RUST DISEASE OF GROUNDNUT

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Abstract

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Up to the late 1960s groundnut rust disease, caused by the fungus *Puccinia arachidis*, was confined mainly to Central and South America. The disease then spread rapidly and is now present in most groundnut-growing countries of the world. It can severely damage the crop, often causing losses in pod yield in excess of 50%.

The bulletin describes disease symptoms, gives data on the morphology and taxonomy of *P. arachidis*, and outlines the disease cycle. The need for an integrated approach to control of the disease is stressed, and consideration is given to the use of cultural, chemical, and biological measures. The need to identify sources of genetic resistance and use them in breeding programs is emphasized, and rust-resistant genotypes available from ICRISAT are listed. The efficiency of some fungicides commonly used against groundnut foliar diseases in controlling rust disease is noted. Ways of modifying cultural practices to reduce the incidence and severity of the disease are discussed. Hyperparasites of the rust fungus occur but there is no immediate prospect of their use in controlling the disease.

The components included in an integrated control system for groundnut rust depend upon environmental, agronomic, and socioeconomic factors. As these are highly variable it is not appropriate to give a single overall recommendation for the control of the disease. But the bulletin provides advice and data on the basis of which extension staff can work out the methods of control best suited to local disease situations.

Résumé

Subrahmanyam, P., and McDonald, D. 1983. Rust disease of groundnut.(*La rouille de l'arachide.*) Information Bulletin No. 13. Patancheru, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

Jusqu'à la fin des années 60, la maladie de la rouille chez l'arachide, due au champignon *Puccinia arachidis*, s'est limitée aux Amériques centrale et du Sud. La maladie s'est ensuite propagée et sévit actuellement dans la plupart des pays producteurs d'arachide où les cultures sont parfois gravement endommagées avec des pertes de rendement en gousses dépassant 50%.

Ce bulletin décrit les symptômes et l'évolution de la maladie ainsi que la morphologie et la systématique de *P. arachidis*. Il faut souligner l'importance de lutter contre cette maladie en prenant des mesures qui intègrent les aspects culturaux, chimiques et biologiques. Il convient également de repérer des sources de résistance parmi le matériel génétique et de les exploiter dans le cadre d'un programme de sélection; ainsi nous présentons une liste des génotypes résistants à la rouille disponibles à l'ICRISAT. Certains fongicides utilisés contre les maladies foliaires sont évalués ici pour leur efficacité contre la rouille. Certaines modifications aux pratiques culturales sont proposées, afin de réduire l'incidence et la gravité de la maladie. Il existe aussi des parasites du champignon de la rouille, mais on n'envisage pas leur utilisation immédiate.

Les composantes du système de lutte intégrée contre la rouille de l'arachide dépendent des facteurs environnementaux, agronomiques et socio-économiques. Compte tenu de leur variabilité, il est impossible de préconiser une seule recommandation globale. Cependant, les conseils et les données fournis dans ce bulletin permettront aux agents de vulgarisation d'élaborer les méthodes de lutte les mieux adaptées à la situation locale.

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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 simple but comprehensive bulletins. Many of the scientific journals containing more detailed research papers are not always accessible to workers in the field, and usually contain only brief specialized reviews of literature.

It is the intention of the ICRISAT Groundnut Improvement Program to produce a series of up-to-date information bulletins on important diseases affecting the crop. We have received many requests for such bulletins from our colleagues and cooperators in many countries.

It is appropriate that the first of these bulletins should concern groundnut rust because it has become such an important worldwide disease in a relatively short time. Much information on the biology of the fungus and the epidemiology of the disease has been obtained through an international network of cooperators, and there are excellent prospects of producing cultivars with enhanced yield potential and stable resistance.

R.W. Gibbons
Director of Research

Introduction

Rust caused by *Puccinia arachidis* Speg. is a destructive disease of groundnut (*Arachis hypogaea* L.) in many important groundnut-producing regions of the world. Figure 1 shows severe rust attack on a farmer's crop in southern India. Such attacks probably result in a loss in pod yield of over 50% and an even greater loss in haulm yield. Losses of this magnitude are common in some parts of the semi-arid tropics (the SAT) and there is a need for research into factors influencing rust incidence and build-up, with the aim of formulating effective and economic control measures. The objectives of this bulletin are to provide research and extension workers with basic information on groundnut rust disease, and to present them with the currently available strategies for control.

Distribution

Prior to 1969 groundnut rust was largely confined to South and Central America. Occasional outbreaks occurred in southeastern USA. The disease was also recorded in the USSR in 1910, in Mauritius in 1914, and the Peoples' Republic of China in 1937, but did not become permanently established in these countries (Fig. 2, top). Commercial production of groundnut is limited in the Caribbean islands and Central America because of rust attack in conjunction with leaf spots (*Cercospora arachidicola* Hori. and *Cercosporidium personatum* (Berk. & Curt.) Deighton). However, rust is not regarded as a serious problem in the USA.

In recent years groundnut rust has spread to, and become established in, many countries in Asia (Brunei, India, Indonesia, Japan, Korea,

Fig. 1. Severe rust attack on a farmer's groundnuts in southern India.

Malaysia, the Peoples' Republic of China, the Philippines, Taiwan, and Thailand), Australasia and Oceania (Australia, Fiji, Papua New Guinea, and the Solomon Islands) and Africa (Botswana, Ethiopia, Ghana, Kenya, Malawi, Mauritius, Mozambique, Nigeria, Republic of Benin, Repub-

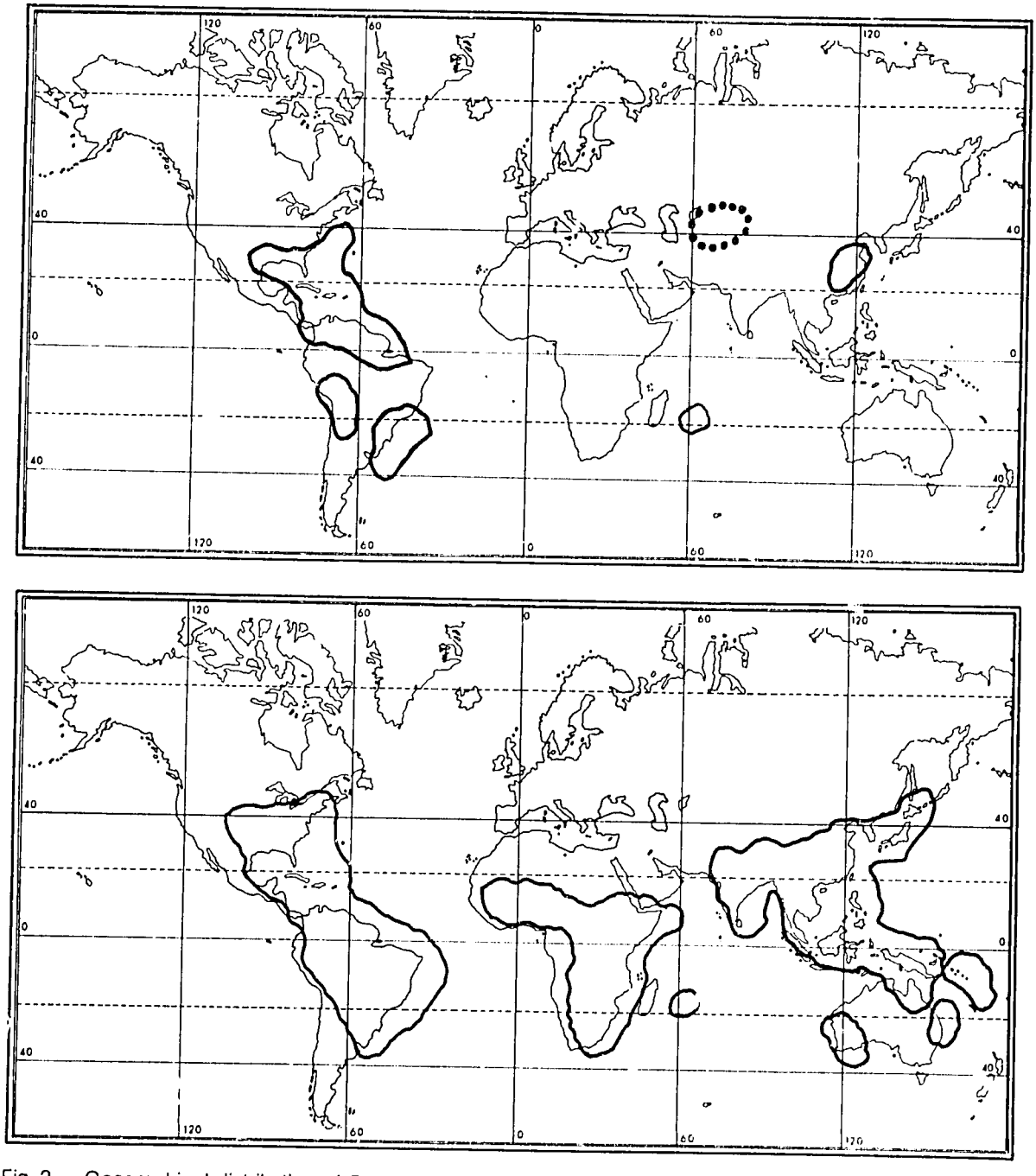


Fig. 2. Geographical distribution of *Puccinia arachidis*. Top: Distribution prior to 1969 (based on Commonwealth Mycological Institute map No. 16, issued on 30 June 1966). Bottom: Distribution in 1983 (based on Commonwealth Mycological Institute map No. 160, issued on 1 April 1980).

lic of South Africa, Senegal, Somalia, Sudan, Tanzania, Uganda, Upper Volta, Zambia, and Zimbabwe) (Fig. 2, bottom). Rust is now of economic importance in almost all groundnut-growing areas of the world.

Symptoms

Rust disease can readily be recognized when the orange-colored pustules or uredinia (uredia) appear on the abaxial (lower) surfaces of the leaves and rupture to expose masses of reddish-brown urediniospores (uredospores) (Fig. 3). Wind-distributed urediniospores land on the leaf surface and, if temperatures are in the 15-30°C range and leaves are wet with dew or rain, the urediniospores germinate and produce appressoria and infection hyphae that penetrate the leaf through the stomata. The incubation period ranges from 9 to 20 days, being greatly influenced by environmental factors and host reaction. Pustules appear first on the abaxial surface and, in highly susceptible cultivars, the original pustules may be surrounded by colonies of secondary pustules. Pustules may later be formed on the adaxial (upper) surface opposite those on the abaxial surface. The pustules are usually circular, and range from 0.5 to 1.4 mm in diameter. They may be formed on all aerial plant parts apart from flowers and pegs. In contrast with the rapid defoliation associated with leaf spots, leaves infected with rust become necrotic and dry up, but tend to remain attached to the plant.

Causal Organism

The accepted authority of the causal organism is cited as follows: *Puccinia arachidis* Spegazzini 1884. Anal. Soc. Ci. Argentina 17: 69-96 and 119-134. Synonyms are:

Uredo arachidis Lagerheim. 1894. Tromso. Mus. Aarsh. 17:106;
Uromyces arachidis P. Henn. 1896. Hedwigia 35: 224; and
Bullaria (?) *arachidis* (Speg.) Arthur and Mains. 1922. North American Flora 7(7):484.

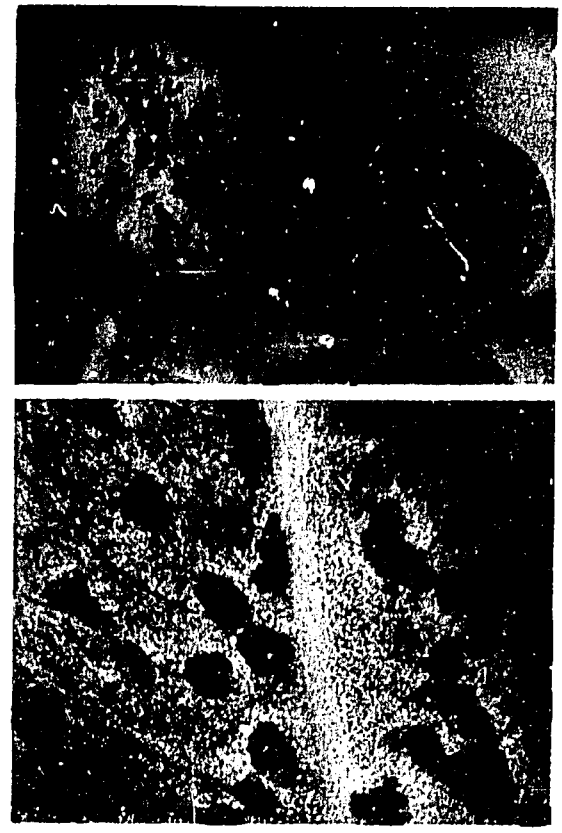


Fig.3. Rust pustules (uredinia) on the under-surface of groundnut leaves (close-up view below).

The following description of *P. arachidis* has been taken from Arthur (1934), Jackson and Bell (1969), Cummins (1978, pp. 181-182) and Hennen et al. (1976).

Stage 0. Spermogonia not known.
Stage I. Aecia not known.
Stage II. The uredinial stage is the most predominant and commonly observed stage. Uredinia are predominantly hypophyllous, scattered or irregularly grouped, round ellipsoid or oblong in shape, dark cinnamon brown in color when mature; ruptured epidermis conspicuous; urediniospores are broadly ellipsoid or obovoid, 16-22 (-24) x (21-) 23-29 (-30) µ in size, wall

is brown in color, 1-2.2 μ thick, finely echinulate, with mostly 2, occasionally 3 or 4 germpores, nearly equatorial, in often flattened areas (Fig. 4, left).

Stage III. Telia chiefly hypophyllous, 0.2 to 0.3 mm in diameter, scattered, prominent, soon naked, chestnut brown or about cinnamon brown becoming gray from germination, or almost black, ruptured epidermis prominent, teliospores oblong or obovate or ellipsoidal or ovate in shape, with rounded to acute and thickened apex, constricted in the middle, somewhat or gradually attenuate at the base or more or less rounded attenuate at both ends, smooth-walled, light yellow or golden yellow or chestnut brown, predominantly 2-ceiled (Fig. 4, center), sometimes with 3-4 cells (Fig.4, right), (33-) 38-42 (-60) x (12-) 14-16 (-18) μ thick at sides, 2.5-4.0 (-5.0) μ thick at the top, apical thickening almost hyaline, pedicel thin-walled, usually collapsing laterally, hyaline, up to 35-65 μ long but usually broken shorter or detached at spore base, germinating at maturity without dormancy.

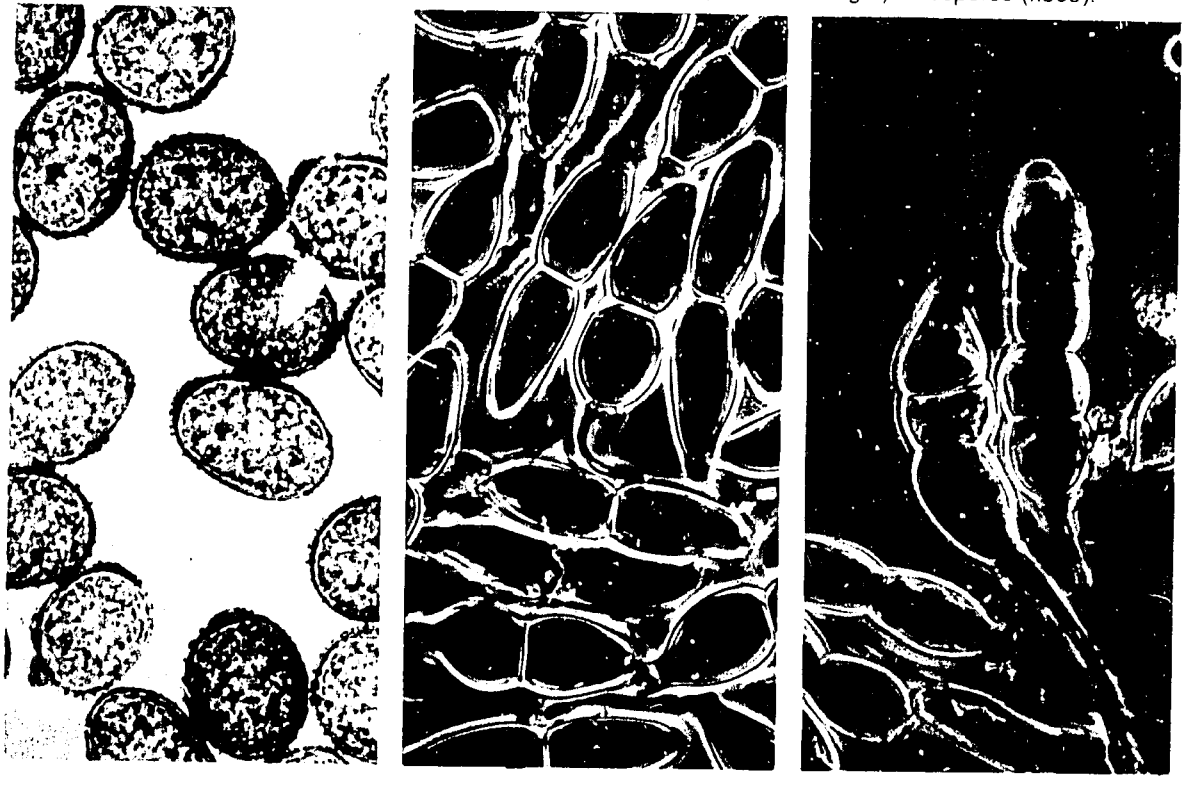
Stage IV. Metabasidia and basidiospores not known.

Taxonomy of *P. arachidis*

Cummins (1978, pp. 181-182) stated that *Puccinia offuscata* Arth. on *Zornia bracteata* J.F. Gmel. and *Z. diphylla* (L.) Pers. is only a variety of *Puccinia arachidis* (*P. arachidis* var. *offuscata* (Arth.) Cumm. 1977. Mycotaxon 5: 402). He found that *P. offuscata* was almost similar to *P. arachidis* in spore morphology but differed in having urediniospores with 2-4, commonly 3, germpores and paler teliospores. No mention was made of cross inoculation tests.

The rust fungi are well known for their often complex life cycles, some species at times pro-

Fig.4. Conidia of the rust fungus: (left) urediniospores (x800); (center and right) teliospores (x800).



ducing five different kinds of spores and requiring two unrelated hosts for completion. Groundnut rust is known almost exclusively by its uredinial stage. However, there are a few records of the occurrence of teliospores, mainly from South America. Teliospores are important because certain nuclear phenomena, caryogamy and meiosis, essential for sexual reproduction, occur during teliospore germination. As a result, basidiospores are formed and disseminated. Under favorable conditions they infect appropriate hosts. No such host is known for *P. arachidis*. Without knowledge of the host and of the structures produced on it the life cycle pattern and taxonomic relationships cannot be determined, and classification can be only tentative.

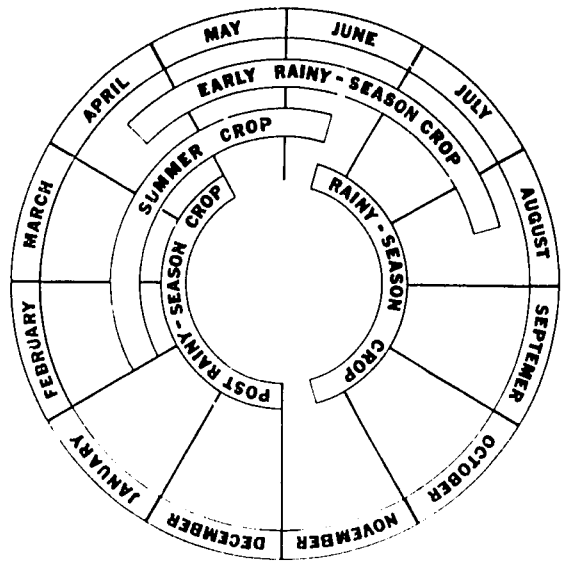


Fig.5. Groundnut cropping seasons in India. Overlapping of these seasons helps to perpetuate rust disease attack.

Disease Cycle

Groundnut rust is known to perpetuate, spread, and produce severe disease outbreaks by means of its urediniospores. There are a few records of the occurrence of the telial stage on cultivated groundnut and on wild *Arachis* species. It is not known if the fungus produces spermatia and aecia or if any alternate host is involved in the life cycle. Groundnut rust is known to attack several other members of the genus *Arachis*, but they can hardly be involved in the perpetuation of groundnut rust outside their native South America.

It has been reported that urediniospores are short-lived in infected crop debris. It is therefore unlikely that the fungus is perpetuated from season to season in crop debris under hot climatic conditions when there is a break of over 4 weeks between crop seasons. The practice of continuous cultivation of groundnuts without any break appears to be an important factor in the perpetuation of groundnut rust in India (Fig. 5).

The pathogen may survive from season to season on volunteer groundnut plants. No authentic host species are known outside the genus *Arachis*.

Long-distance dissemination of the disease may occur via air-borne urediniospores, by the movement of infected crop debris, or by the movement of pods or seeds surface-contaminated with urediniospores or infected crop debris. There is no reliable evidence of groundnut rust being internally seed-borne. If groundnuts are treated with a fungicide, or are stored for 4 weeks or longer at room temperature, there should be no chance of rust disease being carried either in or on them. There is no authenticated report of rust being spread by germplasm exchange.

An optimum temperature of 20°C, the presence of liquid water on the leaf surface, and high relative humidity, favor infection and subsequent disease development. Plants of all ages are susceptible. Spread of the disease within growing crops is facilitated by wind movement, by rain splash, and also by insects. Given favorable conditions disease spread continues throughout the season and may lead to almost total destruction of the crop (as shown in Fig. 1).

Disease Management

Damage to the plant from rust is mainly from the loss of photosynthetic tissues to pustules and to chlo-

rosis and necrosis that may in severe attacks cause death of the whole leaflet. Leaflets may dry up to give the plant a burned appearance. Late rust attack may not reduce yield much, but an early attack can result in considerable losses. In conditions favoring rapid disease build-up, an early attack may cause widespread death of plants and almost total crop failure.

Losses in yield specifically due to rust attack are hard to assess because leaf spots are usually also present and contribute to observed yield losses. The success of chemical control varies because some fungicides effective against rust are totally ineffective against leaf spots, and vice versa. Breeding for resistance is difficult because, ideally, resistance to all three major leaf diseases (early leaf spot, late leaf spot, and rust) should be incorporated into the improved cultivars.

Cultural measures for rust control

Wherever possible, field management should include a clear break in time between successive groundnut crops. Volunteer groundnut plants and "ground-keepers" should be eradicated. If cropping systems permit, times of sowing should be adjusted to avoid infection of the crop from outside sources, and to avoid the environmental conditions conducive to disease build-up. Weeds should be kept under control, because a heavy growth of weeds may encourage disease development through modification of the crop microclimate. Strict plant quarantine regulations should be enforced to avoid the spread of rust on pods or seeds to disease-free areas.

Chemical control

The control of groundnut rust by chemical means has been attempted from time to time, usually on a relatively small scale, and with varying degrees of success. In recent years a large number of fungicides have been tested for their effectiveness in the control of both rust and leaf spots. Some have proved to be effective and economical when used by farmers in the USA; but their use has presented some problems for small-scale groundnut farmers of the SAT.

In the southern groundnut growing areas of the USA fungicides are applied by various kinds of tractor-propelled machines, fixed-wing aircraft, helicopters, and, more recently, through sprinkler irrigation systems. Dust formulations (copper, sulphur, and copper plus sulphur) were the most commonly used fungicides up to the late 1960s, although a number of spray fungicides, such as 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. Benomyl was very effective against leaf spots but ineffective against rust; it is now rarely used. Chlorothalonil is now the most widely used chemical in the USA for the control of rust and leaf spots. For such control to be effective, 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.

Experiments on fungicidal control of rust have been conducted in a number of countries of the SAT (Fig. 6) and large increases in yield of both kernels and haulms have been obtained. Various fungicide formulations have been tested using apparatus ranging from hand-operated dusters and watering cans to sophisticated controlled-droplet application (ultra-low volume) machinery. Although fungicide control has thus been proved effective under research conditions, very few farmers have adopted the practice. Some of the reasons for this are as follows.

- Low basic crop yields. (Average kernel yields in the SAT are between 500 and 600 kg/ha. Even if fungicide application could double this

Fig.6. The chemical control of rust at ICRISAT Center. Plots at the front and rear have been sprayed with fungicides, but the center plot is untreated.

yield, the result would hardly be economic.)

- Difficulties in obtaining fungicides and application machinery and the high costs of these items.
- The 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 and maintenance of spray machinery.
- Low or fluctuating prices for groundnuts (inhibiting investment by farmers).

These problems are not insurmountable. Adoption of improved varieties and of recommended agronomic practices could improve base yields. Government or commercial organizations could improve the supply of fungicides, of application machinery, and of information on how to use them. Recent developments in controlled-droplet application have led to the production of relatively inexpensive "spray" machinery that requires little or no water. Possibilities also exist for contract spraying. The world shortage of oilseeds could also in some areas justify government action in offering subsidies or loan schemes to encourage farmers to purchase equipment and fungicides.

Fungicides in common use against rust and leaf spots include the following.

Copper, sulphur, and copper/sulphur dusts. These give good control of leaf spots and some control of rust. Application rates are high (20-50 kg/ha) and they can be expensive if they have to be imported or 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 sprays are effective for the control of 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 mammalian toxicity than most other leaf spot control fungicides, and may cause phytotoxicity.

Benomyl. This is a systemic fungicide that gives excellent control of leaf spots; but it is liable to stimulate the production of tolerant strains of the pathogens. It is ineffective against rust.

Carbendazim. Similar to benomyl.

Captafol. Applied as a spray it gives good control of leaf spots, but it 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 a number of different firms under various trade names. Manufacturers' recommendations regarding rates of application and numbers of applications should be followed where no local

advisory service recommendations are available. The degree of rust 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 rust control should be recommended has to be made at the local level. Factors to be taken into consideration include the extent of losses suffered, the cost of the control measures, and the returns expected. If control by fungicide is planned, decisions will have to be made on the chemicals to be used, the rate at which they should be applied, and the timing and number of applications. The presence of leaf spot diseases would require that any fungicide used for rust control would also control leaf spots. Disease control and yield responses to different levels of fungicide application are still to be worked out for some situations, and it is difficult to recommend economic disease control measures without such data.

The possible effects of fungicides on non-target organisms should be considered. Backman et al. (1975) 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 rust and leaf spot disease attack may increase the effective growing season of a cultivar by 2-3 weeks. This may have adverse effects upon yield if the cultivar is growing in an area with a very short rainy season. Under water-stress conditions, plants that have retained most of their foliage would be more likely to go into permanent wilting than plants that had lost most of their leaves from rust and leaf spot diseases.

Resistance breeding

Developing resistant cultivars is a very satisfactory means of reducing crop yield losses from disease. It is a policy particularly well suited to the small-scale farmer of the SAT who generally lacks the financial resources and technical expertise required for chemical disease control.

Fig.7. Leaves of rust-resistant cv NC Ac 17090 (left) and rust-susceptible cv TMV 2 (right).

Prior to 1956 there were few reports of research into genetic resistance to groundnut rust. But the rapid spread of rust disease in the late 1960s and early 1970s, and increasing costs of chemical control, have stimulated work in this field and good sources of resistance have been identified (see, for instance, Fig.7). Effective field-screening methods have been evolved for use in areas where there is high natural disease pressure or where such pressure can be artificially induced. Genotypes to be screened are sown in replicated plots with rows of a highly susceptible cultivar arranged systematically through the trial. At ICRISAT Center, where rust disease is severe in each rainy season, the ratio of "infector" rows to rows of test genotypes is 1:4. A higher or lower ratio may be appropriate in other localities. To enhance disease development, the plants in the infector rows can be inoculated with a suspension of rust spores. Inoculation is most successful if done in the evening because strong sunlight inhibits urediniospore germination. Figure 8 shows field screening for rust resistance at ICRISAT Center. The methods can also be used in rust-resistance breeding. Several rust-resistant breeding lines have been released (Table 1) and others can be obtained from various national research institutions. Rust-resistant genotypes available from ICRISAT in 1983 are listed in Table 2. Some of

Fig 8 Field screening for resistance to rust disease at ICRISAT Center.

Table 1. Rust-resistant germplasm jointly released by the United States Department of Agiculture (USDA) and ICRISAT [a] (up to 1983).

Germplasm no.	ICG No. [b]	*Botanical type/variety*	Seed color [c]	Country of origin
Tifrust-1 (GP 18) [d]	7881	*fastigiata*	Purple	Peru
Tifrust-2 (GP 19)	7886	*fastigiata*	Light tan	Peru
Tifrust-3 (GP 20)	7887	*fastigiata*	Purple	Peru
Tifrust-4 (GP 21)	7898	*fastigiata*	Tan	Ecuador
Tifrust-5 (GP 22)	7894	*fastigiata*	Light tan with purple stripes	Peru
Tifrust-6 (GP 23)	7895	*fastigiata*	Light tan	Peru
Tifrust-7 (GP 24)	7896	*fastigiata*	Purple	Peru
Tifrust-8 (GP 25)	7888	*fastigiata*	White with red blotches	Peru
Tifrust-9 (GP 26)	7889	*fastigiata*	Off-white	Peru
Tifrust-10 (GP 27)	7890	*fastigiata*	Purple	Peru
Tifrust-11 (GP 28)	7893	*fastigiata*	Tan with purple stripes	Peru
Tifrust-12 (GP 29)	7891	*hypogaea*	Red	Peru
Tifrust-13 (GP 30)	7883	*hypogaea*	Off-white	Israel/USA
Tifrust-14 (GP 31)	7882	*fastigiata*	Light tan	Peru

a For references to release, see papers by Hammons et al 1982. b ICRISAT Groundnut Accession Number.
c RHS colour chart The Royal Horticultural Society, London, 1966 d Registration number.

Table 2. Sources of resistance to *Puccinia arachidis* available from ICRISAT (in 1983).

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

a. ICRISAT Groundnut Accession Number.
b. RHS colour chart. The Royal Horticultural Society, London, 1966.
c. Also resistant to *Cercosporidium personatum* at ICRISAT.

these genotypes are also resistant to *Cercosporidium personatum*.

Research is in progress in several countries aimed at incorporating rust resistance and high yield into cultivars with agronomic and quality characters suited to different environments. At ICRISAT Center we have several rust-resistant genotypes and advanced-generation rust-resistant breeding lines that significantly outyield the best local commercial cultivars (all of which are susceptible to rust) under severe rust epidemics. 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.

The rust resistance at present available in the cultivated groundnut is of the "slow-rusting" type, i.e., resistant genotypes have increased incubation periods, decreased infection frequency (Fig. 7), reduced pustule size and spore production (Fig. 9), and reduced spore viability. From multilocational testing it appears that the resistance is stable over widely-separated locations. There is no authenticated report of the occurrence of races of differing pathogenicity.

High levels of resistance and immunity to rust have been found in some wild relatives of groundnut (Fig. 10). Wild *Arachis* species accessions found to be resistant to rust at ICRISAT are listed in Table 3. Cytogeneticists in several countries are currently attempting to transfer resist-

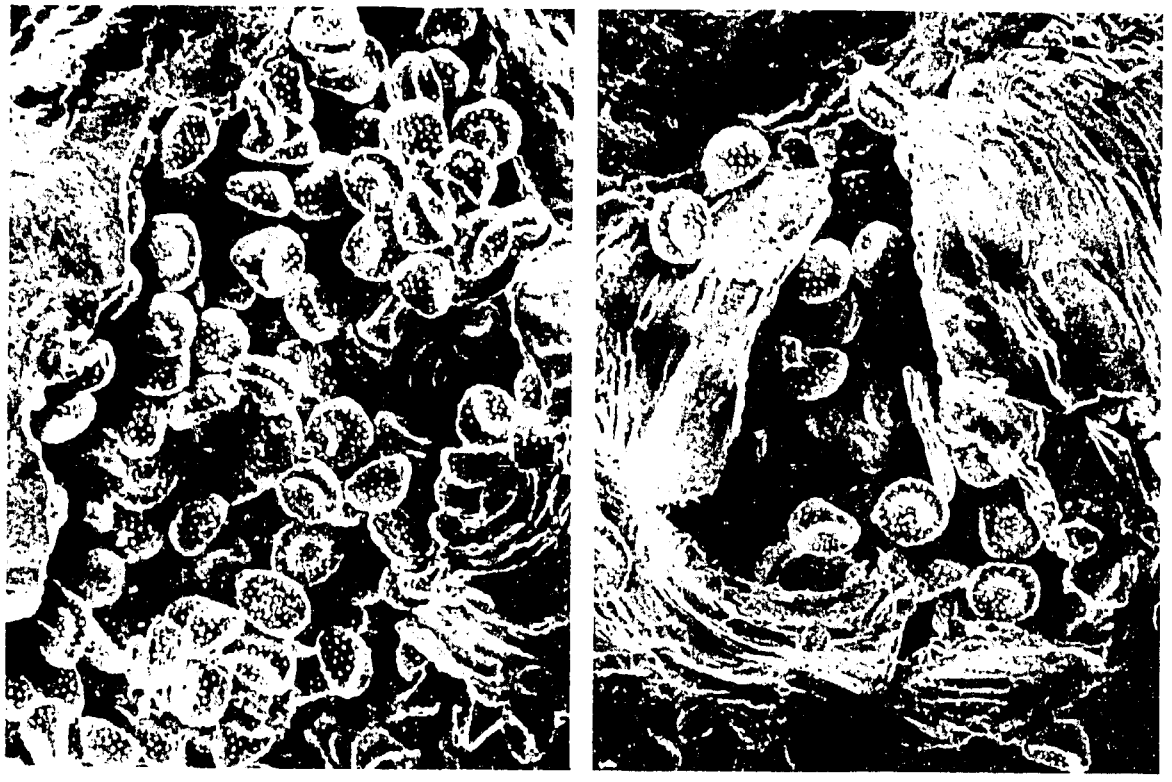


Fig.9. Rust pustules (uredinia (x400): (left) rust-susceptible genotype, and (right) rust-resistant genotype, showing differences in the production urediniospores.

Fig.10. Wild *Arachis* species with immunity to rust: (left) in the field: (right) compared to cv TMV 2 (on the left) in a laboratory test.

ance to rust from several wild species into the cultivated groundnut. Near-tetraploid derivatives of interspecific crosses are being screened for rust resistance at ICRISAT. None has proved to be immune but several have been found to have high resistance.

Table 3. Reaction of some wild *Arachis* species to *Puccinia arachidis* (from Subrahmanyam, Moss, and Rao, 1983).

Section, series and species	USDA plant introduction (PI) number	ICRISAT groundnut accession (ICG) number	Rust reaction
Section: ARACHIS			
Series: Annuae			
A. batizocoi	298639	8124	Immune
A. duranensis	219823	8123	Immune
A. spegazzinii	262133	8138	Immune
Series: Perenne			
A. correntina	331194	4984	Immune
A. stenosperma	338280	8126	Highly resistant
A. cardenasii	262141	8216	Immune
A. chacoense	276235	4983	Immune
A. villosa	210554	8144	Immune
Section: ERECTOIDES			
Series: Tetrafoliate			
A. apressipila [a]		3129	Immune
A. paraguariensis [a]		8130	Immune
Section: TRISEMINALE			
A. pusilla	338449	8131	Immune
Section: EXTRANERVOSAE			
A. villosulicarpa [a]		8142	Immune
Section: RHIZOMATOSAE			
Series: Eurhizomatosae			
A. hagenbeckii	338305	8922	Immune
A. glabrata	338261	8149	Immune

a. No PI number allocated because the source was not the USDA.

Biological control

Mycoparasites, *Verticillium lacani* (Zimmerm.) Viegas, *Penicillium islandicum* Sopp., *Eudarluca caricis* (Fr.) O. Ericks, *Acremonium persicinum* (Nicot) W. Gams, *Darluca filum* (Biv.) and *Tuberculina costaricana* Syd., have been reported to parasitize *Puccinia arachidis*. However, no serious attempts have been made to use them in the biological control of rust.

Integrated control of groundnut rust

Every effort should be made to utilize all available and compatible disease control measures. Breeders should endeavor to combine rust resistance with resistance to leaf spots, and other diseases. If fungicides are to be applied, these should be capable of controlling rust as well as leaf spots, and the possibility of combining the application of fungicides and insecticides should

be considered where pests are a problem. Cultural control measures should be used wherever practicable.

Groundnuts are grown in tropical, subtropical, and temperate regions and under a very wide range of climatic and agronomic conditions. Rust and leaf spot diseases are present in most groundnut-growing regions, but their severity is much influenced by varying environmental conditions. Rust could be severe in one locality but relatively unimportant a few hundred kilometers away. The demand for groundnuts and groundnut products can also vary from place to place and from season to season, with corresponding effects upon prices and returns to the growers. All these variations make it impossible to give a comprehensive and specific recommendation for the control of rust disease. Integrated control measures should be formulated for specific areas and conditions, and should be flexible enough to take into consideration fluctuations in disease severity and farm economics.

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