PANS

ISSN: 0309-7943 (Print) (Online) Journal homepage: http://www.tandfonline.com/loi/ttpm18

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To cite this article: S. K. Hahn (1978) Breeding Cassava for Resistance to Bacterial Blight, PANS, 24:4, 480-485, DOI: 10.1080/09670877809414141

To link to this article: http://dx.doi.org/10.1080/09670877809414141

Published online: 06 Jul 2009.

PANS 24(4): 480–485

Breeding Cassava for Resistance to Bacterial Blight

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Summary. It is noted that cassava bacterial blight (CBB) has been reported in several African countries and that heavy infection with CBB can lead to total crop failure as most local varieties are very susceptible. The best control method is through varietal resistance. IITA has made progress in breeding for resistance to both CBB and cassava mosaic disease (CMD) incorporating simultaneously other desirable agronomic qualities. The cassava breeding work at IITA since 1972 is then discussed covering tests on a total of 583 cassava families from CIAT, East Africa and IITA for sources of high resistance to CBB, further tests on 748 IITA clones for CBB resistance in a given ecological setting of high rainfall, sandy and acid soil from which the cultivar 58308 emerged highly resistant. Other aspects of the breeding work treated are conditions affecting varietal selection, namely: genetic mechanism resistance: stability of resistance to CBB over time and in different areas in Africa; high heritability; genetic correlation between resistance to CBB and CMD; correlation of CBB resistance with other characteristics such as tuber yield and leaf defoliation; and finally some factors affecting CBB field scores which are time of planting, age of plant and time of observation.

It is noted that the sources of high resistance to CBB identified have been quickly and successfully incorporated into promising cassava clones.

In Africa, since cassava (*Manihot esculenta* Crantz) bacterial blight disease *(Xanthomonas manihotis* (Arthaud-Berthet & Bondar) Starr) was first reported in Nigeria in 1972 (IITA, 1972), serious outbreaks of the disease have been reported in Zaire, Cameroon, Togo, Benin, Ghana, Congo, Uganda, Kenya, Tanzania, Burundi, Rwanda and Central Africa (Terry, 1978). Yield loss due to cassava bacterial blight disease (CBB) has not been well assessed. However, CBB can often result in complete crop failure when there is a heavy infection. Most local cultivars are very susceptible to the disease. Such widespread incidence of the disease and susceptibility of the local cassava cultivars suggest that it will be difficult to eradicate. Therefore, the most appropriate and realistic approach for control of the disease is to utilise host-plant resistance. Realising this, the Root and Tuber Improvement Program of the International Institute of Tropical Agriculture (IITA) initiated a cassava breeding programme for resistance to CBB in 1972. This programme has made significant progress in breeding improved cassava in terms of resistance to CBB as well as to cassava mosaic disease (CMD), high yield, improved root characters, low HCN content and resistance to lodging. The key factors which make cassava improvement at IITA most successful are good administrative support, availability of good facilities, a good team approach with cooperation among the relevant disciplines, favourable environmental conditions for evaluation and the use of appropriate breeding methods.

Plant breeding involves too major stages; 1. finding or developing the source populations from which selections can be made and 2. selection.

Source population

The first step taken to improve cassava for resistance to CBB was to identify sources of resistance. It was reported in 1972 that an intermated clone (58308), derived by the Nigerian Federal Research Station, Moor Plantation in 1958, from an interspecific cross of cultivated cassava (*Manihot esculenta*) x ceara rubber (*Manihot glaziovii* Muell.—Arg.), produced about 50% CBB resistant progenies, The intermated local cultivar Isunikakiyan produced only 37% CBB resistant progenies, and the intermated Nigerian recommended variety 60444, only 7% (IITA, 1972). Most of the local cultivars of the germplasm and Latin American sources had a high CBB infection (IITA, 1972). Resistance to CBB was tested on 583 families from IITA hybrids (resulting from crosses with 58308) and on other families from East Africa and CIAT and the results are presented in Table 1 (IITA, 1975). IITA families showed a higher level of resistance to CBB.

About 748 clones were tested for resistance to CBB in a high rainfall (2,771 mm), sandy and acid soil area and the results are summarised in Table 2 (IITA, 1975).

Clone 58308 produced highly resistant clones but Nigerian recommended varieties 60444 and 60447 produced no highly resistant clones. Brazilian source produced a few resistant clones.

Parental values of six cultivars for resistance to CBB were estimated, of which clone 58308 showed high additive parental value for CBB.

The plant breeder is limited to the genes that are present in the populations which he has available. Selection is effective only where significant genetic variation exists. Furthermore, its effectiveness is related to frequencies of the desirable alleles controlling the characters being selected. The breeder must, therefore, have populations within which the genes required for varietal superiority occur in high frequencies.

Genes for resistance to CBB, a simple quantitative trait, are relatively easy to substitute into populations and their effects are easily identified. However, it is difficult to substitute the genes for yield, a complex quantitative trait, which are the ones we ultimately hope to change by population improvement. It is more difficult to substitute genes for these two traits simultaneously and genes for other agronomic traits at the same time. To create source populations of cassava a population improvement scheme using new germplasm introgression, cyclic recombination and selection procedures has been adopted to increase frequencies of genes associated with disease resistance, yield and other agronomic characters, while retaining a high degree of genetic variability. It is proposed by Hahn *et al.* (1973) that in cassava half-sib family selection, a method for population improvement

TABLE 1. COMPARISON OF THREE SOURCES FOR RESISTANCE TO CBB

Source†	Score*					Families tested	% families class 1 and 2	Average score
	1	2	3	4	5			
IITA	32	126	139	16	1	314	50.32	2.45
East Africa	0	5	37	20	2	64	7.81	3.30
CIAT	0	30	31	144	0	205	14.63	3.56

*Score 1 = highly resistant and 5 = highly susceptible.

†CBB scores of IITA source were made after stem inoculation (high pressure) and those of East Africa and CIAT were made under natural infection (low pressure).

TABLE 2. CBB SCORE OF CASSAVA CLONES TESTED IN HIGH RAINFALL (2.771 mm PER ANNUM), SANDY AND ACID SOIL AREA

Source or parent	Score*					Clones tested	% clones score 1 and 2	Average score
	1	2	3	4	5			
58308	0	99	365	12	0	476	20.80	2.82
Brazil	0	3	132	3	0	138	2.22	3.00
60444	0	0	1	4	18	23	0.00	3.67
60447	0	0	65	41	5	111	0.00	3.46

*Score 1 = highly resistant and 5 = highly susceptible.

would be the most appropriate. With this scheme breeding populations for the improvement of disease resistance, yield and other agronomic characters have been successfully upgraded (Hahn *et al.,* 1977). Local cassava and exotics which are susceptible to CBB have been significantly improved in terms of resistance to CBB and CMD, while maintaining the other desirable traits (Hahn *et al.,* 1977).

Selection

Success in plant breeding is particularly dependent upon effective selection. The genetic statistics which affect effectiveness of selection of cassava for resistance to CBB are discussed below, based on currently available information.

Genetic mechanism of resistance

The mechanism of resistance appears to be due to recessive quantitative genes mainly with additive effects but also to some extent to non-additive effects (Hahn *et al.,* 1974).

Stability of resistance to CBB over countries and years in Africa

There appears to be a high relationship in CBB resistance in Nigeria and Zaire (IITA, 1976). Since resistance of cassava to CBB is polygenic, it will remain stable.

Heritability

About 47.95% heritability was estimated, based on variance component, for CBB using the data from 925 clones (IITA, 1975). Heritability of CBB resistance was estimated from the data from half-sib families with about 24% (IITA, 1976). This low estimate of heritability might be due to the very unfavourable environment for symptom expression and due to the fact that the families used are selected for resistance to CBB, resulting in low genetic variation. This relatively high heritability (47.95%) suggests that selection of cassava breeding materials for resistance to CBB is relatively easy and can be made at early breeding stages.

Genetic correlation between resistance to CBB and CMD

It was reported from the clonal data that resistance to CBB is associated with resistance to CMD with r = 0.36** (df = 1.149) – the resistance deriving from relative species, *Manihot glaziovii* (IITA, 1973). From data of CMD and CBB scores for 484 clones and their half-sib offsprings, relationship between the two diseases was estimated in Fig. 1 (IITA, 1975).

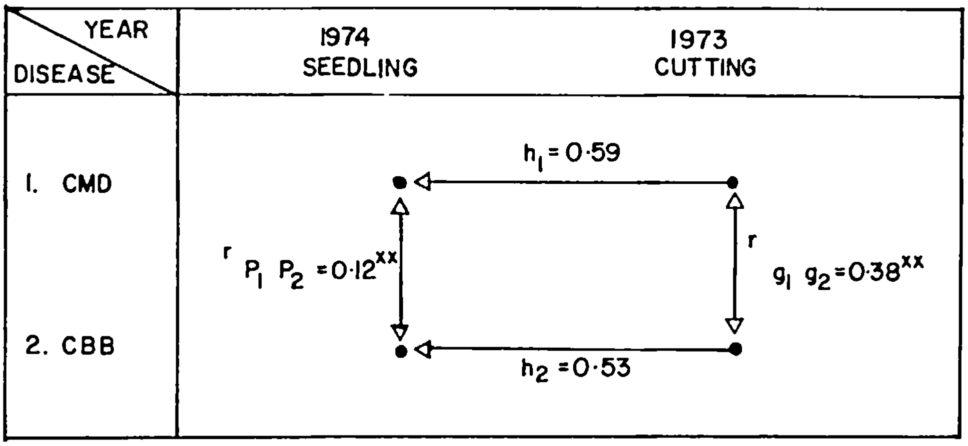

Fig. 1. Path diagram showing relationship between CMD and CBB.

The correlation between CMD and CBB of the 484 clones (cuttings) was highly significant and the relationship held true in families resulting from the intermated seeds among the clones (IITA, 1975). The data from duplicate observations of replicated experiments with 52 half-sib families have phenotypic and genotypic correlations between CBB and CMD resistance of r_p = 0.42 and r_g = 0.90, respectively (IITA, 1976). From the

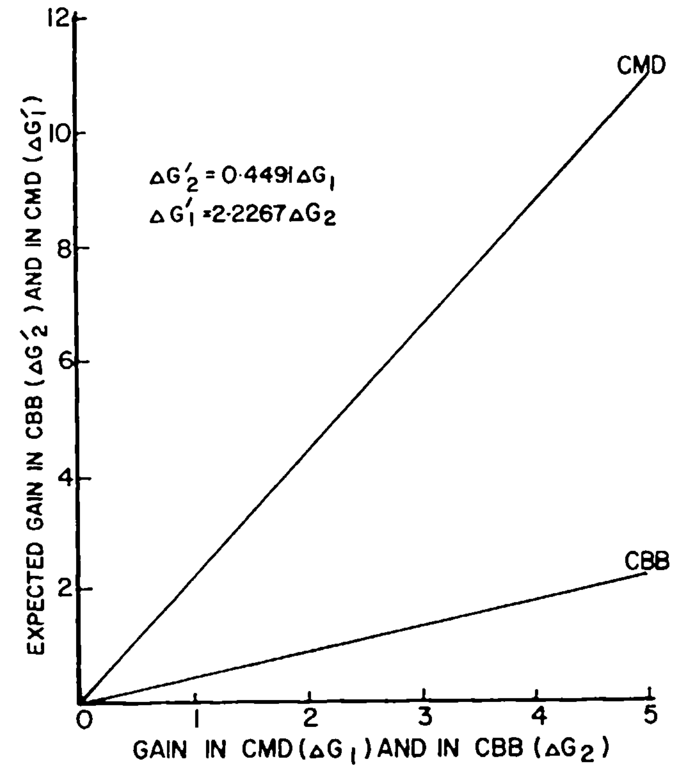

Fig. 2. Expected gain in CMD and CBB resistance as a result of selecting for CBB and CMD resistance alone.

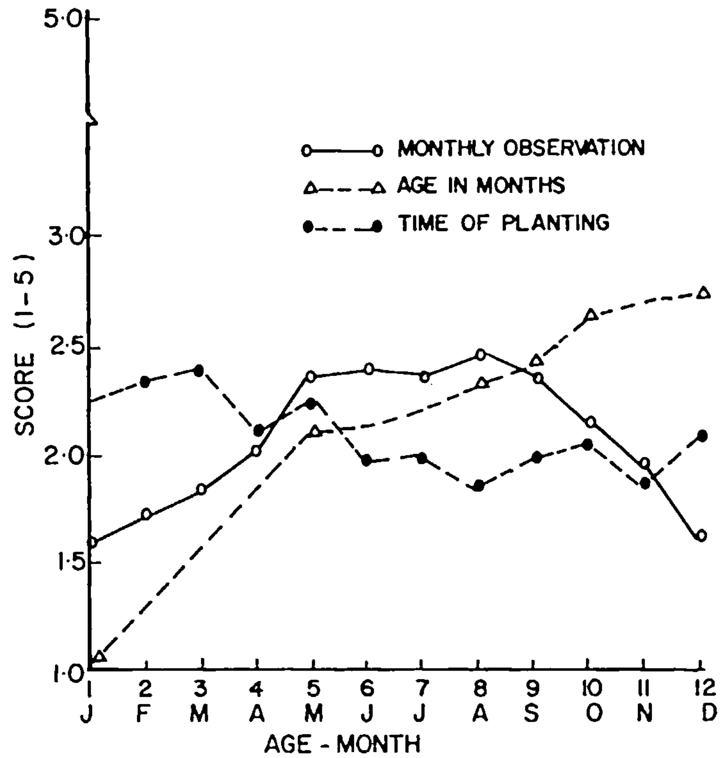

Fig. 3. CBB symptom expression as affected by time of planting, age of plants and time of observation.

crosses of 60444 x 58308 and Isunikakiyan x 58308 (the cultivar 60444 is susceptible and Isunikakiyan moderately susceptible to both CBB and CMD, while 58308 is resistant to both diseases) high correlation coefficients were obtained with 0.85** and 0.51**, respectively (IITA, 1977). Using these correlation coefficients and heritability, the expected gain in CMD resistance (ΔG_1) was estimated as a result of selection for CBB (ΔG_2) (IITA, 1976). The relationship shown in Fig. 2 may indicate that if heritability can be manipulated by providing favourable testing conditions and methods for CBB resistance, the gain in CMD resistance will be high as a result of selection for CBB.

Correlation of CBB resistance with other characters

Tuber yield was negatively associated with CBB incidence with $r = -0.23^{**}$ (df = 952) (IITA, 1975). From the experiment with 52 half-sib families, genotypic correlation of CBB incidence with leaf defoliation was obtained with $rg = 0.55^{**}$ (IITA, 1976).

Some factors affecting CBB field scores

The monthly planting experiment with 15 cultivars showed that CBB field scores depend upon three factors; time of planting, age of plant and time of observation as shown in Fig. 3 (IITA, 1975).

Conclusion

Sources of high resistance to CBB were identified and have been successfully and rapidly incorporated into improved cassava breeding populations, from which selections with high CBB resistance were obtained (see Fig. 4). Such rapid progress in breeding for resistance to CBB was attributed to high heritability of CBB resistance, favourable environments for evaluation and appropriate breeding methods.

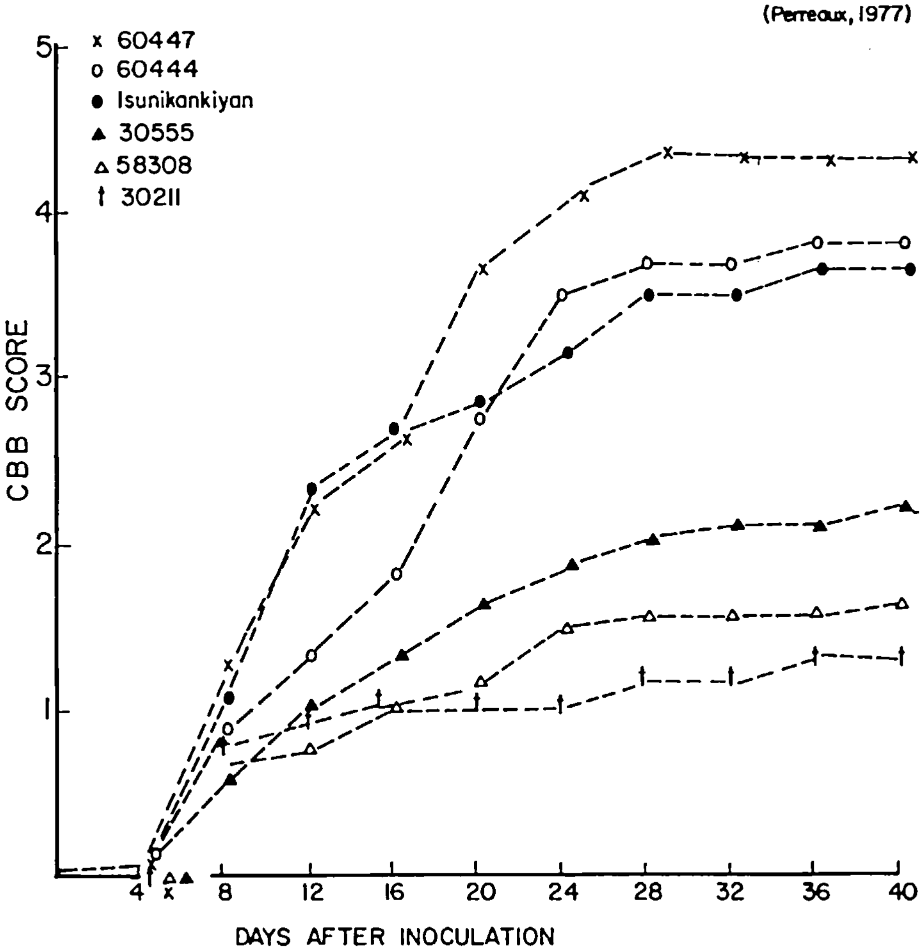

Fig. 4. CBB scores of selections highly resistant to CBB disease (30555 and 30211 are IITA improved varieties).

Correlated response of resistance to CBB with that of CMD made it possible to rapidly improve cassava for resistance to both diseases at the same time, while maintaining other desirable characters.

Since resistance to CBB is polygenic, it may hold well over locations and years, but this needs to be proved further.

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