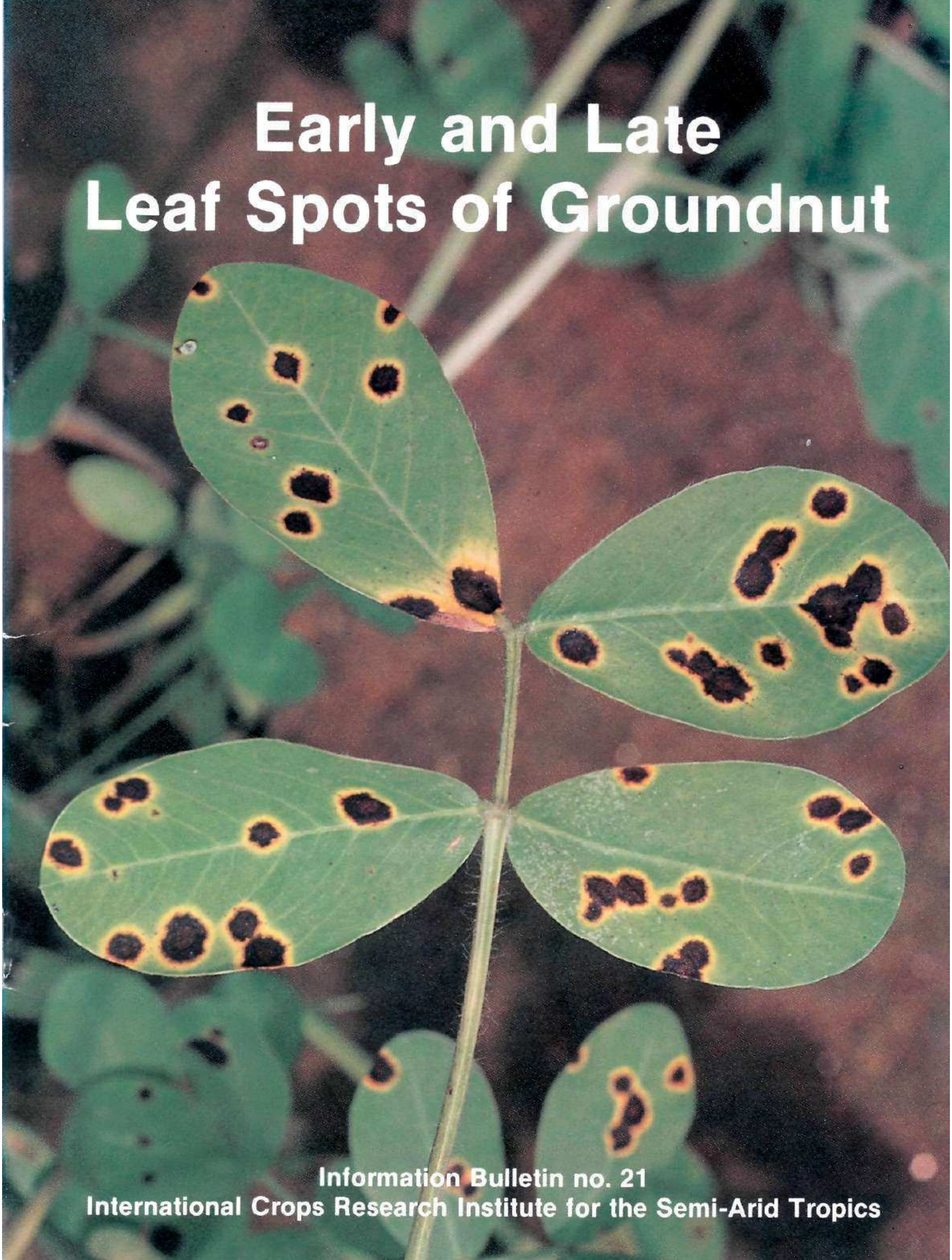
Early and Late Leaf Spots of Groundnut



Information Bulletin no. 21
International Crops Research Institute for the Semi-Arid Tropics

Abstract

McDonald, D., Subrahmanyam, P., Gibbons, R.W., and Smith, D.H. 1985. **Early and late leaf spots of groundnut.** Information Bulletin no. 21. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Early and late leaf spots, caused respectively by *Cercospora arachidicola* and *Phaeoisariopsis personata* (until recently known as *Cercosporidium personatum*), are the most common and serious diseases of groundnut, worldwide. Singly or together they can cause losses in pod yield of over 50%; in areas where rust disease is also present a combined attack of foliar diseases can cause yield losses in excess of 70%.

The text, supported by color illustrations, describes disease symptoms and explains how the two leaf spots can be differentiated. The morphology and taxonomy of each pathogen are also described, and disease cycles are outlined.

An integrated approach to disease management is advocated. Cultural control measures are suggested, fungicides commonly used for control are briefly discussed, and different application methods are assessed. Biological control is considered as a future possibility, and several hyperparasites are described. The prospects for breeding resistant cultivars are discussed. As agronomic, socioeconomic, and environmental factors determine how cultural, chemical, and biological measures can best be integrated into effective disease management systems, it is hoped that the bulletin will assist extension workers in evolving control methods well suited to local disease situations.

Résumé

McDonald, D., Subrahmanyam, P., Gibbons, R.W. et Smith, D.H. 1985. **(Les cercosporioses précoce et tardive de l'arachide.)** Early and late leaf spots of groundnut. Information Bulletin no.21. Patancheru, A.P. 502 324, India : International Crops Research Institute for the Semi-Arid Tropics.

Les cercosporioses précoce et tardive causées par *Cercospora arachidicola* et par *Phaeoisariopsis personata* (connue encore récemment sous le nom de *Cercosporidium personatum*), constituent actuellement les maladies les plus graves et les plus répandues de l'arachide dans le monde. Elles peuvent entraîner, seules ou ensemble, des pertes de récolte de plus de 50%; dans les zones également touchées par la rouille, une combinaison des attaques des maladies foliaires peut occasionner des pertes supérieures à 70%.

La description des symptômes et de la façon dont on distingue, l'une de l'autre, les deux cercosporioses sont soutenues par des illustrations en couleurs. En outre, la morphologie et la taxonomie des deux agents pathogènes sont exposées, et les cycles de développement sont décrits d'une façon générale.

Par ailleurs, on préconise une approche de lutte intégrée contre les maladies. Des méthodes culturales de lutte sont proposées, les fongicides utilisés couramment dans la lutte chimique contre les cercosporioses sont examinés et les divers modes d'emploi sont évalués. La lutte biologique est considérée comme un moyen éventuel et plusieurs hyperparasites sont décrits. Sont également étudiées les perspectives de sélection de cultivars résistants.

L'intégration parfaite des moyens culturaux, chimiques et biologiques dans des systèmes efficaces de lutte contre les maladies, dépend des facteurs agronomiques, socioéconomiques et liés à l'environnement; on espère donc que ce bulletin aidera les vulgarisateurs à mettre au point des méthodes de lutte adéquates et bien adaptées aux conditions locales de l'attaque par les pathogènes.

Early and Late Leaf Spots of Groundnut

D. McDonald, P. Subrahmanyam, R.W. Gibbons and D.H. Smith

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1985

About the authors

D. McDonald, P. Subrahmanyam, and R.W. Gibbons are members of staff of ICRISATs Groundnut Improvement Program.

D.H. Smith is a member of staff of the Plant Disease Research Station, Texas A & M University, Yoakum, Texas, USA.

The use of SI units in this Bulletin

In common with a growing number of scientific publishers, ICRISAT uses SI units in its publications. The SI (the Systeme International d'Unites) provides for our readers an internationally-accepted and reliable way of expressing quantities that is clear and precise, even in countries where other conventions are still used. For readers' guidance the meaning of the two SI units used in this publication are explained as follows:

kg ha^{-1} = kilograms per hectare (previously kg/ha);
µm = micrometer (previously micron: µ).

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Contents

Preface

As new information is gathered on diseases of groundnut, there is a need to disseminate this information to both research and extension workers in short, informative bulletins. This is particularly important for workers in developing countries who may not have ready access to scientific journals containing detailed research papers.

The ICRISAT Groundnut Improvement Program has set out to produce up-to-date information bulletins on important diseases affecting groundnut. The first of these, on groundnut rust, was published in May 1983. With the publication ofthis new bulletin on early and late leaf spots, groundnut workers are now provided with sufficient data on these important diseases to enable them to plan effective disease management systems.

J.S. Kanwar
Director of Research

Introduction

Leaf spots are the most serious diseases of groundnut *(Arachis hypogaea* L.) on a worldwide scale. The two fungi commonly involved are *Cercospora arachidicola* Hori, causing early leaf spot, and *Phaeoisariopsis personata* (Berk. & Curt.) v. Arx[1] causing late leaf spot. The diseases have also been referred to as mycosphaerella leaf spots, cercospora leaf spots, brown leaf spots, peanut cercosporiosis, viruela, and tikka. Leaf spots damage the plant by reducing the available photosynthetic area, by lesion formation, and by stimulating leaflet abscission. Worldwide, yield losses range from 10% to over 50%, but vary considerably from place to place and between seasons. Yield losses are generally substantial when the crop is attacked by both leaf spots and rust *(Puccinia arachidis* Speg.). Figure 1 shows severe damage to groundnut crops caused by early leaf spot in the USA and Malawi, and by the combined attack of late leaf spot and rust in India.

Distribution

The geographical distribution of the leaf spot pathogens is indicated in Figures 2 and 3. Both early and late leaf spots are commonly present wherever groundnut is grown. However, the incidence and severity of each disease varies between localities and seasons, and there can be both short- and long-term fluctuations in their relative proportions.

Symptoms

Leaf spot diseases symptoms are influenced by host genotype and environmental factors. For both diseases, small chlorotic spots appear on leaflets 10 days after infection. The spots then develop in about 5 days into mature, sporulating lesions.

1. Until recently *Phaeoisariopsis personata* was known as *Cercosporidium personatum* (see page 6).

Lesions caused by *C. arachidicola* are subcircular and from 1 to over 10 mm in diameter. They are dark brown on the adaxial (upper) leaflet surface (Fig. 4A) where most sporulation occurs, and a lighter shade of brown on the abaxial (lower) leaflet surface (Fig. 4B).

Lesions caused by *P. personata* are usually smaller, more nearly circular, and darker in color (Fig. 5 A) than those of *C. arachidicola.* On the abaxial surfaces (Fig. 5B), where most sporulation occurs, the lesions are black with a slightly rough appearance.

A chlorotic halo is often present around *C. arachidicola* lesions, but its presence and prominence is altered by host genotype and environmental factors. Similar halos may be found around *P. personata* lesions; therefore, the halo is not a good diagnostic character.

The color of the lesion on the abaxial leaflet surface, light brown for *C. arachidicola* and black for *P. personata* (Fig. 4A and 5A), and distribution of fruiting structures, randomly on the adaxial surface for *C. arachidicola* and in circular rings on the abaxial surface for *P. personata* (Fig. 4B and 5B), are useful characters for distinguishing between the two leaf spots in the field.

The two pathogens can be readily identified by the morphology of conidiophores and conidia (Fig. 6). Examination of sections of diseased leaflets shows that *P. personata* produces haustoria within host cells, whereas C. *arachidicola* does not.

In addition to causing leaf spots, the two pathogens also produce lesions on petioles, stems, and pegs. These are oval to elongate and have more distinct margins than the leaflet lesions. When disease attack is severe, the affected leaflets first become chlorotic, then necrotic, lesions often coalesce, and leaflets are shed.

Causal Organisms

Early leaf spot

Cercospora arachidicola Hori. Annual Report of Nishigahara Agricultural Ex-

Figure 1. Severe damage to a groundnut crop caused by early leaf spot in the USA (A) and Malawi (B), and by a combined attack of late leaf spot and rust in India (C).

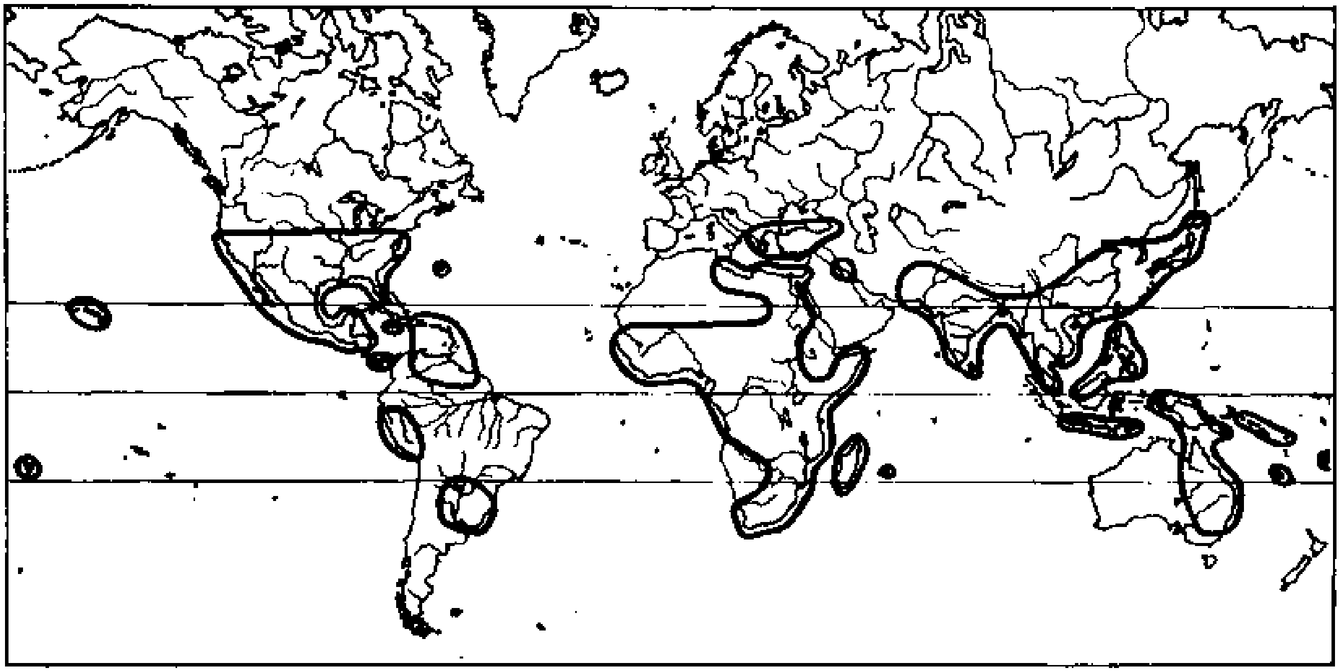

Figure 2. Distribution of *Cercospora arachidicola* (based on Commonwealth Mycological Institute Map no. 166, 1966).

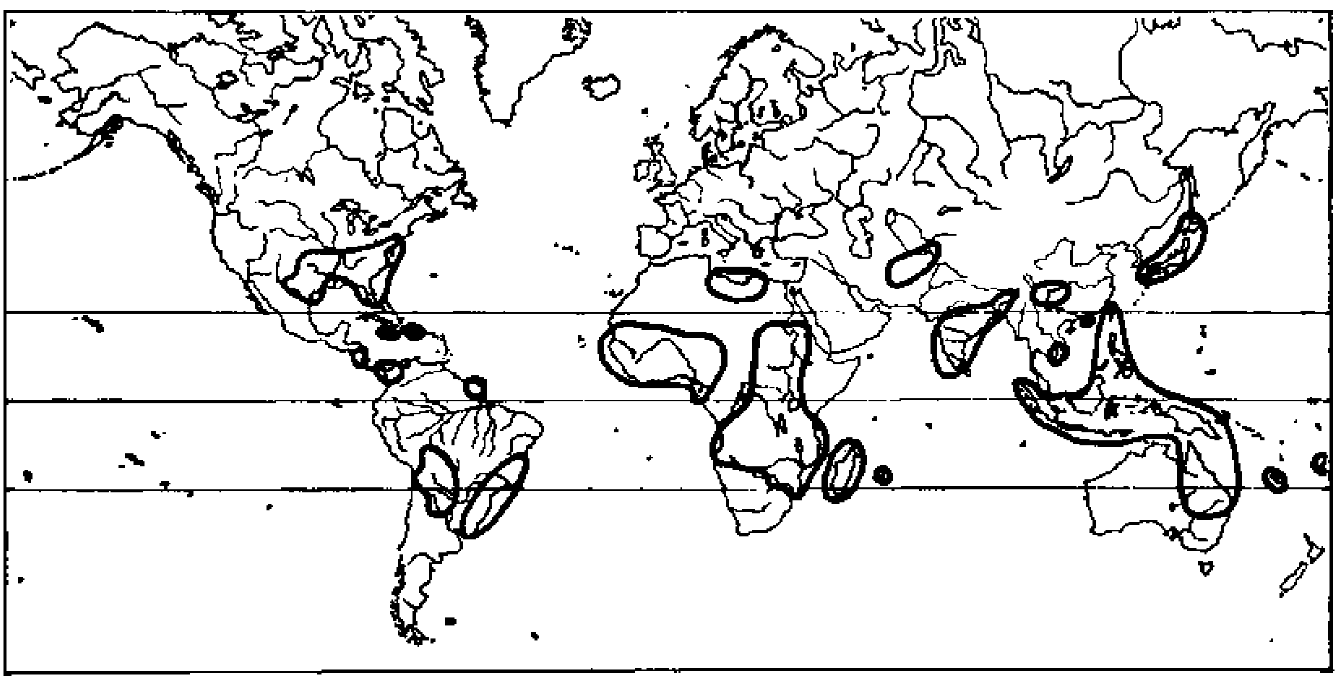

Figure 3. Distribution of *Phaeoisariopsis personata* (= *Cercosporidium personatum)* (based on Commonwealth Mycological Institute Map no. 152, 1967).

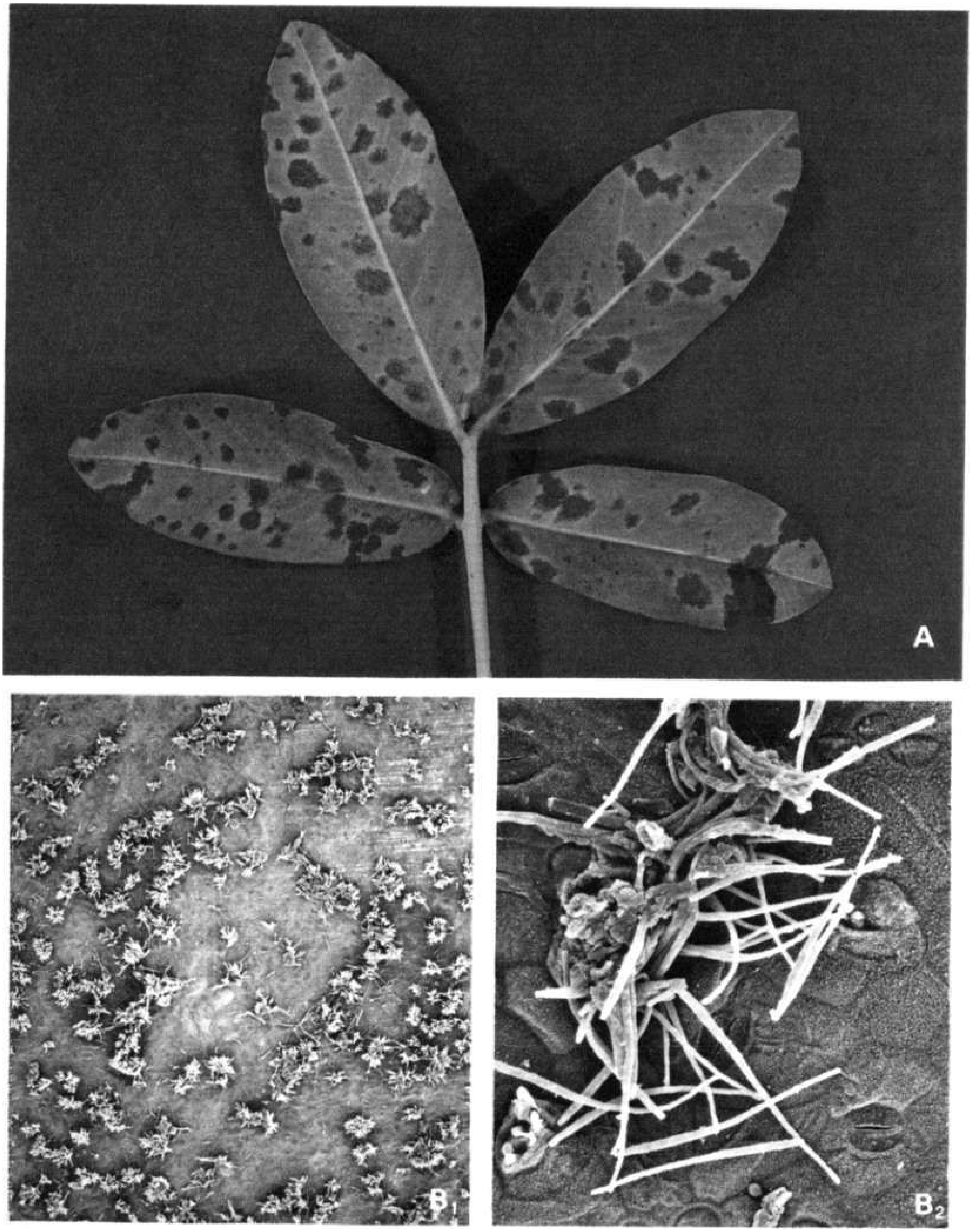

Figure 4. Early leaf spot lesions on the abaxial (lower) surface of groundnut leaflets (A). The sporulating surface of an early leaf spot lesion (B) magnified x 45 (B_1); x 450 (B_2).

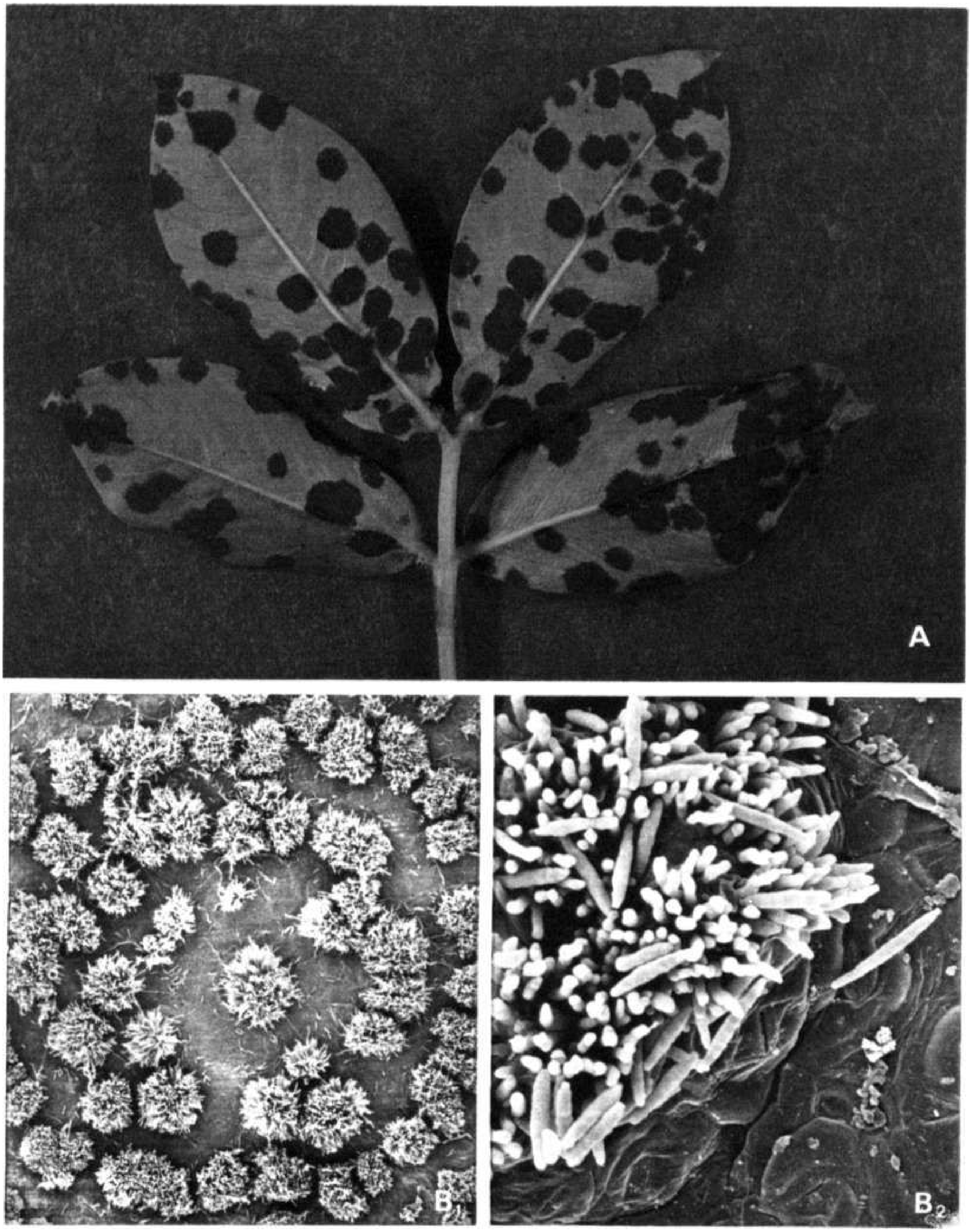

Figure 5. Late leaf spot lesions on the abaxial (lower) surface of groundnut leaflets (A). The sporulating surface of a late leaf spot lesion (B) magnified x 45 (B_1); x 450 (B_2).

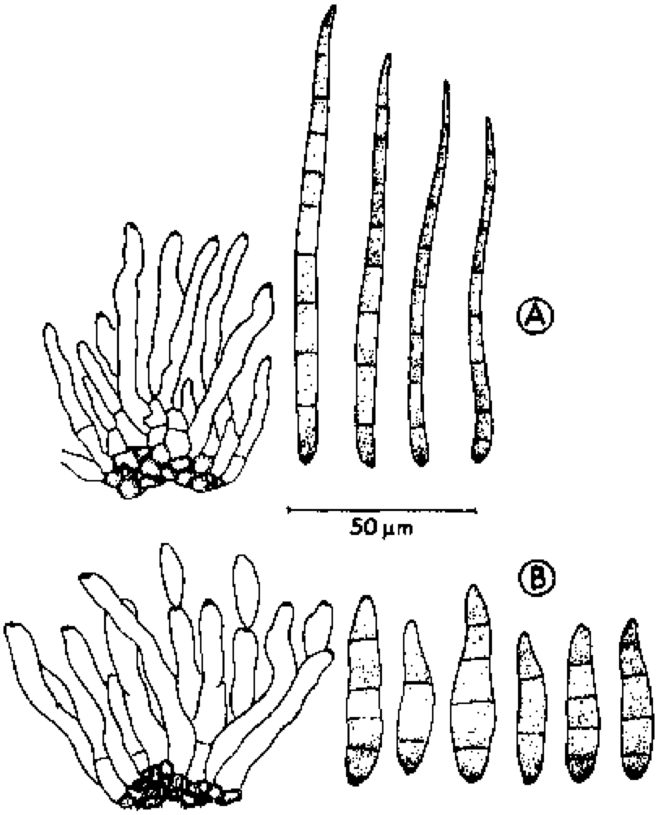

Figure 6. Morphology of conidiophores and conidia: A = *Cercospora arachidicola;* B = *Phaeoisariopsis personata*.

periment Station, Tokyo, 1917, 26 (anamorph);

= *Mycosphaerella arachidicola* W.A. Jenkins. Journal of Agricultural Research 56, 324, 1938.

Mycosphaerella arachidis Deighton. Transactions of the British Mycological Society 50, 328, 1967 (teleomorph).

The anamorph of the fungus has been well described by Jenkins (1939) and by Chupp (1953). Pertinent morphological characters are the following.

Stromata present, slight to 100 *µm* in diameter, dark brown in color. Conidiophores arranged in dense fascicles, 5 to many in number, pale olivaceous or yellowish brown in color and darker at the base, mostly once geniculate, unbranched, 15-45 x 3-6 µm in size. Conidia subhyaline, slight olivaceous, obclavate, often curved, 3-12 septate, base rounded to truncate, tip subacute, 35-110 x 2.0-5.4 µm in size (Fig. 6A).

Jenkins (1938) described the teleomorph as *Mycosphaerella arachidicola,* but it was later found that this name had been applied to another fungus. Deighton (1967) therefore proposed that the name *Mycosphaerella arachidis* Deighton be used for the teleomorph of the early leaf spot fungus. Its morphological characters are the following.

Perithecia scattered, mostly along lesion margin, amphigenous, partly embedded in host tissue, erumpent, ovate to nearly globose, 47.6-84.0 * 44.4-74.0 µm in size, black, ostiole slightly papillate; asci cylindrical, club-shaped, short stipitate, fasciculate, 27.0-37.8 * 7.0-8.4 µm in size, aparaphysate, bitunicate, 8-spored; spores uniseriate to imperfectly biseriate in ascus, bicellular, the upper cell somewhat larger, slightly curved, hyaline, 7.0-15.4 x 3-4 *µm* (average 11.2 x 3.64 µm) in size.

Late leaf spot

Phaeoisariopsis personata (Berk. & Curt.) v. Arx. Proceedings of the Koninklijke Nederlandse Akademie 86(1), 15-54, 1983 (anamorph);

= *Cercosporidium personalum* (Berk. & Curt.) Deighton. Mycological Papers 112, 71, 1967.

= *Cladosporium personata* Berk. & Curt. Grevillea 3, 106, 1875;

= *Cercospora personata* (Berk. & Curt.) Ellis & Everhart. Journal of Mycology 1, 63, 1885;

= *Septogloeum arachidis* Racibolski. Zeitschrift fuer Pflan/.enkrankheiten und Pflanzenschutz 8, 66, 1898;

= *Cercospora arachidis* P. Hennings. Hedwigia 41, 18, 1902;

= *Passalora personata* (Berk. & Curt.) Khan & Kamal. Pakistan Journal of Science 13(4), 188, 1961.

Mycosphaerella berkeleyi W.A. Jenkins. Journal of Agricultural Research 56, 330, 1938 (teleomorph).

The nomenclature of the anamorph of this fungus has undergone several changes in the literature. Until recently the combination *Cercosporidium persona turn* (Berk. & Curt.) Deighton was widely used. In 1983, J.A. von Arx reorganized the anamorphs of the genus *Mycosphaerella.* Twenty-three form genera were enumerated, mainly on the basis of conidionatal structure and position on the host plant, and on the types of scars on the conidiogenous cells and conidia. He proposed the new combination *Phaeoisariopsis personata* (Berk. & Curt.) v. Arx, mainly based on the formation of small synnemata or long conidiophores and by less thickened and darkened, but bulging scars. For the anamorph the pertinent morphological characters are the following.

Stroma dense, pscudoparenchymatous, up to 130 *µm* in diameter; conidiophores numerous, pale to olivaceous brown, smooth, 1-3 geniculate, 10-100 x 3.0-6.5 µm in size, conidial scars conspicuous, prominent, 2-3 µm wide; conidia medium olivaceous, cylindrical, obclavate, usually straight or slightly curved, wall usually finely roughened, rounded at the apex, base shortly tapered with a conspicuous hilum, 1-9 septa not constricted, mostly 3-4 septate, 20-70 x 4-9 µm in size (Fig. 6B).

Pertinent morphological characters of the teleomorph are the following.

Perithecia scattered, mostly along lesion margins, amphigenous, partly embedded in host tissue, erumpent, broadly ovate to globose, 84-140 x 70-112 µm in size, black in color, ostiole slightly papillate, asci cylindrical, club-shaped, short stipitate, fasciculate, 30-40 x 4-6 µm, aparaphysate, bitunicate, 8-spored, spores uniseriate to imperfectly biseriate in the ascus, bicellular, the upper cell somewhat larger, slightly constricted at the septum, hyaline, 10.9-19.6 x 2.9-3.8 µm (average 14.9 x 3.4 µm) in size.

Disease Cycle

Early and late leaf spots pathogens are both soilborne, disease onset being earliest and attack most severe when groundnut follows groundnut in the rotation. As the common names imply, an attack by C. *arachidicola* normally precedes that of *P. personata,* but both diseases may appear within 3-5 weeks after sowing.

Although the teleomorphs of the fungi are known, the ascospores are not generally regarded as important sources of primary inoculum. Conidia are produced directly from mycelium in crop debris in the soil following early rains and, when deposited on the leaves of young groundnut plants by rain splash and wind, they initiate the disease cycle (Fig. 7). Temperatures in the 25 to 30°C range and high relative humidity favor infection and disease development. The first lesions normally develop on the oldest leaves near the soil surface and the conidia produced on them are carried by wind, rain splash, and insects to the later-formed leaves and to adjacent plants. Given favorable conditions, progress of the disease continues throughout the season and may result in nearly total defoliation of plants.

Conidia may be detached from lesions at any time but peak release periods occur when leaf surfaces dry in the morning, and at the onset of rainfall.

The pathogens may survive from season to season on volunteer groundnut plants and infected crop debris. No authentic host species are known outside the genus *Arachis.*

Long-distance distribution of the pathogens may be by airborne conidia, by movement of infected crop debris, or by movement of pods or seeds that are surface-contaminated with conidia or infected crop debris. There is no evidence of either pathogen being internally seedborne.

Disease Management

Losses in yield from leaf spots vary from place to place and among seasons. In the southern USA, where fungicide application is a normal practice,

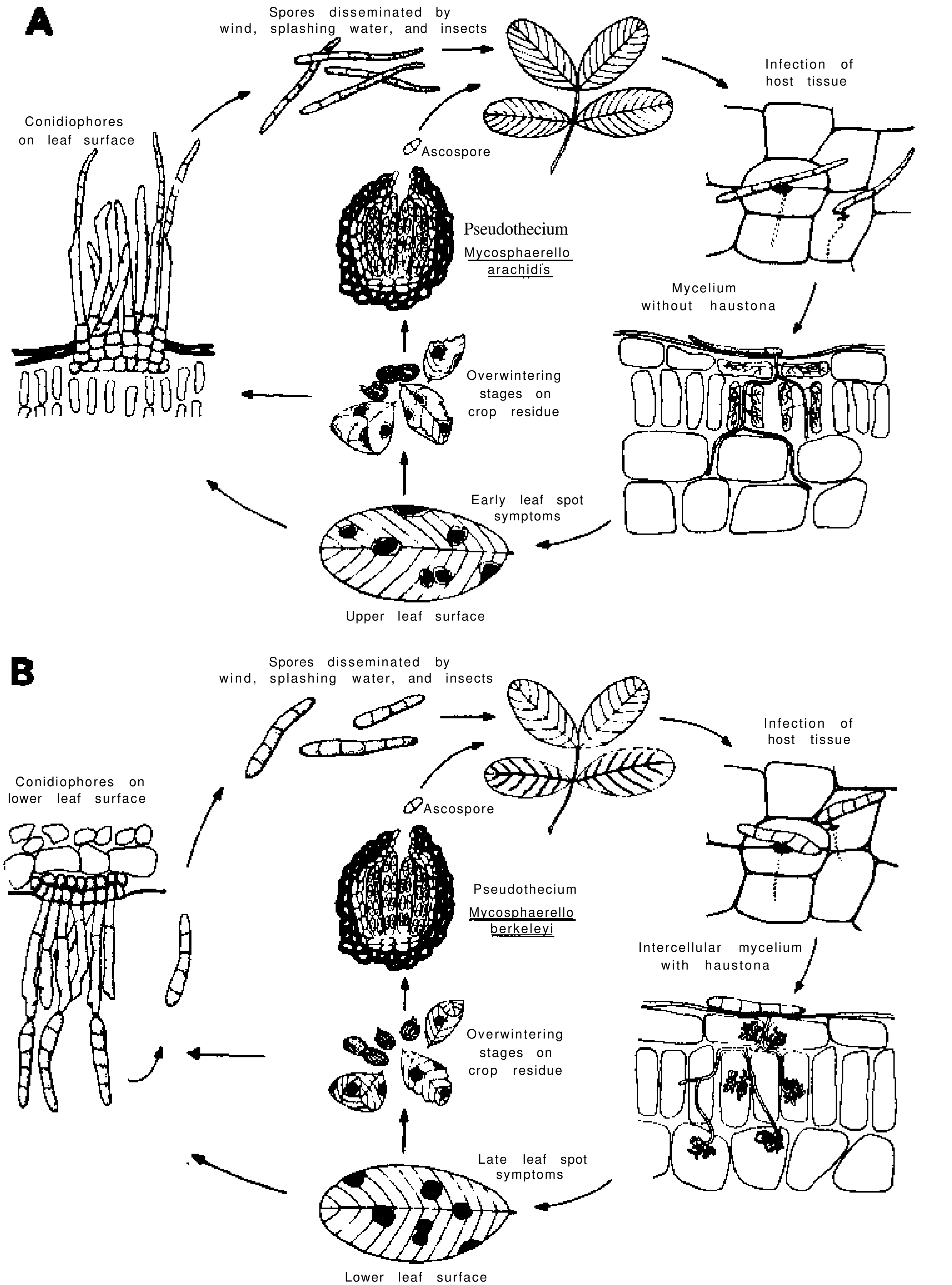

Figure 7. Disease cycles of *Cercospora arachidicola* (A) and *Phaeoisariopsis personata* (B). (Reprinted, by permission, from: Compedium of peanut diseases, published by the American Phytopathological Society, 1984.)

pod yield losses are estimated at around 10%. But for much of the semi-arid tropics, where fungicides are rarely used, losses in excess of 50% are common. Haulm losses from leaf spots normally exceed kernel losses. It is important that effective management of leaf spot diseases be developed and applied.

Cultural and chemical control measures effective against one leaf spot will normally be effective against the other. A recent complication for the Eastern Hemisphere is the appearance and rapid spread of groundnut rust caused by *Puccinia arachidis* Speg. This disease, which has long been a problem in the Western Hemisphere, is more difficult to control with fungicides than are leaf spots, and some chemicals effective against leaf spots are totally ineffective for rust control, and vice versa. There is also the problem in resistance breeding of incorporating resistance to all three diseases into agronomically acceptable cultivars.

Cultural measures for control of leaf spots

Where possible, there should be a distinct break in time between successive groundnut crops. As the diseases are largely soilborne, rotation with other crops is obviously very important. Plant debris should be removed from the field after harvest, burned in situ, fed to animals, or deep-buried. Volunteer groundnut plants and 'ground-keepers'should be eradicated. Depending upon length of the growing season and cultivars grown, the time of sowing may be adjusted to avoid infection of the crop from outside sources and to avoid environmental conditions conducive to disease build-up. Weeds should be kept under control because their heavy growth may encourage disease development through modification of the crop microclimate.

Leaf spots control with fungicides

Fungicidal control of leaf spots is effective and economic when used by farmers in agriculturally advanced countries, where it has been widely adopted. But it has presented some problems for small-scale groundnut farmers typical of many less developed countries of the semi-arid tropics.

The southern groundnut growing areas of the USA are representative of advanced farming countries with a high level of mechanization. Fungicides are applied by various kinds of tractor-propelled machines, fixed-wing aircraft, helicopters, and, more recently, through sprinkler irrigation systems. Dust formulations (copper, sulfur, and copper plus sulfur) were the most commonly used fungicides up to the late 1960s, although a number of spray fungicides, e.g., Bordeaux mixture and the dithiocarbamates maneb and mancozeb, were fairly widely used. According to Smith and Littrell (1980) there was a rapid move towards spray application following the introduction of the highly effective fungicides benomyl, chlorothalonil, and fentin hydroxide in the early 1970s.

While benomyl was very effective against early and late leaf spots, it was ineffective for control of rust that was becoming more important in Texas. After several years of extensive use of the systemic benomyl fungicide, it was found that strains of *C. arachidicola* and *P. personata* tolerant of it were appearing (Littrell 1974; Smith et al. 1978). Benomyl is now rarely used alone as a leaf spots control chemical, but it is used in mixture with protectant fungicides. Chlorothalonil is now the most widely used leaf spots fungicide in the USA; it is also very effective for controlling rust and some minor foliar diseases.

To obtain effective control of leaf spots, fungicides are first applied before or just after the appearance of symptoms, and further applications are made at intervals of 10-14 days until 2-3 weeks before harvest. This normally means that 6-8 applications are made through the season. Intervals between applications may have to be shortened under environmental conditions highly favorable to disease development.

Fungicidal control of leaf spots has been tried in a number of developing countries of the semi-arid tropics (Fig. 8), and large increases in yield of both kernels and haulms have been obtained.

Figure 8. Chemical control of leaf spots and rust at ICRISAT Center.

Various fungicide formulations have been tested with apparatus ranging from hand-operated dusters and watering cans to sophisticated controlled droplet application (ultra-low-volume) machinery. Although fungicidal control has been proved effective under research conditions, very few farmers have adopted the practice. Some of the reasons for this are the following.

- Low basic yields. Average kernel yields in the semi-arid tropics are between 500 and 600 kg ha^{-1}. Even if fungicide application could double this yield, the result would not be economic.
- Difficulties in obtaining fungicides and application machinery, and their high costs for small-scale farmers.
- Problem of access to sources of clean water and of transporting it in sufficient quantities for high- or medium-volume spraying.
- Lack of expertise and lack of advice on the use of spray machinery and on its maintenance.
- Low or fluctuating prices for groundnut can discourage farmers from risk-taking investment in the crop.

These problems are not insurmountable. Adoption of recommended agronomic practices could help farmers to improve upon low-level basic yields. Government or commercial organizations could improve the supply of fungicides, application machinery, and information on how to use them. Recent developments in controlled droplet application have led to the production of relatively inexpensive 'spray' machinery, which requires little or no water—perhaps as little as 2 litres of spray to the hectare. Possibilities also exist for contract spraying. The world shortage of oilseeds could also in some areas justify government subsidies or loan schemes to encourage farmers to purchase equipment and fungicides. Some fungicides in common use against leaf spots are the following.

- Copper, sulfur, and copper/sulfur dusts: These give good control of leaf spots and some control of rust. Application rates are high (20-50 kg ha^{-1}) and the dusts can be expensive if they have to be imported and transported for any distance.
- Bordeaux mixture: Used as a spray it gives good control of rust and leaf spots. It is more difficult to prepare than modern fungicides.
- Dithiocarbamates: Maneb- and mancozeb-type sprays are effective for controlling leaf spots and give some control of rust.
- Fentin hydroxide: Applied as a spray it gives excellent control of both leaf spots and rust. It has higher mamallian toxicity than most other leaf spot control fungicides and may cause phytotoxic symptoms on foliage.
- Benomyl: A systemic fungicide giving excellent control of leaf spots but likely to stimulate production of tolerant strains of the pathogens. Ineffective against rust.
- Carbendazim: Similar to benomyl.
- Captafol: Applied as a spray it gives good control of leaf spots but is considerably less effective against rust.
- Chlorothalonil: Applied as a spray it gives excellent control of leaf spots and good control of rust.

Some of the fungicides mentioned are produced by individual firms but most are available from several firms under various trade names. Manufacturers' recommendations regarding rates of application and number of applications should be followed where no local advisory service recommendations are available. The degree of leaf spots control possible under any specific set of environmental conditions will depend upon the effectiveness of the fungicide, the rate at which it is applied, the number of applications, and the efficiency of application.

The decision as to whether or not leaf spots control should be recommended has to be made at the local level. The factors to be taken into consideration include the extent of losses, the cost of control measures, and economic and other returns expected. If fungicidal control is desired, then decisions will have to be made concerning the chemicals to be used, the rate at which they should be applied, and the timing and number of applications. The presence of rust disease requires that any fungicide used for leaf spots control should also control rust. Disease control and yield responses to different levels of fungicides application are still to be worked out for some situations, and it is difficult to recommend economic disease control measures without such data.

Possible effects of fungicides on nontarget organisms should be considered. Backman et al. (1977) found an increase in levels of *Sclerotium rolfsii* Sacc. attack when Florunner groundnuts were sprayed with benomyl. Porter (1980) found that spraying with chlorothalonil or with captafol increased levels of sclerotinia blight. Controlling severe leaf spots attack may increase the effective growing season of a cultivar by 2-3 weeks. This can have adverse effects upon yield if the cultivar is growing in an area with a very short rainy season. Under drought stress, plants that have retained most of their foliage are more likely to go into permanent wilting than plants that have lost most of their leaves from leaf spot diseases.

Breeding cultivars resistant to leaf spots

Breeding resistant cultivars is one of the best means of reducing crop yield losses from diseases. It is a strategy particularly well suited to help small-scale farmers of the semi-arid tropics who generally lack the financial resources and technical expertise required to use chemical control methods effectively. There is also a need to breed resistant cultivars in developed countries to reduce farmers' dependence on fungicides and thus bring down the cost of groundnut cultivation.

In 1985 there is no agronomically acceptable groundnut cultivar with resistance to either of

Figure 9. Field screening of groundnut germplasm accessions for resistance to *Cercospora arachidicola* at Yoakum, Texas, USA.

the leaf spots. In recent years, screening of groundnut germplasm accessions for resistance to leaf spots has been intensively carried out in different parts of the world (Fig. 9). Effective field and laboratory screening methods have evolved. For example, genotypes to be screened are now sown in replicated plots with rows of a highly susceptible cultivar arranged systematically throughout the trial. Good disease development is ensured by providing inoculum, and sprinkler irrigation, if required. Genotypes belonging to different maturity groups are evaluated on different dates, according to growth development stages. Reactions to each leaf spot pathogen are measured separately.

There is no uniform method for assessing leaf spot resistance. Hassan and Beute (1977) used several disease evaluation methods for early leaf spot and concluded that a visual estimate of percentage of leaves with leaf spots was an efficient evaluation method when large numbers of entries are to be tested. Foster et al. (1981), working with several genotypes previously reported to be resistant to early leaf spot, observed that the number of lesions per leaf and the percentage defoliation were most useful for assessing resistance to early leaf spot. At 1CRISAT Center a 9-point disease scale is used for screening germplasm accessions and breeding lines for resistance to late leaf spot.

Inoculation of potted plants or detached leaves is also useful for assessing resistance to leaf spots in a greenhouse or laboratory (Fig. 10), especially when host or pathogen materials are in short supply, when environmental interactions have to be minimized, and when the effects of other foliar pathogens have to be eliminated. Genotype reactions to leaf spots in the greenhouse have been correlated well with field scores of resistance.

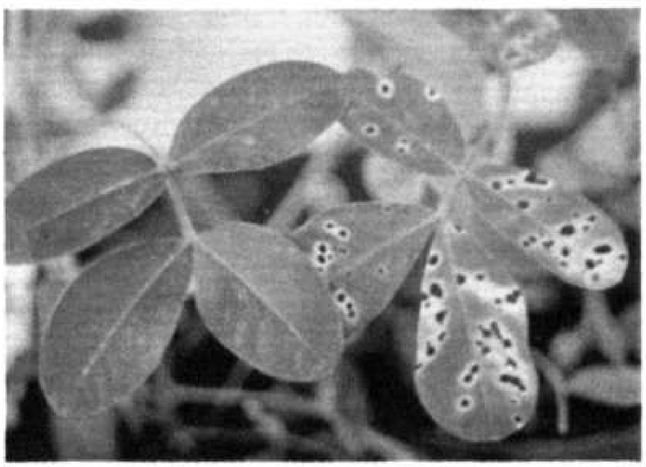

Figure 10. Screening groundnut germplasm accessions for resistance to *Phaeoisariopsis personata* in a greenhouse. Left: resistant genotype PI 259747; right: susceptible cultivar TMV 2.

Several sources of resistance to early and late leaf spots have been reported (Table 1) and are available from various research institutions. Late leaf spot resistant genotypes available from ICRISAT Center in 1985 are listed in Table 2. All of the genotypes listed in this table are also resistant to *Puccinia arachidis.*

Research, in progress in several countries, is aimed at incorporating leaf spot resistance and high yield into cultivars with agronomic and

Table 1. Some genotypes resistant to groundnut leaf spot pathogens *Cercospora arachidicola* and *Phaeoisariopsis personata* in America.

Resistance to *C, arachidicola*	Resistance to *P. personata*
PI 109839	PI 259747
PI 162857	PI 261893
PI 259639	PI 262090
PI 259679	PI 341879
PI 259747	PI 371521
PI 261893	
PI 270806	NC Ac 3139
PI 306230	
PI 350680	
PI 468251	
PI 468253	
PI 468293	
PI 468295	
PI 475871	
PI 476029	
PI 476034	
NC 5	
NC 3033	
NC Ac 3139	
NC 3139	
Kanyoma	

References: Cook, 198!; Foster et al. 1980 and 1981; Gorbet et al. 1982; Hassan and Beute, 1977; Kornegay et al. 1980; Melouk et al. 1984; Mixon et al. 1983; and Sowell et al. 1976

Table 2. Genotypes resistant to *Phaeoisariopsis personata* availlable from ICRISAT (in 1985).[1]

Groundnut genotype	ICG no.[2]	Botanical type/variety	Seed color[3]	Country of origin
EC 76446 (292)	2716	*fastigiata*	Purple	Uganda
USA 63	3527	*fastigiata*	Purple	USA
PI 259747	4747	*fastigiata*	Purple	Peru
PI 350680	6340	*fastigiata*	Purple	Honduras
NC Ac 17133-RF	7013	*fastigiata*	Purple	Peru
PI 215696	7881	*fastigiata*	Purple	Peru
PI 351879	7884	*fastigiata*	Purple	Peru
PI 381622	7885	*fastigiata*	Purple	Peru
PI 390595	7887	*fastigiata*	Purple	Peru
PI 405132	7897	*fastigiata*	Purple	Peru

1. Also resistant to *Puccinia arachidis* at ICRISAT.
2. ICRISAT Groundnut Accession Number.
3. Based on the RHS colour chart, published in 1966 by the Royal Horticultural Society, London.

quality characters suitable to different environments. For instance, the University of Florida in the USA has developed a high-yielding groundnut cultivar, Southern Runner (UF 80202), with resistance to late leaf spot. This variety is in final stages of testing in 1985 and will soon become available to groundnut farmers in the USA. At ICRISAT Center several high-yielding breeding populations, with resistance to late leaf spot and rust, have been developed (Fig. 11). This material could be used immediately for the village-level production of groundnut oil, but some quality characters need to be improved before it would be acceptable for sophisticated markets.

Resistance to leaf spot pathogens has been attributed to various morphological and anatomical characters of the host plant and to different chemical constituents of leaves and seeds. It operates by prolonging incubation and latent periods, and by reducing the number of lesions per unit area of leaf surface, defoliation, and sporulation.

Resistance to leaf spots is recessive and independently inherited. Kornegay et al. (1980) proposed that resistance to leaf spots was quantitatively inherited. Nevill (1982) showed that late leaf spot resistance was determined by recessive alleles at five loci.

There is some evidence of variation in pathogenicity in leaf spot fungi, but races have not been clearly characterized. In areas where the systemic fungicide benomyl has been widely used, strains of both fungi showing tolerance to this substance have appeared.

There has been considerable emphasis on screening wild *Arachis* species for resistance to leaf spots (Fig. 12). Data on late leaf spot reaction of some wild *Arachis* species at ICRISAT

Figure 11. Breeding for resistance to late leaf spot disease of groundnut at ICRISAT Center. Susceptible lines (in brown) show severe leaf damage.

Center are presented in Table 3. Cytogenetic research aimed at incorporating leaf spot resistance from wild *Arachis* species into the cultivated groundnut is in progress in several research institutions. At ICRISAT Center, the tetraploid or near-tetraploid lines derived from crosses between cultivated groundnuts and wild *Arachis* species have been systematically evaluated for their reaction to late leaf spot and other foliar diseases. A very high degree of resistance to late leaf spot and rust has been observed in a number of derivatives (Fig. 13) and some of them have given significantly higher yield than Indian cultivars susceptible to leaf spot.

Biological control

Mycoparasites, *Dicyma pulvinata* (Berk. & Curt.) v. Arx (= *Hansfor dia pulvinata* (Berk. & Curt.) Hughes) (Fig. 14) and *Verticillium lecani* (Zimmerm.) Viegas have been observed to parasitize the early and late leaf spot pathogens of

Table 3. Reaction of some wild *Arachis* species to *Phaeoisariopsis personata* at ICRISAT Center (from Subrahmanvam et al. 1985).

Section, series, and species	USDA Plant introduction (PI) no.	ICR1SAT groundnut accession (ICG) no.	Components of resistance to r. *personata*: Infection frequency (lesions/cm²)	Defoliation (%)	Lesion diameter (mm)	Sporulation index[1]
Section: ARACH1S						
Series: Annuae						
A. duranensis	219823	8123	8.0	35.0	0.49	1.8
A. spegazzinii	262133	8138	12.7	75.0	0.79	3.0
Series: Perenne						
A. correntina	262137	8133	15.9	5.0	0.23	1.0
A. stenosperma	338280	8126	19.4	30.0	0.16	1.0
A. chacoense	276235	4983	17,4	32.6	0.26	1.0
Section: ERECTOIDES						
Series: Tetrafoliate						
A. apressipila		8129	19.8	5.0	0.24	1.0
A. paraguariensis		8130	8.0	0.0	0.22	1.0
Section: TRISEMINALE						
A. pusilla	338449	8131	12.0	25.0	0.45	1.0
Section: EXTRANERVOSAE						
A. villosulicarpa			4.0	33.6	0.47	1.0
Section: RHIZOMATOSAE						
Series: Eurhizomatosae						
A. hagenbeckii	338305	8922	82.3	93.9	0.49	1.0
A. glabrata	338261	8149	11.2	0.0	0.35	1.0
A. burkartii	261851		2.0	0.0	0.09	1.0
A. prostrata			36.1	10.0	0,38	1.0
Section: CAULORHIZAE						
A. repens			22.3	0.0	0.15	1.0

I. Extent of sporulation scored on a 5-point scale where 1 - no sporulation and 5 = extensive sporulation.

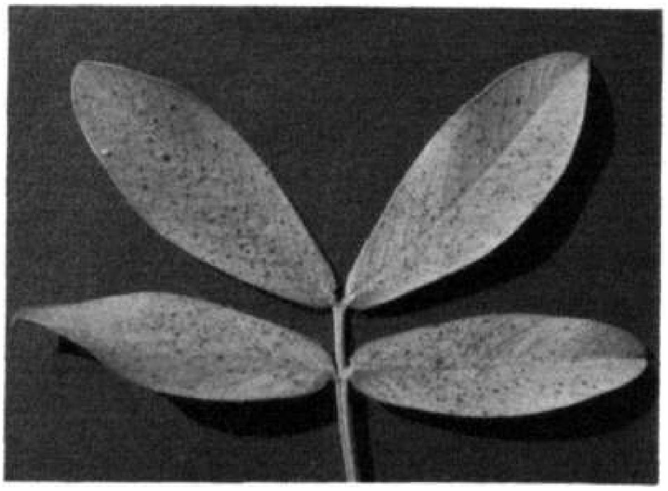

Figure 12. Reaction of a wild *Arachis* species to *Phaeoisariopsis personata* at ICRISAT Center.

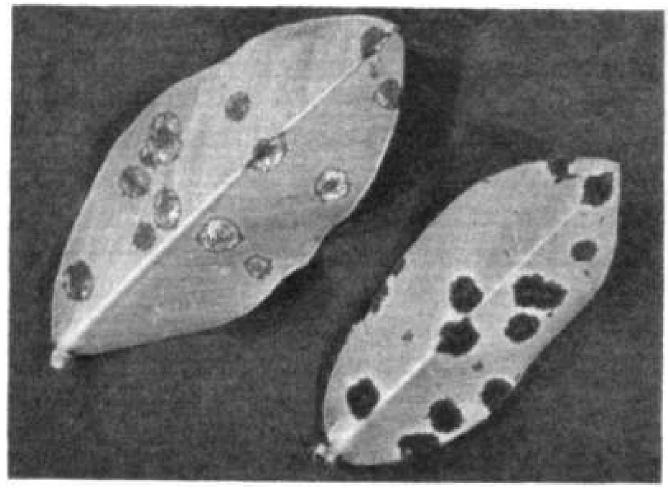

Figure 14. The mycoparasite *Dicyma pulvinata* parasitizing *Phaeoisariopsis personata.*

groundnut. These were found to be effective in controlling leaf spots in greenhouse studies; however, no serious attempts have been made to use them at the field level.

Integrated control of leaf spot diseases

Every effort should be made to utilize all available and compatible disease control measures. Breeders should endeavor to combine leaf spots resistance with resistance to rust and other diseases. *If* fungicides are to be applied, these should be capable of controlling leaf spots as well as rust, and the possibility of applying fungicides combined with insecticides should be considered where insect pests are a problem.

Figure 13. Utilization of wild *Arachis* species in breeding leaf spot resistance in the field at ICRISAT Center, Left: a tetraploid line with resistance to late leaf spot rust; right: a susceptible cultivar from India.

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ICRISAT

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