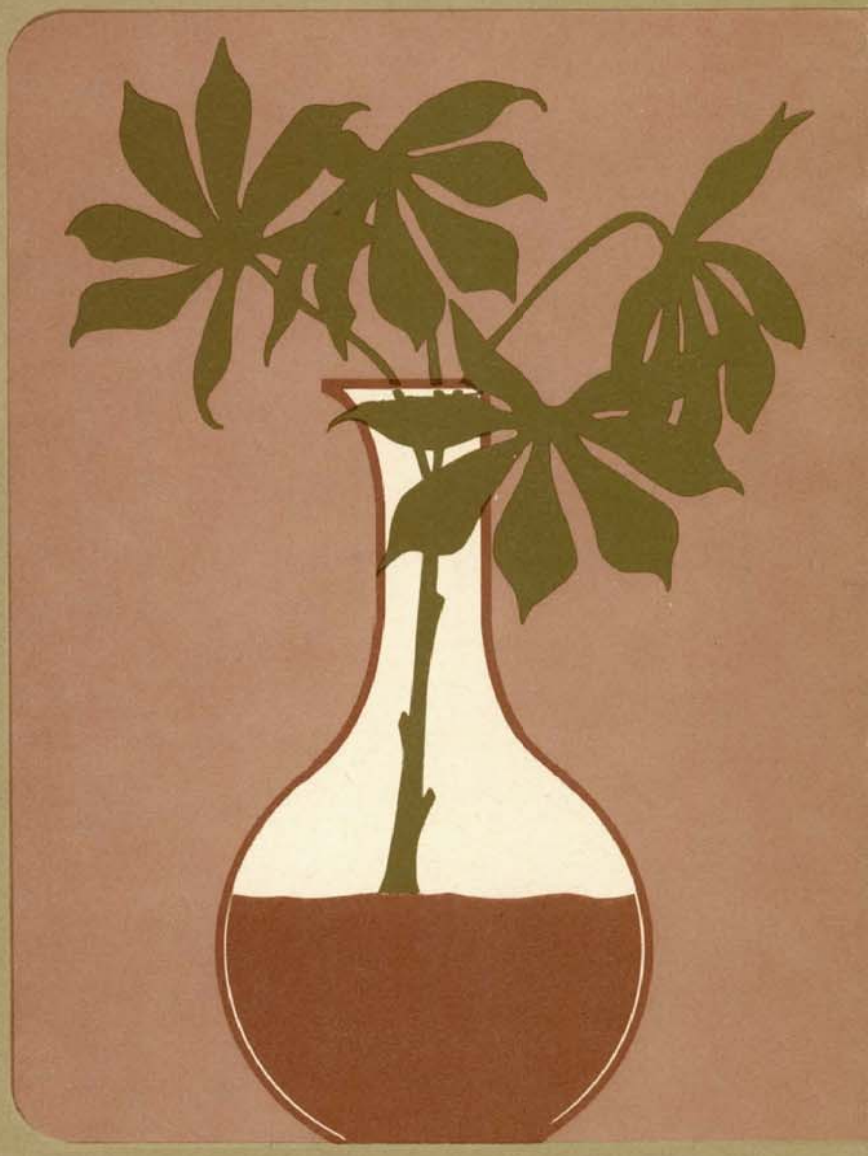
CASSAVA BACTERIAL BLIGHT

report of an
interdisciplinary workshop
held at
IITA, Ibadan, Nigeria,
1-4 November 1976.



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IDRC-096e

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/IDRC publication/. Report of a workshop on the /cassava/ /bacteria/l blight (CBB) /plant disease/ in /Africa south of Sahara/ — discusses the /diagnosis/ and /geographic distribution/ of CBB, influence of shade (/solar radiation/) and /intercropping/ on its incidence, /plant breeding/ for /disease resistance/; /disease control/ efforts in /Nigeria/, /Zaire/ and /Ghana/. Includes /bibliography/s, /list of participants/ and country statements from /Benin PR/, /Congo PR/, Ghana, and /Togo/.

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Editors: **Gabrielle Persley, Eugene R. Terry, and Reginald MacIntyre**

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Foreword

This is the 11th IDRC report on cassava. All but two of them have recorded proceedings of multidisciplinary meetings.

This report covers the proceedings of a workshop held at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, in November 1976. The workshop discussed the subject of cassava bacterial blight (CBB). This disease was only sparsely recorded in the literature before the early 1970s when it was recorded causing serious losses in cassava in Colombia. About 3 years later it was first found to be a significant disease in the African continent when, first in Nigeria and later in Zaire, widespread losses were recorded as a result of the disease. In the last 2 or 3 years the disease has been found in other African countries and it has also been recorded for the first time in certain Asian countries where, however, the strain of organism appears to be less pathogenic than those occurring in Africa or Latin America.

The serious losses resulting from the disease in Africa led to IITA requesting support from IDRC for epidemiological studies to examine the distribution and behaviour of the disease in East, Central, and West Africa. A major feature of the research program emerging from this request is the training of African scientists in the recognition and control of the disease. For various reasons the control measures that had been worked out successfully at the International Centre for Tropical Agriculture (CIAT) at Cali, Colombia, were not always practical in an African context. Although the program of IITA was carried out in close collaboration with that of CIAT, it had to develop, to a large extent, a new approach to control within the specific biological, ecological, and cultural constraints encountered in Africa.

The work in the CBB program at IITA is directed by Dr Eugene Terry, the root crop pathologist at the Centre, and is conducted on a day-to-day basis by Miss Gabrielle Persley, a pathologist from Australia.

The purpose of the workshop, the proceedings of which are described in this report, was to review the findings of the first 18 months of research by Dr Terry and Miss Persley and to do so at a meeting that was attended by root crop specialists from a number of other African countries. In this way the workshop served as a two-way channel of communication with the IITA scientists divulging their research findings and the visitors from other African countries presenting information about CBB in their own countries.

This report presents abbreviated versions of the papers presented at the workshop. Not included is a general presentation by Mr R.A. Woodis on the mechanisms for communicating information about CBB. Copies of this are available directly from the author at IITA. This is the third workshop in this series that has been held at IITA. Dr Terry and Miss Persley were responsible for most of the work associated with the meeting. They were assisted by Dr W.H. Reeves, Head of IITA's Training Program, and Mrs Omole of the Visitor's Section who handled the many logistic problems of this type of meeting in their usual competent manner.

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Diagnosis of Cassava Bacterial Blight Disease

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Cassava bacterial blight (CBB), *Xanthomonas manihotis* (Arthaud-Berthet) Starr, has been observed within the last 5 yr in Zaire (Hahn and Williams 1973; Maraite and Meyer 1975), Nigeria (Williams et al. 1973), Cameroon (Terry and Ezumah 1974), Togo and Ghana (Persley 1975), and Benin (Desmidts, personal communication). This paper covers those aspects necessary for rapid and accurate diagnosis of the disease, with the view to instigating timely and proper control measures.

Symptoms

The characteristic symptoms of CBB are:

(1) angular, "water-soaked" leaf spots that are initially small but later enlarge, coalesce, and eventually turn brown; the affected leaves become blighted and eventually abscise (Fig. 1, *top*);

(2) degrees of leaf wilt ranging from one wilted lamina lobe to many whole leaves (Fig. 1, *bottom*);

(3) yellow–orange gum exudation on the leaf petiole and young shoots (Fig. 2, *left*);

(4) severe defoliation;

(5) tip dieback resulting from vascular necrosis and death of the growing points.

All of the above symptoms except angular leaf spots may be caused by other diseases or adverse conditions, and therefore are not specific for CBB. Their occurrence in the absence of the characteristic water-soaked angular leaf spots should never be the basis for diagnosing the disease as CBB.

Because angular leaf spots are the most definite diagnostic feature of CBB, the following relevant observations may aid accurate diagnosis. The bacterium normally penetrates the host via stomatal openings or through epidermal wounds (Lozano and Sequeira 1974), and initial symptoms appear as water-soaked angular spots that often exude yellowish sticky droplets mostly on the lower leaf surface and along the veins (Fig. 2, *right*). These droplets may dry to form tiny pellets (Terry 1974; Fig. 3, *right*). The spots eventually turn brown, enlarge, and coalesce forming large necrotic areas. These affected areas later turn purplish-brown. When one or more lobes or the entire leaf lamina become necrotic as a result of this disease, the manifestation is called a "blight."

The development of the disease and the pattern of symptom expression resulting from propagating infected cuttings differs from that that occurs after stomatal penetration by the bacterium. With the former, the following may be observed: first, loss of turgidity of one or a few leaves located often on the same side of the stem, followed by rapid wilting. Afterwards, the base of the petiole collapses but the dried leaf remains attached for some time. All leaves located above those showing the first symptoms wilt progressively (Maraite and Meyer 1975). Gum exudation may be observed on the stem near the first wilted leaf. Finally, the unlignified tops or young branches die, while new shoots appear at the junction of the dead and healthy woody stem (Fig. 3, *left*).

Isolation of the Causal Agent

The next important diagnostic step is the isolation of the causal agent in pure culture and the subsequent inducement of the disease.

The following procedure is recommended for the isolation of *X. manihotis*: Nutrient Agar, (Difco) containing 100 ppm Actidione (Cycloheximide) is a suitable isolation medium. The bacterium can be isolated from diseased leaves and stem pieces by the following methods:

Diseased Leaves

A small (1 × 2 mm) portion is cut from the margin of an angular leaf spot, transferred aseptically to a drop of sterile distilled water in a petri dish, and macerated. The macerate is allowed to stand for a few minutes and then a few loopfuls are streaked over the surface of dried agar plates.

Stem Pieces

A portion of stem showing bacterial exudate is surface sterilized by dipping in ethyl alcohol and flaming. A small internal portion (1 × 2 mm) showing brown discoloration is transferred aseptically to a drop of sterile distilled water, where it is macerated and allowed to stand a few minutes. A few loopfuls are then streaked onto dried agar plates. The plates are incubated at 30 °C. *X. manihotis* forms grayish-white circular colonies with a smooth shiny surface, measuring 1–2 mm diameter after 2 days growth.

Pathogenicity

The following methods may be used to confirm

Fig. 1. Top — angular leaf spot; bottom — leaf wilt.

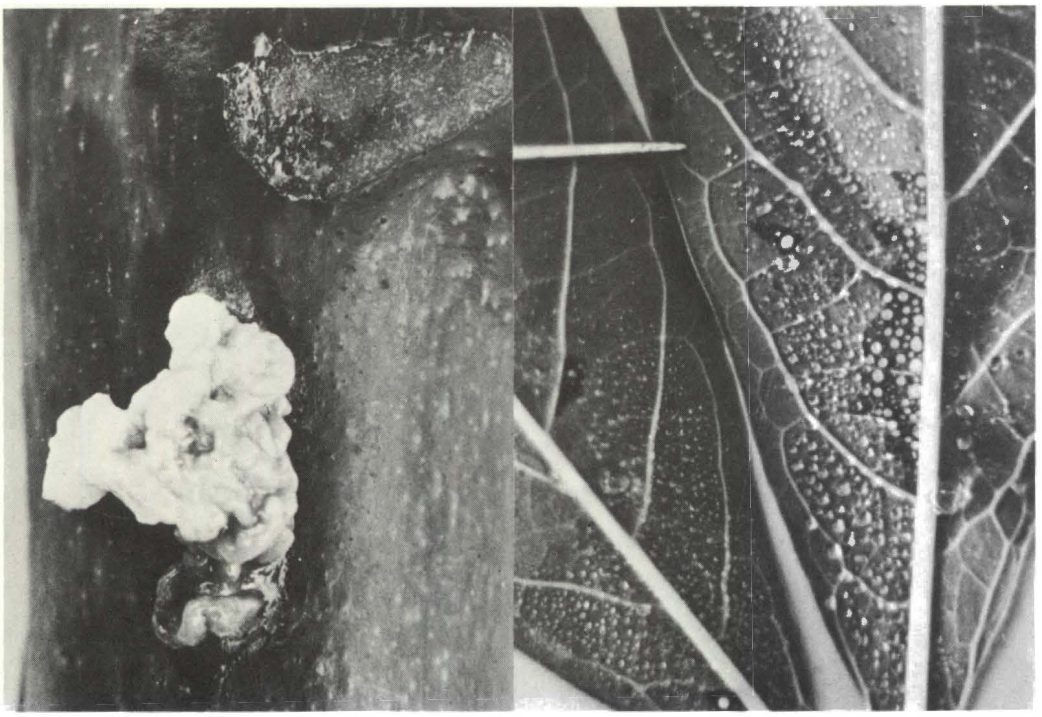

Fig. 2. Left — gum exudation on the stem; right — exudate on lower leaf surface.

pathogenicity. In all cases, plants are kept at 100% relative humidity for 24–48 h, and then placed in the greenhouse at 25–28 °C.

(1) *Spray inoculation* — A bacterial suspension in sterile distilled water is sprayed on cassava leaves.

(2) *Leaf rubbing* — Leaves are rubbed with cheesecloth moistened with a suspension of the bacterium.

(3) *Stem puncture* — Plants are inoculated at the third and fourth leaf axils from the apex by forcing a sharp needle through a drop of the bacterial suspension into the stem.

(4) *Petiole puncture* — Petioles are punctured as in (3).

(5) *Leaf clipping* — Scissors dipped in the bacterial suspension are used to cut portions of the leaf lamina.

The successful inducement of the characteristic CBB symptoms after inoculation with the isolated bacterium is proof of correct diagnosis of the disease and pathogenicity of the isolated bacterium.

Accordingly, the following reactions may occur as a result of the five methods of inoculation listed above. Leaves sprayed with bacterial suspension exhibit water-soaked angular spots 5 days after inoculation. Three days later exudates appear, and after 14 days the leaf spots enlarge and coalesce, resulting in a blight. By the 20th day after inoculation all the inoculated leaves may abscise. Stem dieback may occur at about 28 days after inoculation. A similar pattern of reaction occurs when plants are inoculated by the leaf rubbing method.

With plants inoculated by the stem puncture method, bacterial exudation and leaf wilt may occur near the point of inoculation 6–8 days after inoculation. Leaves distant from the point of inoculation. Stem dieback also may appear during the same period. With petiole puncture inoculation, exudation along the inoculated petioles occurs 6 days after inoculation and leaf wilting about 2 days later. Eventually exudation appears on the stem and dieback occurs (in about 20 days).
later. Eventually exudation appears on the stem and dieback occurs (in about 20 days).

Leaf clipping with contaminated scissors produces water-soaked angular leaf spots 7 days after inoculation and the entire lobes of clipped leaves may be blighted after 15 days. All inoculated leaves may abscise. Bacterial exudation

Fig. 3. Left — tip dieback and growth of new shoots on lower part of stem; right — pellets on lower leaf surface.

may appear on the stems and dieback may be observed after 33 days.

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Distribution and Importance of Cassava Bacterial Blight in Africa

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In Africa, cassava (*Manihot esculenta*) is affected by two major diseases: mosaic, of unknown origin, and cassava bacterial blight (CBB) caused by *Xanthomonas manihotis*. CBB has been recognized as a damaging disease in South America since the early 1900s (Lozano 1975), but was first confirmed in Africa in 1972 (Williams et al. 1973). It now occurs with certainty in seven countries of West or Central Africa. It was first recognized in Nigeria in 1972 (Williams et al. 1973), in Zaire in 1973 (Hahn and Williams 1973), and subsequently in Cameroon (Terry and Ezumah 1974), Benin (Desmidts, personal communication), Togo (Adam, personal communication), Ghana (Doku, personal communication), and Congo Brazzaville (Batsimba and Mabanza, personal communication). With the exception of Congo Brazzaville, I have observed the disease in all these countries and have isolated the bacterium, confirmed the pathogenicity, and characterized it sufficiently to identify it as *X. manihotis*. Cultures from these countries have been deposited at the Commonwealth Mycological Institute (CMI), London.

Bacterial leaf spots on cassava were reported earlier from Madagascar (Bouriquet 1946), Mauritius (Orian 1948), Malawi (Wiehe and Dowson 1953), Uganda (Hansford 1938), and Zaire (Buyckx 1962). Examination of these reports indicates that there is a high probability that a bacterial leaf spot occurred in each case. However, in most instances, the bacteria isolated were not adequately characterized, nor were reference cultures deposited in an accessible culture collection for use by later workers. Therefore, the identity of the pathogen(s) remains uncertain.

One exception is the 1953 report from Malawi by Wiehe and Dowson, where the pathogen isolated was examined and described by Dowson at CMI. He found it to be a yellow xanthomonad, and named it *X. cassavae* Wiehe and Dowson. The description of the symptoms indicates that they differ from those attributed to *X. manihotis*. However, because of the absence of any further records of this disease from Malawi or elsewhere in Africa, it remains an enigma. The report of *X. manihotis* on cassava in Mauritius is probably correct, in that its pathogenicity was determined by Orian and its identity as *X. manihotis* confirmed by Starr (Orian 1948). However, there have been no further references to any of these bacterial diseases in these countries.

This paper presents information on the geographic distribution of CBB, based on recent surveys in Benin, Cameroon, Ghana, Nigeria, and Togo. The possible origin and recent changes in disease severity are also discussed.

Distribution

The first confirmed report of CBB in Africa was in Nigeria in 1972. The known distribution at present and first records of CBB in Africa are shown in Fig. 1.

Cameroon

A detailed survey of CBB in Cameroon was made in June 1976. Data were collected from 155 farms, which were selected by making spot checks at regular intervals along the route, usually every 20 km. At each site, the presence or absence of CBB, mosaic, anthracnose caused by *Glomerella manihotis*, and fungal leaf spots caused by *Cercospora* spp. were noted. In addition, the vegetation, soil type, topography, cropping system, companion crops, age, and vigour of the cassava were recorded.

The farms were given a rating for each disease on a 0–5 scale, based on the frequency and severity of symptoms: 0 — no disease, none; 1 — occasional occurrence, mild; 2 — moderate occurrence, mild; 3 — moderate occurrence, some severe; 4 — frequent occurrence, mostly severe; 5 — very frequent occurrence, severe. Severity was assessed on the basis of symptoms on the aerial parts of the plants.

The incidence of a disease in a particular area was based on the percentage of farms inspected in which the disease was recorded. The severity index in a district was estimated as a percentage of the maximum possible score if all the farms were severely affected: severity index = sum of farm scores on 0–5 scale × 100/total no. of farms × 5. Detailed results of the survey are available elsewhere (Persley 1976).

The route followed and the occurrence of CBB in different vegetation zones are illustrated in Fig. 2.

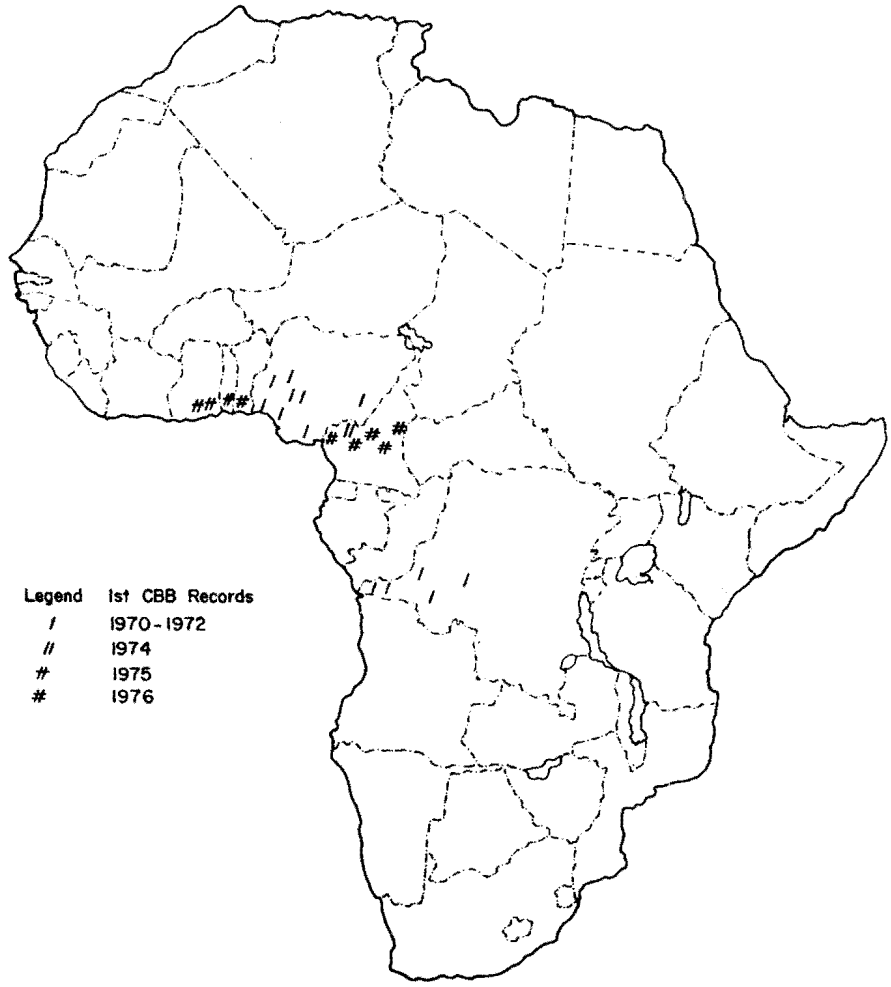

Fig. 1. Known distribution of cassava bacterial blight in Africa (October 1976).

The observed incidence and severity of CBB in Cameroon are summarized in Table 1. The disease occurs in both forest and savanna regions but is more prevalent in the savanna where cassava is grown as a monocrop. It is widely distributed, occurring from the highland savanna around Bamenda and Wum (1700 m altitude), eastwards across the guinea savanna to Garoua Boulai, near the border with the Central African Republic, a distance of some 600 km. It also occurs in a localized area around Victoria and Buea in the west of the country. The high frequency and severity near the border with the Central African Republic suggest that the disease is also likely present in that country.

The disease was not found in cassava examined west of Bamenda to Ekok on the Nigerian border nor for a further 40 km on the Nigerian side of the border. It was also absent from farms inspected between Mamfe and Kumba, an area parallel to the border. Its apparent absence from this part of western Cameroon suggests that it is unlikely that the pathogen moved via this land route from Nigeria to Cameroon or vice versa.

The widespread distribution of CBB in Cameroon, where it sometimes occurs on peasant farms in isolated areas, suggests that it has been there for many years, although its presence was not reported until 1974. CBB is rare in the forest areas between Douala and Bertoua, where cassava is grown on a 12-mo cycle mixed with several other crops. In contrast, the highest incidence and most

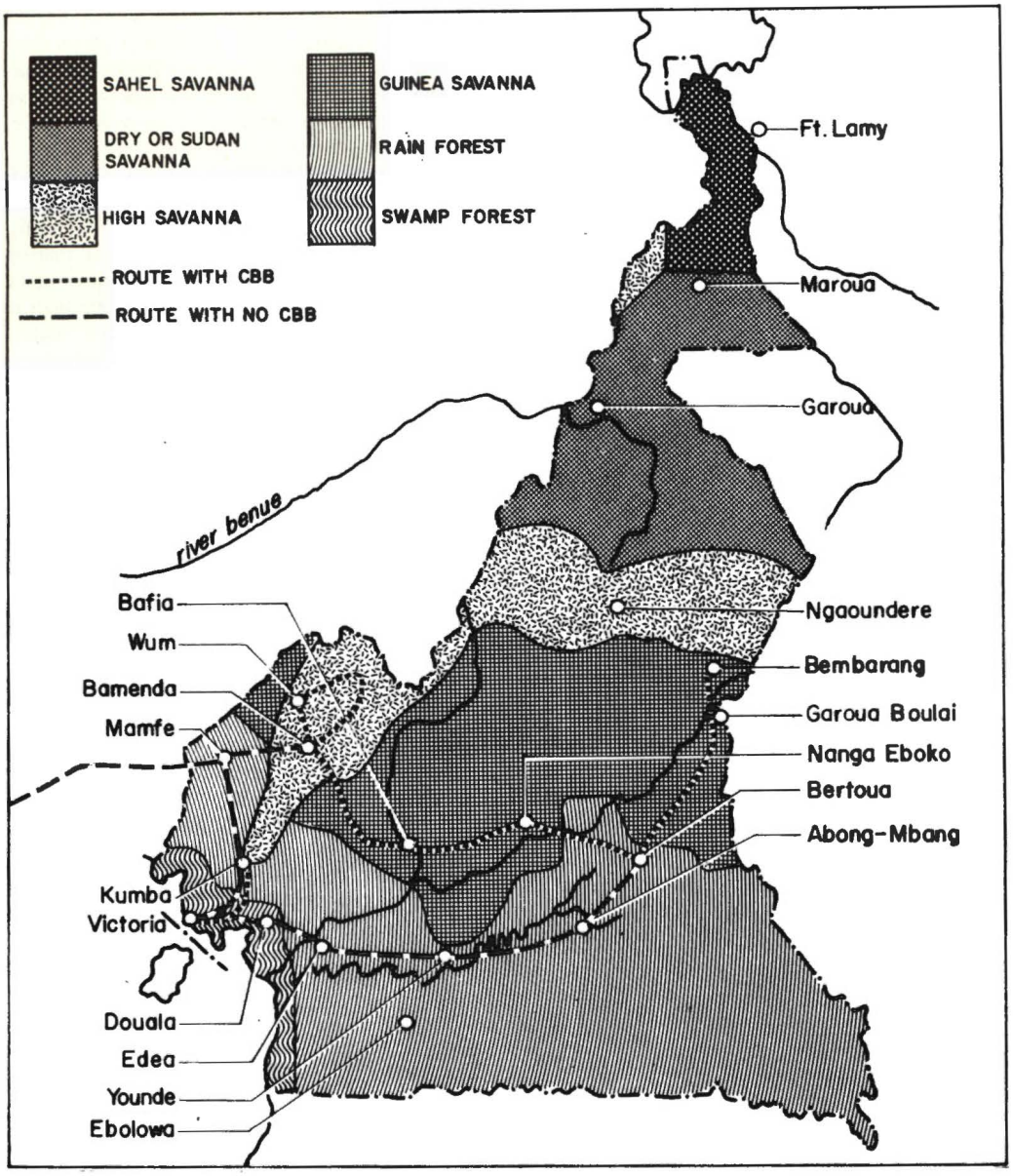

Fig. 2. Distribution of cassava bacterial blight and vegetation zones in Cameroon.

severe symptoms occur in monocropped cassava growing in the savanna region between Bertoua and Garoua Boulai. The cassava here is grown for 18–24 mo before harvest in contrast to a 12-mo cycle in the forest. These observations suggest that there is a correlation between disease development, cropping pattern, and environmental factors.

Cassava was first introduced into Cameroon in the early 1800s, and was an important staple food, especially in the central and eastern regions by 1945 (Jones 1959). However, considering the long history of communications between Latin America and West Africa since 1500, it is possible that cassava may have been introduced much earlier in Cameroon. A cassava variety reported to be resistant to a blight disease that was causing serious damage in southern Cameroon was introduced in the Ebolowa region in 1920. This variety later

became widespread throughout the southern part of Cameroon (Reeves, personal communication). There has been no recent widespread movement of planting material nor introduction of improved varieties in the country.

Nigeria

CBB occurs in most cassava-growing regions, but is reportedly most damaging in eastern Nigeria (Ezeilo 1977). The disease has been most severe on the improved varieties 60444 and 60447, which were released by the Ministry of Agriculture in 1967, although it also occurs on some local farmers' varieties.

In the Umuahia region of eastern Nigeria, I saw the disease in many varieties at the agricultural research station at Umudike, and in field plots established for extension purposes with cuttings taken from the station. It was not seen on cassava growing as a mixed crop on some peasant farms examined in the same area.

From Enugu to Asaba, north of Umuahia, in the forest/savanna transition zone, CBB was more prevalent than in the Umuahia region, occurring on Otuocha Agricultural Station, and on local small farms.

In midwestern Nigeria, the improved cultivars 53101, 60444, and 60447 at Agbarho Agricultural Station near Warri were severely affected by CBB in 1973 and 1974 (Heys 1977). However, the incidence and severity of the disease have fallen drastically over the past 2 yr. There is presently little disease at the station, even in susceptible cultivars such as 60447.

In the western region, CBB occurs on agricultural research stations at Ibadan and on some farms locally. Moving north from Ibadan, it occurs infrequently on local small holdings between Ilorin and Mokwa, and in introduced, improved varieties at Mokwa Agricultural Station.

In summary, the incidence of CBB in Nigeria is higher on government farms and experiment stations, where varieties released since 1960 for high yield and mosaic tolerance are grown, than on peasant farms. The disease is more prevalent in the savanna or forest/savanna transition zone than in the deep forest. It has been found on approximately 40% of farms examined in the savanna region.

People's Republic of Benin

CBB is widely distributed in the south of the country, occurring frequently between Cotonou and Abomey, and in the Savé region, near the Nigerian border, where it was observed in October 1976. In most instances, cassava was being monocropped. There appears to be considerable informal trade of cassava cuttings from western Nigeria to the People's Republic of Benin, especially in the Savé region.

Togo

CBB was seen in the cassava collections at the IRAT stations at Davié and Amoutochou. At Davié, it was present in several blocks, whereas at Amoutochou, it was apparent only in cultivars introduced from Malagasy Republic and an adjacent collection of local cultivars. The material was introduced into Davié in vegetative form in 1970 and later distributed to other IRAT stations,

Table 1. Incidence (% of farms on which disease was recorded) and severity of CBB in Cameroon.

Route	Distance (km)	No. farms	Vegetation type	Incidence (%)	Severity index
Ekok-Batibo	85	19	Rain forest	0	0
Mamfe-Kumba	178	14	Rain forest	7	4
Ekona-Victoria	31	10	Swamp forest	70	32
Nkapa-Loum	35	6	Rain forest	50	30
Douala-Edea	94	7	Rain forest	28	11
Edea-Yaounde	180	7	Rain forest	0	0
Yaounde-Abong-Mbang	300	12	Rain forest	8	2
Bertoua-Bafia	390	24	Rain forest and guinea savanna	33	17
Bertoua-Bembarang	330	15	Guinea savanna	80	64
Bafia-Bamenda	272	13	Guinea savanna to high savanna	15	8
Bamenda-Wum-Nkambe-Batibo	340	28	High savanna	39	21
Total	2255	155		30	17
Forest		99		19	21
Savanna		56		45	31

including Amoutochou. CBB was observed on a local farm near Amoutochou station. At the time (December 1975), CBB appeared to be more common on experiment stations than in farmers' fields. There have been other reports of angular leaf spots, presumably caused by CBB, on local farms along the coast, between Agbessie and the Ghana border (Adam, personal communication).

Ghana

In December 1975 CBB had a limited distribution, occurring in the Volta region, near the Togolese border, and in the Pokoase region, west of Accra, where many of the settlers have come from the Volta region. It has since been found in the coastal savanna areas of central and eastern regions (Korang-Amoakoh, personal communication). Thus it presumably occurs at least from the Togolese border to Swedru, west of Accra.

Discussion

On the basis of the disease surveys, it may be concluded that CBB has been present in limited areas of West Africa for many years, as suggested by its presence on village farms in isolated areas in parts of Cameroon. It was probably introduced on one or several occasions in vegetative material from Brazil at least as far back as the early part of this century. Many of the introductions to francophone countries have come via the Malagasy Republic where angular leaf spots were first reported on cassava in 1935 (Bouriquet 1946, 1973). However, a recent report says that such leaf spots are not now seen on cassava in Madagascar (Arradeau, personal communication).

In Ghana, Nigeria, and other areas of West Africa, the disease was apparently introduced more recently, and spread through attempts to popularize new varieties developed since 1955. In some areas, CBB occurs but is a relatively unimportant disease. There may have been some farmer selection for tolerance among local varieties following introduction and spread of the pathogen. The disease has become more important in other areas with the release of more susceptible varieties. This probably occurred in midwestern and eastern Nigeria after the release in the 1960s of improved varieties 53101, 60444, 60447, and others that were highly susceptible to CBB. Once such varieties were infected the disease spread easily to new areas in infected planting material.

The possibility of introducing CBB into new areas along with cuttings of improved varieties, especially tolerant ones that show few symptoms, should be taken into account during their distribution. Such introductions may intensify the occurrence of CBB even in a localized area. There are some relatively simple means of freeing plants of CBB by rooting shoot-tips under high humidity (Lozano and Wholey 1974). These can form the basis of a clean-seed scheme, provided proper indexing for disease is conducted.

The damage due to CBB may have been exaggerated at times, due to the confounding of defoliation and tip dieback caused by drought, salinity effects, insect damage or other diseases, especially anthracnose, with CBB effects. The presence of angular leaf spots is the most certain symptom indicating presence of CBB, but it is not diagnostic. Leaf wilting and stem exudate are additional diagnostic aids but are less certain. Confirmation must include isolation and characterization of the pathogen.

In relation to introduction and promotion of new varieties, it is important to know the areas of high, medium, and low damage caused by CBB. In addition, it is important to determine the epidemiological competence of the pathogen in different climatic zones with their differing cropping patterns. In areas of low incidence, exclusion becomes useful. In areas of high pathogen competence, resistance becomes increasingly reliable and necessary.

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Control of Cassava Bacterial Blight in Nigeria

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In 1973, cassava production in Nigeria was about 9.6 million tonnes, thus making it the world's fourth largest cassava producer, after Brazil, Zaire, and Indonesia. Cassava is a major staple food in Nigeria, and comprises 25–50% of the diet in southern Nigeria. A projected annual per capita demand of 112 kg of cassava in the country in 1972 compares with 108 kg for yams, 14 kg for maize, 32 kg for millet, 29 kg for sorghum, and 6 kg for rice (Olayide et al. 1972). Cassava is used as a primary human food, the major products being "gari" and "fufu."

Production of cassava is largely by small-scale farmers. The average yield of 6 t/ha is low, not only because the crop is planted in the poorest soils, usually without fertilizer, but also because low-yielding, local varieties are susceptible to cassava mosaic disease (CMD), which is known to reduce yields by more than 30% (Ezeilo et al. 1975). They are also susceptible to the more serious disease, cassava bacterial blight (CBB), which causes losses as high as 50–60% at Ibadan (Anonymous 1975) or even total crop failure in the wetter parts of southern Nigeria.

CBB was first recorded in Nigeria in 1972 when it caused widespread damage to cassava throughout the southern part of the country (Williams et al. 1973). By 1973, estimated yield losses in the most affected areas were about 75%, resulting in a loss of ₦24 million (approximately $38 million) in the former East Central State (Anonymous 1973).

Preliminary Control Measures

The following interim control measures were suggested by the Federal Agricultural Research and Training Stations, Umudike:

(1) early planting to enable the cassava to establish before the peak of disease incidence during the rainy season;

(2) use of "clean" planting material obtained from noninfected plants;

(3) the use of balanced NPK fertilizers applied 4 wk after planting to enable the plants to establish quickly;

(4) the use of tolerant local varieties, in the absence of resistant materials;

(5) crop sanitation involving uprooting and burning infected plants to minimize the spread of the disease;

(6) crop rotation to avoid repeated cropping of cassava on the same land; and

(7) research to find better ways of controlling the disease, including screening for resistant varieties.

In October 1973, the Ministry of Agriculture in the former East Central State mounted an education campaign warning farmers that crop damage could reach 80–100%. Symptoms of CBB and its economic importance were described, and interim control measures were recommended.

The first workshop on CBB in Nigeria was held at Umudike in April–May 1974, and the interim control measures outlined above were revised (Anonymous 1974). However, the participants realized that most farmers were unable to obtain disease-free planting materials, nor were they able or willing to carry out crop sanitation involving uprooting and burning of infected plants. Also, since there was no special program for distributing tolerant varieties, farmers resorted to planting whatever was available according to traditional cropping practice and rotation. Also, there was a poor supply of fertilizers to farmers in 1973 and 1974, and farmers tended to apply available fertilizers on the more highly valued crops such as rice and yams, rather than on cassava.

The Cassava Program of the National Accelerated Food Production Project (NAFPP)

To solve the problem of the slow rate of increase in the production of certain staple foods, namely cassava, maize, rice, sorghum/millet, and wheat against rapidly increasing population, and to provide the nation with a plan for agricultural development, the Federal Ministry of Agriculture and Rural Development established the National Accelerated Food Production Project (NAFPP) in 1971.

Objective of NAFPP

The NAFPP plans to stimulate small-scale farmers to rapidly increase production of food crops by adopting a package of improved technology, involving the use of high-yielding varieties, large quantities of fertilizers, modern cultural practices, and adequate credit, processing, and marketing facilities. Thus, through an integrated extension/research effort, research results are speedily transferred to farmers by testing and demonstrating in farmers' fields.

Strategy for Achieving Objective

(1) Development of economically viable package of improved varieties and cultural practices — A National Cassava Centre, Zonal Substations, and State Extension networks were established to carry out applied research, "pre-minikit" trials, demonstrations, and production kits. Special features of this Research/Extension network include commodity research and extension, extensive training of staff, and speeding of transfer of research results by testing in farmers' fields by the farmers themselves, thus allowing them to benefit from new technology 3–4 yr sooner than by conventional methods.

(2) Adoption of package of practices by organized, trained, progressive farmers — This was accomplished through selection of project areas and progressive farmers, and by farmer-group training, using demonstrations, in which the adoption process is speeded because farmers "learn-by-doing" under group opinion pressure. Also "group approach" facilities, e.g., formation of cooperatives to cater for supply services such as inputs, marketing, storage, and processing were provided.

(3) Adequate supply of inputs, processing, storage, marketing facilities — This was achieved through the transfer of commercial-type activities to the private sector (e.g., cooperatives, firms, individuals (Agro-Service Centres)). Two specific NAFPP objectives to remove CBB disease constraints toward increased production of cassava include the promotion of recommended tolerant varieties, while intensifying efforts toward making disease-resistant cassava varieties available in commercial quantities to replace all susceptible and tolerant varieties.

NAFPP Farming Practices

(1) Intercropped cassava — Cassava interplanted with maize is more profitable than the single cropping (Okigbo, personal communication) and this is in line with the customary practice. Also, because intercropping reduces the incidence of CBB (Arene, personal communication), NAFPP farmers were trained on the improved mixed cropping package of technology using two recommended tolerant cassava varieties, Nwugo and 60506. Each participating farmer in 1975 planted a demonstration plot of 0.05 ha in which half of the plot was allotted to the recommended cassava variety interplanted with FARZ 7 or FARZ 27 maize, treated with fertilizers, and planted at recommended rates on ridges. The other half was planted with local cassava, interplanted with local maize, without fertilizers, and planted in the traditional manner. Reduced disease incidence was apparent in the NAFPP demonstration plots. This was also true in the production kits planted by farmers in 1976, which were based on the package of practices used in the 1975 demonstrations. The NAFPP practice out-yielded local practice in the case of maize 6:1, the cassava 3:1, and the gross proceeds (cassava plus maize) 4:1.

(2) Use of disease-resistant cassava cultivars — Research at IITA and the National Root Crops Research Institute is aimed at developing cassava varieties that are high yielding, resistant to diseases (especially mosaic and CBB), and with improved quality and quantity of starch, gari quality, and other desirable characteristics.

Many cassava clones from IITA screened in 1974–75 outyielded the recommended varieties by 2–18 times, primarily because of their resistance to disease, especially CBB (Anonymous 1975).

In 1975, 209 clones were selected from 3000 on the basis of high yield and resistance to CMD and CBB at Mbato, Imo State, after 12 mo of field evaluation. In September 1976 after harvest, 64 were selected as having a yield potential of 20–50 t/ha and resistance to CBB and CMD. The 18 best clones were included in the 1976 farmer-level "minikit" variety trials.

CBB-resistant cultivars are now being multiplied at Umudike by rapid propagation techniques and by conventional means in preparation for the extension of the NAFPP cassava program to other states of Nigeria in 1977.

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Cassava Improvement in the Niger Delta of Nigeria

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In all Shell-sponsored rural development projects, a detailed survey is made of the project areas to identify factors critical for the economic and social development of the local people. When Shell-BP Petroleum Development Company of Nigeria Limited was conducting a survey in the early 1970s in parts of Bendel State, they found that cassava accounted for 80% of the local diet. They also found that locally grown varieties yielded only 5–6 t/ha compared with 24 t/ha for the newer varieties that were available and had been developed for higher yields, improved palatability, starch and dry matter content.

However, when these newer varieties were being multiplied for farmers it was discovered they were susceptible to cassava bacterial blight (CBB) caused by *Xanthomonas manihotis*. This was a problem with a far wider significance than for our relatively localized project areas.

The Nigerian Federal Department of Agricultural Research had developed several good cassava varieties, such as 53101, 60444, 60447, and 60506. Shell-BP were interested in obtaining these varieties for demonstration and multiplication in their project villages, but, in early 1972 none of these varieties were available in Rivers State and only 4 ha of 60447 in Bendel State.

Bendel State Ministry of Agriculture (MANR) had planted 12.5 ha of 60447 at their Agbarho Agriculture Station and made available sufficient planting material to Shell-BP to plant 0.5 ha in the Rivers and Bendel states. At the same time the Federal Department made available small quantities of 53101, 60444, 60447, and 60501, plus some single plants of other varieties.

CBB Incidence and Severity

During July 1972 the Agricultural Superintendent at Agbarho Farm noticed that a few cassava plants were wilting from the top leaves and beginning to dieback from the growing shoots. He approached scientists in his own Ministry to establish the nature of the disease and how it might be controlled. Over the next 2 mo the number of affected plants increased but did not exceed 50 in the area of 12.5 ha.

At the end of September the affected cassavas began to regenerate from just below the dieback area and it was concluded that the problem might have been physiological. The varieties being multiplied by Shell-BP were carefully observed but no disease was found.

In July 1973 the disease manifested itself on an alarming scale and by September about 75% of the 45 ha planted at Agbarho were affected. In the Shell-BP program, the cassava obtained from Agbarho was unaffected but all the varieties obtained from FAR in the previous year, except 60506, were diseased.

IITA Involvement

IITA was interested in two aspects. Dr E.R. Terry noted disease-free 60506 growing between infected plots of 53101 and 60444. Dr S.K. Hahn was interested in disease resistance in improved varieties, and imported cassava seeds from all the main cassava-producing areas in the world.

Hahn had already selected 10 000 seedlings; some were being crossed by open pollination and some high-yielding plants were being hand-crossed with highly resistant tree cassavas or known low-yielding, resistant crosses from them. He was also interested in Shell-BP's work on selection under disease pressure of locally grown cassava clones from the Bendel and adjoining states. These had been selected because of known yield and palatability, but by late 1973 many were infected with the disease.

It was agreed that Hahn's selections should be included in the Shell-BP program and 4 ha were set aside in the Delta area of Bendel State, an area where rainfall was twice that at Ibadan. Shell-BP also asked the Bendel Ministry of Agriculture to allocate 4 ha at Agbarho as the incidence of the disease at that station would provide stringent conditions for IITA selections.

In April 1974, 1000 clones selected from 10 000 IITA clones and 300 clones selected as the best cassavas grown at IITA in the 1973–74 season were planted at Agbarho. Simultaneously, 3 ha in the Shell-BP area were planted with half-cross cassava (one known parent) and a few hand-

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crosses. All had been selected on an individual plant basis for yield and root formation.

Control Measures

The Ministry of Agriculture was reluctant to participate in the April 1974 planting on the grounds that even diseased 60447 outyielded local cassavas. Shell-BP, realizing the seriousness of the disease, which had become apparent when harvesting began in early 1974, offered as an inducement to pay half the labour bill at Agbarho and lend them a tractor to prepare the land. The cassava clone 60447, which had previously been yielding 24 t/ha on the relatively unfertile sand/silt soils of Agbarho, dropped to 2.5 t/ha in 1973–74.

However, using different planting dates, Shell-BP had shown that early September planting, even of diseased material, gave some 8–9 mo of uninterrupted growth before the disease manifested itself. Planting at the normal time (February/March) gave only 4–6 mo growth before attack. The plants did not recover and root development was insufficient to give any yield.

Field Day

In late October 1974, Shell-BP organized a field day at Agbarho, on behalf of the Bendel Ministry of Agriculture and IITA, that attracted senior field and research officers from the five Southern States of Nigeria, as well as federal staff and members of farmers organizations. The field day created widespread interest and although some clones had succumbed to the disease, many exhibited high resistance and it was agreed to send Rivers State's Department of Agriculture 100 of the best clones from the 1300 as a nucleus of disease-resistant material.

Selections of Varieties

At the end of March 1975 the 1300 clones planted in April 1974 were harvested. Hahn made 137 selections from these of which 16 were outstandingly good yielders. These were tested for starch and gari production and palatability. Several groups of people participated in the testing and all but one of the 16 varieties were judged as "high quality." Yields on the basis of eight stands for each clone ranged from 25 to 32 t/ha. Over 500 selections were made from the Shell-BP-grown clones on the basis of single plant evaluation.

Continuing Program

Shell-BP is continuing its efforts to develop an improved cassava program, and among other activities in 1975 it: (1) provided the East Central State, now Imo and Anambra states, with 2 ha of 60506; (2) helped the Bendel Agricultural Department clear 21 ha from bush at Agbarho and plant 14 ha during the 1975 season; (3) held more field days at Agbarho; one was on behalf of IITA, for the Cassava Breeders of Africa, attending the Workshop for the International Exchange and Testing of Cassava Germ Plasm in Africa in November 1975; (4) in 1976, Shell-BP helped the Ministry of Agriculture in Bendel State to continue the development work at Agbarho where there are now 17 ha of improved disease-resistant cassava growing; (5) supplied the Rivers State MANR with planting material. We have helped some local farmers to grow some of the IITA-selected cassava and we hope to encourage more to do so in the future; (6) helped initiate and establish a cassava rapid multiplication program to hasten the dissemination of the improved, high-yielding, disease-resistant cassava most suitable for the climate and poor soils in the Niger Delta.

Control of Cassava Bacterial Blight in Zaire

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Cassava bacterial blight (CBB) was first observed in the Gungu area of Bandundu Region of Zaire in 1970. Since then, it has been found in many parts of the country. Although the mode of dissemination cannot be traced accurately, several hypotheses may be made as to how it reached other regions. Lozano and Sequeira (1974) showed that the most efficient means of spread was by the use of infected cuttings. Infected clones are known to have been transferred to many areas in Zaire. Several manioc clones were reported to be resistant to CBB, including 02864, 02715, 0704/64, Masadisadi. At that time, the causal organism of CBB was reported to be *Pseudotheraptus devastans* (Dubois and Mostade 1973). Many reportedly tolerant clones have been transferred to some INERA (Institut national pour l'étude et la recherche agronomique) stations far from Gungi. Recent evaluations by PRONAM (Programme national manioc) staff and Maraite and Meyer (1975) have shown that these varieties are susceptible. Their movement may have contributed to CBB spread.

CBB and Vegetable Protein Supply in Zaire

Cassava leaves are widely used as a vegetable and protein source in Zaire, particularly in regions like Shaba and Kivu where the crop is grown mainly for its leaves. Damage by CBB has led to a shortage of leaves. The shortage became so acute in 1971 that fish farming was encouraged in Bandundu Region as a substitute for cassava leaf protein. However, this was not widely accepted.

The serious effects of CBB and other diseases and pests on vegetable protein supply occur because epidemics of CBB during the rainy season reduce leaf supply when new flushes and plentiful supply would normally be expected. Little or no leaves are retained by cassava during the dry season when CBB incidence is low and mealybug damage is severe.

Breeding Program

Since December 1974, attempts have been made by PRONAM and INERA staff to identify clones showing field resistance to CBB. Briefly, broad-based germ plasm is screened for disease resistance, and preliminary and advanced yield trials are then conducted at different locations, emphasizing areas with maximum disease pressure.

Germ Plasm Collection

PRONAM base population comprises several thousand seeds of wide genetic base from IITA, INERA stations, and farmers' fields as well as clonal selections from previous cassava improvement projects in Zaire. The materials were screened quantitatively for field resistance to CBB (Anonymous 1975) and other pests and diseases as well as for tuber shape and leaf retention.

Although the main source of materials is IITA, local seeds have been produced and established for screening. These are recombinants of IITA and local selections under (*a*) isolated conditions (partially controlled); (*b*) as polycrosses in open pollinated fields; and (*c*) as controlled crosses between promising local clones and IITA selections.

Although many of the selections from the IITA stock show field resistance or tolerance to CBB and other diseases, they are susceptible to mealybugs, which have become a serious pest. This problem is especially severe in Bas Zaire.

Fluctuations in CBB Incidence

CBB incidence varies with the season and from year to year, and is higher during the rainy season, because of more suitable environmental conditions for the survival and development of the causal organism *Xanthomonas manihotis* (Anonymous 1974; Lozano 1975; Terry 1975). The annual fluctuations may be related to the virulence of *X. manihotis* strains dominating from year to year. However, there is no evidence to support this hypothesis.

Multilocation Disease Evaluation

The strategy employed initially was to establish seedling nurseries at M'Vuazi, evaluate these, and to test selected clones in preliminary yield trials at several locations with varying ecological conditions (Ezumah et al. 1975). This strategy has now been modified by establishing seedling nurseries at selected locations. Seedling establishment is preferable because: (1) cost of transporting cuttings

Table 1. CBB scores on mean family bases (given as % in class) of seedling nurseries at three locations at 6 mo.

Location	I	II	III	IV	V[a]	Total
M'Vuazi	3	19	32	22	24	206
Lowe[b]	43	56	2	—	—	101
Vanga	11	23	19	28	19	150
Kigaka	—	No evidence of CBB			—	102

[a] Class I, resistant; class V, highly susceptible.
[b] Dry season: CBB incidence was low.

Table 2. CBB scores[a] from two locations in Zaire (given as % in class): Nkielelo (rich fallowed soil) and Boko (highly cropped derived savanna underlain by sandy soil).

	Clones from Nkielelo			Clones from Boko		
Source	I	II	Total	I	II	Total[b]
IITA						
Families	31.7	61.6	271	0.0	5.8	361
IITA-A	33.3	24.7	81	0.0	20.7	92
IITA-B	7.4	24.5	94	2.2	24.4	90
IITA-C	30.3	51.3	76	0.0	38.0	8
INTERA-D	26.2	26.2	84	0.9	5.7	105
Farmers	0.0	22.2	9	0.0	0.0	8
INERA-F	6.0	40.0	50	—	—	—

[a] Scores taken during rainy season, 1976.
[b] Total includes all clones in classes 1–5. Thus for Boko 94.2% were in class III, IV, and V.

is reduced; (2) the risk of introducing a pest such as mealybugs to other locations in Zaire is eliminated; and (3) heterozygous seeds provide wider genetic variability at each location. Results of CBB scores for four PRONAM nursery centres in Zaire are presented in Table 1. Selected clones will be carried forward to the preliminary yield trials phase next season.

Soil Effects

Results from two of several locations are used to illustrate the effects of relatively rich soil conditions at Nkielelo (derived savanna area fallowed for 5 yr before cropping with cassava) and poor soil conditions in the sandy Boko area where cassava is intensively cropped. Fewer cassava varieties were rated class I (resistant) at Boko than in Nkielelo (Table 2). The mean annual rainfall at Boko (1411 mm) and Nkielelo (1359 mm) are similar.

Conclusion

Efforts are being made by PRONAM to produce resistant cassava cultivars. Preliminary data suggest a correlation between the severity of CBB and soil fertility. Rapid screening under controlled conditions could increase the possibility of field resistance and reduce the number of clones established at multilocational sites. Evaluation of clones exposed to varying ecological conditions will continue to be emphasized.

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Control of Cassava Bacterial Blight in Ghana

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Cassava bacterial blight (CBB) caused by *Xanthomonas manihotis* has devastated large fields of cassava in Nigeria and Zaire. It has recently been observed in Ghana, where it was first reported in September 1975 (Korang-Amoakoh, personal communication).

In view of its wide distribution and the socioeconomic problems that will occur if it is not controlled, it is important that steps be taken to control the disease. The ideal way is by the use of resistant varieties, but until such improved varieties become available, cultural control measures are necessary.

The disease is disseminated from one area to another and between countries and seasons mainly by the use of infected planting material. In Ghana, varieties within a locality are uniform and there is little exchange of cuttings between farmers. High incidence of the disease in a particular farm resulting from planting infected cuttings can occur. Rain splash is also an important means of dissemination in localized areas. The highest incidence is during the major rainy season.

Control Measures

Control measures are twofold: (1) preventing the disease from entering, spreading, and becoming established in a country; and (2) eradicating or minimizing effects of the disease after it has become established.

(1) Prevention

Where the outbreak is in a neighbouring country or has just been reported in a country, as in Ghana, the following precautions are suggested:

(*a*) Prohibit importation of cuttings into the country; seed may be introduced only through the phytosanitary authorities.

(*b*) For areas with two rainy seasons — a major and a minor — plant only in the minor season or toward the end of the major rains if minor rains are not reliable. For areas with one long rainy season, plant toward the latter part of the season. In both cases, plant early maturing, vigorous varieties.

(*c*) If areas near sources of infection have high rainfall, prohibit cassava planting in these areas or plant only resistant varieties. This can only be done if steps have already been taken to introduce and test resistant varieties, as has been done in Ghana. African countries that have not already started introducing seed of resistant varieties (e.g., from IITA) are urged to do so now to ensure against future outbreaks that are almost certain to occur.

(*d*) Where the disease is already present at the borders or is in isolated pockets, assessment of the level of resistance of varieties in different environments should be made by planting them on previously infected farms.

(*e*) In selecting resistant varieties, branching habit and general plant vigour should be rated highly because, should resistance per se break down, these morphological characters will minimize the effect of the disease through the production of new branches as older ones die and thus extend the productive life of the plant.

(2) Eradication

(*a*) Farmers should be taught to recognize the disease.

(*b*) CBB survey teams should be established to confirm reports of outbreaks and to do random checks on cassava farms.

(*c*) There should be no movement of cuttings within or from infected areas. Infected farms should be burned, fallowed for 2–3 yr, and crop rotation or mixed cropping with cereals and legumes practiced.

(*d*) A certified disease-free stock scheme should be established and controlled by the phytosanitary authorities.

(*e*) The normal peasant practice of wide spacing and intercropping should be encouraged. The best spacing of intercrops and intercropping systems for large-scale mechanized farms, which will maximize total yield per unit of intercropped area, should be found.

Breeding for Resistance to Cassava Bacterial Blight

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Cassava bacterial blight (CBB) has become serious in the cassava-growing areas in Africa. It is recognized as a potentially more serious disease than cassava mosaic disease (CMD) because it may often cause complete failure of the crop. Serious outbreaks have been reported in Nigeria, Zaire, Cameroon, Benin, Togo, and Ghana, and its high incidence in at least two of these countries suggests that it will be difficult to eradicate. Therefore, the most practical approach is to utilize host-plant resistance to the disease.

The Root and Tuber Improvement Program at IITA has given high priority to breeding for resistance to the disease between 1972 and 1976. Sources of resistance have been identified and efforts have been made to incorporate this resistance into other varieties that are susceptible but that possess other desirable agronomic traits.

Extensive hybridization of selected parents has been made with the resistant clones, and large numbers of progenies of the crosses have been tested for resistance in the field over the past 5 yr. Many clones and families have proven to be consistently highly resistant to the disease in a wide range of environments covering many different ecological areas in Nigeria and Zaire.

The selected individual plants have been cloned and further evaluated for lodging, resistance to other diseases, root and plant characteristics, and yield potential. The most promising clones selected have undergone evaluations in preliminary and advanced yield trials.

Significant progress has been made in producing improved cassava clones with resistance to diseases, especially CBB and CMD, high yield, improved root characteristics, and resistance to lodging. Their quality and acceptability have been tested and found to be good, and a few elite clones have shown consistently superior performance over the years. They have been multiplied and planted in farmers' fields in selected locations in Nigeria. The clones with the best performances under local conditions and cultural practices have now been made available to farmers.

Survival of *Xanthomonas manihotis*, the Cassava Bacterial Blight Pathogen

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Cassava bacterial blight (CBB) caused by *Xanthomonas manihotis* has been reported from Brazil (Bondar 1912), Argentina (Zyngier de Resnik 1968), Nicaragua and Guatemala (Normanha 1971), Venezuela and Colombia (Lozano 1975), Madagascar (Bouriquet 1946), Mauritius (Orian 1947), Nigeria (Williams et al. 1973), Zaire (Williams, personal communication), Malaysia (Bradbury, personal communication), Thailand (Lozano, personal communication), and Taiwan (Leu and Chen 1972).

The rapid spread of this disease across the cassava-growing areas of the world in recent years has highlighted the importance of the survival of the pathogen in considering how it is carried over from one rainy season to another to reinfect new crops.

Some workers have suggested that the movement of CBB-infested soil during cultural operations and the use of infected cuttings as planting stock are partially responsible for the spread of the bacterial blight disease from place to place (Drummond and Hipolito 1941; Lozano 1975). It is therefore important to investigate the survival of the CBB pathogen in these ecological niches to identify the most important factor in the spread of the disease. Possible methods of cultural control arising from the results are also discussed.

Materials and Methods

Soil Survival

The three types of soils used were from the following sites in Colombia: CIAT (pH 6.8), Jamundi (pH 4.2), and Popayan (pH 4.5). All soils were used for cultivating cassava but only Jamundi soil carried plants infected by CBB. Soils were inoculated with a suspension of *X. manihotis* in sterile distilled water to give a concentration of 3.2×10^7 cells/g of soil.

Numbers of *X. manihotis* cells in the soil were estimated by serial dilution and plate count techniques on medium Ds (Kado and Heskett 1970). Plate counts were made at the time of CBB inoculation into the soils and subsequently at intervals of 7 days. The population was followed in both sterile and nonsterile soil.

Experiments and Results

Survival in Sterile and Nonsterile Soil

The results given in Fig. 1 show that there was a rapid decline of CBB numbers after soil inoculation, the rate being less in sterile than nonsterile soils. Survival was longer in CIAT soil (near neutral) than in Jamundi and Popayan soils (acidic). CBB cells did not survive in Popayan soil.

Field Survival

To determine the vertical distribution of CBB in infested soil, Jamundi soil was collected from a plot from which diseased plants had recently been removed and from a plot carrying diseased plants. Samples were taken at 10-cm intervals to a depth of 50 cm. Samples of plant debris on the soil surface were also taken from the plot of diseased plants.

Results (Table 1) show that bacterial cells were present in the infected plant debris on the soil surface and in the 0–5-cm zone of the plot carrying diseased plants. There were fewer CBB cells in the 0–5-cm zone of the soil from which infected plants had been removed.

Survival at Different pH

The survival of CBB in soils at different pH was recorded in sterilized and nonsterilized Jamundi soils. The pH of each 1-kg sample was raised by steps of 0.5 to pH 7.25 using $CaCO_3$. Water dilutions of CBB cells were added to a concentration of 8.0×10^7 cells/g of soil and bacterial counts were taken immediately and at intervals of 7 days.

There was a general decline of CBB numbers

Table 1. Vertical distribution of cassava blight bacterium (CBB cells/g of debris or soil; mean of three replicates) in soil samples taken from an infected plantation.

Origin	Treatment	
	Infected plants removed	Infected plants present
Surface debris	None	3.7×10^7
Surface soil	0	0
0–5 cm	2.7×10^4	1.9×10^7
Over 5 cm	0	0

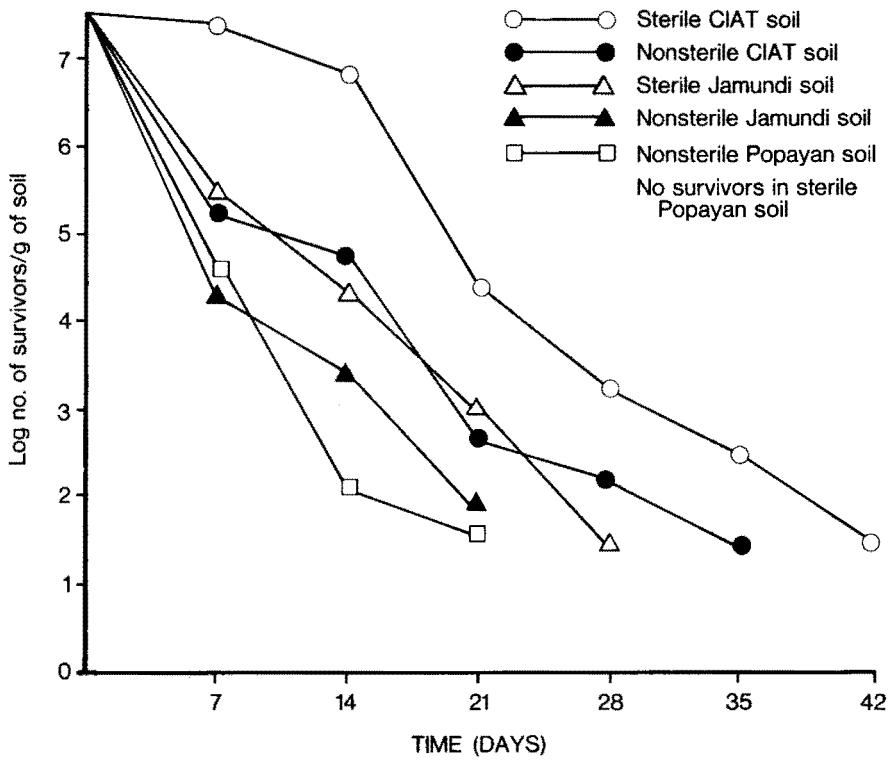

Fig. 1. The survival of X. manihotis in three types of soil.

from the time of inoculation. CBB cells survived a little longer in sterile than in nonsterile soils and better at pH 5.0, 5.5, 6.0, and 6.5 than at pH 4.0, 4.5, 7.0, and 7.25. The optimum pH for CBB survival was 6.0–6.5.

Flooding and Desiccation

The survival of CBB was also determined in flooded and desiccated soils. To each 1-kg soil sample, CBB cells were added up to a concentration of approximately 3.2×10^7 cells/g of soil. Samples for the flooding experiments were packed into plastic tubes (15 cm diameter × 20 cm high), which were submerged in water. Bacterial counts were taken immediately before and after flooding and at intervals of 7 days.

For the studies on survival in desiccated soil, 20-g portions of each soil inoculated to a concentration of 3.2×10^7 CBB cells/g of soil were spread in petri dishes and allowed to dry over anhydrous calcium chloride in a desiccator. In the controls, soils were not desiccated. Plate counts were taken before soil was placed in the desiccator and afterwards at intervals of 7 days.

Results show that CBB did not survive for more than 7 days in flooded and desiccated Popayan and in flooded Jamundi soils. They survived for 14 days in desiccated and in flooded and desiccated CIAT soils. In soils at field capacity CBB cells survived for 21 days in Popayan and Jamundi soils and for 35 days in CIAT soil.

Infectivity of CBB in Soil

Infectivity of CBB in Jamundi soil was studied by using infected soil for leaf-spray inoculation and as a growth medium for healthy cassava cuttings. A sample of 50 g of soil was infected with CBB (3.2×10^7 cells/g of soil) and suspended in 50 ml sterile distilled water. Suspensions were sprayed immediately and at intervals of 7 days on healthy cassava leaves maintained in a mist chamber for 48 h and 25 °C and then in a glass house at 80–90% RH and 25 °C. Uninoculated soil was used for control.

There was a direct relation between concentration of CBB in soil and the number of leaf spots that developed when leaves were sprayed with suspensions of CBB-infested soils. Below a population of 10^3 CBB cells/g of soil, leaf spots did not develop. Using a similar concentration of CBB, more leaf spots occurred using suspensions of bacteria in sterile distilled water than with CBB-infested soil suspension.

Table 2. Disease development in plots after different postharvest treatments of soil/no. of viable cassava blight bacterium (CBB).

Time of replanting after harvest (days)	Debris removed		Debris removed, surface hoed		Debris on surface	
	No. diseased plants	CBB/g soil	No. diseased plants	CBB/g soil	No. diseased plants	CBB/g soil
0	6(24%)	2.7×10^6	3(12%)	1.3×10^5	6(25%)	3.1×10^7
7	7(28%)	2.0×10^3	—	1.3×10^2	16(64%)	2.7×10^5
14	—	—	—	—	21(84%)	1.3×10^5
21	—	—	—	—	25(100%)	2.1×10^4

Growth of Cuttings in Infested Soil

An area of land 25 × 25 m was divided into nine plots of 5 × 5 m, each plot separated by 3 m. Each plot was planted with 100 cassava cuttings at 50 cm spacing along and between rows. Four weeks later plants were inoculated with CBB. Six weeks after inoculation, plants were removed and the plots were treated as follows: (*a*) plants removed; (*b*) plants removed and soil surface hoed; and (*c*) infected plant remains left on the plots.

Each plot was divided into four subplots. These were replanted with another 100 healthy glasshouse-grown plants: 25 on the day of clearing of plots, and 25 at intervals of 7 days up to 21 days after clearing. Plants were scored for symptoms of disease at weekly intervals. Counts of CBB in soil samples (from the 0–5-cm zone) from each plot were also taken on each occasion. Table 2 shows the number of plants that developed disease symptoms when planted in cleared plots that had previously supported infected plants. The data suggest that, after 7 days, there was insufficient CBB in soil in which diseased plants were removed to infect leaves but that where debris was left on the soil surface, numbers remained high enough to cause infection for up to 21 days. Correspondingly, in treatments (*a*) and (*b*), no more plants became infected after 7 days whereas in plot (*c*) numbers of infected plants continued to increase so that by 21 days all were infected.

Discussion

In naturally infested soils, CBB seems to be restricted to the 0–5-cm zone. This is the part of the soil that is usually disturbed during cultural practices and suggests that numbers of CBB bacteria in soil can be reduced considerably by loosening and exposing the soil surface for a period of time before replanting in infested soil. Leu and Chen (1972) did not observe infected plants on planting cassava cuttings in fields from which infected plants had just been cleared. However, if good control is to be achieved, the infected plant debris on the soil surface of infected plots must be cleared and burned.

Generally, survival of CBB in soil was poor (21–28 days) but was longer in near-neutral soil than in acid soils. Planting cassava in acid soils or soils of low pH may be a way of reducing the risk of infection through soil splashes.

Survival of CBB in sterile soil was longer than in nonsterile soil. This is because xanthomonads lack competitive ability as saprophytes. Hence in sterile soil where all the microbial competitors have been eliminated, CBB survived longer. The introduction of antagonistic microorganisms to infested soil may be useful in keeping CBB numbers low and reduce risk of infection of healthy plants. The lack of surviving cells in sterile Popayan soil may be due to the fact that substances toxic to CBB were released from the volcanic soil during sterilization.

Both flooding and desiccation decreased the longevity of CBB in soil. However, flooding has its attendant problems in that it may drastically alter soil structure and ecological balance in favour of harmful indigenous soil-borne pathogens. Also, it may leach essential minerals from the soil. By planning periods of cultivation so that the dry season falls between one cropping season and another CBB can virtually be eradicated through natural soil desiccation.

A problem arising from soil infestation by CBB is that plants become infected from soil splashes during rainstorms. Fortunately, this is important only when the soil is heavily infested with CBB and contains more than 10^4 CBB cells/g. Again regular loosening of the surface soil to expose it to the sun and dry air is likely to be useful in keeping the population of CBB in soil low, hence the incidence of disease resulting from soil splashes will be low.

Ikotun (1976) has shown that *X. manihotis* cells survived for up to 24 mo in dried bacterial exudate and for more than 30 mo in dried infected cassava stems. These results are similar to those obtained by Terry (1974) in which *X. manihotis* survived

and retained infectivity after 22 mo of dry storage at room temperature.

Comparison of survival times of CBB in bacterial exudate and host tissues indicates that the soil is not a favourable niche for survival. The most important niches in the survival of CBB that aid carryover of viable and infective cells from one cropping season to another are the bacterial exudate and the host tissues. *X. manihotis* therefore belongs to group A of Buddenhagen's classification (1963) of pathogens whose soil phase is one of a rapid decline in numbers. Populations are developed mainly in the host, and survival is mainly in the host plants and their remains. As CBB does not form spores, it is at a disadvantage and has to survive in a niche that offers protection, such as exudate and host tissues. It is known that CBB cells are surrounded by an extracellular heteropolysaccharide (Ikotun, unpublished data). This slimy substance is similar to that produced by *X. phaseoli* (Leach et al. 1957) that confers protection on the bacterial cells against toxic chemicals, radiation, and desiccation.

These results emphasize the importance of bacterial exudates and infected host plant materials in the survival and carryover of CBB from one cropping season to another. Due to the long periods of survival of CBB in exudates and plant materials, it is important to remove dead infected plant parts from the field and burn or bury them to prevent disease carryover. It is also important to use clean planting material to prevent the establishment of the disease in a new plantation.

Acknowledgments

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Influence of Shade and Intercropping on the Incidence of Cassava Bacterial Blight

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National cassava surveys and germ plasm collections were commenced in Nigeria in 1973 to assess local farm practices and factors affecting production. The latter includes incidence of cassava bacterial blight (CBB). At least two of the farms in each area visited were homestead farms and the others distant farms. In both Imo and Anambra states where the survey was carried out between July and October, CBB incidence was consistently lowest in homestead farms and highest in distant farms (Arene 1975).

Generally in the areas surveyed, homestead farms are characterized by continuous intercropping under compound shade trees. Fertility is maintained by use of farmyard manure and household refuse. In distant farms, monocropped cassava with crop rotation is the general practice.

The experiments reported below were designed to determine the effect of shade and intercropping on CBB incidence on cassava.

Effects of Shade

Twelve 15-cm clay pots filled with sterile soil were grouped into four sets and arranged in a randomized block design with four replicates to compare the effects of soil infestation and shading on CBB. Shading was achieved by placing the pots under a white, transparent polythene shade. Infected cassava debris served as source of inoculum. This was thoroughly mixed with the soil for infestation. Two apparently healthy cassava cuttings of variety 53101 were planted in each pot. These were regularly watered. The percentage of diseased shoots was estimated monthly for 5 mo.

Effects of Intercropping

A randomized block experiment with 10 replications was used to compare CBB incidence as affected by the following treatments: (1) cassava planted alone; (2) cassava interplanted with maize; (3) cassava interplanted with melon; and (4) cassava interplanted with melon and maize.

Variety 53101 was used as the test crop. Each plot was 0.0076 ha and was planted at a plant population density of 9259 cassava stands/ha (90 cm on 120-cm ridges). Maize was planted on both sides of the ridges between cassava stands; melon was planted on the ridges after every other cassava stand. CBB was recorded after 4 mo when the melon had been harvested.

Results

The effect of shading on the percentage of diseased shoots at various times after planting was estimated by multiple regression analysis using the equation:

$$y = 29.06 + 20.30x_1 + 2.87x_2 - 3.28x_1x_2 - 6.02x_3 - 2.56x_1x_3$$

where x_1 = shading, x_2 = infestation, and x_3 = time from planting (months; the coefficient of determination $r^2 = 0.566$).

The infestation of the soil per se was not significant in contributing to the number of diseased shoots, but shading significantly affected incidence of the disease. (Fig. 1). Thus there were no differences between infested and noninfested pots when both were either shaded or unshaded, but the difference between shaded and unshaded pots was significant with CBB incidence higher in unshaded pots. Except for the 5th mo after planting, which had the highest percentage of incidence, there were no significant differences in incidence with time.

The highest incidence (22.8%) was found in the cassava planted alone. This was significantly higher than the incidence in any of the other three intercrop treatments.

Discussion

Although the combinational differences in the variables (shading, soil infestation, and time) contributed 56.6% of the variation in incidence of CBB among cassava plants, soil infestation alone was not a significant contributor. Variations in shading contributed a major share of the variations (cf. 45, 3.7, and 1.0% unique contributions of shade, time, and soil infestation to the total sums of squares).

Movement of the bacteria in highly lignified tissue is very limited (Lozano 1973). It seems unlikely that direct penetration of the woody cutting by the bacteria from the soil and the subsequent infection of the young shoots occurs. Arene (1974) had earlier suggested that inoculum

may be carried from the soil via rain splashes to young shoots where they initiate secondary infection. We have also observed this, where the shading of the soil surface reduced CBB infection and consequently, incidence. The melon reduced the impact of raindrops and hence the height of the splashes whereas the maize served as a sideshield from raindrops and splashes. Therefore, CBB incidence was lower in the intercropped plots than in the plots cropped with cassava alone.

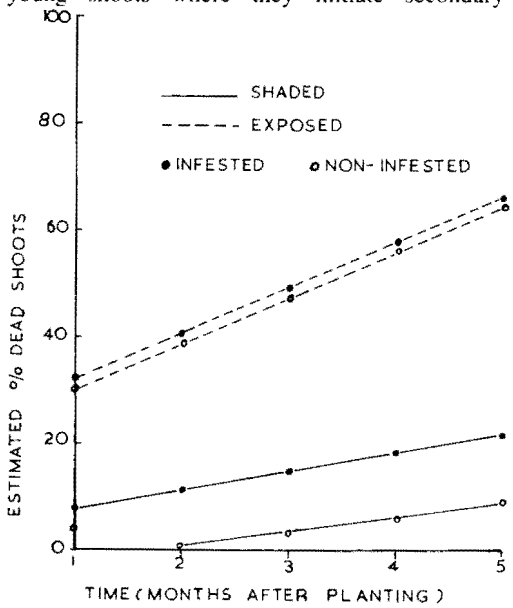

Fig. 1. Estimated percentage of diseased shoots at different time intervals after planting as affected by shading.

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Country Statements

People's Republic of Benin

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Cassava bacterial blight (CBB) was first officially recorded in the People's Republic of Benin (PRB) in September 1976. However, evidence from local farmers suggests that the disease has been present since at least 1968 and CBB symptoms were identified by IITA scientists in 1974. It is now found in many areas in the central and southern parts of the country.

Epidemiology

CBB was first observed in PRB in varieties imported from Nigeria. The cultivation of infested cuttings and their distribution to new areas have probably contributed to the extension of the disease. Local varieties are apparently more tolerant to the disease.

There is a long history of an illegal traffic in cassava cuttings into PRB from Nigeria, especially along the border where the soils are less favourable for cassava production. This makes it impossible for the Plant Quarantine Service to control the entry and distribution of new varieties into the country.

Control

The recommended measures are to: (1) forbid the transfer of vegetative material out of infested areas; (2) forbid the introduction of vegetative material from other African countries; (3) improve quarantine services at all border posts; (4) advise farmers of the seriousness of the disease and the importance of preventing its further spread; and (5) progressive replacement of susceptible cultivars with resistant ones.

People's Republic of the Congo

J. Batsimba and J. Mabanza

Ministry of Scientific Research with the collaboration of the Ministry of Rural Economy and Laboratory of Phytopathology of ORSTOM

Bacterial isolates were obtained from cassava collected in several regions. The isolates produced yellowish-white, gram-negative colonies on potato dextrose agar. Cultural characteristics are being studied further, but they are probably isolates of *Xanthomonas manihotis*, the causal agent of cassava bacterial blight (CBB).

Symptoms

The blight usually begins as a rapid withering of one or more leaves on an apparently healthy shoot. The leaves wither and die in a few days. The leaf wilting and defoliation is generally accompanied by darkening of the stalk and exudation of a yellowish gum. The symptoms then appear on other leaves, as shown by the exudation of a yellow-orange gum that precedes the progressive darkening of the branches and the appearance of dark necrotic spots.

Histological sections from a blighted branch, taken from the advancing margin of the necrotic lesion, show darkening of the conducting vessels of the wood, indicating localization of the pathogen in the vascular tissue.

After isolating the bacterium, its pathogenicity was confirmed by injecting it into the petioles of young cassava plants, with a needle inserted into the axil of the petioles. After 6–10 days, the inoculated leaf wilted and a dark necrotic spot formed at the point of inoculation. Histological studies have shown that the withering of the petiole is due to the mechanical blocking of the conducting vessels of the stalk by the bacterial cells and their gum exudate.

The blight can progressively infect the whole shoot and lead to its complete defoliation after a few weeks. Certain fields, especially those of

highly susceptible varieties such as Odzion, can be completely defoliated.

In some instances, less severe symptoms occur. These are dark, water-soaked, necrotic leaf spots. These spots can coalesce into large lesions, leading to the desiccation of the upper part of the branch. These spots can be confused with those of anthracnose.

Geographic Distribution

Surveys are being made to assess the distribution of CBB and the extent of its damage.

Brazzaville Region

The symptoms of CBB were seen first near the capital, however the damage caused was not extensive.

Brazzaville–Gomboma

Almost all the plantations near highway 2 were infected. At Olano and in the Odziba and Ngo areas, many fields were severely damaged. At Gomboma, symptoms of CBB were seen, but were less widespread than in the preceding localities.

Ngo–Djambala–Lekeme

Severe attacks were observed along the Ngo–Nsa–Djambala road. On the Koukouya plateau (Lekana zone), mild leaf spotting was the most frequently observed symptom.

Odziba-Ngaba

This zone is heavily infected. At the state farm at Mbe, a 40-ha field of Odzion was severely affected while two other similar-size fields of the variety N'ganfoud had low incidence.

Brazzaville–Kinkala–Boko

A few small and probably new disease centres were seen along the Brazzaville–Kinkala Road. At Kinkala, there was severe infection at the state farm in 12-mo-old cassava. In the cassava collection, the variety Odzion was highly susceptible whereas others such as N'ganfoud and Moundele were tolerant. CBB has recently appeared on village farms in the Kinkala zone.

Centres with a high rate of infection were found between Kinkala and Boko. CBB is widespread in this region, but is causing only moderate damage.

Kinkala-Loudina

CBB was observed outside Missafou.

Mouyondzi Region

Severe attacks have been seen on the variety Ngouangouala on village farms.

The initial surveys show that the main centres of CBB are in the north of Brazzaville from the Gabonese frontier to the Congo River. These probably correspond to the areas of introduction of disease into the Republic.

Epidemiology

The modes of transmission of CBB are not precisely known. However, it is probable that insects, rain, and streams play an important role in the spread of CBB over short distances. Over long distances in the Congo, the most efficient means of spread of CBB has been by the transportation of infected cuttings. The absence of necrotic lesions on the woody stems masks the presence of the pathogen, misleads the farmers, and favours the dissemination of infected cuttings.

The symptoms of CBB become more pronounced during the rainy season. The considerable defoliation during the period of maximum growth of the cassava affects final yields.

Economic Consequences

The damage caused by CBB may be measured by the destruction of the leaves (which are eaten in large quantities), the disturbance of tuberization, and the weakening of the plant, which makes it more sensitive to other unfavourable factors. The effect on yield probably depends on the age of the cassava and the time of infection. Because cassava is a staple food for most Congolese, a considerable fall in yield becomes quickly apparent on the market, especially in urban centres.

Control

The extent of the damage on severely attacked plantations shows clearly the potential danger of this disease. If the blight extended to all regions of the Republic, the economic consequences would be disastrous. It is therefore imperative that the disease be controlled through phytosanitary measures and further research.

Immediate Phytosanitary Measures

(1) Isolation of epidemic zones — It appeared in many cases that new areas became infected following the importation of blighted cuttings, which should be avoided in future. Transportation of cassava stems outside Pool and Plateaux regions should be prohibited. It is important also that farmers be informed of the danger inherent in planting infected cassava stems.

(2) Destruction of heavily attacked fields — On state farms, fields showing heavy attacks should be destroyed as they are sources of infection for insect vectors. Sanitary trimming of plantations at the beginning of attack may also be useful.

Research Objectives

The above measures may delay the extension of the epidemic, but they are not sufficient to solve the problem. It appears desirable that in-depth research be carried out to define efficient, longer-term control measures.

(1) Epidemiological study — A systematic inventory of all the major centres of infection should be made. The study could include work on insect vectors. The presence of CBB in the Congo follows closely on the great cochineal attack observed in 1974. An ecological study is also necessary to demonstrate if the Plateaux region favours the evolution of an epidemic, as is indicated by field observations.

(2) Etiological study — The characteristics of the bacteria should be clearly described. Also, the means of entry of the pathogen into the host and its subsequent development should be clarified. It would also be interesting to verify if the shoots attacked by cassava mosaic are more susceptible to bacterial invasion.

(3) Resistant varieties — The solution to the CBB problem will probably be the planting of resistant or tolerant varieties selected from a wide range of material. It is necessary to carry out a thorough inventory of the Congolese varieties, and to assemble as wide as possible a collection of these in a centre where their resistance can be evaluated by artificial inoculation with different bacterial isolates. If there is no useful resistance amongst Congolese varieties it will be necessary to import new material from other cassava-growing countries, such as Colombia.

Conclusion

CBB seems to be sufficiently localized at present that stringent quarantine precautions should delay the extension of the epidemic. However, the number of cassava varieties cultivated in the Congo is relatively small, and these varieties are probably not sufficiently resistant to stop the natural dissemination of the pathogen with time. It is desirable, therefore, to prevent the blight from spreading to the village farms where control is difficult.

Ghana

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Cassava bacterial blight (CBB) was first observed by me in Ghana in the Amasaman/Pokoase areas of the Greater Accra Region in August 1975. It was later observed in Legon in the Greater Accra Region (Doku, personal communication), and Angloga, Keta, Denu, Adina, and Ohau areas of the Volta Region (Addision, personal communication). The symptoms observed were angular leaf spots, leaf wilt, defoliation, stem exudation, and tip dieback, which are similar to those described for CBB in other countries. The causal agent, however, has not been isolated and characterized.

The disease is now known to occur in the coastal savanna areas of Greater Accra and Volta regions and the southern parts of the Eastern and Central regions. The resulting losses have not been accurately estimated, but casual observations suggest that they may be high.

Epidemiology

No work has been done on this aspect of the disease in Ghana, but there are clear indications that the disease is spread mainly through the use of infected cuttings and by rain splash. The disease was quite localized in 1975, but after the 1976 major rains (March–May) and subsequent planting the disease has been reported far from areas where it was first observed. Most varieties are susceptible.

Control Measures

The presently recommended control practices are: (1) planting of new farms at least 1 km away from known affected farms, and using disease-free planting material; (2) on fields from which infected plants have been harvested, all debris should be collected and burnt, the land ploughed and harrowed, fallowed for 6 mo, and then replanted

with disease-free cuttings; (3) removal and burning of plants showing early symptoms of the disease. This is not popular with farmers, and resistant or tolerant varieties need to be made available to farmers at the same time; (4) intercropping of cassava with nonhost crops, such as maize; (5) planting horizontally to encourage development of more shoots, which may sustain production even if some become infected; and (6) planting branching varieties for the same reason.

Togo

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Distribution

Cassava bacterial blight (CBB) was first found in Togo in July 1975, in the fields of l'Institut de Recherche d'Agronomie Tropicale (IRAT) stations and at the University of Benin. At the latter site, 20–25% of the plants were affected. The Plant Protection Service subsequently commenced a systematic survey in all regions to evaluate the distribution and importance of the disease.

CBB is presently localized in the coastal region and occurs throughout the southern part of the country. It has been progressively moving up from the coast since 1975 and it is likely that it will spread further into the interior. However, most cassava (92%) is grown in the southern part of the country, where the soil is poor. Many varieties are susceptible to the disease.

Epidemiology

The disease was apparently introduced into the country by the accidental importation of infected cuttings. Water appears to be an important factor in the local spread of the disease.

Control Measures

The following control measures are recommended: (1) prevent the movement of cuttings from one area to another; (2) prevent the planting of cuttings from diseased plants; (3) destroy diseased plants by burning; and (4) identify resistant varieties.

Concluding Statement by Participants

The major diseases of cassava in Africa are cassava mosaic (CMD) and cassava bacterial blight (CBB). CMD has been confirmed in Africa since 1894 and has long been regarded as a widespread and serious disease. Bacterial blight has been confirmed as a damaging disease in South America since 1900. In Africa, it was first identified in Nigeria and Zaire in 1972, and has subsequently been found in Ghana, Togo, the People's Republic of Benin, Cameroon, and the People's Republic of the Congo. It is likely, however, that the disease was present in these countries for several years before it was identified. It may also be present in other African countries, especially in West and Central Africa. It apparently does not occur in Ethiopia, Kenya, or Tanzania.

Estimates in Nigeria suggest that the losses due to CBB in the former East Central State in 1973 amounted to ₦24 million. Approximately 75% of the crop was lost in the most severely affected areas. Serious economic losses have also been reported from Zaire, Togo, Ghana, and the People's Republic of the Congo.

In addition there are social and economic implications with the loss of tubers, an important staple food, the destruction of cassava leaves, which are a major source of protein in some areas (e.g., Zaire), and the loss of starch for agroindustrial projects (e.g., Ghana).

Immediate Control Measures

(1) Prevent the movement of cuttings from infected areas to areas where the disease is not known to occur.

(2) Select local cultivars tolerant to the disease until CBB-resistant, high-yielding cultivars are available. Planting material of such varieties should be made available to farmers. They should preferably be planted on fertile soils or supplied with fertilizer to encourage vigorous growth.

(3) Destroy young infected crops to reduce sources of inoculum.

(4) Encourage shifting cultivation in areas where it is practiced. In areas where there is pressure on the availability of land, all cassava plants and debris should be removed from the field after harvest and burnt to destroy the pathogen. The field should be fallowed or planted with a crop other than cassava for at least 6 mo. Deep ploughing of the field after harvest may also aid the destruction of the pathogen in soil and plant debris.

(5) Encourage mixed cropping with crops appropriate to the region rather than monocropping cassava in areas where the latter practice is preferred.

(6) Where practicable, change time of planting to avoid the period of peak disease development, which is during the middle of the rainy season (i.e., plant cassava toward the end of the rains).

(7) Use early maturing varieties where these are available.

Suggestions for Future Research

(1) Study of strain differences in the bacterial blight pathogen *Xanthomonas manihotis* in different countries. Such a study would be coordinated by IITA because of its implications in screening varieties for resistance.

(2) Surveys on the distribution and importance of CBB in countries where it is known to occur. Surveys to identify its presence in countries where it has not yet been reported, with particular emphasis on areas where cassava is introduced into the country (e.g., frontiers, agricultural stations).

(3) Organization of a network in Africa for evaluating cassava seedlings for their resistance to important diseases and insect pests, desirable agronomic characters, and high yield potential.

(4) Establishment of facilities for the rapid multiplication of high-yielding, disease-resistant cultivars once these have been identified. In the meantime, such facilities could be used for the propagation of local varieties tolerant to CBB that could be used by farmers until improved varieties are available.

(5) Further study of the effects of agronomic factors on the development of CBB with the view to clarifying and improving methods for cultural control.