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EPIDEMIOLOGY OF FOLIAR DISEASES AND CROP LOSSES IN GROUNDNUT IN WESTERN AFRICA

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Groundnut is submitted to a large number of diseases in Western Africa. Many studies have been conducted on groundnut pathology in this part of the world, each dealing with some aspects of the biology of one particular disease (e.g., Cheveaugeon, 1952; Savary, 1986), or providing lists of pathogens (e.g. Resplandy et al., 1954; Fauquet & Thouvenel, 1980). The appearance of rust in Western Africa (Subrahmanyam et al., 1985; Savary et al., 1988), and the continuing threat to groundnut production due to leaf spots and rosette gave recently rise to renewed interest for research in groundnut-pathology and protection.

ORSTOM and the Wageningen Agricultural University initiated in the early 80s a joint research programme on groundnut pathology in Ivory Coast. This project, which initially concentrated on groundnut rust epidemiology, progressively focused on the analysis of losses caused by rust and leaf spots. The project has methodological as well as practical issues: it is a case study on a tropical multiple pathosystem, where fungal foliar diseases predominate, and its results could be used as a reference data base for the development of management strategies at highly varying crop intensification levels. To address this research programme, several approaches have been selected:

- surveys in farmers' fields and survey data analysis with, as main objective, an overall scheme of the relationships between crop growth and the dynamics of constraints;
- epidemiological studies on the major components of the multiple pathosystem;
- disease modelling, aiming at a synthesis of the available information;
- damage/loss studies and crop loss experiments at varying intensification levels.

Some of this approaches are illustrated in this paper.

Groundnut diseases in Ivory Coast

In Ivory Coast, groundnut is traditionally grown by smallholders. The average pod yields are low, within the range of 800-1200 kg/ha. Although most of the acreage is concentrated in the northern and central savanna regions, groundnut is also cultivated in the southern humid part of the country. Superimposed to these great ecological differences is a large variation of cropping systems - from shifting, slash and burn cultivation in the south to partially mechanised cultivation with crop rotation in the north, or as a component of household gardens. Although mainly cultivated for family or village consumption, groundnut is also cultivated in damp valley bottoms for sale on local markets.

18 groundnut fungal pathogens (Savary, 1987a; Savary et al., 1988) have been identified in Ivory Coast, among which six are observed frequently:

- rust, caused by *Puccinia arachidis* Speg.;
- late leaf spot, caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton = *Phaeoisariopsis personata* (Berk. & Curt.) von Arx;

- early leaf spot, caused by *Cercospora arachidicola* Hori;
- Aspergillus damping-off, caused by *Aspergillus niger* van Tiegh.
- Sclerotium stem rot, caused by *Sclerotium rolfsii*, and
- Botryodiplodia collar rot, caused by *Botryodiplodia* sp.

With the exception of Botryodiplodia collar rot, these diseases occur in all regions in Ivory Coast. Table 1 shows large regional differences in disease spectra. The overall importance of foliar diseases is also shown.

In addition to these fungal diseases are several other major constraints, including weeds and viral diseases: rosette, clump and eyespot.

Table 1 : Groundnut diseases in Ivory Coast, with mean regional severities (%) of foliar pathogens at midcycle and mean regional prevalence (%) of wilt fungi

	Regions in Ivory Coast							
	South		Centre				North	
Pathogens	Sa	Sb	Ca	Cb	T	O	Bo	K
Foliar								
P. arachidis	17,0	3,5	0,5	1,9	5,6	1,3	0,7	2,9
C. personatum	20,0	9,4	0,6	4,7	8,2	4,2	2,0	0,8
C. arachidicola	0,3	0,1	3,9	11,0	12,0	6,6	11,0	2,4
Wilt								
A. niger		7,1		19,0		2,9	9,1	11,0
S. rolfsii	14,0	37,0	41,0	13,0	12,0	16,0	15,0	20,0
Botryodiplodia sp.	8,8	0	0	0	0	3,2	4,8	5,7

A survey of groundnut diseases in farmers' fields. Distinctive epidemiological features of foliar diseases

A survey of groundnut foliar diseases was conducted from 1982 to 1984 in several regions of Ivory Coast with the following objectives:

a. to describe groundnut fields, cropping conditions, climatic conditions and intensities of the various diseases,
b. to investigate the relationships between fungal diseases, climate, crop growth and development, and cropping techniques,
c. to compare the results of the survey with results from experiments on the epidemiology of rust and leaf spots diseases, and
d. to elaborate a data base which would be combined to results from specific epidemiological experiments and produce a basis for risk assessment of groundnut fungal foliar diseases.

During this survey, each field was visited once, providing a unique data set on intensity of diseases, crop growth and development and cultural practices. The resulting data included quantitative, continuous variables (e.g., disease intensities, weather) and qualitative discrete variables (e.g., cropping techniques, regions). The recoding of quantitative variables into qualitative discrete variables was a preliminary to the analysis of contingency tables, and correspondence analysis (Benzecri et al., 1973).

The analysis of survey data resulted in an overall scheme for the epidemiology of the three major foliar diseases, which can be compared one another (Savary, 1987a; 1987b). As for weather variables, correspondences were found between maximum rust severities, optimum temperature and rainfall conditions. These results are in agreement with experimental studies on groundnut rust epidemiology (Savary, 1986). The behaviour of late leaf spot was similar to that of rust, but its weather requirements seemed to be more flexible than those of rust. The variation of early leaf spot severity could not be related to any definite rainfall or temperature patterns, since high disease severities were observed at both extremes of rainfall and temperature.

Groundnut rust development appears to be favoured by healthy young plants, rather than stressed senescing ones (Savary, 1986), as are most other biotrophic pathogens (Zadoks & Schein, 1979). A correspondence analysis of the relations between cultural practices, crop growth, and foliar diseases supported this hypothesis. In figure 1, the path representing increasing rust severity (R) resembles that of increasing relative growth (Fr) of the host plant. Increasing levels of rust also correspond to decreasing weed density (MH) and, to a lesser extent, to increasing crop density (DS).

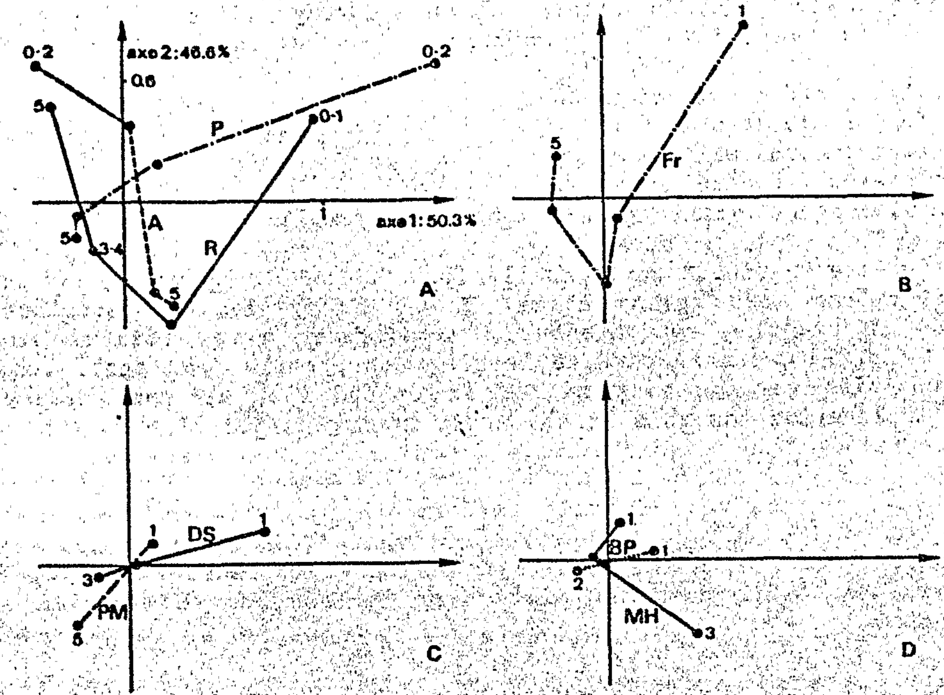

Figure 1 : effects of cultural practices and relative plant growth on severities of groundnut foliar diseases: a correspondence analysis

Variables
R : rust severity
P : late leaf spot severity
A : early leaf spot severity
R, A or P=1: low
R, P or A=5: high severity
DS: crop density
DS=1: low
DS=3: high crop density
MH: weed density
MH=1: low
MH=3: high weed density

Fr: relative plant growth
Fr=1: poor growth
Fr=5: vigorous growth
PM: crop mixture status
PM=1: pure stands
PM=5: mixed stands
BP: crop establishment
BP=1: on flat
BP=2: on raised seedbed

Dots indicate the position of classes for each variable. Curves can be read as paths.

Increasing levels of late leafspot (P) correspond to increasing crop density, and to some extent, to increasing relative growth of the host. In contrast, high levels of early leaf spot (A) correspond to high weed density. This analysis therefore suggests that high rust severities, frequently in combination with high late leaf spot severities, correspond to well-growing, carefully weeded, and relatively dense stands. Poorly growing, weed-covered stands correspond to high early leaf spot severities. The conclusions are based on statistically significant associations (contingency tables and Chi-square tests; Savary, 1987b).

A survey of groundnut yields in farmers fields. Distinctive features of foliar diseases as yield constraints.

A survey was conducted in 1989 in the northern part of Ivory Coast to produce additional information on yields and yield determining factors in farmers' groundnut crops. The survey included 51 fields, either upland or valley bottom crops. Each of them was visited monthly from sowing to harvest time, when a harvest sample was taken to assess yield.

A preliminary analysis of the results of this survey indicates that a classification of biotic constraints to groundnut yield can be summarised as follows:

- proliferation and growth of weeds
- fungal foliar diseases
- fungal root rot and wilt diseases
- viral diseases (rosette)
- pods harmful agents (insects, millipedes and fungi)

Strong difference in yields were usually found between damp valley bottoms (1570 kg/ha) and upland (850 kg/ha) crops. These differences are attributable to differences in cropping conditions and environment (e.g. soil moisture) and probably, to differences in disease levels. Rust, early leaf spot, rosette and clump intensities were usually higher in upland than in damp valley bottom crops. An explanation for this is the early sowing period of damp valley bottom crops which resulted in reduced primary inoculum for some diseases.

Another result is the poor overall performance of long cycle cultivars (880 kg/ha) as compared to medium (760 kg/ha) or short (920 kg/ha) cycle types. One possible interpretation is the increased period of exposure to polycyclic disease constraints, which does not allow long cycle types to valorize a longer filling period.

Some results from crop loss experiments

Crop losses caused by combinations of foliar fungal diseases, i.e. varying levels of rust, early leaf spot, and late leaf spot had to be quantified. Several experiments were conducted in which the levels of rust and leaf spots were manipulated either by means field inoculation of each of the components, or combinations of fungicides. With attainable yields (i.e. disease levels reduced to nil) of approximately 1700 kg/ha, losses as high as 40-70% were observed due to rust or leaf spots alone or in combinations (Savary et al., 1988).

The results in Figure 2 are typical of such trials. They correspond to an experiment laid out as Latin square with 5 fungicide treatments (n = 25). The plane representing the regression equation of yield (Y, in kg/ha) on rust (R) and leaf spot (C) severities (in %, early and late leafspot accumulated) is shown. This equation:

$$Y = 1771 - 27{,}4 * R - 5{,}8 * C \quad (R^2 = 0{,}95)$$

suggests that losses are increasing faster with rust than with leaf spot severity.

The hypothesis that attainable yields, disease severities of each of the component of the considered pathosystem and resulting crop losses are related needed to be tested and quantitatively documented.

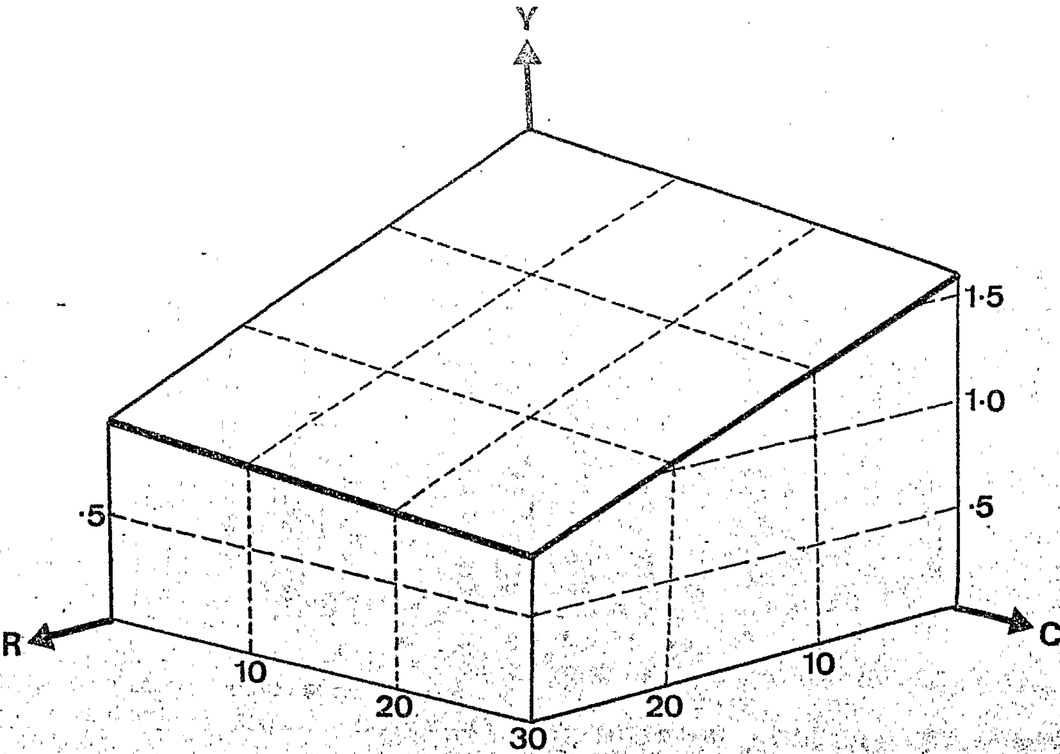

Figure 2 : An experiment on crop losses in groundnut.

The experiment was laid out as a Latin square with five fungicide treatments (n=25). The plane representing the regression ($R^2 = 0.95$, see text) of yield (Y, in tons/ha) on rust (R) and accumulated early and late leaf spots (C) severities (%) is shown.

In a first stage, on-farm experiments in farmers fields indicated that higher losses in weight (lower in percent) are observed in crops with high attainable yields (Table 2; Savary et al., 1988). Further analysis of the data indicated that the contribution of rust to losses was small or negligible at low attainable yields, whereas it was considerable at high attainable yields.

Table 2 : Results of a crop loss experiments with foliar diseases in Ivory Coast

No of plots	Yield range (kg/ha)	Disease severity range (%) rust	leaf spots*	Loss range (kg/ha)
low input	185-785	0.5-12.3	4.7-30.0	0-492
high input	1303-1875	1.4-25.0	0.7-45.0	127-832

On-farm experiments do not allow to accurately manipulate the levels of each disease component, or to use appropriate statistical designs where disease*crop input, or disease*disease interactions can be tested (Gomez & Gomez, 1984; Johnson et al., 1986). Several of such experiments have been conducted, a typical example of which is given in figure 3. This experiment consisted of three groundnut cultivars grown at four different intensification levels, with or without fungicide protection, in a strip-split-plot design (Gomez & Gomez, 1984), with three replications.

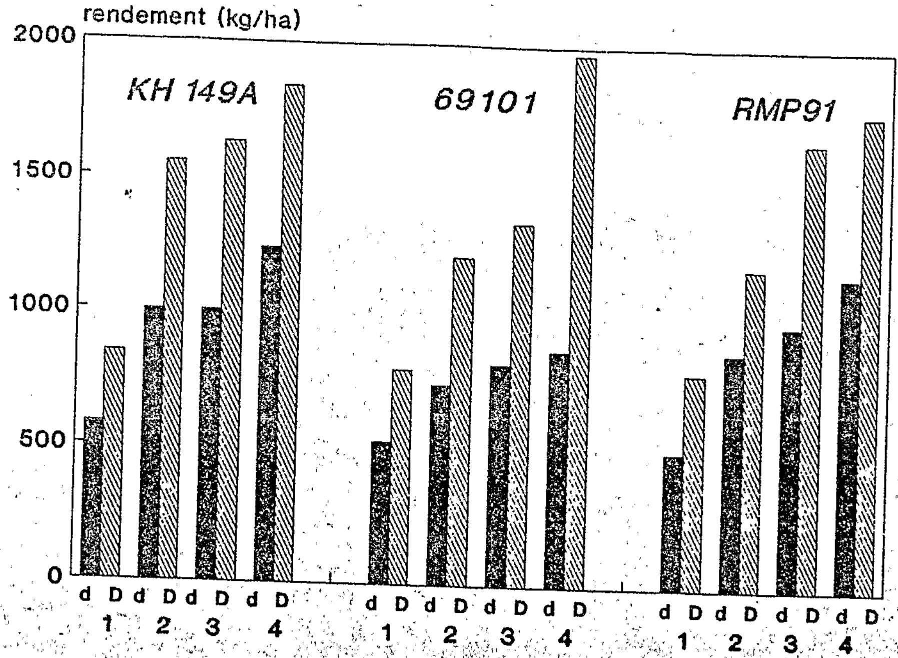

Figure 3 : Interaction of intensification levels and foliar diseases intensities on groundnut yields in three cultivars.

Abscissa : treatment combinations
d : unprotected plot
D : plot treated with a protective fungicide
1,2,3,4 : intensification levels
KH 149A, 69101, RMP91 : groundnut cultivars

Ordinates : groundnut yields (kg dry pods/ha)

Each bar represents the mean of three replications

The three chosen cultivars correspond to short, medium and long cycle types, arranged in strips in each replication. These strips were divided into four units randomly attributed to the four considered intensification levels, and each unit was divided at random into two sub-units: treated or untreated plots. The four chosen intensification levels were:

1. low sowing rate, minimum weeding, no fertilisers
2. low sowing rate, regular weed control, no fertilisers
3. high sowing rate, regular weed control, no fertilisers
4. high sowing rate, regular weed control, fertiliser application

These four levels can be considered as four stages of an intensification process. The fungicide used was chlorothalonil, with weekly sprays starting three weeks after sowing.

During this experiment, fungicide protection reduced the areas under disease progress curves from 350 to 6 %.days, from to 2%.days, and from 198 to 4%.days for rust, early leaf spot, and late leaf spot respectively. An ANOVA of the yield data indicates a significant (F=116, P<0.01) yield increase (from 690 to 1500 kg/ha) with increasing intensification levels, and a significant (F=120, P<0.01) yield decrease due to foliar diseases (1400 vs. 870 kg/ha). In addition the results indicate a significant (intensification level) * (disease control) interaction (F=4.80, P<0.01). This interaction corresponds to a discrepancy in yield increase from level 1 to level 4 between an unprotected intensification process (from 550 to 1110 kg/ha) and a protected intensification process (from 830 to 1890 kg/ha). These figures indicate that disease control allows to fully valorize the considered intensification process. They also demonstrate that fungal foliar diseases, as a whole, represent a considerably larger risk at high attainable groundnut yields than at low attainable yields.

Perspectives for the development of management strategies

The development of a disease management programme is based upon knowledge in three areas: crop economics, population dynamics, and disease control technology (Zadoks & Schein, 1979). Progress has been made in the two latter fields, but very little on groundnut cropping economics in Western Africa. Information in this area is needed to estimate damage thresholds pertaining to each disease in given agro-economical environments.

The relationships between crop inputs and disease constraints in tropical agriculture (Zadoks, 1974) is still a neglected research area and requires specific research efforts. As our knowledge broadens, it appears more clearly that technically efficient and durable management strategies for groundnut constraints in Western Africa not only depend on reliable control methods, but will be possible only when detailed information are available on:

1. the contribution of each of the components to crop losses within the considered multiple pathosystem, and
2. the potential variation of each loss component with varying cropping techniques

Among the possible approaches which may be considered to address these problems, three may play a particular role:

- surveys are still essential to obtain information on actual farmers' fields situation; survey methods, and survey data analysis methods have evolved to produced either a quantitative, synoptic information (Stynes, 1980), or a qualitative, general synthesis (Savary, 1987a, 1987b)
- analysing multiple-constraints losses at varying crop input levels is essentially a matter of interactions. New, more appropriate experimental designs can be used to address these complex problems (Johnson et al., 1986). Simpler experimental designs may also be considered where the facilities are insufficient to consider sophisticated designs; in this field, correspondence analysis may also prove very useful.
- recent progress have been made in modelling groundnut growth and development (Boote et al., 1985) and groundnut diseases, especially leaf spot (Knudsen et al., 1987) and rust (Savary et al., 1990). Simulation modelling may provide support for prospective studies and development of control techniques. One example is the use of a rust simulation model to compare components of resistance and assist in the selection of resistant varieties (Savary et al., 1990)

As in many other tropical crops, these information would contribute to adapt the protection efforts of groundnut crops to diverse environments and to agricultural intensification.

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Résumés

Epidémiologie et pertes de récoltes provoqués par les maladies foliaires de l'arachide en Afrique de l'Ouest

Des enquêtes conduites en Côte d'Ivoire en 1982, 83, 84 et 89 montrent que la rouille et les cercosporioses de l'arachide sont des contraintes majeures pour la production en culture traditionnelle. La diversité des situations agroécologiques rencontrées dans ce pays rendent ces enquêtes représentatives de beaucoup de régions d'Afrique de l'Ouest où l'arachide est cultivée. La comparaison des caractéristiques épidémiologiques de ces maladies foliaires suggère qu'une intensification agricole pourrait modifier leurs dynamiques respectives, et, en particulier, favoriser le développement de la rouille. Des pertes de récolte importantes sont aujourd'hui occasionnées par ce pathosystème multiple en culture paysannale traditionelle. Des résultats préliminaires d'expérimentations suggèrent que les maladies foliaires, dans leur ensemble, constituent un risque nettement plus important lorsque les rendements accessible sont accrûs; en *d'autres termes, le contrôle de ces maladies permettrait de valoriser le processus d'intensification envisagé. L'intégration de stratégies de gestion de ces contraintes dans un processus d'intensification de la culture est discutée.*