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Web Blotch Disease of Groundnut

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Abstract

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Web blotch disease caused by *Phoma arachidicola* affects groundnut crops in several major producing countries, where it can reduce yields by about 40%. In this illustrated bulletin its distribution, economic importance, and symptoms are described. Details of the causal organism are presented, disease cycle and epidemiology explained, and methods of disease management suggested.

Résumé

La maladie foliaire de l'arachide due à Phoma arachidicola. La maladie foliaire due à *Phoma arachidicola* affecte les cultures de l'arachide dans plusieurs pays producteurs importants où elle peut réduire les rendements d'environ 40%. Ce bulletin illustré expose la distribution, l'importance économique et les symptômes de la maladie. En outre, les détails de l'organisme causal sont présentés, avec une explication du cycle et de l'épidémiologie de la maladie. Quelques méthodes de contrôle sont également proposées.

Resumo

A doença causado por *Phoma arachidicola* ataca a cultura do amendoim em muitos paises, e que pode reduizir a produção em cerca de 40%. Neste boletim ilustrativo, é descrito a importançia económica, simtomes e distribução da doença. São apresentados os detalhes do agente causador, o ciclo do doença e epidemiologia, e os methodos do control sugeridos.

Cover: Leaves of web blotch susceptible and resistant groundnut genotypes from field screening trials in Zimbabwe.

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D L Cole, D H Smith, and D McDonald

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Distribution and Economic Importance

Web blotch of groundnut (*Arachis hypogaea* L.), is also known as phoma leaf spot, ascochyta leaf spot, net blotch, muddy spot, and 'spatselvlek' (Taber 1984). The disease has been reported in Angola, Argentina, Australia, Brazil, Canada, Japan, Lesotho, Malawi, Mauritius, Nigeria, People's Republic of China, South Africa, Swaziland, USA, the erstwhile USSR, Zambia, and Zimbabwe (Taber 1984; Subrahmanyam et al. 1990; P. Subrahmanyam, unpublished) (Figure 1). It is one of the most important foliar diseases of groundnut in Zimbabwe, where it occurs mainly on irrigated long-duration cultivars (Cole 1981, 1985; Hildebrand 1987); in South Africa, especially in the Vaalharts, Transvaal, and Natal regions (Marasas et al. 1974, Young et al. 1980) and in the USA in western Texas (T A Lee, personal communication).

In the USA, web blotch was first observed in Texas (Pettit et al. 1973) and subsequently in Florida, Georgia, New Mexico, Oklahoma, and Virginia (Taber 1984). Yield losses of about 40% incurred by combined attacks of web blotch and leaf spots (especially early leaf spot caused by *Cercospora arachidicola* Hori) have been reported in South Africa (Blamey et al. 1977) and in Zimbabwe (Hildebrand 1987).

In seasons when early leaf spot is less severe than usual in Zimbabwe, yield losses in the range of 10 to 18% have been reported (Cole 1982).

Symptoms

Symptoms first appear on the adaxial (upper) surface of the lower leaves as scattered tan-colored specks or streaks, forming a webbed pattern. The discolored areas expand, to form large, nearly circular, purplish-brown to dark brown blotches which have inconspicuous margins. These blotches often coalesce and cover entire leaflets (Figure 2). Advanced lesions are almost black, with a roughened surface; they become dry and crack irregularly.

On the abaxial (lower) leaf surface, symptoms become visible only after the blotches on the adaxial surface are well developed. The web and blotch symptoms may develop in sequence on the same leaflet or independently on different leaflets. The web symptoms develop when environmental conditions do not favor extensive disease development. Each strand of the web is associated with a single hyphal strand growing below the cuticle. When environmental conditions are favorable, hyphal growth is extensive, and leaf tissues are severely damaged, resulting in the development of blotch symptoms. Petioles, stipules, and stems may also be infected.

Severe web blotch development (Figure 3 a) leads to premature defoliation (Figure 3 b) and a subsequent reduction in pod yield (Philley 1975; Taber 1984; Pettit et al. 1986; Subrahmanyam et al. 1992b).

Causal Organism

Anamorph

Phoma arachidicola Marasas, Pauer & Boerema. Phytophylactica 6:195–202, 1974.

= *Ascochyta arachidis* Woronichin, Notulae Systematicae Instituto Cryptogamico Horti Botanici Reip. Ross. 3:31, 1924.

= *Ascochyta adzamethica* Schoshiaschvili. Izvestiya Gruzinskoi Opytnoi Stantsii Zashchity Rastenii 2:272, 1940.

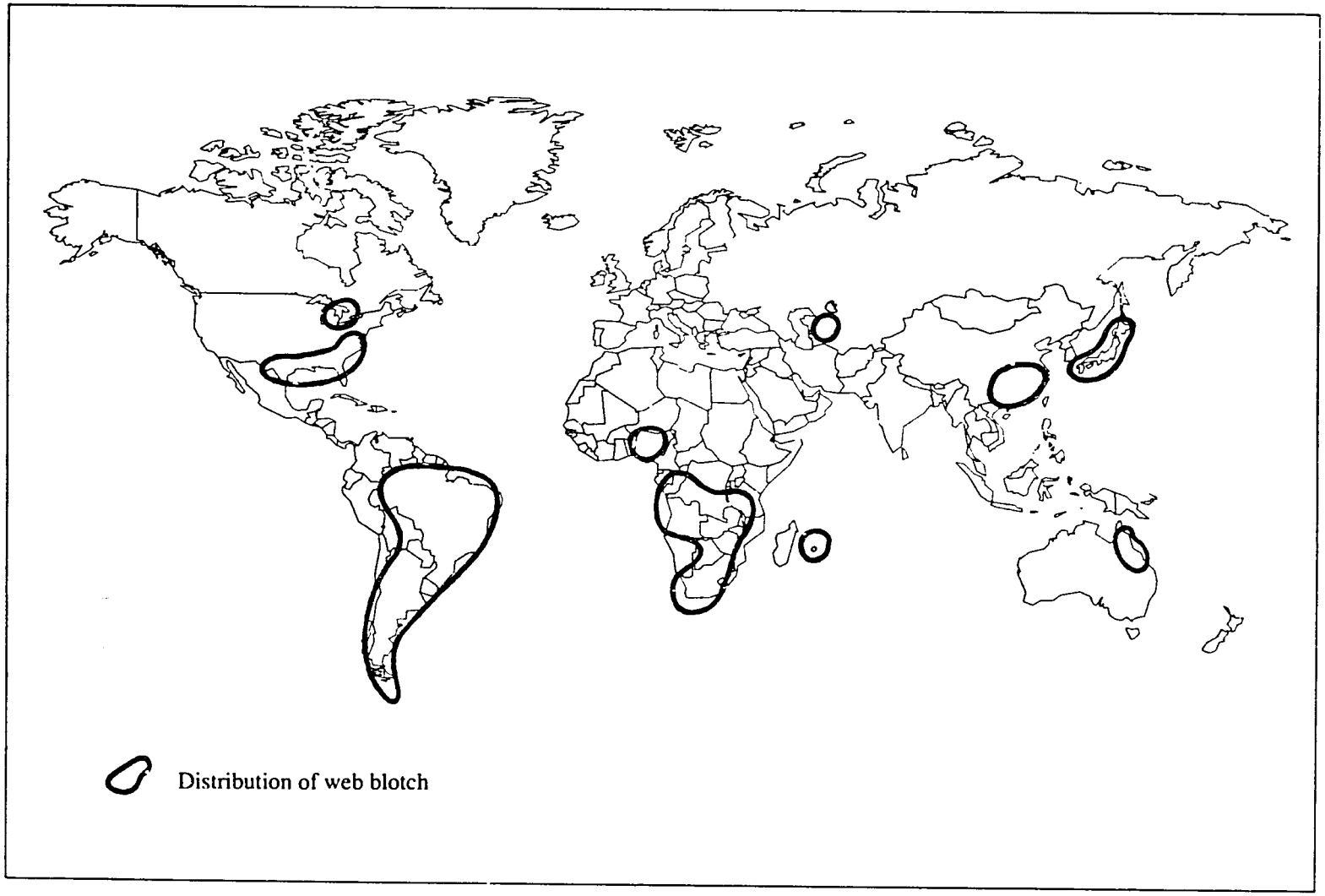


Figure 1. Geographical distribution of groundnut web blotch.

Figure 2. Web blotch symptoms on a groundnut leaf.

Teleomorph

Didymella arachidicola (Chochrjakov) Taber, Pettit & Philley. Peanut Science 11:109–114, 1984.

= *Mycosphaerella arachidicola* Chochrjakov. Bolezni i Vreditelimaslichnykh Kul'ter 1(2):29, 1934.

= *Mycosphaerella argentinensis* Frezzi. Revista de Investigaciones Agropecuarias, Series 5,6:147–153, 1969.

= *Didymosphaeria arachidicola* (Chochrjakov) Alcorn, Punithalingam & McCarthy. Transactions of the British Mycological Society 66(2):351–355, 1976.

Anamorphic state

Pycnidia of *P. arachidicola* are pale to dark brown, separate, globose to flask-shaped, ostiolate, amphigenous, and immersed in leaf tissues (Figure 4 a). Pycnidial size varies with the substrate and isolate, but, in general, pycnidia are 85–240 µm in diameter. The wall of a pycnidium is composed of light brown to brown pseudoparenchymatous cells that are produced abundantly in light, particularly near-ultraviolet light. Pycnidia are produced in concentric rings corresponding to periods of light and dark. Pycnidiospores arise as buds on the conidiogenous cells (phialides).

Figure 3 a. Groundnut crop in Swaziland showing severe web blotch damage to foliage.

b. Groundnut crop prematurely defoliated by web blotch.

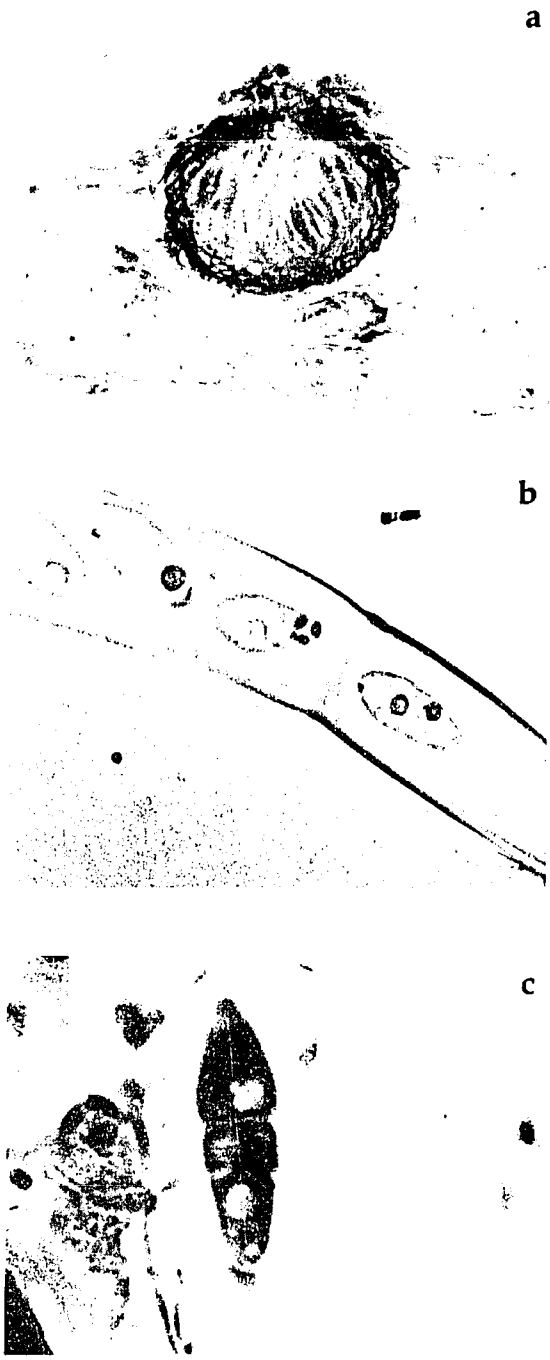
Figure 4 a. Cross section of pycnidium showing pycnidiospores.
b. Septate and nonseptate pycnidiospores.

They are hyaline, smooth-walled, sub-globose to ellipsoidal with rounded ends. They are extruded from the ostioles at maturity. Pycnidiospore (Figure 4 b) size varies with the substrate and septation. Single-celled spores produced in culture are 4–9 µm long and 2.5–4 µm wide. On host material, spores may be larger and are often septate. Spore size is influenced by temperature, e.g., at 25°C, 10–40% of the spores fall in the smaller size range; as temperatures decrease spores tend to increase in size.

Taxonomic disposition of the anamorphic state. The taxonomic position of the anamorphic state of the web blotch fungus was clarified in 1974 by Marasas et al. They described the anamorph as *P. arachidicola* Marasas, Pauer & Boerema, based on interpretation of electron microscopic studies on conidiogenesis. The fungus was earlier identified as a species of *Ascochyta* by numerous workers. Marasas et al. (1974) redescribed the web blotch fungus based on the differences between *Phoma* and *Ascochyta* as described by Boerema (1965). They determined that species of *Phoma* produce single-celled pycnidiospores as a result of conidiogensis, but spores could become septate with maturation, while members of the genus *Ascochyta* produce septate pycnidiospores as a result of conidiogenesis (i.e., all the spores in a pycnidium are necessarily septate). The web blotch fungus therefore conforms to the criteria for inclusion in the genus *Phoma*. Rajak and Rai (1985) provided a key to the identification of *Phoma* species including *P. arachidicola* in pure culture.

Teleomorphic state

Pseudothecia (Figure 5 a) of the teleomorph of *P. arachidicola* are dark brown, sub-globose to globose, separate, usually immersed in host tissue, ostiolate, and 65–154 µm in diameter. Cell walls are mostly isodiametric and angular to round. Asci (Figure 5 b) are hyaline, cylindrical to somewhat clavate, mostly with a differentiated foot, 8-spored, and distichous. Ascospores (Figure 5 c) are uni-septate, smooth, hyaline at first, becoming dark with maturity. The upper cell of the ascospore is broader and more sharply tapered than the lower cell. Dimensions in lactophenol blue mounts are 4.5–6.5 × 13–17 µm. Structures



Fgure 5 a. Cross section of a pseudothecium showing asci containing ascospores.
b. Portion of a young bitunicate ascus containing dislodged, normally distichous immature ascospores.
c. Mature uni-septate ascospore.

interpreted to be pseudoparaphyses are thin-walled, hyaline, and occasionally septate. These structures may be difficult to find in some isolates, partly because of their size (1–1.8 µm diameter) and also their position within the pseudothecium. Pseudothecia form most readily on autoclaved groundnut leaves on agar.

Taxonomic disposition of the teleomorphic state. The teleomorph of *P. arachidicola* has been identified as a *Mycosphaerella*, a *Didymella*, and a *Didymosphaeria* by various authors. Confusion over taxonomy centers around the interpretation of the identity of sterile elements in the pseudothecium, and differing opinions on the development of pigmentation of the ascospores.

Luttrell (1973) included all three genera, *Mycosphaerella*, *Didymella*, and *Didymosphaeria*, in the Loculoascomycetes. He placed *Mycosphaerella* in the Dothideales, family Dothidiaceae, based on aparaphysate asci housed in perithecioid locules. He characterized the genus as having separate pseudothecia with uni-septate hyaline to finally brown ascospores (8 ascospores per ascus) immersed in host tissue. He treated *Didymella* and *Didymosphaeria* in the Pleosporales, members of which are characterized by having perithecioid pseudothecia containing asci interspersed wi. pseudoparaphyses, or with paraphysoidal hyphae that branch at the tips to form an epithecium in medium- to large-sized locules. He placed *Didymella* in the Venturiaceae, based on the hyaline, uni-septate, smooth-walled ascospores produced in separate but immersed pseudothecia. Luttrell considered *Didymosphaeria* to be a member of the Pleosporaceae, a family based on the formation of pseudothecia with non-septate to

single- to many-septate, hyaline to dark brown ascospores. He distinguished *Didymosphaeria* on the basis of uni-septate brown ascospores contained in immersed, globose pseudothecia.

In 1987 van Wyk et al. concluded that this fungus may not be accommodated in either *Didymella*, *Didymosphaeria*, or *Mycosphaerella*. They reported the production of hyaline ascospores that became dark after discharge and the presence of 'thread-like' strands, apparently remnants of the pseudoparenchymatous centrus, interspersed among the asci. They speculated that the strands may be interthecial elements and fundamentally different from pseudoparaphyses.

Luttrell (personal communication to R A Taber) observed that many hyaline ascospores turn brown shortly before or after discharge from the pseudothecium; he considered the brown pigmentation in such cases as an ageing process of the hyaline ascospores, and recommended that ascospore color should be determined before discharge. This interpretation is in keeping with color development in ascospores of the web blotch fungus. It is interesting to note that Barr (1990) commented in her review of Hanlin's publication on the Illustrated genera of ascomycetes (Hanlin 1990) that the figure representing *Didymosphaeria arachidicola* 'is surely a species of *Didymella*'.

Cultural characteristics

Cultural characteristics of *P. arachidicola* vary with the isolate, temperature, light, and medium (Philley 1975; Taber et al. 1984). Cultures on potato dextrose agar and malt extract agar are at first creamy white, and flattened, with little aerial growth. Colonies eventually turn dark brown, mostly with a white appressed margin (Figure 6 a). The production of dark pigmentation may vary (Figure 6 b) and a yellowish color may or may not be produced in the agar medium. Growth rates vary with the isolate, medium, and temperature. Optimum temperature for radial mycelial growth of most isolates is 20°C on malt extract agar. Pycnidial production is greatest at 25°C. No growth occurs at 35°C and little, if any, at 5°C.

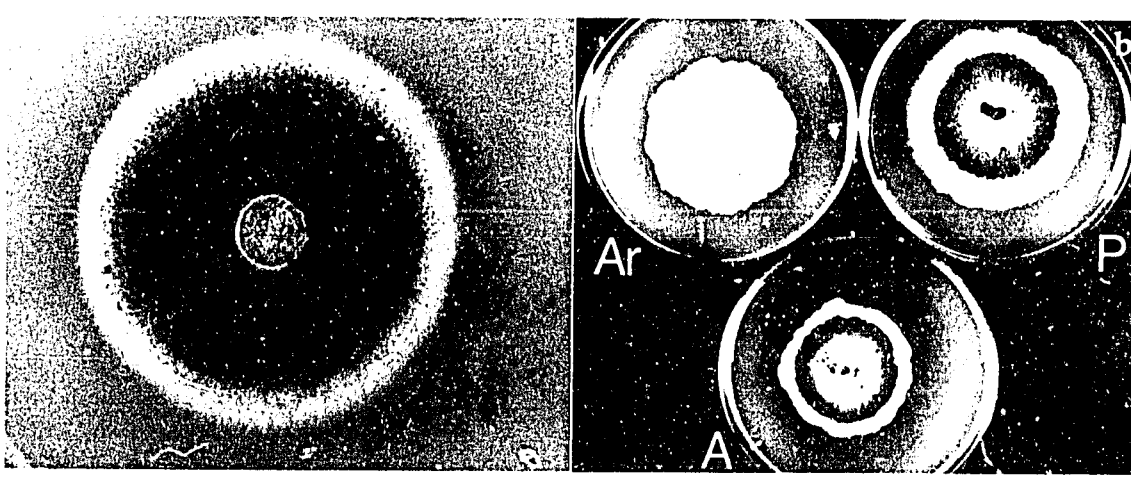


Figure 6 a. Typical culture of web blotch pathogen on potato dextrose agar.
b. Pigmentation formed by some isolates at 25°C.
Ar = Argentina isolate, P = Pearsall, Texas isolate, A = African isolate.

Reproduction is influenced by light quality; near-ultraviolet light is stimulatory (Philley 1975). Pseudothecia traditionally do not form on agar cultures; they can be induced to form only in some isolates on autoclaved groundnut leaves at lower temperatures (15–20°C).

Chlamydospores may be formed by some isolates. They are brown, thick-walled, may be formed singly or in chains, and are 8–19 × 8–17 µm in size. Chlamydospore shape may vary from round to irregular and they may be single-celled or multicellular.

Disease Cycle and Epidemiology

The pathogen can survive in infected crop residues, or on volunteer groundnut plants (Philley 1975; Pettit et al. 1986). Pycnidia and pseudothecia develop on fallen leaves in the field, and provide the initial inoculum that infects subsequent groundnut crops (Philley 1975; Luttrell and Smith 1981; Pettit et al. 1986). Web blotch was found to be more severe on irrigated crops than on rainfed groundnut crops in the USA (Philley et al. 1974; Liddell 1990) and Zimbabwe (Rothwell 1962; Chiteka 1990).

Blamey et al. (1977) and Young et al. (1980) investigated the effects of climatic factors on the development of web blotch and leaf spots [*C. arachidicola* and *Phaeoisariopsis personata* (Berk. & Curt.) v. Arx (syn. *Cercosporidium personatum* (Berk. & Curt.) Deighton] in South Africa. They reported that web blotch development in the field was severe under cool (15–20°C), moist conditions, whereas leaf spot development was more rapid under warmer, moist conditions. The optimum temperature for development of web blotch was lower than that for leaf spots. Liddell (1990) reported that temperatures below 29°C and diurnal cycles of relative humidity above 85% with periods over 95% favor web blotch development in New Mexico, USA. A regional disease prediction system is being developed using a terrain-sensitive weather interpolation system for web blotch control (Liddell et al. 1991). Subrahmanyam and Smith (1989) found a highly positive correlation between temperature and leaf wetness period on web blotch development in the laboratory. Increasing the duration of the leaf-wetness period from 2 to 8 days increased disease development at 15°, 20°, and 25°C, but not at 30° and 35°C. Prolonged leaf wetness periods at temperatures between 15° and 25°C favor disease development (Figure 7). Short periods of leaf wetness (>1 day) were insufficient for disease development even at temperatures between 15° and 25°C. Disease development was negligible at 30° and 35°C, even with longer periods of leaf wetness. Temperature and the length of the leaf wetness period were therefore considered to be interdependent and important factors in web blotch development.

Plant age is an important factor in web blotch development. Younger plants are more susceptible than older plants under laboratory conditions (Subrahmanyam and Smith 1989). However, under field conditions in Zimbabwe, web blotch in later groundnut sowings was not so evident when plants were young, as it was in earlier sowings. Symptoms were rarely seen in the field earlier than 50 days after sowing (Hildebrand 1987).

Although groundnut is the primary host, the web blotch pathogen can also infect such other legumes as soybean, sweet clover, alfalfa, and hairy vetch (Philley 1975; Smith and McGee 1981; Pettit et al. 1986).

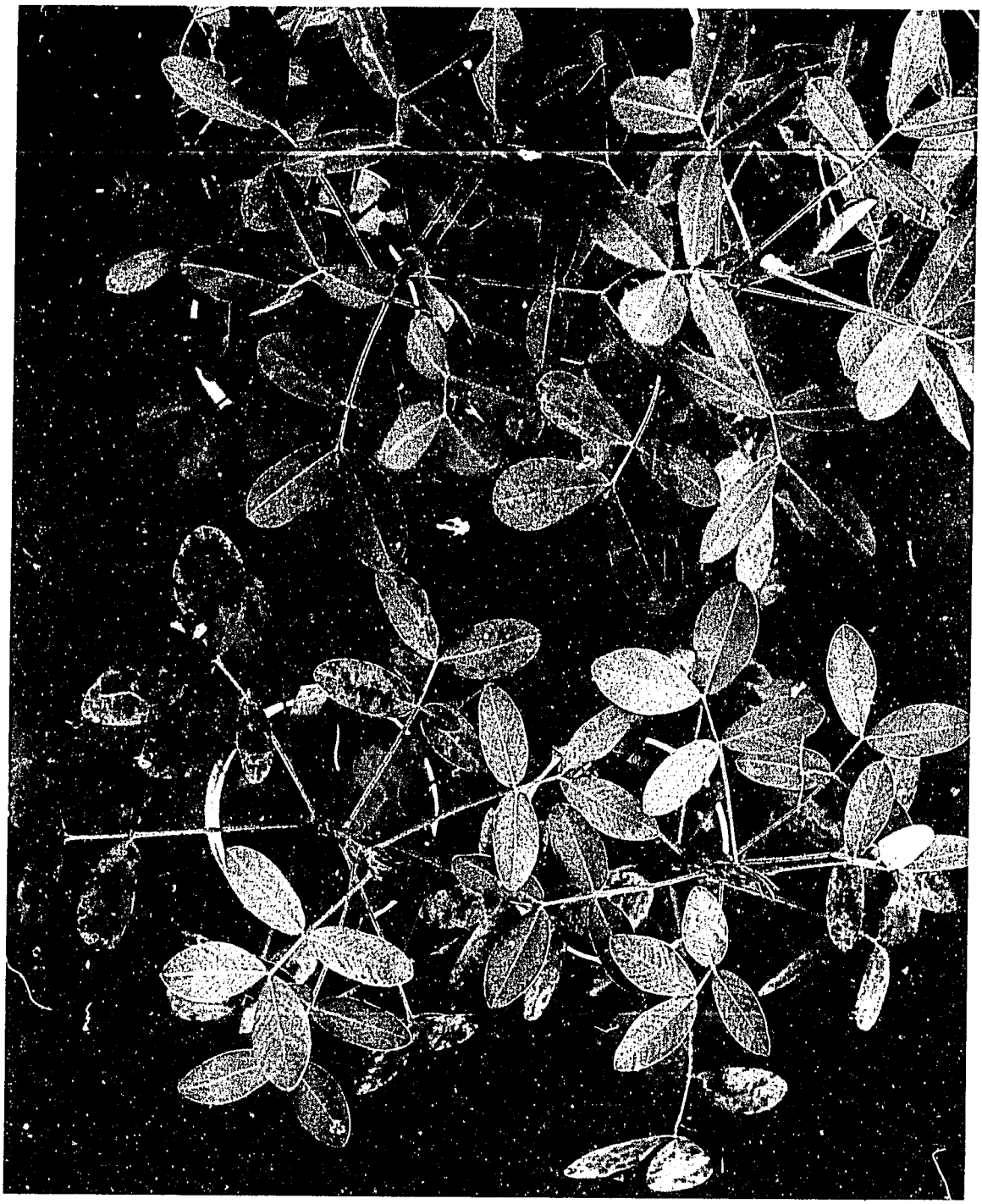


Figure 7. Effect of leaf wetness period on web blotch development on groundnut (cv Tamnut). Plants above were inoculated with web blotch pathogen and incubated at 20°C for a 1-day leaf wetness period. Plants below were also incubated at 20°C but for a 5-day leaf wetness period. Note severe disease development under longer periods of leaf wetness.

Disease Management

Cultural measures

Crop rotation with non-hosts of the web blotch pathogen and the eradication of infected crop debris and volunteer groundnut plants are useful ways to eliminate the primary sources of inoculum (Subrahmanyam et al. 1992a).

Chemical control

A mixture of mancozeb and benomyl (1 kg of Dithane M45® 77% WP plus 250 g of Benlate® 50% WP ha^{-1}) or chlorothalonil (2 L of Bravo® 500 ha^{-1}) were found to be effective against web blotch in Zimbabwe (Cole and Chingombe 1981). Blamey et al. (1977) also used a mixture of mancozeb and benomyl to successfully control web blotch in South Africa, but at a much higher rate of mancozeb (2.25 kg ha^{-1}) than that used in Zimbabwe. However, under severe disease pressure none of these fungicides was very effective. Recently, Cole (1986) recommended procymidone (Sumislex®, 1.25 L ha^{-1}) for the control of web blotch, but reported that it did not give satisfactory control of early leaf spot. Cole (unpublished) found tebuconazole (Folicur 30®, 0.6 L ha^{-1}) was also very effective in controlling web blotch. However, where both early leaf spot and web blotch occur, the fungicides most effective against web blotch are not necessarily the ones recommended because it makes economic sense to use a fungicide that controls both pathogens to some extent.

Symptoms of early leaf spot appear 2 to 3 weeks earlier than those of web blotch, and web blotch does not appear on leaves infected with early leaf spot. If early leaf spot is controlled from the first appearance of its symptoms, web blotch levels rise significantly compared to plants on which early leaf spot control is delayed (Cole 1981). Early leaf spot is very easily controlled by a range of fairly inexpensive fungicides, whereas those which control web blotch are more expensive. Cole (1981, 1982) found that by delaying the first sprays against both diseases until early leaf spot was seen on all plants, the colonization of leaves by web blotch was suppressed and it could be controlled by less effective but cheaper fungicides. It appears that phytoalexins produced during the interaction of the early leaf spot pathogen and groundnut inhibit the growth of the web blotch pathogen (Cole 1981). Pettit et al. (1973) reported that mancozeb, chlorothalonil, and isobac alone or in combination are effective against web blotch in Texas. A calendar-based spray schedule of chlorothalonil is currently used to control web blotch on valencia type groundnuts in New Mexico, USA (Liddell et al. 1991).

Genetic resistance

Sources of resistance. Alcorn et al. (1976) reported that valencia (bot. var *fastigiata*) and spanish (bot. var *vulgaris*) groundnut genotypes were more susceptible to web blotch than virginia (bot. var. *hypogaea*) types in Australia. In Zimbabwe, several hundred germplasm lines were screened for web blotch resistance under field conditions during the 1976/77 crop season. Three genotypes were found to be resistant; PI 274190 and 48-14 scored 0, and 48-21 scored 1 on a 0–4 scale (Hildebrand 1981, 1984). Smith et al. (1979) screened 17 genotypes for resistance to web blotch under field conditions in southern Texas. Disease development was measured by

counting, on the main stems, the total number of leaves with web blotch symptoms and the number of missing leaves. Smith et al. (1979) concluded that virginia and runner types were generally more resistant to web blotch than the spanish types. Florunner, the most commonly grown groundnut cultivar in the USA, is resistant to web blotch. Moraes et al. (1983) screened 18 genotypes for resistance to web blotch under field conditions in Brazil. Five genotypes did not develop symptoms, and two genotypes had very few leaves with symptoms. Phipps (1985) evaluated 14 groundnut genotypes for resistance to web blotch under greenhouse conditions in Virginia, USA. He used percentage leaf area damaged by the fungus as a criterion, and rated three genotypes as resistant (Table 1).

Subrahmanyam et al. (1985) reported web blotch resistance in various accessions of wild *Arachis* species under greenhouse conditions in Texas. Disease development was assessed by measuring infection frequency (lesions cm^{-2}), lesion diameter, defoliation (%), leaf area damaged (%), and remaining green leaf area (%). Accessions classified as resistant included five of *A. batizocoi*, twelve of *A. duranensis* nom. nud., three of *A. appressipila* nom. nud., one each of *A. sylvestris*, *A. cardenasii* nom. nud., *A. paraguariensis*, *A. glabrata*, *A. pintoi* nom. nud., and *A. monticola*, five unnamed species of section *Arachis* nom. nud., and one each of sections Ambinervosae nom. nud., and Erectoides nom. nud. One accession of *A. glabrata* was immune to *D. arachidicola* (Table 2). In general, the resistant accessions had low infection frequency, small lesions, minimal defoliation and leaf area damaged, and a large amount of unaffected green leaf area. Hildebrand (unpublished) also found several accessions of wild *Arachis* species

Table 1. Some sources of resistance to web blotch in *Arachis hypogaea*.

Genotype identity	Reaction to web blotch[1]	Reference
48-36	MR	Hildebrand 1984
48-44	MR	Hildebrand 1984
48-14	HR	Hildebrand 1981
48-21	MR	Hildebrand 1981
Cabocla	HR	Moraes et al. 1983
Early Bunch	MR	Smith et al. 1979
Falcon	R	Hildebrand 1984
Florunner	R	Smith et al. 1979
GA/45/20	MR	Hildebrand 1984
GK 19	R	Smith et al. 1979
GK 53	MR	Smith et al. 1979
Goldin 1	R	Smith et al. 1979
Macro	R	Moraes et al. 1983
Manfredi 68 A	R	Hildebrand 1985
Manfredi 68 B	R	Hildebrand 1985
NC 6	R	Phipps 1985
NC 3033	R	Phipps 1985
NC Ac 17133-RF	R	Hildebrand 1985
P 84/5/244	R	Hildebrand 1984
P 84/5/256	MR	Hildebrand 1984
P 84/5/23	MR	Hildebrand 1984
P 105/3/7	MR	Chiteka 1984
Penapolis	HR	Moraes et al. 1983
PI 274190	HR	Hildebrand 1981, 1984
RMP 89	MR	Hildebrand 1984, 1985
RMP 93	MR	Hildebrand 1984
SO 266	HR	Moraes et al. 1983
SO 269	HR	Moraes et al. 1983
SO 464	HR	Moraes et al. 1983
SO 407	R	Moraes et al. 1983
Southern Runner	R	Gorbet (pers. comm)
Tifton 8	R	Phipps 1985
10/7/36	MR	Hildebrand 1984
31/6/18	MR	Hildebrand 1984
321/66	MR	Hildebrand 1985
325/66	MR	Hildebrand 1984

1. HR = highly resistant
R = resistant
MR = moderately resistant

Table 2. Some sources of resistance to web blotch in wild *Arachis* species[1].

Section and species	Identity	Reaction to web blotch
Arachis		
A. batizocoi	PI 298639	Resistant
A. batizocoi	PI 468326	Resistant
A. batizocoi	PI 468327	Resistant
A. batizocoi	PI 468328	Resistant
A. batizocoi	PI 468329	Resistant
A. duranensis	PI 468197	Resistant
A. duranensis	PI 468198	Resistant
A. duranensis	PI 468200	Resistant
A. duranensis	PI 468201	Resistant
A. duranensis	PI 468202	Resistant
A. duranensis	PI 468203	Resistant
A. duranensis	PI 468324	Resistant
A. duranensis	PI 468325	Resistant
A. duranensis	PI 475844	Resistant
A. duranensis	PI 475845	Resistant
A. duranensis	PI 475846	Resistant
A. duranensis	PI 475847	Resistant
A. cardenasii	PI 262141	Resistant
A. monticola	PI 468196	Resistant
Arachis sp	PI 468154	Resistant
Arachis sp	PI 468337	Resistant
Arachis sp	PI 468340	Resistant
Arachis sp	PI 468168	Resistant
Arachis sp	PI 475873	Resistant
Erectoides		
A. paraguariensis	PI 262842	Resistant
A. appressipila	GKP 10002	Resistant
A. appressipila	PI 261877	Resistant
A. appressipila	PI 261878	Resistant
Arachis sp	PI 475985	Resistant
Extranervosae		
A. sylvestris	PI 476135	Resistant
Ambinervosae		
Arachis sp	PI 476136	Resistant
Rhizomatosae		
A. glabrata	PI 421707	Resistant
A. glabrata	PI 262817	Immune
Caulorhizae		
A. pintoi	PI 338447	Resistant

1. Source: Subrahmanyam et al. 1985.

[*A. duranensis* (PI 219823), *A. burkartii* (PI 338325), *A. pusilla* (PI 262133), and *Arachis* sp (PI 338279)] to be resistant to web blotch under field conditions in Zimbabwe.

Components of resistance. In resistant genotypes, the disease has long incubation periods, reduced infection frequencies, and small lesions (Subrahmanyam and Smith 1987). The rate of lesion enlargement is slower in resistant genotypes than in susceptible ones. Resistance to *P. arachidicola* in groundnut genotypes appears to be manifest as fewer successful infections from pycnidiospores. Even if the fungus successfully enters the leaf tissues, development is slowed down as indicated by an increased incubation period and smaller lesions.

Utilization of resistance. A few sources of resistance have been used in breeding programs, notably PI 274190, 48-14, and 48-21 (Hildebrand 1981, 1984). PI 274190 exhibited the highest degree of resistance in Zimbabwe, but there were reservations as to its use as a parent because of its prostrate growth habit, low yield potential, and purple testa (Hildebrand 1981). However, from the limited number of crosses made with this genotype, it was possible to select high-yielding genotypes with a spreading-bunch growth habit, tan colored seeds, and good resistance to web blotch (Hildebrand 1981, 1987).

Chiteka (1984) reported resistance to web blotch and gray mold (*Botrytis cinerea* Pers. ex Fries) in the breeding line P 105/3/7 [(PI 261911 × PI 262092) × Egret]. Several breeding lines, including C 346/5/8, C 347/5/6, and P 105/3/7, with high levels of resistance, have already been bred in Zimbabwe (Chiteka 1984; Hildebrand 1984, 1985).

Most of the selections made from the cross (PI 274191 × PI 274203) showed an unusual reaction to web blotch. Their leaflets became extensively affected by a net-like blotch, often covering most, if not all, of the adaxial surface (Hildebrand 1983). Microscopic examination revealed that the fungus was confined to the area just below the epidermis (see also Philley 1975). It is not clear if this is an expression of hypersensitivity, but these genotypes did not defoliate rapidly, and produced high pod yields.

Integrated disease management

Cultural practices including crop rotation and eradication of infected crop residues and volunteer groundnut plants are useful ways to eliminate the primary sources of inoculum, and thus to delay disease on-set and severity. However, cultural practices alone may provide only partial control of the disease. Fungicidal control is very effective, but a large number of spray applications are required to satisfactorily control the disease. This may not be economically feasible for smallholder farmers in the rainfed agricultural systems in the semi-arid tropics. If fungicides are to be used, these should be cost-effective and capable of controling both web blotch and other foliar diseases. As observed in Zimbabwe, delaying fungicidal control of early leaf spot may be beneficial in reducing the severity of web blotch attacks. The formulation of integrated disease control measures using cultural practices and the judicious application of fungicides is urgently required. Every effort should be made to develop groundnut genotypes with adequate levels of multiple resistance to web blotch and other foliar diseases such as leaf spots and rust (*Puccinia arachidis* Speg.). The cultivation of resistant varieties in crop rotations should be highly beneficial in reducing disease severity and its impact on yield.

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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.

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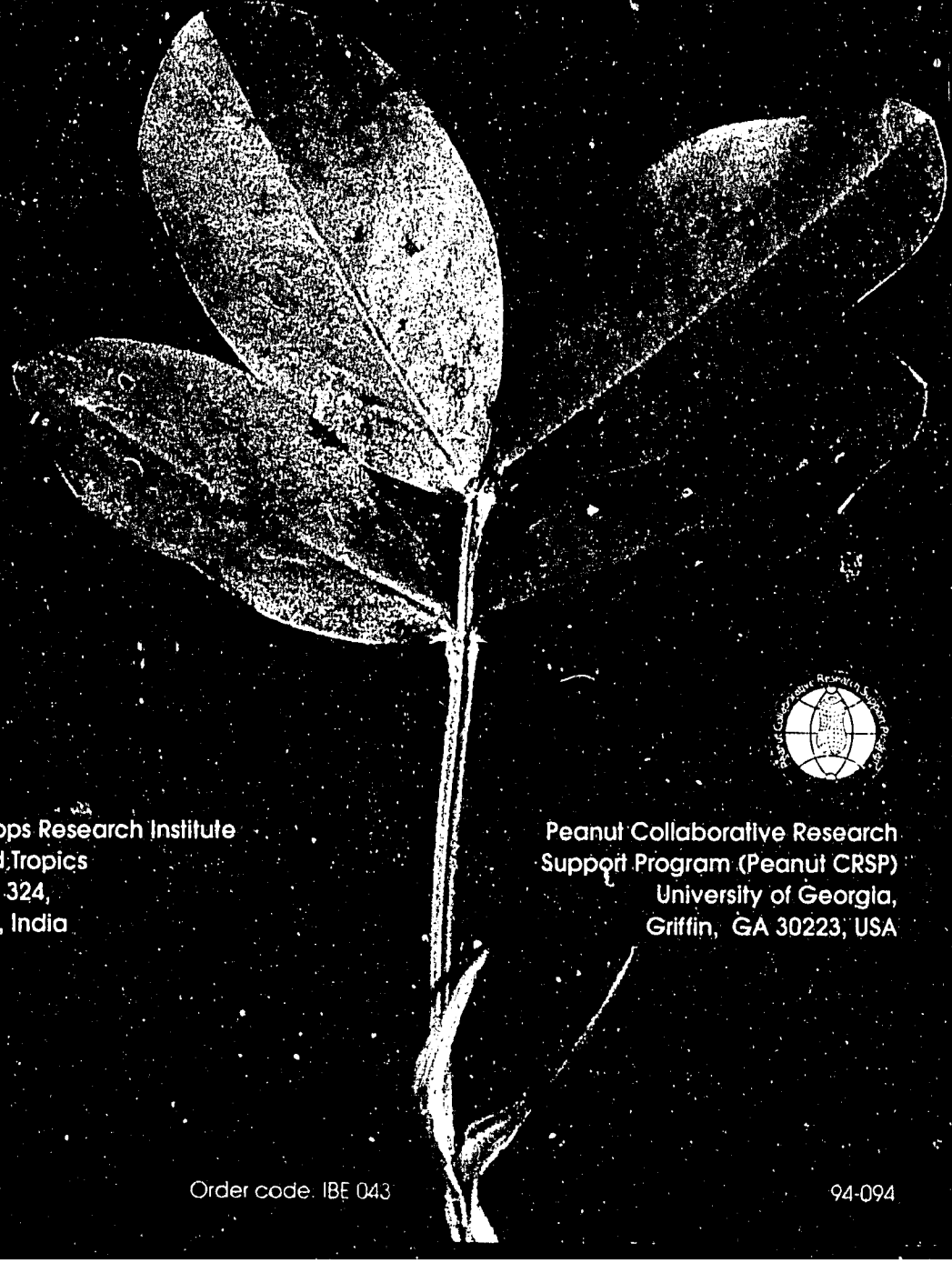

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