf spot spore suspensions.

3. Transplant the rust-infected spreader plants into the center of each infector row to provide additional sources of inoculum. Approximately 540 spreader plants are required per hectare (1:4 ratio of infector:test rows, 4 m long, 75 cm apart).
4. Provide perfo or sprinkler irrigation (Fig. 7) for about 1 hour in the evening of the following day, and subsequently when the first generation of urediniospores is produced, i.e., approximately 2 weeks after inoculation. If the weather is dry, provide additional perfo or sprinkler irrigation to increase disease pressure. If perfo or sprinkler irrigation facilities are not available, provide furrow irrigation.
5. Spray infector rows with carbendazim (0.05%) to control late leaf spot as and when required.

Late leaf spot

1. Prepare the conidial suspension and inoculate the infector rows 15 days after sowing, as described for rust.
2. Ten days after sowing, scatter infected leaf debris (collected from the previous season's harvest) throughout the field or along the infector rows.
3. Transplant late leaf spot infected spreader plants into the infector rows.
4. Irrigate as described for rust.
5. Spray infector rows with tridemorph (0.05%) to control rust as and when required.

Disease assessment

1. Ensure adequate and uniform disease pressure. This can be accurately judged from disease development on the susceptible control cultivars.

2. Entries in different maturity groups should be scored on different dates. For an accurate assessment, several plants of each entry should be examined for disease severity. All leaves on the main stem should be examined, and care must be taken to eliminate leaf damage due to factors other than rust or late leaf spot.
3. Score each test entry twice—at the pod-filling stage (R6) and just before harvest (R8) (see Table 1 for descriptions of the growth stages).
4. At IAC a 9-point disease scale is used to screen germplasm and breeding lines for sources of resistance to rust and late leaf spot (Table 2). This scale has proved to be very effective for germplasm, but less so in evaluating genotypes and breeding lines with low resistance levels, because any entry with more than 50% foliage damage is rated 9 (highly susceptible).
5. The modified 9-point scales for rust (Table 3) (Fig. 8) and late leaf spot (Table 4) (Fig. 9) are based mainly on the extent of leaf area damaged. For late leaf spot, the extent of defoliation is also incorporated into the scale. The visual scores (1 to 9) and the extent of leaf area destroyed (0 to 100%) are linearly related. The modified 9-point scale can also be used for rapid quantification of disease levels. Each entry can be assessed at close intervals during the crop season to measure the rate of disease progress. The scale is also useful for accurate assessments of disease severity during disease surveys.

Sources of resistance

A comprehensive list of resistance sources identified from ICRISAT's world collection of over 12000 groundnut accessions is given in the Appendices.

Figure 7. Irrigation with overhead sprinklers to increase disease development.

Table 1. Reproductive growth stages of groundnut (after Boote 1982).

Stage		Description[1]
R1	Beginning bloom	One open flower at any node on the plant
R2	Beginning peg formation	One elongated peg (gynophore)
R3	Beginning pod formation	One peg in the soil, with swollen ovary at least twice the width of the peg
R4	Full pod formation	One fully-expanded pod, to dimensions characteristic of the cultivar
R5	Beginning seed-filling	One fully-expanded pod in which seed cotyledon growth is visible when the fruit is cross-sectioned (past the liquid endosperm phase)
R6	Full seed-filling	One pod with cavity apparently filled by the seeds when fresh
R7	Beginning maturity	One pod showing visible natural coloration or blotching of inner pericarp or testa
R8	Mature, ready to harvest	Two-thirds to three-fourths of all developed pods (depending on cultivar, lower for virginia types) have testa or pericarp coloration
R9	Over-mature pod	One undamaged pod showing orange-tan coloration of the testa and/or natural peg deterioration

1. Growth stages should not be averaged during analysis. Each stage lasts till 50% of the plants in the sample demonstrate the trait(s) characteristic of the next stage. An individual plant is considered to have reached a particular reproductive stage with the first occurrence of specific trait(s) characteristic of the stage.

Table 2. The 9-point scale used for field-screening groundnut genotypes for resistance to rust and late leaf spot (after Subrahmanyam et al. 1982a, b).

Rust	Score	Late leaf spot
No disease	1	No disease
A few, very small pustules on some older leaves	2	A few, small necrotic spots on older leaves
A few pustules, mainly on older leaves, some ruptured; poor sporulation	3	Small spots, mainly on older leaves; sparse sporulation
Pustules small or big, mostly on lower and middle leaves; disease evident	4	Many spots, mostly on lower and middle leaves; disease evident
Many pustules, mostly on lower and middle leaves; yellowing and necrosis of some lower and middle leaves; moderate sporulation	5	Spots easily seen on lower and middle leaves; moderate sporulation; yellowing and defoliation of some lower leaves
As for rating 5, but pustules sporulating heavily	6	As for rating 5, but spots sporulating heavily
Pustules all over the plant; lower and middle leaves withering	7	Disease easily seen from a distance; spots all over the plant; defoliation of lower and middle leaves
As for rating 7, but heavy withering	8	As for rating 7, but heavy defoliation
Plants severely affected; 50–100% leaves withering	9	Plants severely affected; 50–100% defoliation

Table 3. Modified 9-point scale used for field-screening groundnut genotypes for resistance to rust.

Disease score	Description	Disease severity (%)[1]
1	No disease	0
2	Pustules sparsely distributed, largely on lower leaves	1–5
3	Many pustules on lower leaves, necrosis evident; very few pustules on middle leaves	6–10
4	Numerous pustules on lower and middle leaves; severe necrosis on lower leaves	11–20
5	Severe necrosis of lower and middle leaves; pustules may be present on top leaves, but less severe	21–30
6	Extensive damage to lower leaves; middle leaves necrotic, with dense distribution of pustules; pustules on top leaves	31–40
7	Severe damage to lower and middle leaves; pustules densely distributed on top leaves	41–60
8	100% damage to lower and middle leaves; pustules on top leaves, which are severely necrotic	61–80
9	Almost all leaves withered; bare stems seen	81–100

1. Percentage leaf area damaged by the disease.

Table 4. Modified 9-point scale used for field-screening groundnut genotypes for resistance to late leaf spot.

Disease score	Description	Disease severity (%)[1]
1	No disease	0
2	Lesions present largely on lower leaves; no defoliation	1–5
3	Lesions present largely on lower leaves, very few on middle leaves; defoliation of some leaflets evident on lower leaves	6–10
4	Lesions on lower and middle leaves but severe on lower leaves; defoliation of some leaflets evident on lower leaves	11–20
5	Lesions present on all lower and middle leaves; over 50% defoliation of lower leaves	21–30
6	Severe lesions on lower and middle leaves; lesions present but less severe on top leaves; extensive defoliation of lower leaves; defoliation of some leaflets evident on middle leaves	31–40
7	Lesions on all leaves but less severe on top leaves; defoliation of all lower and some middle leaves	41–60
8	Defoliation of all lower and middle leaves; severe lesions on top leaves; some defoliation of top leaves evident	61–80
9	Almost all leaves defoliated, leaving bare stems; some leaflets may remain, but show severe leaf spots	81–100

1. Percentage leaf area damaged by the disease.

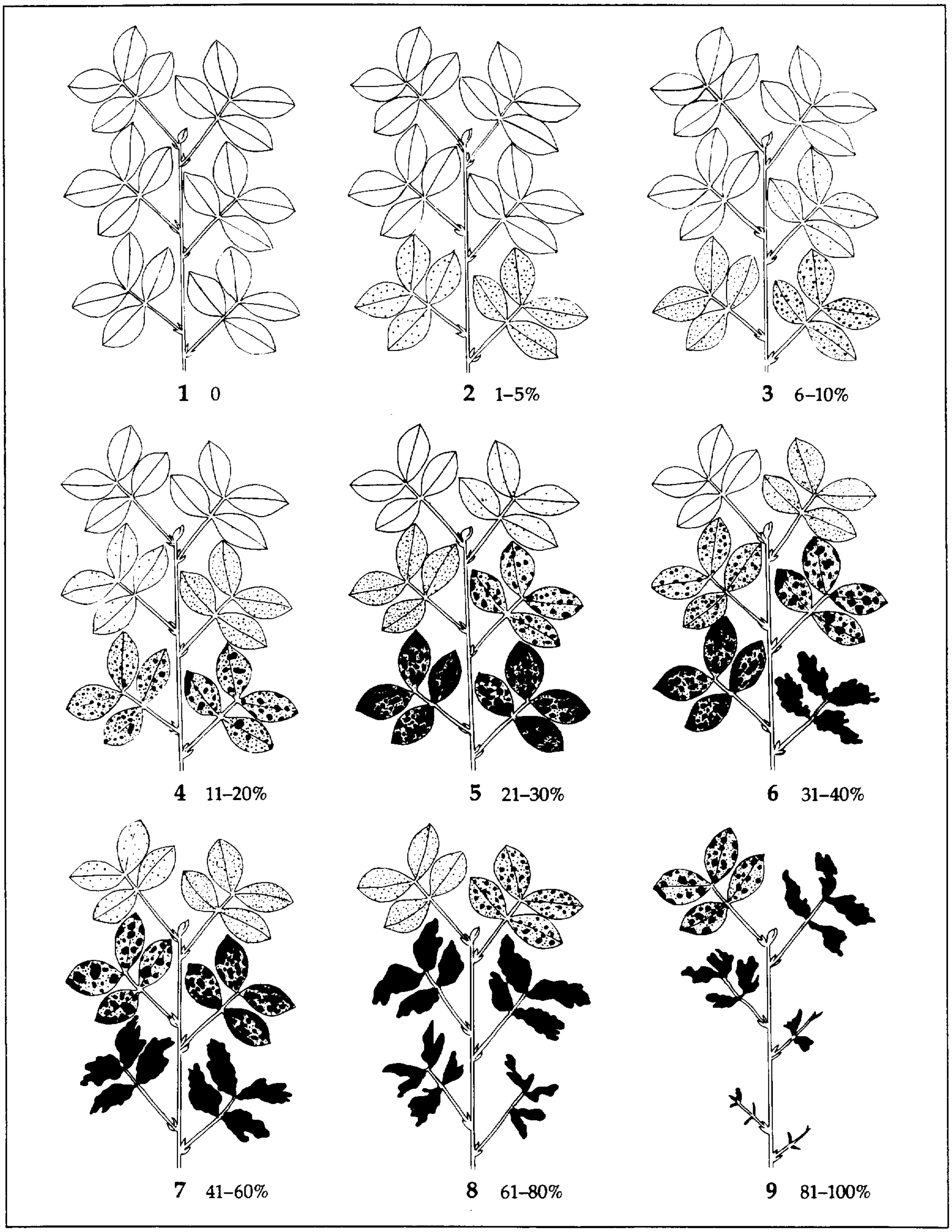


Figure 8. The modified 9-point scale for field evaluation of rust.

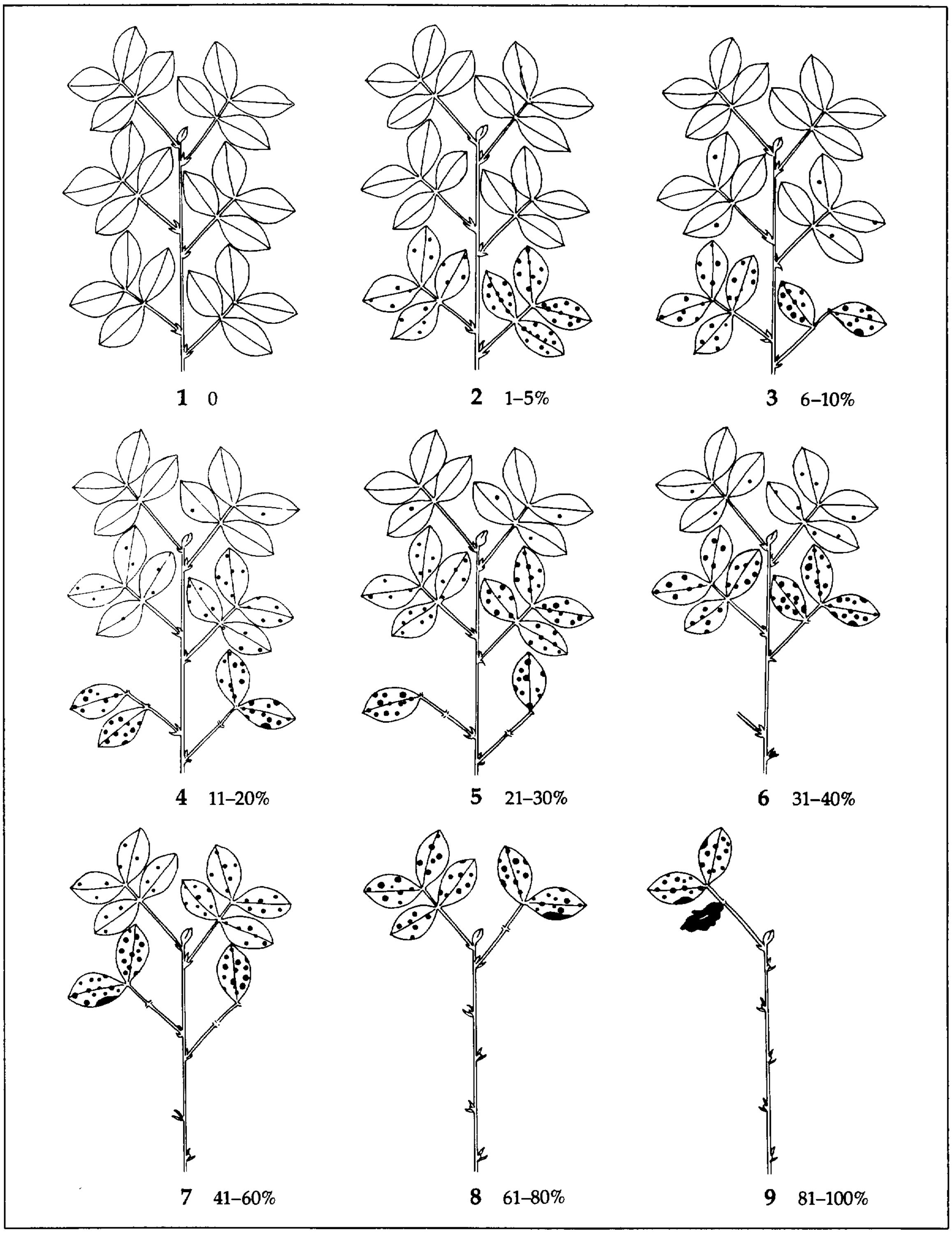


Figure 9. The modified 9-point scale for field evaluation of late leaf spot.

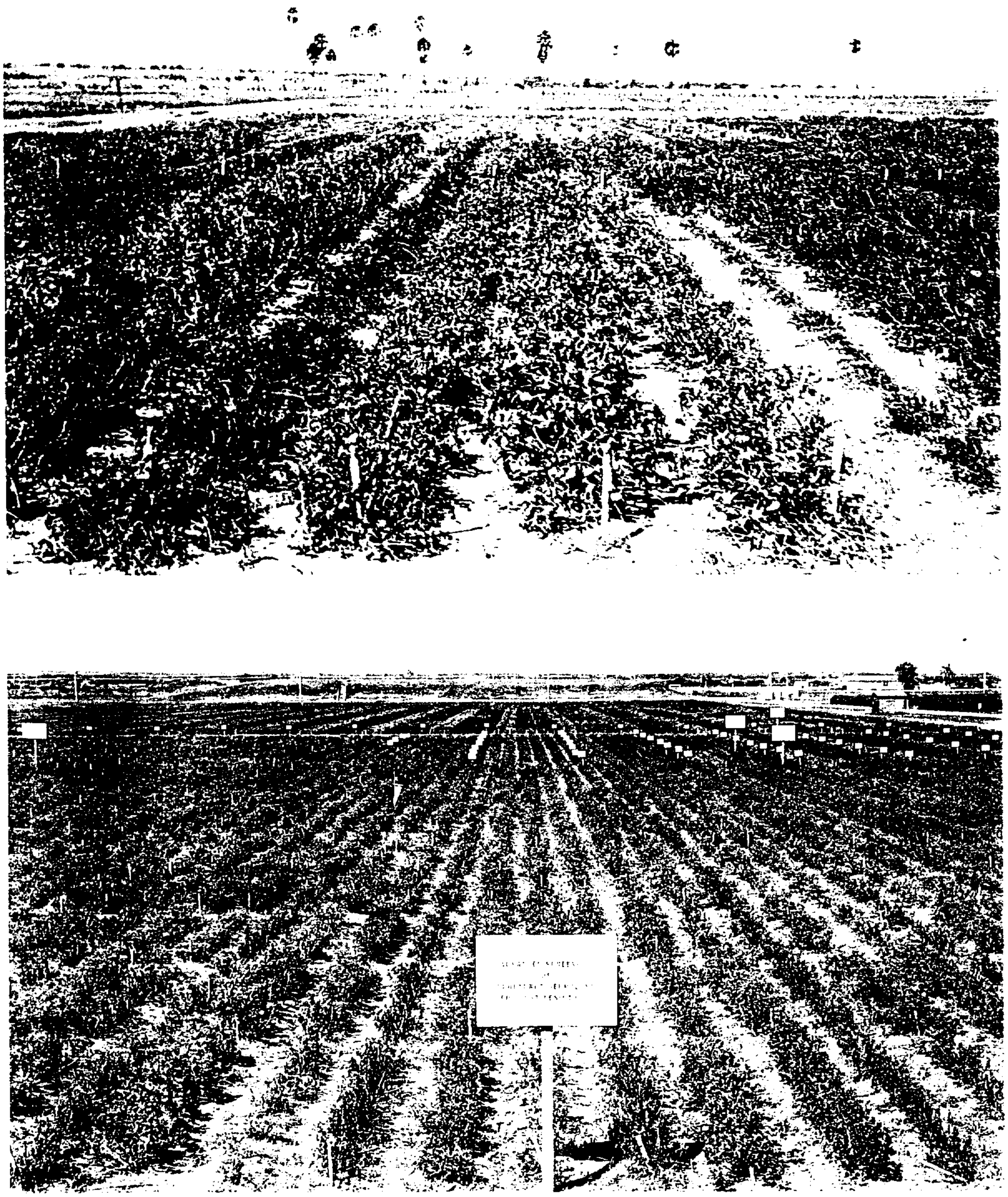


Figure 10. Field screening of groundnut germplasm for resistance to rust and late leaf spot at IAC. Top, preliminary screening in nonreplicated field plots; bottom, advanced screening in replicated field plots.

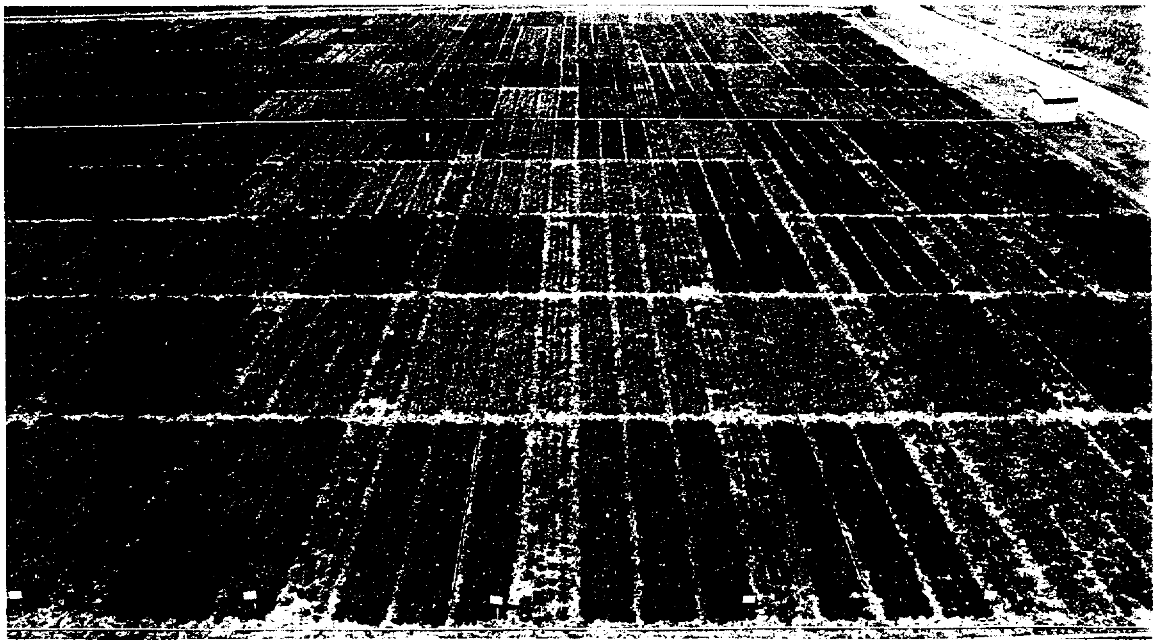


Figure 11. Resistant (dark green rows), moderately resistant (pale green), and susceptible (brownish rows) groundnut genotypes in field screening for resistance to rust and late leaf spot.

Using the screening methods described in this Bulletin, the accessions were systematically evaluated for their reaction to rust and late leaf spot (Figs. 10 and 11). One hundred and twenty four lines resistant to rust (Appendix 1), 54 lines resistant to late leaf spot (Appendix 2), and 29 lines resistant to both diseases (Appendix 3) were identified. Approximately 90% of these resistant lines belong to *A. hypogaea fastigiata* var *fastigiata*, and over 70% of them originated from Peru, which is one of the secondary centers of origin of groundnut.

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Appendix 1. Sources of resistance to rust identified at ICRISAT Asia Center (till 1990).

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	Rust score[3]
1697	NC Ac 17090	*fastigiata*	Tan	Peru	2.3
1703	NC Ac 17127	*fastigiata*	Gasp (tan/purple)	Peru	4.7
1707	NC Ac 17132	*fastigiata*	Purple	Peru	4.0
1710	NC Ac 17135	*fastigiata*	Purple	Peru	4.0
2716	EC 76446 (292)	*fastigiata*	Purple	Uganda[4]	3.3
3527	USA 63	*fastigiata*	Purple	USA	4.3
4746	PI 298115	*hypogaea*	Off-white	Israel[4]	2.7
4747	PI 259747	*fastigiata*	Purple	Peru	3.7
4995	NC Ac 17506	*fastigiata*	Purple	Peru	4.3
5043	NC Ac 2240	*hypogaea*	Purple	USA	5.0
6022	NC Ac 927	*fastigiata*	Purple	Sudan	4.0
6284	NC Ac 17500	*hypogaea*	Red	Bolivia	5.0
6330	PI 270806	*hypogaea*	Tan	Zimbabwe	2.7
6340	PI 350680	*fastigiata*	Purple	Honduras	3.0
7013	NC Ac 17133 (RF)	*fastigiata*	Purple	India	3.3
7296	203/66; WCG 190	*fastigiata*	Tan	Peru	2.7
7320	NC Ac 17656	*vulgaris*	Gasp (tan/purple)	Unknown	4.3
7340	WCG 182; 198/66	*fastigiata*	Tan	Peru	4.3
7353	PI 262129	*fastigiata*	Tan	Peru	4.0
7433	NC Ac 17518	*fastigiata*	Gasp (tan/purple)	Brazil	4.7
7620	NC Ac 17505	*fastigiata*	Gasp (tan/purple)	Peru	4.7
7621	NC Ac 17718	*hypogaea*	Tan	USA	2.7
7630	WCG 190; 204/66	*fastigiata*	Tan	Peru	2.7
7881	PI 215696	*fastigiata*	Purple	Peru	4.3
7882	PI 314817	*fastigiata*	Tan	Peru	3.3
7883	PI 315608	*hypogaea*	Off-white	Israel	3.0
7884	PI 341879	*fastigiata*	Purple	Israel	3.0
7885	PI 381622	*fastigiata*	Purple	Honduras	3.0
7886	PI 390593	*fastigiata*	Tan	Peru	2.7
7887	PI 390595	*fastigiata*	Purple	Peru	3.7
7888	PI 393516	*fastigiata*	White/Tan	Peru	4.7
7889	PI 393517	*fastigiata*	White	Peru	3.3
7890	PI 393526	*fastigiata*	Purple	Peru	2.3
7891	PI 393527 A	*hypogaea*	Red	Peru	2.7
7892	PI 393527 B	*hypogaea*	Dark red	Peru	3.3
7893	PI 393531	*fastigiata*	Gasp (tan/purple)	Peru	2.0
7894	PI 393641	*fastigiata*	Gasp (tan/purple)	Peru	4.0
7895	PI 393643	*fastigiata*	Tan	Peru	3.0
7896	PI 393646	*fastigiata*	Light purple	Peru	3.0
7897	PI 405132	*fastigiata*	Purple	Venezuela	2.7
7898	PI 407454	*fastigiata*	Tan	Ecuador	3.3
7899	PI 414331	*hypogaea*	Tan	Honduras	2.7

Continued......

Appendix 1. *Continued.....*

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	Rust score[3]
7900	PI 414332	*hypogaea*	Tan	Honduras	2.7
8044	NC Ac 10034	*fastigiata*	Tan	South Africa	2.7
9185	PI 343419	*fastigiata*	Overo (rose/red)	Israel	2.7
9294	58-295	*hypogaea*	Tan	Burkina Faso	4.7
10010	PI 476143	*fastigiata*	Gasp (tan/purple)	Peru	4.0
10014	PI 476145	*fastigiata*	Tan	Peru	2.7
10020	PI 476149	*fastigiata*	Tan	Peru	2.7
10021	PI 476149	*fastigiata*	Dark purple	Peru	2.3
10022	PI 476151	*fastigiata*	Dark purple	Peru	2.3
10023	PI 476152	*fastigiata*	Tan	Peru	4.3
10025	PI 476162	*fastigiata*	Tan	Peru	3.0
10028	PI 476163	*fastigiata*	Purple	Peru	4.7
10029	PI 476164	*fastigiata*	Gasp (tan/purple)	Peru	4.3
10030	PI 476166	*fastigiata*	Gasp (tan/purple)	Peru	2.0
10031	PI 476168	*fastigiata*	Tan	Peru	2.3
10032	PI 476168	*fastigiata*	Tan	Peru	3.0
10034	PI 476172	*fastigiata*	Tan	Peru	2.7
10035	PI 476172	*fastigiata*	Purple	Peru	4.0
10037	PI 476174	*fastigiata*	Tan	Peru	2.7
10039	PI 476174	*fastigiata*	Purple	Peru	2.7
10040	PI 476176	*fastigiata*	Gasp (tan/purple)	Peru	4.7
10042	PI 476177	*fastigiata*	Light purple	Peru	2.3
10047	PI 476179	*fastigiata*	Light purple	Peru	2.7
10048	PI 476179	*fastigiata*	Tan	Peru	2.7
10049	PI 476180	*fastigiata*	Tan	Peru	2.3
10051	PI 476180	*fastigiata*	Light purple	Peru	2.7
10052	PI 476182	*fastigiata*	Tan	Peru	2.3
10053	PI 476183	*fastigiata*	Tan	Peru	2.0
10054	PI 476183	*fastigiata*	Light red	Peru	2.7
10055	PI 476183	*fastigiata*	Striped (tan/purple)	Peru	4.3
10056	PI 476184	*fastigiata*	Tan	Peru	3.3
10057	PI 476184	*fastigiata*	Light purple	Peru	2.7
10058	PI 476185	*fastigiata*	Tan	Peru	2.7
10059	PI 476185	*fastigiata*	Light purple	Peru	3.0
10060	PI 476186	*fastigiata*	Tan	Peru	3.0
10061	PI 476186	*fastigiata*	Purple	Peru	2.3
10062	PI 476187	*fastigiata*	Purple	Peru	2.7
10063	PI 476188	*fastigiata*	Purple	Peru	2.3
10064	PI 476189	*fastigiata*	Tan	Peru	3.0
10065	PI 476189	*fastigiata*	Purple	Peru	2.3
10067	PI 476191	*fastigiata*	Red	Peru	2.7
10068	PI 476192	*fastigiata*	Red	Peru	2.3

Continued......

Appendix 1. *Continued.....*

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	Rust score[3]
10069	PI 476193	*fastigiata*	Tan	Peru	3.0
10070	PI 476193	*fastigiata*	Purple	Peru	3.7
10073	PI 476197	*fastigiata*	Light purple	Peru	2.3
10074	PI 476198	*fastigiata*	Purple	Peru	2.7
10884	PI 475981	*hypogaea*	Overo (red/white)	Bolivia	2.7
10888	PI 476015	*fastigiata*	Gasp (tan/purple)	Peru	2.7
10889	PI 476016	*fastigiata*	Dark red	Peru	3.3
10915	PI 476148	*fastigiata*	Gasp (tan/purple)	Peru	2.3
10918	PI 476151	*fastigiata*	Tan	Peru	2.7
10919	PI 476151	*fastigiata*	Light purple	Peru	3.3
10925	PI 476159	*fastigiata*	Tan	Peru	3.0
10927	PI 476160	*fastigiata*	Gasp (tan/purple)	Peru	2.7
10928	PI 476160	*fastigiata*	Tan	Peru	2.7
10932	PI 476165	*fastigiata*	Tan	Peru	2.7
10933	PI 476166	*fastigiata*	Tan	Peru	2.7
10935	PI 476168	*fastigiata*	Purple	Peru	2.3
10936	PI 476168	*fastigiata*	Purple	Peru	4.3
10937	PI 476169	*fastigiata*	Purple	Peru	3.0
10939	PI 476172	*fastigiata*	Gasp (tan/purple)	Peru	2.3
10940	PI 476173	*fastigiata*	Gasp (tan/purple)	Peru	2.3
10941	PI 476174	*fastigiata*	Grayed orange	Peru	4.7
10943	PI 476175	*fastigiata*	Purple	Peru	2.7
10945	PI 476175	*fastigiata*	Rose	Peru	3.0
10954	PI 476180	*fastigiata*	Purple	Peru	3.0
10962	PI 476186	*fastigiata*	Light purple	Peru	2.7
10963	PI 476186	*fastigiata*	Light purple	Peru	2.7
10964	PI 476188	*fastigiata*	Light purple	Peru	2.3
10966	PI 476188	*fastigiata*	Tan	Peru	3.0
10969	PI 476190	*fastigiata*	Light purple	Peru	2.3
10974	PI 476195	*fastigiata*	Light purple	Peru	2.3
10978	PI 476197	*hypogaea*	Light purple	Peru	2.3
11073	PI 476151	*fastigiata*	Light purple	Peru	3.0
11080	PI 476169	*fastigiata*	Tan	Peru	2.7
11088	PI 476196	*fastigiata*	Light red	Peru	2.7
11108	PI 476195	*fastigiata*	Light purple	Peru	2.7
11182	PI 476015	*fastigiata*	Tan	Peru	2.7
11183	PI 476020	*fastigiata*	Light purple	Peru	2.7
11285	PI 476165	*fastigiata*	Gasp (tan/purple)	Peru	2.3
11485	PI 393530	*fastigiata*	Purple	Peru	5.0
Susceptible control cultivars					
221	TMV 2	*vulgaris*	Tan	India	8.3
799	Robut 33-1	*hypogaea*	Tan	India	7.7

1. ICRISAT groundnut accession number.
2. Gasp = gaspid (flecks of color), overo = blotched.
3. Scored on a modified 9-point disease scale where 1 = 0%, 2 = 1–5%, 3 = 6–10%, 4 = 11–20%, 5 = 21–30%, 6 = 31–40%, 7 = 41–60%, 8 = 61–80%, and 9 = 81–100% damage to foliage; ICRISAT Asia Center, 1989 rainy season.
4. Origin doubtful (Rao 1987).

Appendix 2. Sources of resistance to late leaf spot identified at ICRISAT Asia Center (till 1990).

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	LLS score[3]
1702	NC Ac 17124	*fastigiata*	Gasp (tan/purple)	Peru	5.0
1703	NC Ac 17127	*fastigiata*	Gasp (tan/purple)	Peru	5.0
1705	NC Ac 17130	*fastigiata*	Tan	Peru	4.7
1707	NC Ac 17132	*fastigiata*	Purple	Peru	4.0
1710	NC Ac 17135	*fastigiata*	Purple	Peru	4.0
2716	EC 76446 (292)	*fastigiata*	Purple	Uganda	3.7
3527	USA 63	*fastigiata*	Purple	USA	4.7
4747	PI 259747	*fastigiata*	Purple	Peru	4.0
4790	Krapovickas 16	*fastigiata*	Purple	Argentina	4.3
4995	NC Ac 17506	*fastigiata*	Purple	Peru	4.3
6022	NC Ac 927	*fastigiata*	Purple	Sudan	4.0
6330	PI 270806	*hypogaea*	Tan	Zimbabwe	3.3
6340	PI 350680	*fastigiata*	Purple	Honduras	4.0
7013	NC Ac 17133-RF	*fastigiata*	Purple	India	4.0
7232	PI 262127	*fastigiata*	Purple	Peru	4.3
7406	PI 262121	*fastigiata*	Purple	Peru	4.7
7621	NC Ac 17718	*hypogaea*	Tan	USA	5.0
7628	PI 275747	*fastigiata*	Dark purple	Peru	5.0
7712	NC Ac 16167	*fastigiata*	Tan	Peru	5.0
7777	SAM COLL.186	*fastigiata*	Red	Unknown	5.0
7881	PI 215696	*fastigiata*	Dark purple	Peru	3.7
7884	PI 341879	*fastigiata*	Purple	Israel	3.7
7885	PI 381622	*fastigiata*	Purple	Honduras	4.3
7888	PI 393516	*fastigiata*	White/Tan	Peru	3.3
7894	PI 393641	*fastigiata*	Gasp (tan/purple)	Peru	4.7
7897	PI 405132	*fastigiata*	Purple	Venezuela	4.0
10010	PI 476143	*fastigiata*	Gasp (tan/purple)	Peru	5.0
10016	PI 476146	*fastigiata*	Gasp (tan/purple)	Peru	4.7
10023	PI 476152	*fastigiata*	Tan	Peru	4.7
10028	PI 476163	*fastigiata*	Purple	Peru	5.0
10029	PI 476164	*fastigiata*	Gasp (tan/purple)	Peru	5.0
10035	PI 476172	*fastigiata*	Purple	Peru	3.7
10038	PI 476174	*fastigiata*	Purple	Peru	4.0
10075	PI 476204	*fastigiata*	Red	Peru	5.0
10450	PI 215724	*fastigiata*	Purple	Peru	4.7
10889	PI 476016	*fastigiata*	Dark red	Peru	4.3
10891	PI 476018	*fastigiata*	Red	Peru	5.0
10903	PI 476036	*fastigiata*	Tan	Peru	4.3
10915	PI 476148	*fastigiata*	Gasp (tan/purple)	Peru	5.0
10920	PI 476152	*fastigiata*	Tan	Peru	4.0

Continued......

Appendix 2. *Continued.....*

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	LLS score[3]
10931	PI 476164	*fastigiata*	Light tan	Peru	3.7
10936	PI 476168	*fastigiata*	Purple	Peru	4.0
10940	PI 476173	*fastigiata*	Gasp (tan/purple)	Peru	5.0
10941	PI 476174	*fastigiata*	Grayed orange	Peru	4.7
10949	PI 476178	*fastigiata*	Dark purple	Peru	4.3
10951	PI 476178	*fastigiata*	Purple	Peru	4.0
10975	PI 476195	*fastigiata*	Dark purple	Peru	3.7
10979	PI 476199	*fastigiata*	Tan	Peru	4.7
10980	PI 476200	*fastigiata*	Red	Peru	5.0
11075	PI 476158	*fastigiata*	Gasp (tan/purple)	Peru	5.0
11182	PI 476015	*fastigiata*	Tan	Peru	5.0
11185	PI 476167	*fastigiata*	Gasp (tan/purple)	Peru	4.3
11186	PI 476180	*fastigiata*	Gasp (tan/purple)	Peru	5.0
11485	PI 393530	*fastigiata*	Purple	Peru	3.7
Susceptible control cultivars					
221	TMV 2	*vulgaris*	Tan	India	8.0
799	Robut 33-1	*hypogaea*	Tan	India	7.3

1. ICRISAT groundnut accession number.
2. Gasp = gaspid (flecks of color).
3. LLS = late leaf spot development, scored on a modified 9-point disease scale where 1 = 0%, 2 = 1–5%, 3 = 6–10%, 4 = 11–20%, 5 = 21–30%, 6 = 31–40%, 7 = 41–60%, 8 = 61–80%, and 9 = 81–100% damage to foliage; ICRISAT Asia Center, 1989 rainy season.

Appendix 3. Sources of combined resistance to rust and late leaf spot available at ICRISAT Asia Center (till 1990).

ICG number[1]	Identity	Botanical type	Seed color[2]	Origin	Disease score[3] Rust	LLS
1703	NC Ac 17127	*fastigiata*	Gasp (tan/purple)	Peru	4.7	5.0
1707	NC Ac 17132	*fastigiata*	Purple	Peru	4.0	4.0
1710	NC Ac 17135	*fastigiata*	Purple	Peru	4.0	4.0
2716	EC 76446 (292)	*fastigiata*	Purple	Uganda	3.3	4.7
3527	USA 63	*fastigiata*	Purple	USA	4.7	4.7
4747	PI 259747	*fastigiata*	Purple	Peru	3.7	4.0
4995	NC Ac 17506	*fastigiata*	Purple	Peru	4.3	4.3
6022	NC Ac 927	*fastigiata*	Purple	Sudan	4.0	4.0
6330	PI 270806	*hypogaea*	Tan	Zimbabwe	2.1	3.3
6340	PI 350680	*fastigiata*	Purple	Honduras	3.0	4.0
7013	NC Ac 17133-RF	*fastigiata*	Purple	India	3.3	4.0
7881	PI 215696	*fastigiata*	Dark purple	Peru	4.3	3.7
7884	PI 341879	*fastigiata*	Purple	Israel	3.0	3.7
7885	PI 381622	*fastigiata*	Purple	Honduras	3.0	4.3
7886	PI 390593	*fastigiata*	Tan	Peru	4.7	3.3
7894	PI 393641	*fastigiata*	Gasp (tan/purple)	Peru	4.0	4.7
7897	PI 405132	*fastigiata*	Purple	Venezuela	2.7	4.0
10010	PI 476143	*fastigiata*	Gasp (tan/purple)	Peru	4.0	5.0
10023	PI 476152	*fastigiata*	Tan	Peru	4.3	4.7
10028	PI 476163	*fastigiata*	Purple	Peru	4.7	5.0
10029	PI 476164	*fastigiata*	Gasp (tan/purple)	Peru	4.3	5.0
10035	PI 476172	*fastigiata*	Purple	Peru	4.0	3.7
10889	PI 476016	*fastigiata*	Dark red	Peru	3.3	4.3
10915	PI 476148	*fastigiata*	Gasp (tan/purple)	Peru	2.3	5.0
10936	PI 476168	*fastigiata*	Purple	Peru	4.3	4.0
10940	PI 476173	*fastigiata*	Gasp (tan/purple)	Peru	2.3	5.0
10941	PI 476174	*fastigiata*	Grayed orange	Peru	4.7	4.7
11182	PI 476015	*fastigiata*	Tan	Peru	2.7	5.0
11485	PI 393530	*fastigiata*	Purple	Peru	5.0	3.7
Susceptible control cultivars						
221	TMV 2	*vulgaris*	Tan	India	8.3	8.0
799	Robut 33-1	*hypogaea*	Tan	India	7.7	7.3

1. ICRISAT groundnut accession number.
2. Gasp = gaspid (flecks of color).
3. Scored on a modified 9-point disease scale where 1 = 0%, 2 = 1–5%, 3 = 6–10%, 4 = 11–20%, 5 = 21–30%, 6 = 31–40%, 7 = 41–60%, 8 = 61–80%, and 9 = 81–100% damage to foliage; ICRISAT Asia Center, 1989 rainy season. LLS = late leaf spot.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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