Physiological Studies on Foliar Diseases: Varietal Differences in Response to Use of Fungicides

J.H. Williams[1], V.M. Ramraj[2], and M. Pal[3]

Abstract

*The physiological effects of foliar diseases (*Puccinia arachidis *Speg. causing rust, and* Phaeoisariopsis personata *(Berk. and Curt.) v. Arx., causing late leaf spot) on yield achievement in groundnut have been investigated. The relationship between green leaf area remaining at maturity and yield was linear in most genotypes investigated.*

The yield response to fungicide application (leaf area protection) varied with genotype. Generally, the control of the diseases resulted in small increases in yield in resistant types and larger increases in susceptible types. However, for some resistant genotypes certain fungicides could greatly increase yield without greatly influencing green leaf area. Of the germplasm accessions tested, no line combined resistance to the two diseases with high yield potential. The information so far available points to the existence of a "yield/resistance" barrier.

Résumé

Etudes physiologiques sur les maladies foliaires—différences variétales dans la réponse aux fongicides : *Les effets physiologiques des maladies foliaires, notamment la rouille due à* Puccinia arachidis *Speg. et les taches foliaires dues à* Phaeoisariopsis personata *Berk. et Curt. v. Arx. sont étudiés par rapport aux rendements obtenus chez l'arachide. On constate une relation linéaire entre la superficie foliaire encore verte à maturité et le rendement chez la plupart des génotypes étudiés.*

La réponse en termes de rendement, à l'application de fongicides pour protection de la superficie foliaire, varie selon le génotype. En général, l'augmentation du rendement après traitement de la maladie, est plus importante chez les types sensibles par rapport aux types résistants. Cependant, l'application de certains fongicides entraîne un accroissement considérable du rendement de certains génotypes résistants sans effet significatif sur la superficie foliaire verte. Parmi les accessions sous étude, aucune lignée n'associe une résistance à ces deux maladies à un haut potentiel de rendement. Toutes les données obtenues laissent supposer la présence d'un obstacle "résistance/rendement".

The importance of foliar diseases has long been recognized by groundnut breeders who have also been aware of the existence of resistance to some of them. However, the resistances were apparently associated with low yield potential and little interest was taken in their exploitation. The improved availability of groundnut germplasm and the spread of rust (caused by *Puccinia arachidis* Speg.) to most groundnut-producing areas during the 1970s has led to renewed interest in the utilization of genetic resistances. Many germplasm accessions having appreciable resistance to *P. arachidis* and to the late leaf spot pathogen (*Phaeoisariopsis personata* (Berk. & Curt.) v. Arx), or to both, have now been identified (Subrahmanyam et al. 1980a, 1980b, 1984, Bromfield and Cevario 1970) and utilized in breeding for improved resistance. Aided by pathologists and breeders, the Groundnut Physiology Subprogram at ICRISAT has been investigating the physiology of groundnut genotypes infected with these diseases.

1. Principal Physiologist; 2 Physiologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P. 502 324, India. 3. Formerly Physiologist, ICRISAT, now at Forest Research Institute, Dehra Dun, India

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1987 Groundnut rust disease Proceedings of a Discussion Group Meeting, 24-28 Sep 1984, ICRISAT Center, India Patancheru, A.P. 502 324, India ICRISAT (CP 407)

Relationship Between Remaining Green Leaf and Yield

Using data from fungicide × genotype trials it was found that the relationship between disease severity (1-9 rating) of rust or late leaf spot and the yield achieved was poor To some extent, this was due to the fact that the research was not dealing with a single disease, so that a genotype resistant to one could be resistant or susceptible to the other Additionally, the disease scale used to measure the response of a genotype to foliar diseases provided only a visual score of disease on the remaining leaf and is not an accurate measure of the loss of photosynthetic area The pathologists have shown that defoliation occurs at different severities with different diseases and genotypes

Leaf area had to be considered if the effects of resistances and foliar fungicides on yield were to be accounted This was done by combining percentage defoliation (A) and the percentages of leaf area on the remaining leaves damaged by leaf spots (B) and rust (C) at 110 days after sowing Remaining green leaf (RGL) was estimated by

$$RGL = (100-A)\ [(100-A) \times (B+C)\ 100]$$

The yield achieved was linearly related to RGL in most genotypes although the response pattern varied considerably Four examples are provided in Figure 1

In the susceptible genotype Robut 33-1 the yield was greatly increased by treatments that increased RGL, but in the equally susceptible genotype TMV 2 the yield response was very much smaller In resistant lines two types of response were detected Some genotypes, for example EC 76446 (292), responded only slightly to increased RGL but the genotype PI 259747 showed a much larger response to fungicides that could not be attributed to changes in RGL since a 15% increase in RGL resulted in a 100% yield increase (Subrahmanyam et al 1984)

These results show the importance of investigating the response to fungicide applications for individual genotypes It is clearly erroneous to extrapolate the results of fungicide trials on one genotype to other genotypes

The results also suggest that the 9-point disease rating system, when used alone, may be a poor indicator of the effect of disease on yield This occurs because the RGL accounts for a large proportion of the yield variation, and defoliation percentage dominated the RGL However, RGL also has its limitations because defoliation is not solely attributable to diseases

Shading in the canopy can also induce defoliation hence the agronomic environment in which the crop is placed may influence the results Foliar diseases are more severe, and defoliation greater, in high plant populations than when plants are widely spaced This must be taken into consideration when assessing foliar diseases Perhaps the ultimate measurement for relating yield to foliar phenomena will be intercepted radiation and the reflectance of red and green light

Using these data it was also possible to investigate the association of yield potential (i e , yield in the absence of stress) with integrated levels of resistance (RGL) to foliar disease This was done by plotting (for 20 genotypes) the yield in the absence of disease against resistance (RGL) (Fig 2) It was observed

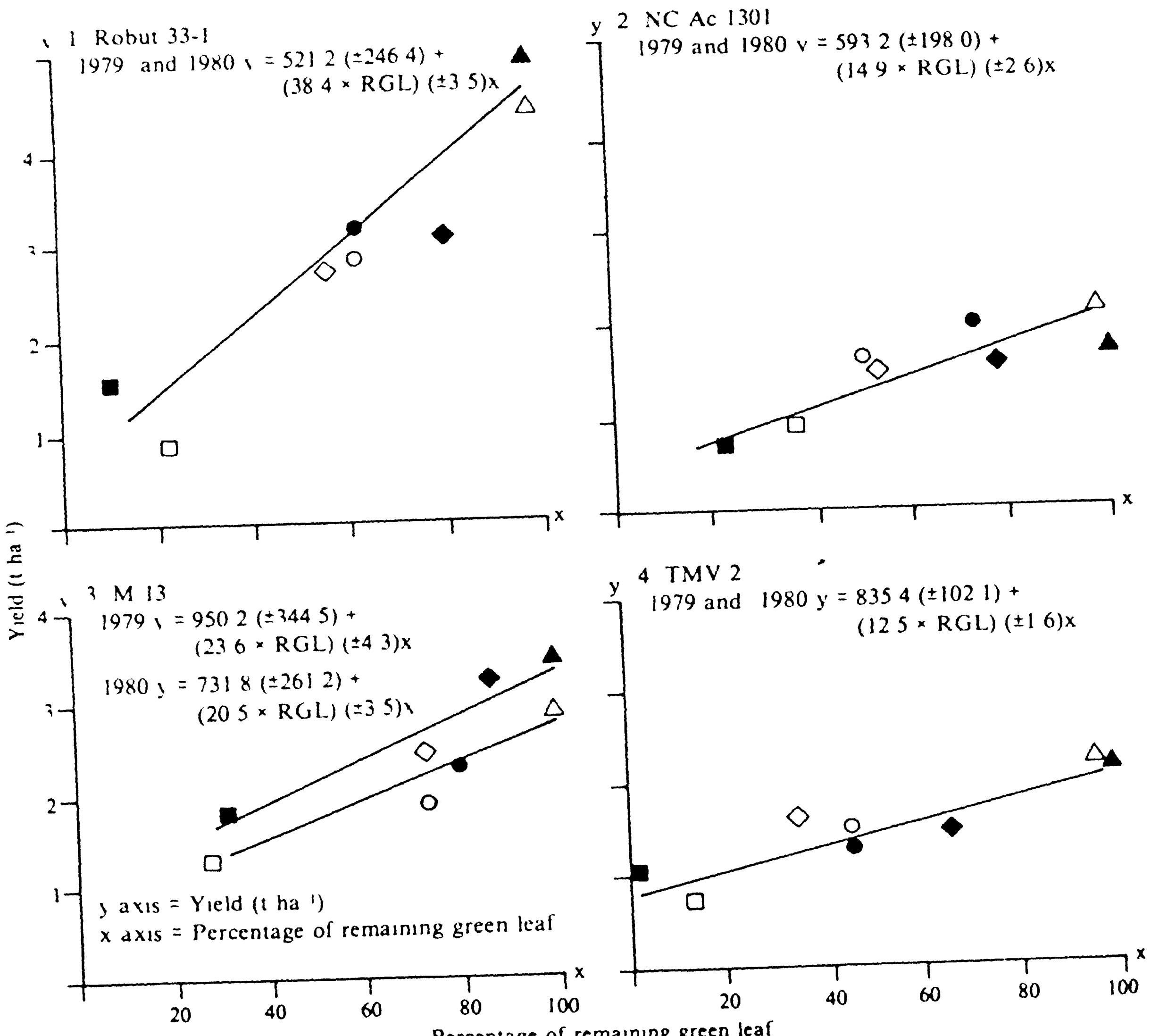
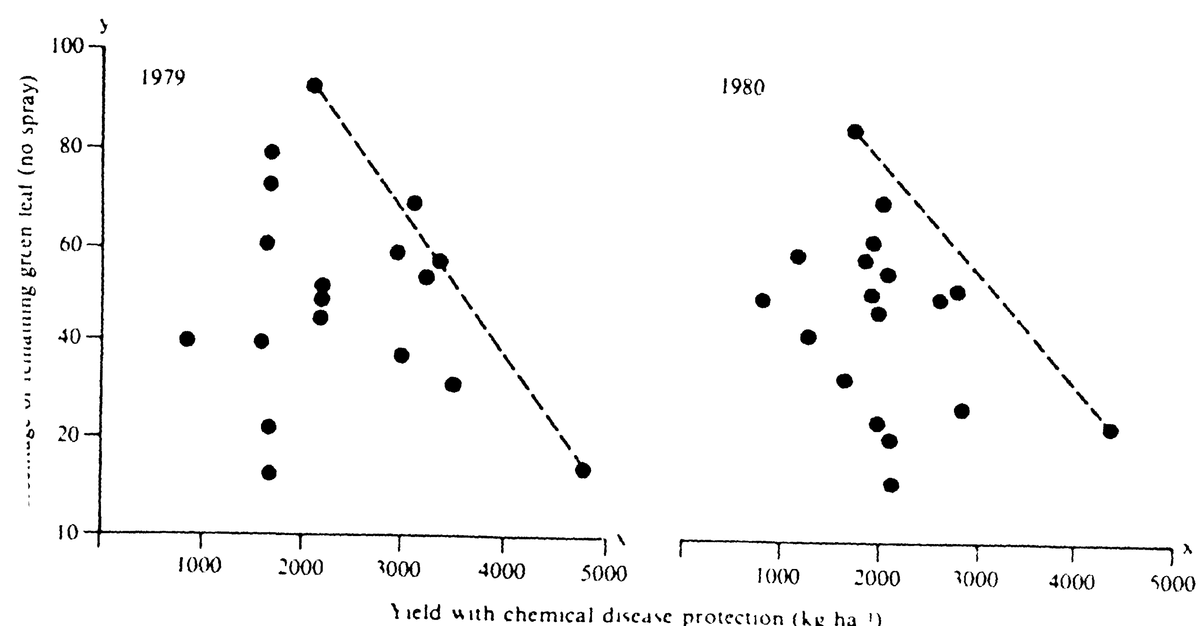


Figure 1. Changes in pod yield and percentage of remaining green leaf in response to sprays with water (1979■, 1980□;), carbendazim (1979 ●; ;) tridemorph (1979◆; 1980◇;), chlorothalonil (1979▲; 1980△;),for four genotypes with differing disease resistances. Values in parentheses are SEs (Subrahmanyam et al. 1984).



igure 2. Resistance to foliar disease as measured by percentage of remaining green leaf plotted against yield otential for 20 groundnut cultivars grown at ICRISAT. The most resistant cultivars and the greatest yield otential are joined by the broken line (Subrahmanyam et al. 1984).

that some genotypes had high yield potential but were susceptible to disease (low RGL), others had low yield potentials and were also susceptible. However, those with disease resistance had low yield potentials. None of the genotypes examined combined high yield potential with a high level of resistance.

The physiology of these phenomena is currently being investigated, as is the impact of breeding for foliar disease resistance. In the genotypes initially examined there seems to be a "resistance/yield barrier". The implications of this to crop improvement are substantial.

- If selection for resistance is conducted in a disease nursery without simultaneous yield selection, how much of the selected material will have yield potential high enough to increase yield for the farmer?
- If the resistance/yield barrier is a physiologically based phenomenon, then the strategies for disease control become complex, since the probability of other yield-limiting factors (such as drought) occurring may determine the emphasis that should be placed on chemical, or genetic control of these diseases. If the resistance/yield barrier cannot be overcome, then chemical control would seem to be the best approach where the risk of crop failure from other factors is small and the yield potential of a genotype can be achieved. Where the risk of crop failure is higher it may be more sensible to sacrifice yield potential for the cheaper genetic control of the diseases.

Evidence from other crops and other aspects of groundnut physiology have been assembled to explain the phenomena and speculate on the options that exist if the basic hypothesis is correct. For this, the physiological basis for yield potential and the possible physiological basis for resistance/susceptibility needs to be discussed.

Yield Potential in Groundnuts

The yield potential of groundnuts is dependent on three factors: the duration of growth, the amount of energy intercepted, and the distribution of growth between fruit and stems.

The duration of crop growth is a major factor in determining the yield potential of a genotype. The authors' unpublished data, and the findings of Will-

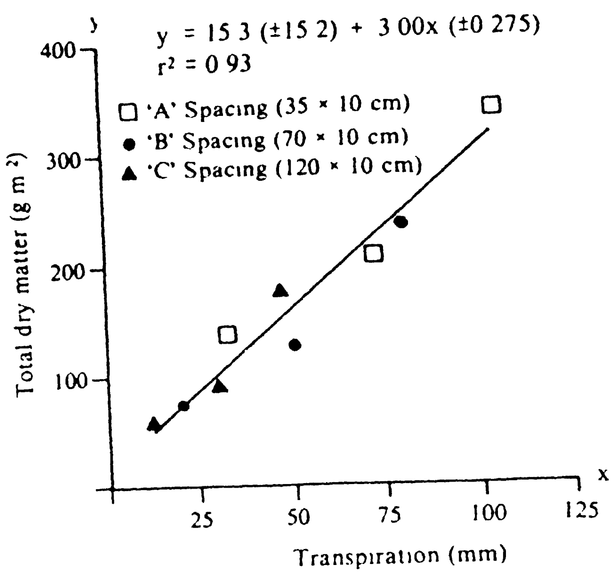


Figure 3. The relationship between transpiration and total dry mass accumulated (including roots) for groundnuts (Cv. TMV 2) at ICRISAT (ICRISAT Annual Report 1985).

iams et al (1976) and Duncan et al (1978), show that, provided energy interception is complete, the crop accumulates between 16 and 22 g m^{-2} day^{-1} of dry matter. This increases total shoot dry matter by between 1 and 1.5 t ha^{-1} $week^{-1}$. A genotype that matures two weeks later than another can have up to 3 t ha^{-1} more dry matter than the earlier-maturing line. When one considers that groundnut at ICRISAT matures in 80 to 130 days, scope for yield potential to vary with duration of crop growth is very large. However, if adjustments are made for the differences in time to maturity then the relationship between dry matter accumulated and energy intercepted (Fig 3) is constant for groundnuts (Azam-Ali 1983). This is supported by the observation that crop improvement by selection for yield in Florida has not influenced crop growth rates (Duncan et al. 1978). It has been found that the growth rates of susceptible and resistant genotypes are similar, providing that the interception of radiation is comparable.

The remaining factor that influences yield potential is the distribution of the carbon assimilated between the fruit and shoot—the partition factor. This has been found to be a major determinant of differences in yield potential between genotypes (Duncan et al 1978). Recent research at ICRISAT has shown that up to 95% of the assimilates in high-yielding genotypes, such as Robut 33-1 and its derivatives, is used for reproductive growth. The resistant genotypes have appreciably lower partitioning.

Phytoalexin Precursors

Phytoalexins having sucrose as a precursor have been associated with resistances to diseases in other legumes (Strange—these Proceedings). If similar compounds are involved in the resistances of groundnut to foliar diseases, the high partitioning necessary for high yield may limit the expression of resistance. For those genotypes where the yield potential is based on a high partitioning factor, the fruit receive most of the carbon assimilated, and it seems reasonable to suggest that the sucrose concentration in the leaves would be less than in those genotypes where the fruit receive less than 50% of the photosynthetic production. If the resistance is based on phytoalexins, which have sucrose as their precursor, it may not be possible to combine resistance with high yield potential. In support of this speculation is the observation that high yield potential and high RGL were not found together in the genotypes investigated.

Many questions remain unanswered. These RGL estimates were established in the face of a combined rust/late leaf spot disease epidemic and some of the lines have very high levels of resistance to one or other of the diseases. Would RGL have been different if only one of these diseases was present? Does an upper limit to resistance (resistance potential) exist? Are phytoalexins the basis for resistances in all the genotypes found to be resistant? Can resistances based on other mechanisms be identified and exploited to get round the "yield potential RGL barrier"? Many uncertainties exist in this field but it should be emphasized that these physiological aspects are of vital importance in the improvement of the groundnut crop for most crop circumstances.

Another intriguing aspect of these yield/resistance interactions is the possible effect that photoperiod may have on the expression of resistance. We are finding that extensions of photoperiod can have major impacts on partitioning. For those genotypes where yield potential and resistance are interacting, the resistance of a genotype to disease may be changed according to latitude. Conventionally, the geneticists would implicate "races" but this may not be correct. So far the evidence for this effect is currently limited to one year's data on the response of the rust-resistant germplasm line NC Ac 17090. It has been found that the yield of this genotype is influenced by photoperiod. Dr Zhou reports from China (where the day length is longer than at ICRISAT) that NC Ac 17090 is only moderately resistant to rust in Guangdong province although it is highly resistant at ICRISAT Center. Much remains to be investigated in this field but the possibilities are very stimulating.

References

Azam-Ali, S W 1983 Crop production in relation to plant spacing water use, and light Ph D thesis, University of Nottingham, Nottingham, UK

Bromfield, K.R., and Cevario, S.J. 1970 Greenhouse screening of peanut (*Arachis hypogaea*) for resistance to peanut rust (*Puccinia arachidis*) Plant Disease Reporter 54 381 383

Duncan, W G, McCloud, D E, McGraw, R L, and Boote, K.J 1978 Physiological aspects of peanut yield improvement Crop Science 18 1015 1020

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1984 Annual Report 1983 Patancheru, A P 502 324, India ICRISAT

Subrahmanyam, P, Gibbons, R W., Nigam, S N., and Rao, V.R. 1980a Screening methods and further sources of resistance to peanut rust Peanut Science 7 10-12

Subrahmanyam, P., Mehan, V.K., Nevill, D J., and McDonald, D. 1980b Research on fungal diseases of groundnut at ICRISAT Pages 193-198 *in* Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India, Patancheru, A P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

Subrahmanyam, P., Williams, J H, McDonald, D., and Gibbons, R.W. 1984 The influence of foliar diseases and their control by selective fungicides on a range of groundnut (*Arachis hypogea* L) genotypes Annals of Applied Biology 104 467-476

Williams, J.H., Wilson, J H H, and Bate, G.C 1976 The influence of defoliation and pod removal on growth and dry matter distribution in groundnuts (*Arachis hypogaea* L cv Makulu Red) Rhodesian Journal of Agricultural Research 14 111-117