TROPICAL PEST MANAGEMENT, 1991, 37(3), 259–269

Diseases of groundnut in West Africa and their management: research priorities and strategies†

(*Keywords:* Groundnut, peanut, arachide, disease resistance, West Africa.)

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Abstract. Diseases are major constraints to groundnut production in West Africa. Leaf spots, rust, rosette and seedling diseases are present throughout most of the region and cause substantial losses in yield. Crop growth variability is a major yield-limiting factor in the Sahel. Aflatoxin contamination is a serious quality problem in the region. Strategies for management of these major diseases are briefly discussed with particular emphasis on the utilization of genetic resistance.

Résumé. En Afrique de l'Ouest, les maladies sont l'une des principales contraintes de la production de l'arachide. Les cercosporioses, la rouille, la rosette et les maladies des plantules, présentes dans presque toute la région, causent des pertes importantes de rendement. La variabilité de la croissance des cultures est l'un des principaux facteurs limitant cette production au Sahel. La contamination par les aflatoxines réduit la qualité de l'arachide cultivée dans la région. Les stratégies de lutte contre ces maladies sont brièvement présentées, notamment l'utilisation de la résistance génétique.

1. Introduction

West Africa is the largest groundnut (*Arachis hypogaea* L.) producing region of Africa, contributing about 54% of the total groundnut production of the continent. The major groundnut producing areas are located around 12° N latitude (Figure 1). Senegal and Nigeria are the largest groundnut producers in West Africa, followed by Cameroon, Ghana, Gambia and Mali (Anonymous, 1987) (Table 1). The crop is grown to some extent in the other countries of the region including the humid rainforest areas. Groundnut is one of the most important cash and food crops in gross value of agricultural produce and export (Anonymous, 1982). Many countries in West Africa were major exporters of groundnut products to Europe in the past. However, in recent years, groundnut production in West Africa has declined drastically (Anonymous, 1982; Gillier, 1982).

The crop is grown almost entirely by small-scale farmers under low crop production inputs. The average yield of groundnut in West Africa is about 730 kg ha^{-1} (Anonymous, 1987). Some of the major constraints to groundnut production in West Africa are erratic rainfall patterns leading to severe drought at any stage of crop development, poor agronomic practices and epidemics of pests and diseases (Gillier, 1982; Cummins and Jackson, 1982; Anonymous, 1982). Fluctuations in the commercial market and low producer prices discourage farmers from growing groundnut. Aflatoxin contamination lowers the quality of the produce, thus reducing its marketability and export value (Gillier, 1982).

2. Diseases of groundnut in West Africa

Diseases are major yield-limiting factors for groundnut in West Africa (Gillier, 1982; Cummins and Jackson, 1982). A number of fungal, viral and nematode diseases of groundnut have been reported from West Africa (McDonald, 1969a; Merny *et al.*, 1974; McDonald, 1978; Emechebe, 1980; Fauquet and Thouvenel, 1980; Germani, 1981; Dollet *et al.*, 1986; Savary, 1987a; Khan and Misari, 1987; Baujard, 1988; Subrahmanyam *et al.*, 1989) (Table 2). Most of the diseases are widespread in the region and may be considered as components of a multiple pathosystem (Savary *et al.*, 1988), but only a few are economically important throughout the region. Information presented in this review has been obtained by systematic disease surveys in some countries, from personal contacts with groundnut scientists and from a literature search.

Leaf spots, rust, rosette, and seedling rots are the most economically important diseases, and aflatoxin contamination is a serious quality problem of groundnut in West Africa. Crop growth variability is a major yield-limiting factor in sandy soils of the Sahel. Although pod rot, peanut clump, stem rot, charcoal rot, fusarium wilt and parasitic nematodes are serious in some countries, they are not regarded as diseases of regional importance. Diseases that are considered to be regionally important are leaf spots, rust, rosette, seedling diseases, aflatoxins and crop growth variability, and these are being accorded high priority by national and/or international research institutions involved in the improvement of groundnut crop productivity in West Africa. The strategies for management of these major diseases are briefly discussed, with particular emphasis on utilization of genetic resistance.

2.1. Foliar diseases

2.1.1. Leaf spots. Both early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot (*Phaeoisariopsis*

† Submitted as journal article No. 922 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

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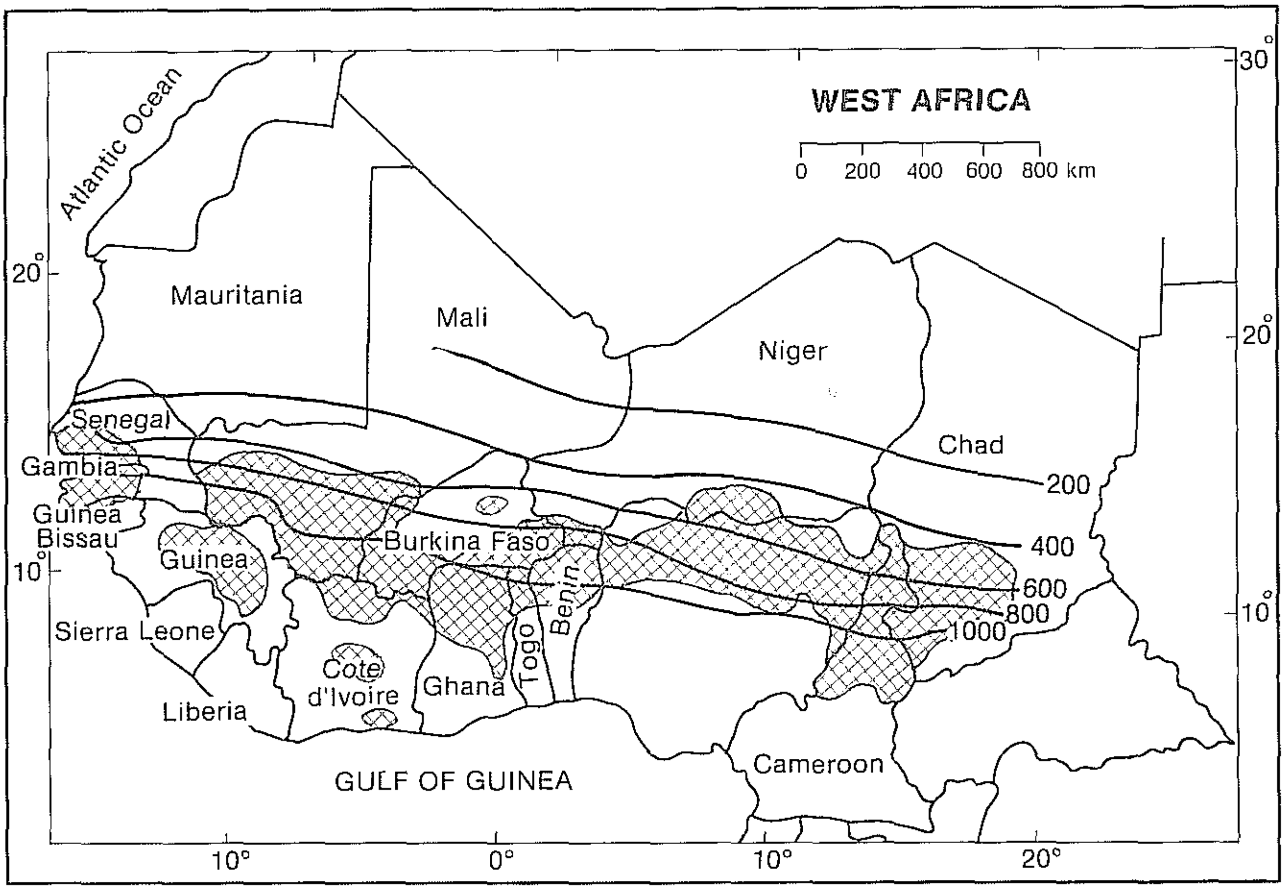

Figure 1. Distribution of major groundnut growing areas and rainfall isohyetes in West Africa.

personata (Berk. & Curt.) v. Arx) are commonly present throughout West Africa wherever groundnut is grown. However, their relative importance varies between geographic locations and seasons, and is largely dependent on climatic factors (McDonald *et al.*, 1985; Savary, 1987a). In general, early leaf spot is predominant and destructive in high-rainfall areas (Guinea Savanna). However, there can be both short- and long-term fluctuations in the relative proportions of the two leaf spots within geographic locations. For instance, in Gaya, Niger, late leaf spot was predominant in 1986 and 1988 but early leaf spot was predominant in 1987 (Subrahmanyam *et al.*, 1989).

Table 1. Area, production and yield of groundnut in some countries in West Africa in 1985

Country	Area (× 1000 ha)	Production (× 1000 mt)	Yield (t ha^{-1})
Benin	88	70	0·80
Burkina Faso	200	77	0·39
Cameroon	320	140	0·44
Chad	170	80	0·47
Côte d'Ivoire	85	80	0·94
Gambia	100	120	1·20
Ghana	117	128	1·10
Guinea	130	75	0·58
Guinea Bissau	85	30	0·35
Mali	200	120	0·60
Niger	100	40	0·40
Nigeria	600	600	1·00
Senegal	605	587	0·97
Sierra Leone	14	14	1·00
Africa	5284	4001	0·76
West Africa	2814	2161	0·73

The pathogens may survive from season to season on volunteer and groundkeeper plants and in infected crop debris. No authentic host species are known outside the genus *Arachis*. Long-distance distribution of the pathogens may be by air-borne 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 (McDonald *et al.*, 1985).

Leaf spots damage the plant by reducing the available photosynthetic area by lesion formation, and by damaging the photosynthetic apparatus of neighbouring, apparently healthy tissues, they also stimulate leaflet abscission (Boote *et al.*, 1983; Savary, 1987a). In addition to causing leaf spots, the two pathogens also produce lesions on petioles, stems and pegs. When disease attack is severe the affected leaflets first become chlorotic, then necrotic; lesions often coalesce; and leaflets are shed (Smith, 1984).

2.1.2. Rust. Groundnut rust caused by *Puccinia arachidis* Speg. was recorded in the mid-1970s in almost all groundnut growing areas in West Africa. Rust is very severe in southern parts of West Africa where rainfall is usually high (over 1000 mm) (Sankara, 1987; Savary, 1987a). Rust also occurs in other groundnut growing areas of the region and may occasionally become severe depending on climatic

Table 2. A checklist of groundnut diseases in West Africa

Fungal diseases
Aflaroot (*Aspergillus flavus* Link. ex. Fr.)
Alternaria leaf spot (*Alternaria arachidis* Kulk.)
Anthracnose (*Colletotrichum capsici* (Syd.) Butler & Bisby)
Ascochyta leaf spot (*Ascochyta arachidis* Woronichin)
Charcoal rot (*Macrophomina phaseolina* (Tassi.) Goid.)
Cladosporium leaf spot (*Cladosporium* sp.)
Cochliobolus leaf spot (*Cochliobolus lunatus* Nelson & Harris)
Collar rot (*Aspergillus niger* van Tieg.)
Damping-off (*Pythium myriotylum* Drechs.)
Early leaf spot (*Cercospora arachidicola* Hori)
Fusarium wilt (*Fusarium oxysporum* Schlecht emend Sny. & Hans)
Gloeosporium leaf spot (*Gloeosporium* sp.)
Grey spot (aetiology unknown)
Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curt.) v. Arx)
Leaf scorch and pepper spot (*Leptosphaerulina crassiasca* (Sechet) Jackson & Bell)
Pestalotiopsis leaf spot (*Pestalotiopsis adusta* (Ell. 6 Ev.) Steyaert, *P. versicolor* (Speg.) Steyaert, *P. arachidis* Satya)
Phyllosticta leaf spot (*Phyllosticta arachidis-hypogaea* V. Rao)
Pleospora leaf spot (*Pleospora infectoria* Fck.)
Pod rot (*Rhizoctonia solanj* Kuhn, *Macrophomina phaseolina* (Tassi.) Goid., *Fusarium oxysporum* Schlecht emend Sny. & Hans, *F. solani* (Mart.) Sacc.)
Pseudoplea leaf spot (*Pseudoplea trifolii* (Rostr.) Petr.)
Rhizoctonia leaf blight (*Rhizoctonia solani* Khun)
Root rot (*Rhizoctonia solani* Kuhn)
Rust (*Puccinia arachidis* Speg.)
Seed and seedling rot (*Aspergillus niger* van Tieg., *A. flavus* link. ex. Fr., *Botryodiplodia theobromae* Pat., *Cochliobolus bicolor* Paul & Par., *Penicillium citrinum* Thom., *P. funiculosum* Thom., *Rhizopus* spp., *Fusarium* spp., *Pythium* spp., *Rhizoctonia solani* Kuhn, *Macrophomina phaseolina* (Tassi.) Goid.
Stem rot (*Sclerotium rolfsii* Sacc.)
Web blotch (*Didymella arachidicola* (Chock) Taber, Pettit & Philley)

Virus and mycoplasma diseases
Groundnut rosette (GRV, RAV)
Peanut clump (PCV-AG, PCV-AV)
Groundnut eyespot (GESV)
Groundnut crinkle (GCV)
Groundnut chlorotic spot (GCSV)
Tomato spotted wilt (TSWV)
Peanut mottle (PMV)
Groundnut streak (GSV)
Groundnut mosaic
Groundnut golden mosaic
Groundnut flecking
Cowpea mild mottle (CMMV)
Cucumber mosaic virus (CMV)
Witches' broom

Nematode diseases
Root-knot (*Meloidogyne incognita* (Kofoid & White) Chitwood
Testa nematode (*Aphelenchoides arachidis* Bos)
Lesion nematode (*Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Steckhoven)
Chlorosis and stunting (*Scutellonema cavenessi* Sher and *Aphasmatylenchus straturatus* Germani)
Other nematodes: Species of *Tylenchus, Ditylenchus, Tylenchorhynchus, Telotylenchus, Helicotylenchus, Rotylenchus, Hoplolaimus, Xiphinema, Longidorus, Trichodorus, Paratrichodorus, Trichotylenchus, Criconemella, Hemicycliophora, Filenchus, Coslenchus, Pratylenchus, Peltamigratus, Scutellonema, Hemicycliophora, Paratylenchus, Gracilacus, Aphelenchus, Macroposthonia* and *Siddiqia*

Bacterial disease
Wilt (*Pseudomonas solanacearum* E. F. Smith)

Phanerogamic root parasite
Witch weed (*Alectra vogelii* Benth.)

factors. Temperatures in the mid 20–30°C range, free water on the leaf surface and high relative humidity favour infection and subsequent disease development (Savary, 1985a,b). It is not known if the fungus can produce spermagonia and aecia, or if any alternative host is involved in the life cycle (Subrahmanyam *et al.*, 1985). There is no record of any hosts other than the genus *Arachis*, and no reliable evidence of groundnut rust being internally seed-borne or being spread by germplasm exchange (Subrahmanyam and McDonald, 1982). Urediniospores are short-lived. It is believed that the humid tropical zones of the Gulf of Guinea, where groundnut may be found throughout the year, serve as reservoirs of rust inoculum in West Africa (Savary, 1987b).

2.1.3. Management of foliar diseases. Rust and leaf spots are regarded as the most important among the fungal diseases of groundnut in West Africa. Yield losses are generally substantial when the crop is attacked by both leaf spots and rust. Field trials conducted over several years in Nigeria (Salako, 1987) using fungicides have clearly shown that losses from leaf spots and rust are substantial (Table 3). Results from other locations in West Africa also indicate that leaf spots and rust cause substantial losses in pod yield (Table 4). Experiments where rust and leaf spot diseases were set at various levels using combinations of fungicides indicated that, in high-input crops, losses increased faster with rust than with leaf spot severity (Savary *et al.*, 1988; Figure 2).

Eradication of volunteer groundnut plants and groundkeeper is important in reducing the primary sources of rust and leaf spot inoculum. Crop rotation is useful in avoiding early-season infection by leaf spot pathogens (Subrahmanyam and McDonald, 1982; McDonald *et al.*, 1985, Savary, 1986).

Table 3. Losses in pod yield of groundnut from leaf spots and rust in nigeria (from Salako, 1987)

Year	No. of trials	Pod yield (t ha^{-1})		Percentage yield loss
		Unsprayed	Fungicidal control	
1980–1981	4	2·00	2·81	29
1981–1982	12	1·25	2·59	52
1983–1984	6	1·61	3·00	46
1984–1985	6	1·87	3·37	45
1986	3	1·28	2·46	48

Table 4. Potential losses in pod yields of groundnut from leaf spots and rust in West Africa

Country	Percentage yield loss	Reference
Nigeria	45	Salako (1987)
Burkina Faso	29	Picasso (1987)
Niger	24	Subrahmanyam *et al.* (1988)
Ghana	20	Atuahene-Amankwa *et al.* (1988)
Senegal	30–40	Gautreau and De Pins (1980)
Cote d'Ivoire	40–70	Savary *et al.* (1989)

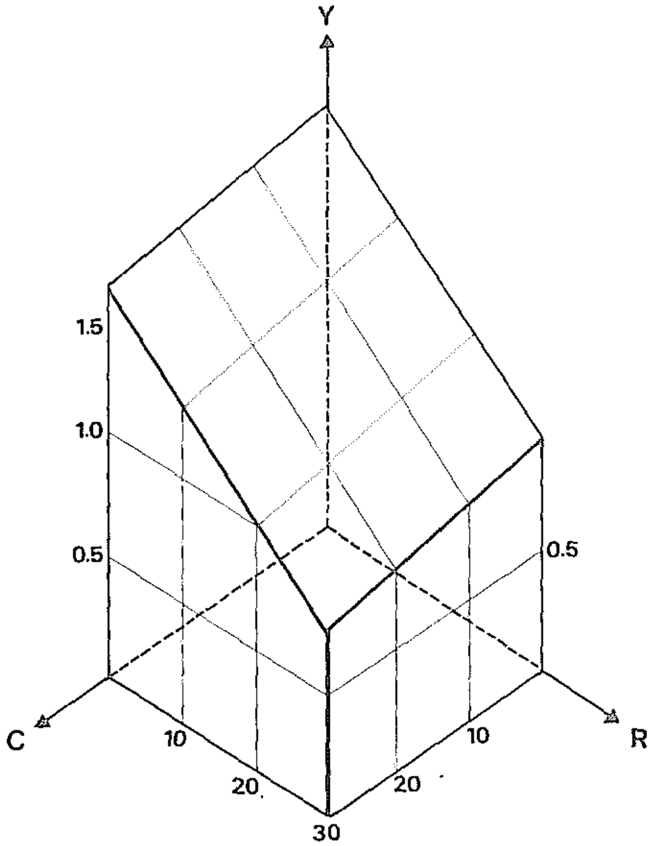

Figure 2. *A regression plane ($Y = 1771 - 27{\cdot}4\ R - 5{\cdot}8\ C$, $R^2 = 0{\cdot}95$) of yield (Y, in kg ha^{-1}) on rust (R) and leafspot (C) severity (%) from an experiment on crop loss assessment in groundnut (from Savary* et al., *1988).*

Leaf spots and rust can be controlled by the application of certain fungicides (McDonald and Fowler, 1976; Salako, 1987; Picasso, 1987). It is doubtful that at the present time fungicide spraying is economically feasible for small-scale farmers in West Africa. Hence, developing resistant cultivars is one of the best means of reducing crop losses from these diseases, and is particularly well suited to small-scale farmers of West Africa, who generally lack the financial resources, logistic means, and technical expertise required for chemical control. Almost all groundnut varieties currently grown by farmers in West Africa are susceptible to leaf spots and rust (Table 5). In recent years, screening the world collection of groundnut germplasm at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Center, India, has resulted in the identification of several sources of resistance to rust and late leaf spot (Tables 6 and 7) (Subrahmanyam *et al.*, 1982, 1983, 1985; McDonald *et al.*, 1985; Subrahmanyam and McDonald, 1987). Some of these sources of resistance were evaluated through multi-locational trials in West Africa and the resistance to rust and late leaf spot was found to be stable (Table 8) (Sankara, 1987). In addition, some cultivated genotypes have shown partial resistance in specifically designed experiments (Savary and Zadoks, 1989). Transferring resistance to these diseases into agronomically acceptable varieties is being carried out at ICRISAT Center, and cultivars with acceptable levels of resistance to rust and late leaf spot have been bred (Reddy *et al.*, 1987). They include derivatives of interspecific hybrids between *Arachis hypogaea* and *A. cardenasii*. Some breeding lines have given promising yields in a preliminary trial in Niger (Table 9).

Table 5. *Recommended groundnut varieties and their reactions to principal diseases in West Africa*

Variety	Cycle (days)	Disease reaction[a]				
		Early leaf spot	Late leaf spot	Rust	Rosette	*Aspergillus flavus*
Spanish						
55-437	90	S	S	S	S	R
CN 49 C	90	S	S	S	S	
TE 3	90	S	S	S	S	
TS 32-1	90	S	S	S	S	
KH 149 A	90	S	S	S	R	
KH 241 D	90	S	S	S	R	
QH 243 C	90	S	S	S	R	
73-30	95	S	S	S	S	R
796	90	S	S	S	S	
47-10	90	S	S	S	S	
Georgia	110	S	S	S	S	
Philippine Pink	90	S	S	S	S	
Virginia						
69-101	120	S	S	S	R	
59-426	120	S	S	S	R	
RMP 91	150	S	MR	S	R	
RMP 12	150	S	MR	S	R	
73-33	110	S	S	S	S	MR
28-206	120	S	S	S	S	
57-313	125	S	S	S	S	
57-422	110	S	S	S	S	
GH 119-20	110	S	S	S	S	
756 A	125	S	S	S	S	
73-27	125	S	S	S	S	
73-28	125	S	S	S	S	
47-16	120	S	S	S	S	
59-127	120	S	S	S	S	
Mani Pintar	125	S	S	S	S	
Valencia						
A 124 B	90	S	S	S	S	

[a] S = Susceptible, MR = moderately resistant and R = resistant.

Several sources of resistance to early leaf spot have been identified in the USA (see McDonald *et al.*, 1985) but their performance in various agroecological situations in West Africa has yet to be established. In recent years screening of a large collection of groundnut germplasm lines has resulted in identification of some useful levels of resistance to early leaf spot at ICRISAT Center, India and SADCC/ICRISAT, Malawi (Waliyar *et al.*, 1988).

2.2. *Rosette*

Groundnut rosette disease was first observed in Tanzania (Zimmerman, 1907) and was subsequently recorded in many African countries. The disease is apparently restricted to Africa, south of the Sahara. Two types of groundnut rosette diseases, chlorotic rosette and green rosette, are distinguished on the basis of their foliar symptoms. A mosaic

Table 6. Sources of resistance to Puccinia arachidis *available from ICRISAT (from Subrahmanyam and McDonald, 1982)*

Genotype	ICG No.[a]	Botanical type/variety	Seed colour[b]	Country of origin
NC Ac 17090	1697	*fastigiata*	Light tan	Peru
EC 76446 (292)	2716	*fastigiata*	Purple	Uganda
PI 259747	4747	*fastigiata*	Purple	Peru
NC Ac 927	6022	*fastigiata*	Purple	Sudan
PI 350680	6340	*fastigiata*	Purple	Honduras
NC Ac 17133-RF	7013	*fastigiata*	Purple	Peru
PI 215696	7881	*fastigiata*	Purple	Peru
PI 314817	7882	*fastigiata*	Light tan	Peru
PI 315608	7883	*hypogaea*	Off-white	Israel/USA
PI 341879	7884	*fastigiata*	Purple	Peru
PI 381622	7885	*fastigiata*	Purple	Peru
PI 390593	7886	*fastigiata*	Light tan	Peru
PI 390595	7887	*fastigiata*	Purple	Peru
PI 393517	7889	*fastigiata*	Off-White	Peru
PI 393527-B	7892	*hypogaea*	Red	Peru
PI 393641	7894	*fastigiata*	Light tan with purple stripes	Peru
PI 393643	7895	*fastigiata*	Light tan	Peru
PI 393646	7896	*fastigiata*	Purple	Peru
PI 405132	7897	*fastigiata*	Purple	Peru
PI 407454	7898	*fastigiata*	Tan	Ecudor
PI 414331	7899	*hypogaea*	Tan	Honduras
PI 414332	7900	*hypogaea*	Tan	Honduras

[a] ICRISAT Groundnut Accession Number.
[b] RHS colour chart. Royal Horticultural Society, London, 1966.

Table 7. Genotypes resistant to Phaeoisariopsis personata *available from ICRISAT (from McDonald* et al.*, 1985)*

Genotype	ICG No.[a]	Botanical type/variety	Seed colour[b]	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

[a] ICRISAT Groundnut Accession Number.
[b] Based on the RHS colour chart. Royal Horticultural Society, London, 1966.

rosette has also been reported from southern Africa. Green rosette is usually prevalent in West Africa whereas chlorotic rosette is more common in East and Central Africa. Groundnut rosette is transmitted by several species of aphids (Gibbons, 1977; Fauquet and Thouvenel, 1980; Reddy, 1984).

Groundnut rosette is well recognized as one of the major constraints of groundnut production in West Africa (Fauquet and Thouvenel, 1980). Although the rosette epidemics in West Africa are sporadic, yield losses are substantial

Table 8. Rust reactions of some groundnut genotypes in India and Burkina Faso

ICG No.[a]	Genotype	Rust scores[b]	
		India[c]	Burkina Faso[d]
Resistant genotypes			
1697	NC Ac 17090	2·2	2·0
1704	NC Ac 17129	3·8	4·0
1707	NC Ac 17132	3·8	2·5
2716	EC 76446 (292)	2·8	2·1
4746	PI 298115	4·0	3·0
4747	PI 259747	3·0	2·2
6022	NC Ac 927	3·6	3·3
6340	PI 350680	3·0	2·3
7013	NC Ac 17133 (RF)	3·3	3·2
7881	PI 215696	3·3	4·2
7882	PI 314817	3·0	2·3
7884	PI 341879	2·5	2·1
7885	PI 381622	3·0	2·0
7886	PI 390593	2·8	2·0
7887	PI 390595	3·5	2·0
7888	PI 393516	4·3	4·0
7889	PI 393517	3·2	2·0
7890	PI 393529	4·2	2·1
7892	PI 393527-B	3·0	2·0
7893	PI 393531	3·4	2·0
7894	PI 393641	3·8	2·3
7895	PI 393643	3·0	2·0
7896	PI 393646	2·4	2·0
7897	PI 405132	2·4	2·0
7898	PI 407454	2·8	2·0
7899	PI 414331	2·8	2·0
7900	PI 414332	2·4	3·3
Susceptible genotypes			
4580	EC 76446	9·0	8·5
6446	NC 3033	9·0	8·3
221	TMV 2	9·0	9·0
799	Robut 33-1	9·0	8·6

[a] ICRISAT groundnut accession number.
[b] Rust scores on a nine-point scale (Subrahmanyam *et al.*, 1982).
[c] Mean rust scores of 1979–1982 field screening trials at ICRISAT Center, Patancheru, Andhra Pradesh, India.
[d] Rust scores of 1983 field screening trials at the Agricultural Research Station, Niangoloko, Burkina Faso.

Table 9. Pod and haulm yields of six groundnut breeding lines resistant to late leaf spot and rust diseases in a preliminary field trial during the 1988 rainy season in Niger

Breeding line	Yield ($t\ ha^{-1}$)	
	Pod	Haulms
ICGV 87185 (ICG (FDRS) 70)	2·23	4·04
ICGV 87156 (ICG (FDRS) 2)	2·23	4·40
ICGV 87183 (ICG (FDRS) 42)	2·21	4·35
ICGV 87160 (ICG (FDRS) 10)	2·12	4·02
ICGV 87172 (ICG (FDRS) 28)	2·01	5·10
ICGV 87157 (ICG (FDRS) 4)	1·95	5·08
Controls		
55-437	1·49	3·22
28-206	1·51	4·53
SE	±0·15	±0·51
CV (%)	16	20

whenever the disease occurs in epidemic proportions. The 1975 rosette epidemic in some West African countries is a good example. In Nigeria about 0·7 million ha of the crop were destroyed incurring a loss of over N (Naira) 137 million (Yayock *et al.*, 1976). In the same year in Niger, groundnut production was reduced by almost 80% with an average yield of 131 kg ha^{-1} as compared with yields in previous years (Anonymous, 1987; Subrahmanyam *et al.*, 1989). In subsequent years in Niger, although groundnut rosette occurred sporadically, the disease attained epidemic proportions only in 1987 (Subrahmanyam *et al.*, 1988). The reasons for these fluctuations in rosette epidemics in West Africa are not fully understood. Further studies on the viruses, the vector, and their interaction with the environment are necessary to understand the epidemiology of groundnut rosette, to forecast epidemic outbreaks, and to formulate suitable management practices.

Groundnut rosette can be managed by controlling the vectors using insecticides. Careful monitoring of aphid infestation and timely application of insecticides are important to achieve satisfactory control of groundnut rosette. Chemical control may not be economically feasible to resource-limited farmers in West Africa. Early planting at high plant density can significantly reduce disease incidence. Eradication of volunteer groundnut plants and groundkeepers may be useful in preventing the perpetuation of virus inoculum during the off-season (Reddy, 1984).

Pioneering research on development of groundnut cultivars with resistance to rosette was done by the IRHO (Institut de Recherches pour les Huiles et Oléagineux) in West Africa. Sources of resistance to rosette were first discovered in 1952 after an epidemic of the disease almost completely destroyed a large collection of groundnut germplasm at Bambey, Senegal (Catherinet *et al.*, 1954). However, a few germplasm lines originating from the frontier region between Burkina Faso and Côte d'Ivoire were able to withstand the epidemic. These sources formed the basis for rosette resistance breeding programmes throughout Africa. Cultivars with acceptable levels of yield and rosette resistance were bred in Burkina Faso, Senegal, Nigeria, Malawi and to a limited extent in other countries (Dhery and Gillier, 1971; Gibbons and Mercer, 1972; Gillier and Bockelee-Morvan, 1975; Gillier, 1978; Gautreau and De Pins, 1980; Misari *et al.*, 1980; Soumano and Diallo, 1982; Harkness and Salako, 1982; Bockelee-Morvan, 1983; Nigam, 1987; Bock, 1987; Soumano and Traore, 1988; N'Diaye, 1988; Misari *et al.*, 1988). In the early years the rosette-resistant cultivars bred were long cycle (120–150 days) Virginia types (e.g., RMP 91, RMP 21, 69–101 and 59–426) (Table 5), suitable for cultivation only in the wetter Guinea Savanna region of West Africa. However, in recent years short cycle (90 days) Spanish types (e.g. KH 149 A, KH 241 D and QH 243 C) (Table 5) have been bred for cultivation in the dry Sahel–Sudanian region of West Africa. Unfortunately, most of these rosette-resistant cultivars are susceptible to leaf spots and rust. Combining rosette resistance with late leaf spot and rust resistances in short–medium cycle (90–115 days) material is important for the Sahel–Sudanian region, and such material would also be valuable for the wetter regions where farmers often wish to plant groundnut late after completion of weeding in the cereal crops, but cannot do this as current high-yielding short-cycle varieties are susceptible to all these diseases. Obtaining such combinations will be difficult, but attempts have already been made. The rosette-resistant, short-cycle varieties from the IRHO such as KH 194 A, and rust and late leaf spot-resistant varieties from ICRISAT Center should be useful as parents. RG 1 (bred in Malawi) is another possible source of rosette resistance in late material; its seed type is somewhat more acceptable as an edible nut than RMP 12.

2.3. *Seedling diseases*

Young seedlings are attacked by a variety of seed- and soil-borne fungi including *Aspergillus flavus* Link. ex Fr., *A. niger* van Tiegh., *Botryodiplodia theobromae* Pat., *Cochliobolus bicolor* Paul & Par., *Rhizoctonia solani* Kuhn., *Macrophomina phaseolina* (Tassi.) Goid., species of *Penicillium, Rhizopus, Fusarium* and *Pythium*, resulting in pre-emergence mortality. The infected seedlings are reduced to a shrivelled, dark brown or black spongy mass of rotted tissue covered with a mat of mycelium on which masses of fructifications are produced. Decay is most rapid when infected seeds are planted, and the fungus becomes active as the seeds hydrate. Post-emergence seedling diseases include collar/crown rot (*A. niger*), aflaroot (*A. flavus*) and root rot (*R. solani, M. phaseolina* and *Pythium* spp.).

Seedling diseases are present throughout West Africa wherever groundnut is grown, and are particularly serious when poor-quality seed is used for planting. Severe fluctuations in soil moisture soon after planting, which are common in West Africa, may lead to high incidence of seedling diseases. Disease surveys carried out in Niger in 1987 (Subrahmanyam *et al.*, 1989) and in Côte d'Ivoire in 1983–85 (Savary, 1987b) have shown that reduction in plant stand due to seedling diseases is severe in many farmers' fields. Field trials conducted at three locations in Niger in 1987 using seed-protectant chemicals showed a high reduction in plant stand on non-treated plots due to seedling diseases: Sadoré (27%), Bengou (23%) and Maradi (26%). The losses in pod yields were 24% in Sadoré, 19% in Maradi, and 4% in Bengou. Although there was considerable reduction in plant stand in Bengou, the yield loss was only 4% because of vigorous plant growth compensating the yield. Such a compensation is not to be expected in farmers' fields, where the seed rate is usually very low. Yield losses from seedling diseases are substantial in low-fertility areas and when the crop is subjected to drought resulting in poor crop growth.

Seedling diseases can be to some extent controlled by using high-quality seed for planting. Deep planting should be avoided as etiolated seedlings are highly susceptible to these pathogens. There is abundant literature on the use of seed-protectant chemicals for controlling seedling diseases of groundnut in West Africa. Field trials have been conducted in many locations in West Africa and a number of fungicides were found to be useful. Recommendations have been made to the farmers on the use of seed-protectant fungicides or mixtures of fungicide and insecticide.

Sources of resistance to collar rot (e.g. U4-47-7) and aflaroot (e.g. J 11) are also available, but at the present time breeding efforts to transfer these resistances into cultivars agronomically acceptable in West Africa may not be immediately required, since seed treatment with fungicides is simple and economical and is already being done by a reasonable proportion of farmers in some parts of West Africa.

2.4. *The aflatoxin problem*

Contamination of groundnut with aflatoxins, the secondary toxic metabolites produced by fungi of the *Aspergillus flavus* group, is a serious quality problem in many parts of West Africa. *A. flavus* may invade groundnut seeds before harvest, during post-harvest drying, and during storage if the seeds are rewetted. Invasion of seeds by *A flavus* and aflatoxin production can be minimized by crop rotation, prevention of drought stress by supplemental irrigation, harvesting at optimum maturity, drying pods under appropriate temperature and air-flow conditions, and storage of produce at low moisture content and in insect-free conditions (McDonald, 1966; McDonald and Harkness, 1967; Pettit and Taber, 1968; McDonald, 1969b; Subrahmanyam and Rao, 1974; Pettit, 1985). However, from the continued high levels of contamination reported, especially from the SAT (semi-arid tropics) countries, it appears that farmers have not yet adopted these recommendations (Mehan and McDonald, 1984). It has therefore become necessary to investigate the possibilities of genetic resistance in the hope of developing cultivars with seeds which *A. flavus* cannot invade or which, if invaded, do not support aflatoxin production.

In recent years, several laboratory and field screening techniques have been developed to screen groundnut for resistance to *A. flavus* infection and/or aflatoxin production. Several genotypes with resistance to seed invasion in the field and also in *in vitro* inoculation tests in the laboratory have been reported (Mixon, 1979; Mehan *et al.*, 1982; Mehan and McDonald, 1984) (Table 10). Some genotypes support only very low levels of aflatoxin production when seeds were invaded by *A. flavus*. Of the groundnut lines with resistance to *A. flavus*, J 11 and AH 7223 have shown reasonable agronomic performance in preliminary field trials in Niger. Progress has been made in developing breeding lines with stable resistance to seed colonization and with acceptable yield and quality. It is worth noting that the variety 55–437, grown in many countries in West Africa, has shown seed resistance to *A. flavus* invasion in both field and laboratory tests (Zambettakis *et al.*, 1977). This variety is being crossed with J 11 as the start of a breeding program for *A. flavus* resistance at ICRISAT Sahelian Center, Niger. Some breeding lines with *A. flavus* resistance from ICRISAT Center have also shown promising agronomic performance in a preliminary trial in Niger (Table 11).

Table 10. Sources of Resistance to colonization of rehydrated stored seed by Aspergillus flavus

Genotype	Botanical type	Seed colour
AH 7223	Spanish	Salmon
J 11	Spanish	Salmon
Var 27	Valencia	Red
UF 71513	Valencia	Salmon
U4-47-7	Spanish	Light Salmon
UI-2-1	Virginia bunch	Tan
Faizpur	Valencia	Salmon/tan
55-437	Spanish	Tan
73-30	Spanish	Salmon
73-33	Virginia bunch	Pink

2.5. *Crop growth variability*

Variation in crop growth is a major limiting factor for groundnut production in the Sahel. During our surveys in Niger in 1986 and 1987, we observed large variations in crop growth in farmers' fields, especially in sandy soils, in all major groundnut producing areas of the country. Affected plants were usually present in patches intermixed with apparently healthy plants. These patches were always randomly distributed in the field irrespective of the field contour (Subrahmanyam *et al.*, 1988).

Three distinct types of symptoms were observed on affected plants:

1. Plants severely stunted, chlorotic, with poor shoot and root development. Necrosis of roots severe with shredding of cortex tissues. Pods few in number with necrotic lesions on surfaces. Plant mortality evident in many cases.
2. Plants severely stunted, bushy, dark green with mild mosaic symptoms on young leaves. Plants become chlorotic towards maturity.
3. Plants severely stunted (as in category 1) but older leaves showing black necrotic lesions on margins.

The relative incidence of plants showing the above symptoms varies over locations. The factors contributing to variation in crop growth are not yet fully elucidated.

Table 11. Pod and haulm yields of six groundnut breeding lines with seed resistant to Aspergillus flavus *in a preliminary field trial during the 1988 rainy season in Niger*

Breeding line	Yield (t ha^{-1})	
	Pods	Haulms
ICGV 87088	2·82	3·07
ICGV 87118	2·65	3·23
ICGV 87078	2·58	2·22
ICGV 87104	2·57	3·22
ICGV 86168	2·56	2·81
ICGV 87087	2·50	2·41
Controls		
TS 32-1	2·39	2·11
55-437	2·24	2·32
JL 24	1·89	2·23
J 11	1·51	1·83
SE	±0.15	±0·21
CV (%)	12	16

2.5.1 Occurrence of peanut clump and parasitic nematodenes. Peanut clump virus (PCV) particles were observed in ultra-thin sections of leaves collected from bushy, dark green, stunted plants present in patches. The PCV was found to be serologically related to Indian and West African PCV isolates by ELISA (enzyme-linked immunosorbent assay) tests. Reactions on various indicator hosts in artificial inoculation also clearly showed the presence of PCV. PCV is definitely one of the factors contributing to the variation in crop growth.

Analysis of soil samples collected from rhizosphere and geocarposphere zones, and of the roots of affected plants, showed high populations of plant parasitic nematodes, especially *Scutellonema clathricaudatum* Whitehead, *Xiphinema attorodorum* Luc, and *Telotylenchus indicus* Siddiqi. These seem to be major contributing factors to crop growth variability in groundnut. However, the relative importance of PCV, plant parasitic nematodes, and their interaction in crop growth variability in groundnut in the Sahel has still to be established.

2.5.2. Effect of pesticides. Soil treatment with carbofuran especially at high doses (8–10 kg a.i. ha^{-1}) was effective in reducing nematode populations and the variation in crop growth. Plants in carbofuran-treated plots showed normal growth, whereas in control plots, plants were severely stunted and chlorotic. There was a three-fold increase in pod yields and a two-fold increase in haulm yields following carbofuran treatment (10 kg a.i. ha^{-1}) (Subrahmanyam *et al.*, 1988).

Further trials conducted at Sadoré, Niger, indicated that soil treatment with carbofuran (10 kg a.i. ha^{-1}) and farmyard manure (FYM) (10 t ha^{-1}) was extremely satisfactory in reducing nematode populations and variation in crop growth, and in increasing yields (Table 12). Soil treatment with FYM alone was not effective (Subrahmanyam *et al.*, 1988).

The efficacy of four pesticides (dibromochloropropane, dazomet, carbofuran and aldicarb) in controlling variation in crop growth was investigated both under rainfed and irrigated conditions. Dibromochloropropane was most effective in reducing nematode populations and variation in crop growth, and increasing pod and haulm yields under irrigation. Aldicarb was most effective under rainfed conditions (Table 13). Plots treated with dibromochloropropane (irrigated conditions) and aldicarb (rainfed conditions) showed vigorous plant growth, as assessed by plant height, root length and number of leaves on the main

Table 12. Effect of carbofuran and farmyard manure on plant height and yield of groundnut (cv. 55-437) at Sadore, Niger, rainy season 1987 (from Subrahmanyam et al., *1988)*

Treatment[a]	Plant height (cm)		Yield (t ha^{-1})			
	Irrigated	Rainfed	Irrigated		Rainfed	
			Pods	Haulms	Pods	Haulms
Carbofuran + farmyard manure	25	16	3·04	2·55	1·75	1·23
Carbofuran	21	15	2·14	1·30	1·67	1·05
Farmyard manure	14	10	1·10	1·03	0·78	0·70
Control	11	8	0·84	0·80	0·66	0·61
SE	±2	±1	±0·20	±0·14	±0·10	±0·06
CV (%)	24	22	27	25	16	14

[a] Carbofuran (10 kg a.i. ha^{-1}) and farmyard manure (10 t ha^{-1}) were applied to field plots just before sowing.

Table 13. Effect of four pesticides on plant height and yield of groundnut (cv. 55-437) at Sadore, Niger, rainy season 1987 (from Subrahmanyam et al., *1988)*

Treatment[a]	Plant height (cm)		Yield (t ha^{-1})			
	Irrigated	Rainfed	Irrigated		Rainfed	
			Pods	Haulms	Pods	Haulms
Dibromochloropropane	32	15	3·85	3·41	1·86	1·78
Dazomet	25	12	2·89	2·59	1·10	1·00
Carbofuran	17	14	2·50	1·98	1·93	1·66
Aldicarb	18	18	1·97	1·71	2·25	1·96
Control	12	11	1·19	1·09	1·09	0·92
SE	±2	±1	±0·33	±0·33	±0·12	±0·20
CV (%)	23	12	27	30	17	30

[a] Dibromochloropropane (20 l in 85 l of water/ha), carbofuran (6 kg a.i ha^{-1}) and aldicarb (4 kg a.i ha^{-1}) were applied to the field plots on the day of sowing. Dazomet (300 kg ha^{-1}) was applied 15 days before sowing.

stem and pods per plant. Nodulation was good. Plants in control plots were stunted, chlorotic with severely necrosed root systems (Subrahmanyam *et al.*, 1988).

Crop growth variability in groundnut in sandy soils of the Sahel seems to be largely due to parasitic nematodes and PCV. Roots invaded by nematodes become necrotic and may not be effective in utilizing available moisture and nutrients. Colonization by mycorrhiza and rhizobium is also drastically reduced. It is clear that crop growth variability in groundnut can be easily managed by soil application of some pesticides. It is interesting to note that both nematode populations and PCV incidence can be reduced using pesticides such as carbofuran. However, it is not economically feasible to control crop growth variability using pesticides for farmers in West Africa. Further studies are required to determine the roles of these two biotic factors in crop growth variability. Agronomic practices such as crop rotation and tillage need to be tested to see if they affect crop growth variability.

12. Conclusions

1. Leaf spots, rust, rosette, and seedling diseases are responsible for considerable losses all over the groundnut producing regions of West Africa. In addition, aflatoxin contamination is a serious seed-quality problem in West Africa. Crop growth variability is one of the major limiting factors of groundnut production in sandy soils of the Sahel.
2. The distribution of various diseases of groundnut needs to be determined through systematic disease surveys in various agroclimatic zones of the region to facilitate the identification of suitable locations for screening of germplasm and breeding lines for resistance to these diseases.
3. Combining resistance to these major diseases into agronomically acceptable varieties should receive high priority.
4. Seedling diseases can be controlled very effectively and economically by seed dressings. Hence, efforts to develop groundnut varieties with resistance to these diseases may not be required. Breeding for resistance to seedling diseases may also not be very successful, since a variety of fungi are associated with seedling diseases. Farmers should be advised to use good-quality seed for sowing and to apply seed protectant chemicals.
5. The levels of aflatoxin contamination in different geographical locations in West Africa need to be determined. There is a need to educate farmers in simple agronomic and cultural practices that are useful to reduce aflatoxin contamination. Research on transferring resistance to *A. flavus* invasion and/or aflatoxin production should be intensified.
6. Further testing of germplasm for stability of resistance to late leaf spot, rust, rosette and *A. flavus* should be carried out through multilocational trials in West Africa.
7. Studies on the alternative hosts of groundnut rosette viruses and spread of the disease by the principal vectors are necessary to understand the epidemiology of groundnut rosette and to formulate suitable management practices.
8. The distribution and economic importance of plant parasitic nematodes and of PCV in West Africa need to be determined. The relative importance of these two biotic factors in crop growth variability in groundnut in the Sahel needs to be established.
9. Suitable agronomic practices might be developed to reduce crop losses due to crop growth variability.
10. Cooperation between ICRISAT, IRHO, IIRSDA, ORSTOM (Institut Français de Recherche Scientifique pour le Développement en Cooperation), and Peanut CRSP (Collaborative Research Support Program) and the national programmes involved in the improvement of groundnut crop productivity in the region is essential for achieving these goals.

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