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Selection for resistance to black pod disease and yield gains prediction by use of selected cocoa varieties in Cameroon

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Abstract

Research on resistance to black pod caused by *Phytophthora megakarya* has been carried out in Cameroon for 40 years. It has yielded a significant database which is currently being exploited for the modelling of disease resistance levels of the major clones selected as candidate parents for the creation of new resistant and consequently more productive cocoa varieties. These outputs are expected to meet the increasing need of producers for improved planting material to extend cultivation into emerging cocoa-growing areas or to renew old cocoa production basins. These outputs have been made possible through an international collaborative effort and, more recently, within the scope of regional or international initiatives sponsored by CFC/ICCO/IPGRI and by CAOBISCO. New selection approaches and methodologies, such as rapid field assessment and early screening tests, have been promoted, along with the use of molecular tools for genome mapping and disease resistance quantitative trait locus (QTL) identification. Promising material has been introduced, evaluated in the laboratory and on-farm, and compared to the local cocoa germplasm. The basic knowledge developed from this local database has enabled the definition of an empirical disease resistance sorting and subsequently a prediction of the yield gains expected from the use of different cocoa clones and possible combinations (progenies) available on-station and in farmers' stands in different agro-ecological growing conditions; or which have to be created following strategies in the new breeding programme.

Keywords: black pod; cocoa; disease resistance; selection

Introduction

Cocoa production in Cameroon has remained stable over several decades (120,000 tonnes). This stability is due to many factors. The main ones are the high incidence of diseases and pests that can cause up to 80–90% losses in the absence of chemical protection, and a lack of improved resistant and productive varieties. Early selection activities in Cameroon began in 1957 using local and introduced Trinitario clones (SNK[1] and ICS[2], respectively). Several crosses among these materials, and later with some upper Amazonian clones introduced from Ghana, were carried out. Since 1960, many of such 'hybrid' varieties, reproduced in bi-clonal seed gardens,

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[1] Selection of Nkoemvone: clones selected at Nkoemvone Research Station (IRAD), South Cameroon.
[2] Imperial College Selection: clones introduced from Trinidad and available in IRAD collections.

have been distributed to farmers and planted in different cocoa production zones. Discussions held with producers during field surveys in different cocoa-growing conditions have indicated that these materials are presently considered unsatisfactory (E. Mousseni, unpublished data). Analysis of field performance has often revealed low vigour and high susceptibility to black pod disease. Furthermore, the high susceptibility to mirids of these materials appears to induce, in some cases, a progressive dieback of whole trees.

Research on resistance to black pod

Research carried out in the 1970s in cocoa collections revealed the presence of different levels of partial resistance to black pod based on polygenic systems (Partiot, 1975; Blaha and Lotodé, 1977). The resistance of 100 clones was evaluated by inoculation of attached fruits, demonstrating significant variation in resistance to infection and colonization (Blaha and Lotodé, 1976). A 6 × 6 diallel mating design, without the selfs, was set up in 1974 to study both heritability of resistance and productivity traits. Parents of the crosses involved six clones with different levels of resistance. Analysis of natural infection from 1985 to 1990 revealed significant family effects on annual disease development (Berry and Cilas, 1994a). Inheritance of this trait was mainly additive (Cilas *et al.*, 1995). The best trees in the diallel trial have been identified by a selection index combining high yield levels and field resistance. Clonal trials were set up recently with individuals selected within the diallel trial for yield and field resistance. Field resistance is to be confirmed and other agronomic traits measured. The best clones could be candidates for new more resistant varieties.

Selection of crosses or of individual trees that are less susceptible to *Phytophthora megakarya* remains the main priority for cocoa breeding in Cameroon. Despite significant efforts worldwide, only a few cultivars of cocoa have been selected with effective resistance to black pod disease within the scope of the CFC/ICCO/IPGRI project[3] 'Cocoa Germplasm Utilization and Conservation: a Global Approach' and the CAOBISCO project[4] 'Genetic Basis of Cocoa Tree Resistance to *Phytophthora* Diseases'. Considering that field evaluation of pod losses needs at least three annual seasons of field observations on the incidence of the disease to obtain rapid progress in breeding, an early screening test using artificial inoculation of leaf discs was developed (Nyassé *et al.*, 1995). Using this test, the resistance of several clones and crosses was successfully evaluated (Nyassé, 1997; Nyassé *et al.*, 2003). Evaluation of the old 'German Cocoa' population introduced in Cameroon from Sao Tomé et Principé in 1892 (Nya Ngatchou, 1981; Wood, 1991) indicates the presence of relevant sources of resistance. Significant correlations were observed between this test and field attack (pod rot rate) of the parental clones of the diallel in Cameroon (Nyassé *et al.*, 2002), and between resistance of parental genotypes and field resistance of their progenies in Côte d'Ivoire (Tahi *et al.*, 2000). Significant genetic differences in resistance and relatively high broad sense heritabilities (0.5–0.7) were observed with this test (Nyassé, 1997). Genetic correlation between this test and the pod test were also positive (Nyassé, 1997), while environmental correlations tended to be non-significant or negative. Resistance assessed by leaf test appeared to be well correlated with field resistance, when the study is based on the average effects of a clone or of a progeny; but this correlation decreases when individual trees are concerned.

Environmental and genetic correlations were also calculated between the level of black pod and potential yield (total number of cherelles and pods produced) in the diallel trial. The positive environmental correlation shows that the more pods a tree bears, the more black pod it supports. However, the genetic correlation is slightly negative which is interpreted to mean that the most resistant families had slightly higher production potential. Duration of pod maturation may also be important in the expression of the disease in the field, since the time pods are exposed to the pathogen is variable (Berry and Cilas, 1994b). This could contribute to the high susceptibility in Cameroon of most Trinitario clones in the field (Berry and Cilas, 1994b). Typical Trinitario clones, like ICS, take 7 months to ripen, whereas other types, like Upper Amazon Forastero, take only 4 months to ripen and are therefore less exposed to disease.

Based on this escape mechanism and on true resistance, Amazon genotypes, such as old Amelonado cocoa types and some upper Amazonians such as those actually introduced (SCA6, P7, PA107, PA150 or T85/799),[5] should participate in the creation of more resistant varieties in Cameroon. The level of resistance of several of these clones has been quite stable over different

[3] Developed under the aegis of the International Cocoa Organization (ICCO) and substantially funded by the Common Fund for Commodities (CFC). The International Plant Genetic Resources Institute (IPGRI) is the Project Executive Agency.

[4] Funded by the European Biscuit and Chocolate Manufacturers' Organisation (CAOBISCO).

[5] International clones introduced from the Quarantines of the University of Reading (UK) and CIRAD Montpellier (France) through the CFC/ICCO/IPGRI Project.

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Table 1. Estimated variation in resistance of cocoa varieties to black pod disease expressed by the percentage of rotten pods and yield in the presence of *Phytophthora megakarya* in Cameroon

	Level of resistance of cocoa varieties				
	HS	S	MS	R	HR
1. Variation in attack observed in breeding trials, due to *P. megakarya*	80	60	40	20	10
2. Variation encountered in germplasm collections in Cameroon	+	++	++	+	+
Introduced and selected clones (T60/877, UPA134, PA150, P7, PA107, SCA6, SCA12, IMC47)			+	+	+
3. Expected variation for resistance in traditional varieties in Cameroon					
Amelonado (A)		++			
Trinitario (T)	++	++	+		
Mixed Upper Amazon (UA)		++	+	+	
4. Variation in distributed hybrids in Cameroon (T × A, UA × A, UA × UA)	+	++	+		
5. Expected variation among selected hybrid varieties (MS × R, MR × MR, MR × R, R × R)			+	++	
6. Variation in net yield (kg dry cocoa per ha) for farmers by use of varieties with different resistance level and with potential yield, in absence of black pod disease, of 800 kg/ha for *P. megakarya*	160	320	480	640	720

HS, highly susceptible; S, susceptible; MS, moderately susceptible; R, resistant, HR; highly resistant.
++, frequent; +, less frequent.

environments and in relation to the different *Phytophthora* species that cause the disease (Eskes, 2003).

Expected gain in productivity using resistant varieties

The main purpose of this article is to present an empirical analysis on progress that can be expected in selecting for resistance, based on the results obtained in different studies on resistance to black pod disease of cocoa in Cameroon. Relevant studies involve the use of the leaf disc test to evaluate resistance of clones and progenies from a diallel trial that has resulted in significant genetic differences and relatively broad sense heritabilities (0.5–0.7) (Nyassé, 1997). In addition, after exhibiting a high resistance level with the leaf disc test, four promising progenies created in Côte d'Ivoire and introduced in Cameroon are currently performing well on-farm. Parental clones PA150, P7, T60/887 and T79/501 were used to create these progenies. Good sources of resistance to black pod were identified in a few local clones available at the Nkoemvone collection (South Cameroon) and belonging to the SNK600 Series.[6] Therefore, they have been selected as parental clones of varieties proposed for the creation of Regional Variety trials in African producers countries (Côte d'Ivoire, Ghana, Nigeria, Cameroon). The incidence of black pod in Cameroon (Table 1) is based on natural disease incidence and known variation for resistance in different populations of cocoa present in collections or in farmers' fields. The level of disease incidence (% rotten pods) is compared for varieties with resistance levels varying from highly resistant (HR) to highly susceptible (HS).

The example given is based on variation observed in variety trials in relation to *P. megakarya* and *P. palmivora*. This corresponds to situations reported in Cameroon (e.g. Ndoumbé *et al.*, 2001), with variation from 20 to 60% rotten pods between the most susceptible and most resistant hybrid varieties, and in Côte d'Ivoire (e.g. Tahi *et al.*, 2000) with variation from 10 to 30% rotten pods for the same type of varieties. More extreme levels of resistance (HR) and susceptibility (HS) have been postulated than have been found in the above hybrid trials. This is probably because more variation is present in germplasm collections, such as in the International Cocoa Genebank in Trinidad (ICG,T) or in the collections in African countries (Table 1). Some cocoa populations (e.g. Trinitario) are known to be highly susceptible, whereas selected clones in germplasm

[6] Cloned progenies of promising local/introduced Trinitario clones × local/introduced Upper Amazonian clones planted in the clonal collection at Nkoemvone Station (IRAD).

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collections are known to be highly resistant (e.g. SCA6, P7, IMC47, PA150 and T85/799).

Present knowledge indicates that the prevailing cocoa planting material in Cameroon (Amelonado, Trinitario and a low amount of mixed Upper Amazon populations, as well as hybrid varieties distributed to farmers) is composed of mainly highly susceptible (HS), susceptible (S) and moderately susceptible (MS) trees (Table 1). Based on the variation in germplasm collections, it should be feasible to create new hybrid varieties with higher levels of resistance than found in the existing breeding materials, by making crosses among resistant and highly resistant clones (such as IMC47 × SCA6 or P7 × PA150).

The difference in susceptibility between the varieties cultivated presently in Africa and selected resistant varieties represents probably a threefold reduction in losses due to black pod, from 30 to 10% for *P. palmivora* and from 60 to 20% for *P. megakarya*. This would result in a gain in net yield for the farmer of approximately 30% in the presence of *P. palmivora* and of 100% in the presence of *P. megakarya* in Cameroon (Table 1). This empirical deduction made from research results shows that breeding of cocoa varieties for black pod resistance can be highly rewarding.

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