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Research Article

Geographical Distribution and Incidence of Cassava Bacterial Blight (*Manihot esculenta* Crantz) Caused by *Xanthomonas axonopodis* pv. *manihotis* in Two Agro-ecological Zones of Côte d'Ivoire

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Abstract

Background and Objective: Cassava (*Manihot esculenta* Crantz) is the second largest food crop in Côte d'Ivoire after yam. It is cultivated for its fleshy roots rich in starch and for the richness of its leaves in minerals (calcium, phosphorus and iron). However, this crop is subject to numerous biotic constraints of which one of the most formidable is bacterial blight caused by *Xanthomonas axonopodis* pv. *manihotis*. In Côte d'Ivoire, no concrete study has been conducted on this emerging disease with the aim of reducing its impact on the yield of tuberous roots of traditional and improved varieties. The objective of this study is to study the distribution of bacterial blight on the one hand and to assess the sensitivity of 8 varieties through an epidemiological study in two agro-ecological zones of Côte d'Ivoire on the other hand. **Materials and Methods:** Survey missions conducted in 2013 and 2014 have helped establish the health map of the different cassava production zones, followed by an epidemiological study of the disease with 8 cassava varieties of which four are improved, in two cassava production zones (Yamoussoukro and Ferkéssédougou). **Results:** The results showed that bacterial blight was observed in all agro-ecological zones with an incidence ranging from 2.17-66.67%. As for the epidemiological study, it showed a contrast between the two areas of study. The severity of the disease was very low in the dry season (December-March) corresponding to the 7th until the 10th month of this study. Moreover, the rainy season contributed to an expansion of the disease. Diarrassouba and Yacé (traditional varieties) and Bocou 1 (improved variety) were the most susceptible to the disease. **Conclusion:** A fight against this disease must be envisaged before it spreads to all cassava cultivation zones in Côte d'Ivoire.

Key words: Cassava, bacterial blight, distribution, incidence, *Xanthomonas axonopodis*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz, Euphorbiaceae) is an important crop in Africa, where it contributes to food security in many rural and urban households[1,2]. It can be used in a wide spectrum of industrial activities, including food industry, pharmaceutical laboratories, textile, paper and glue-making industry, as well as raw material for the production of biofuel ethanol[3]. It is also consumed in several forms[4,5]. In the early 1980s, following the fall in prices of agricultural raw materials such as cocoa and coffee on the international market, many farmers in the tropical zone engaged in cassava production not only for self-consumption of producing households, but also for marketing[6]. Cassava cultivation is less demanding in terms of input. Its cultivation is suitable for poor soils and arid climates. This hardiness, combined with its multiple food uses makes it an important food crop for food security[7,8].

In 2013, the annual national yield of cassava in Côte d'Ivoire, which was estimated at 2,436,496 t, rose to 4,239,303 t in 2014 with 500,000 ha of cultivated area[9]. However, diseases and pests are the main causes of decline in yields of this crop. Thus, the damage caused by virus diseases and *Xanthomonas axonopodis* pv. *manihotis* bacterial blight can be considered as the main yield-limiting factors in all cassava cultivation zones[10,11]. Cassava bacterial blight caused by *Xanthomonas axonopodis* pv. *manihotis*, appears as the most important restrictive bacteria for this crop[10,12]. Bacterial blight was reported for the first time in Latin America in 1912 and appeared in Nigeria and Africa, in 1972 and is now extending to many countries of the African continent[13]. In most severe cases, bacterial blight can cause a total loss in tuberous roots and foliage, a reduction in starch content and a destruction of planting material. Decrease in yield vary[14] from 20-100%. This bacterial disease, however could have significant economic consequences if preventive measures are not adopted by farmers. The use and exchange of plant material between producers may be an important source of disease spreading. Faced with this situation, studies are needed so as to prevent or control the spread of this bacterial disease in Côte d'Ivoire. Thus, the assessment of the distribution and incidence of bacterial blight in farmers' fields Côte d'Ivoire are all preliminary work to be carried out. This study therefore focused on the assessment of the distribution and incidence of bacterial blight in cassava cultivation zones in Côte d'Ivoire. It consisted in assessing the behavior of 8 cassava varieties on-farm vis-à-vis *Xanthomonas axonopodis* pv. *manihotis* in two distinct agro-ecological zones of the country. In that respect, two experimental plots were established in 2014 in the center in Yamoussoukro and in the North in Ferkéssédougou respectively.

MATERIALS AND METHODS

Two studies were carried out, on the one hand by performing a survey aiming at quantifying the importance of infections by bacterial blight in the main cassava cultivation zones of Côte d'Ivoire while identifying the heavily infested zones that can serve on the other hand as sites for cassava variety screening tests. Thus, two agro-ecological zones were selected basing on infection rate and ease of access.

Localization and description of experimental sites on-farm: The experiments were conducted in two agro-ecological zones namely the agro-ecological zones (AEZ) IV and VI. One of the trials was set up on the plot with the following coordinates: 005°135.54′ North latitude, 06°479.42′ West longitude and 232 m altitude. This test is located in central Cote d'Ivoire, in the department of Yamoussoukro in AEZ IV. As for the second test, its set up occurred in Koutiénédougou at 005°159.17′ North latitude, 09°265.28′ West longitude and 380 m altitude, in the department of Ferkéssédougou in Northern Côte d'Ivoire in AEZ VI. These test plots were chosen basing on the level of infection by bacterial blight, land availability, accessibility, topography, climate and soil type. Both trials were conducted in farmers' fields from 2014-2015. The agro-ecological zones (AEZ) where these behavioral tests were conducted are in the dense humid and semi-deciduous forest and the humid tropical Savannah respectively. The AEZ IV has an altitude ranging from 0-200 m, with a rainfall regime showing a bimodal shape and an annual average oscillating between 1300 and 1750 mm while that of AEZ VI varies from 300-500 mm, with an annual rainfall ranging[15] between 1150 and 1350 mm.

The study area of Yamoussoukro is located in the center of Côte d'Ivoire. The climate of the region corresponds to the attenuated transitional equatorial regime (Baouléen climate) characterized by four seasons of which two rainy seasons (long rainy season from March-June and short rainy season from September-October) and two dry seasons (short dry season from July-August and very marked long dry season from November-February, however with some isolated rainfalls). The interannual average temperature of the Yamoussoukro region is about 26°C. The relative humidity varies from 75-85% with falls at 40% during the harmattan period. The region is marked by a succession of several soil types ranging from reddish soils that are more or less gravelly, having fine to medium texture and well-draining to yellow-brownish or brownish soils that are more or less gravelly having medium texture and quick-draining[16].

The department of Ferkéssédougou is characterized by a tropical sub-humid or sub-Sudanese transition climate,

between the equatorial and hot desert type[17]. It has two seasons: A rainy one, extending from March-October and a dry one, from November-February. Between mid-November and February, the harmattan, a hot dry wind of Saharan origin from the Northern sector, blows and influences the climate of the region. The average daily temperature reaches 27°C with generally low thermal shifts except during the period marked by the harmattan (15-20°C) which extends from mid-November to February[18]. In this region, there are gallery forests along streams, consisting of wooded and shrub Savannah vegetation[19,20]. It consists mainly of remolded ferralitic soils, strongly to moderately desaturated. Very heterogeneous in space, these soils are characterized by a strong tendency to induration and sensitivity to compaction[18].

Plant material: In order to study the distribution and incidence of bacterial blight, the surveys focused on cassava plants (*Manihot esculenta*) of cultivated local and improved varieties. As for the study of the varietal behavior of cassava plants on-farm, three improved varieties originating from the National Center for Agronomic Reserach (CNRA), one improved variety originating from the Swiss Center for Scientific Research (CSRS) in Côte d'Ivoire and four other traditional (local) ones were under on-farm trial in two distinct agro-ecological zones. These included Bocou 1, Bocou 2, Bocou 3 and Yavo for improved varieties and Yacé, Akama, Diarrassouba and Dankwa and for local varieties (Table 1).

Survey and sampling method: Farmers' cassava fields were visited between July and August, 2013 and 2014, in six of the seven agro-ecological zones of Côte d'Ivoire. The observations were carried out during the rainy season of the year, corresponding to the most favorable period for the observation of symptoms. Only agro-ecological zone VII (AEZ VII) corresponding to the Northeast, where cassava cultivation is low, could not be visited during these surveys. Agro-ecological zones were defined by Halle and Bruzon[15] depending on weather conditions, soil type, importance of the predominant ecosystem and major biotic and abiotic constraints of the crop. In each agro-ecological zone, several cities were visited. Several fields were observed in each city. The number of plots visited in a city was based on the phenological stages of cassava plants. The first field of each city was visited. Then the other prospection were carried out each time a distance of at least 30 km was covered. The observations were made along the main roads linking cities from North-South and from East-West. The surveys concerned only the seedlings of 3-6 months and 8-11 months after planting and dominant varieties of the visited plot. In each parcel visited, observations were made according to diagonals. The parameters rated for each plot were the name of the city of the prospected plot, the geographical coordinates and altitude, the age of the plants, the estimation of the plot surface area and the rating of phytosanitary parameters. Geographical coordinates and altitude were taken using a GARMIN GPS. For the rating of phytosanitary

Table 1: Characteristics of four traditional varieties of Côte d'Ivoire and four improved varieties disseminated

Varieties	Cycle (months)	Average yield (t ha^{-1})	Characteristics	Common usage
Yacé	11-18	20	Variety sensitive to mosaic, mites and scale insects, Dry matter content 40% Good for processing into attiéké	Attiéké, placali
Diarrassouba	*	*	Sensitive to mosaic, mites, bacterial blight and scale insects	Attiéké, placali, foutou
Dankwa	*	*	Study in progress	Attiéké, placali
Akama	*	*	Sensitive to mosaic, mites, bacterial blight and scale insects	Attiéké, placali, foutou
Bocou 1 (CNRA)	12-20	25	Variety having a very good vegetation cover Sensitive to mites High yield Dry matter content 39%	Attiéké, placali, foutou
Bocou 2 (CNRA)	11-16	25	Variety having a very good vegetation cover Sensitive to mites Sensitive to root rot Easy harvesting High yield Dry matter content 38%	Attiéké, placali, foutou
Bocou 3 (CNRA)	12-16	25	Variety having a very good vegetation cover Virus disease-tolerant Sensitive to root rot High yield Dry matter content 37%	Attiéké, placali
Yavo (CSRS)	*	*	Variety having a good vegetation cover	Attiéké, placali, foutou

N'Zue *et al.*[14] modified, *Undetermined

parameters, 15 plants were randomly selected and rated on a scale of 1-5 according to the method recommended by Boher and Agbobli[21] and IITA[22].

During these surveys, leaves or stems of cassava plants showing symptoms of the disease were removed and placed into khaki envelopes and then stored at room temperature before being sent to the laboratory for isolation of the pathogen. Confirmation of the presence of the pathogen is obtained by isolation, inoculation and observation of symptoms.

Distribution and incidence of bacterial blight in Côte d'Ivoire: The study of the distribution of bacterial blight was conducted on the basis of the disease symptoms (bacterial blight) observed in the plots visited. It consisted in rating the presence of bacterial blight and disease severity.

In order to determine the distribution of cassava bacterial blight in the production areas on a map, a classification of the agro-ecological zones prospected was made from medium impact data. Thus, the agro-ecological zones were grouped into four classes: incidence (1: 0-15%, 2: 15-35%, 3: 35-55% and 4: >55%).

Preparation of plots and planting material: In view of their size which does not require the use of agricultural machinery and wishing to remain in producers' conditions, the experimental plots were plowed manually using a hoe. Cuttings measuring 25 cm long having 4-6 germ nodes were used as seed. On each experimental plot, the different cassava varieties were planted the same day. The plots were weeded each using a hoe 4-5 times throughout the duration of the study.

Experimental designs: The experimental design consisted of a three-block Fisher design (3 repetitions) spaced 2 m from each other. The trials were set up during the crop year 2014 in Yamoussoukro and Ferkéssédougou, respectively. The experimental designs were bi-factorial of three blocks of which the city represented the first factor and cassava varieties the second factor. The main plot (Block) represented respectively an area of 8000 m^2 in Ferkéssédougou and Yamoussoukro. It was subdivided into three sub-blocks of 2500 m^2. The sub-blocks were separated by a distance of 2 m used as path. Each sub-block was subdivided into 8 plots (elementary) of 300 m^2, which were separated by an interval of 1.5 m and each of them contained a variety of cassava. In each elementary plot, 10 lines of 30 feet were noted and cassava plants were arranged at 1×1 m with 224 feet in the usable area. This usable area did not include plants that were placed within the border lines of each elementary plot. Each variety was represented once in each of the three sub-blocks. No phytosanitary treatment was applied throughout this study. The cuttings were obliquely planted on mounds in Ferkessédougou and on flat land in Yamoussoukro.

Symptomatology of cassava bacterial blight: Two months after planting the cuttings, 30 cassava plants of each elementary plot were selected and marked with tags. From that period, the trials were monitored so as to observe the possible presence of typical symptoms of bacterial blight. The observations were made monthly in two crop cycles on both sites. The symptoms were photographed and then described. Bacterial blight development monitoring was made according to a visual diagnosis based on the observation of characteristic symptoms appearing on the leaves and stems of cassava plants.

Assessment of the incidence of bacterial blight on two successive crops cycles: Two months after planting, the percentage of symptomatic plants was calculated by counting the plants showing symptoms of bacterial blight in relation to the total number of plants in the plot, according to the equation of Bansal *et al.*[23]:

$$\text{Disease incidence (DI\%)} = \frac{\text{No. of diseased plants}}{\text{Total No. of planrts}} \times 100$$

The calculation of the incidence enabled to know the number of cassava plants attacked and not attacked.

Assessment of the severity of bacterial blight symptoms on cassava plants: In order to assess the severity within the trial plots, 30 plants were randomly observed on two diagonals of each farm. The degree of severity of foliar symptoms began 30 days after the planting of cuttings on a monthly basis. This assessment was made on the underside of leaves of field plants with the rating scale established by the International Institute of Tropical Agriculture[23] which indicates the severity of bacterial blight symptoms.

This scale consists of five degrees or ratings ranging from 1-5. Thus, the following ratings were defined 1 = no symptoms, 2 = presence of angular leaf spots only, 3 = limited leaf burn, wilt, defoliation, the presence of a gummy exudate on the stems and petioles, 4 = widespread foliar burns, wilt, defoliation and necrosis of extremities (die-back) and 5 = complete defoliation and cauline necrosis, stunting and necrosis of side branches with vegetative stop.

The disease Severity Index (SI%) was calculated using the equation adapted by Song *et al.*[24]:

$$\text{Severity index (SI\%)} = \frac{\sum(\text{Scale} \times \text{No. of plants infected})}{(\text{Highest scale} \times \text{Total No. of plants})} \times 100$$

Statistical analysis of data: The data were collected and recorded with the Excel spreadsheet (2007), before being subjected to analysis of variance (ANOVA) using Statistica software version 7.1 on data from both crop cycles.

A post ANOVA analysis was performed in each case for the classification of averages at 5% threshold using the Newman-Keuls test.

RESULTS

Distribution and incidence of cassava bacterial blight in Côte d'Ivoire: The surveys conducted in the six agro-ecological zones have helped detect the presence of bacterial diseases caused by plant pathogenic bacteria on cassava plants. Indeed, the infected plants were young ones and adult ones. The infection reached the leaves as well as the stems, making the plant more vulnerable. The typical symptoms of bacterial blight are expressed in leaves in the form of small brown spots of irregular shape surrounded by a yellow halo of variable diameter up to 3 mm. These spots are less frequent on the stems. Over 160 plots visited during the surveys, cassava bacterial blight was observed in 15% of the plots. Symptoms of bacterial blight were observed in all the agro-ecological zones prospected (Fig. 1). However, a variable incidence was recorded from one plot to another, from one city to another and from one agro-ecological zone to another. In the East and Southwest, bacterial blight was not observed in the visited farms. In cities where it was observed, the infection rates were between 0 and 67%. Thus, the attacks of the bacteria are stronger in AEZ V and VI with the highest incidence values (60 and 66.67% respectively). Agro-ecological zones I and II, showed the lowest values (2.17 and 2.70%, respectively). As for agro-ecological zones III and IV, they had respective intermediate values of 24 and 13.33% (Fig. 2). In AEZ VI wilt strewn with die-back were observed on the plants. In the other AEZs, the disease was overall expressed by angular spots without significant wilt.

Symptoms of bacterial blight observed on two experimental sites: During the two crop cycles on both experimental sites, different types of symptoms of cassava bacterial blight were observed on all 8 cassava varieties tested, traditional varieties (Yacé, Akama, Diarrassouba and Dankwa) as well improved varieties (Bocou 1, Bocou 2, Bocou 3 and Yavo). But the symptoms were stronger on local varieties (traditional ones). During the whole period of observation, bacterial blight symptoms were more visible in the rainy than in the dry season. The disease was more severe on young plants than on old plants.

Overall, such symptoms appeared in the beginning on leaves in the form of necrotic spots with moist appearance (lesions). These lesions appeared between leaf veins and were more visible on the underside of leaves (Fig. 3a). They were small in size of angular shapes. Then these angular lesions merged and became progressively bigger spots that destroyed the leaf blade. The latter turned brown later on and carried at the front end of the brown spot a soaked spot (Fig. 3b). These attacks lead to leaf "burns" that wilt (Fig. 3c), die and fall, causing defoliation and die-back (Fig. 3d) or the final death of the shoot. The leaf "burn" first appeared on the blade, then gradually reached the petiole. The latter takes a horizontal position before the fall of the leaf (Fig. 3d). Drops of a brownish gum were also observed on leaves, petioles and stems of infected plants.

Incidence and severity of cassava bacterial blight in the two study sites: The results of Fig. 4 and 5 and Table 2 show that the 8 cassava varieties tested proved sensitive to bacterial blight, with nuances in the cities of study. These varieties showed low to very high incidences that ranged from 1-89% depending on the city (Fig. 4, 5). Overall, the highest incidence values were obtained on both study sites between the 3rd and 6th months after planting the cuttings (Fig. 4, 5) with peaks in the 4th month. The traditional varieties (Diarrassouba and Yacé) and the improved variety (Bocou 1) were the most sensitive with higher attack rates. In contrast, the local varieties Akama and Dankwa and the improved ones Yavo, Bocou 2 and Bocou 3 showed a relatively low incidence of bacterial blight over the same period. Overall, the lowest incidence was recorded in the 2nd month and the highest one in the 4th month. In that period, there was a general increase of the disease on both sites.

Thus, in the city of Yamoussoukro (Fig. 4), the average incidents observed on plants of 2-10 months were inferior to 60%. In this city, in the 4th month, corresponding to the period when the strongest attacks were recorded, the incidence of bacterial blight symptoms ranged from 20-56.67%. The highest incidences were observed on traditional varieties Diarrassouba (56.67%), Yacé (42.22%) and Akama (35.56%), while the lowest ones were observed on improved varieties Yavo (20%) and Bocou 2 (21.11%). As for

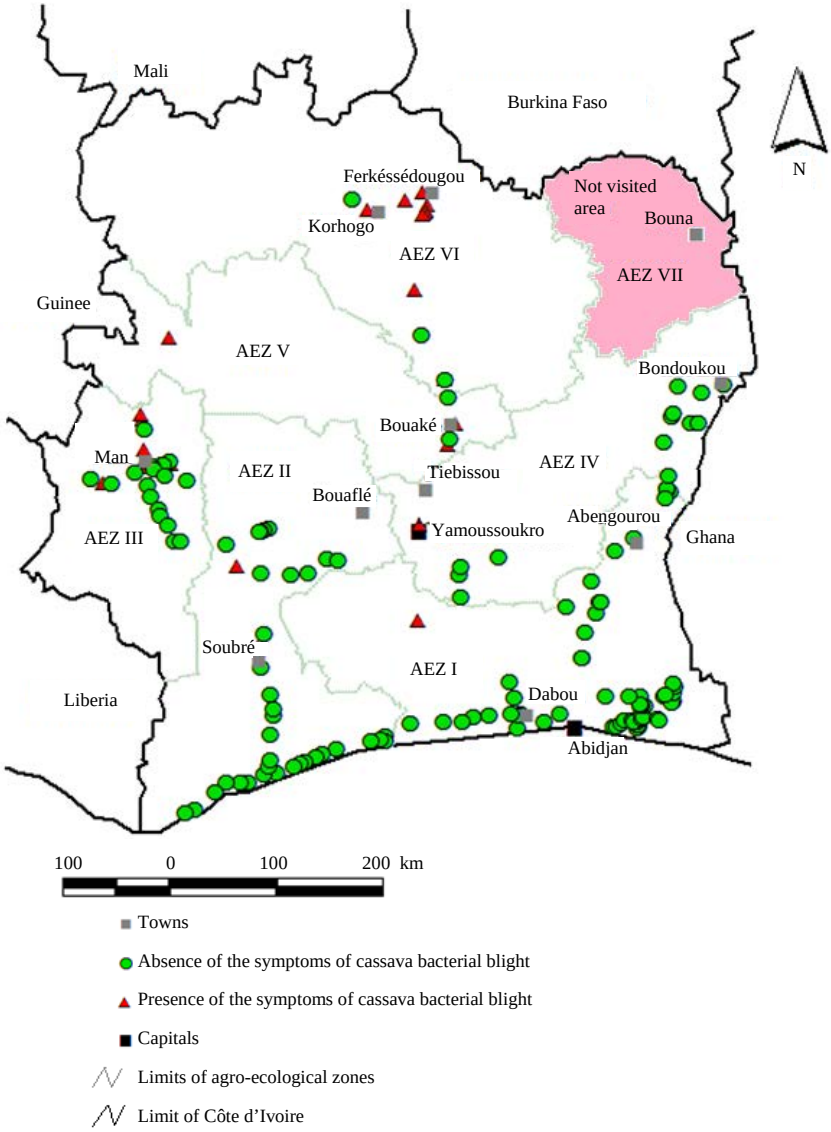

Fig. 1: Distribution of bacterial blight in Côte d'Ivoire in 2013

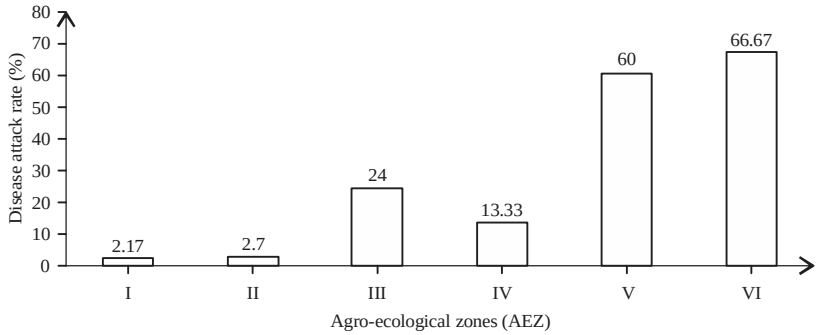

Fig. 2: Incidence of bacterial blight on cassava plants depending on the agro-ecological zones (AEZ)

the city of Ferkessédougou (Fig. 5), the highest average incidences observed on the plants in the 4th month after the planting the cuttings ranged between 24.44 and 88.89%. The traditional varieties Diarrassouba and Yacé recorded the

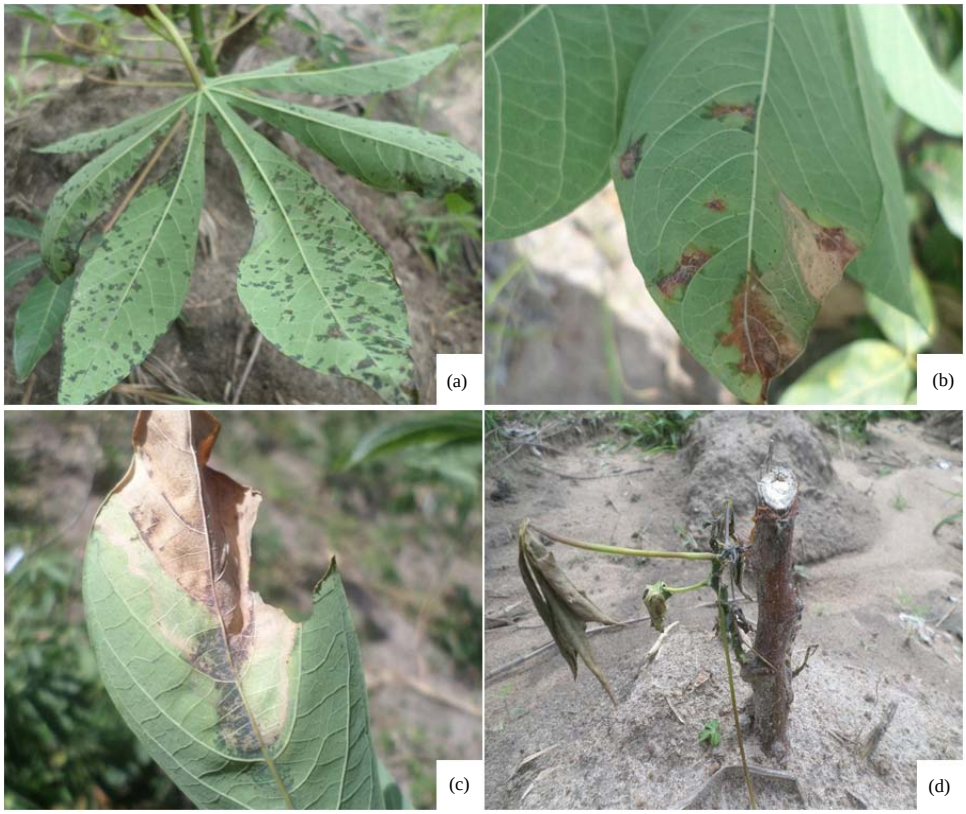

Fig. 3(a-d): Symptoms of cassava bacterial blight seen on the leaves of local varieties and improved varieties on the study sites: (a, b) Wet aspect lesions on the leaves of the variety Diarrassouba in Ferkéssédougou, (c) Angular spots on leaves of the variety Yacé in Yamoussoukro and (d) Die-back on a young plant of the variety Bocou 1 in Ferkéssédougou

Table 2: Level of severity of bacterial blight on the different varieties of cassava on the two study sites

		Severity of infection (%) in different months								
City	Varieties	2	3	4	5	6	7	8	9	10
Yamoussoukro	Yacé	21.11^{b}	26.22^{ab}	32.22^{ab}	31.78^{a}	27.78^{ab}	23.11^{ab}	23.78^{a}	22.00^{a}	23.78^{a}
	Akama	20.22^{a}	28.67^{a}	30.22^{b}	26.89^{b}	22.67^{c}	22.22^{ab}	22.22^{ab}	20.00^{b}	20.00^{b}
	Dankwa	20.22^{a}	23.33^{b}	26.22^{bc}	25.33^{bc}	23.56^{bc}	20.44^{b}	22.22^{ab}	21.33^{ab}	20.88^{b}
	Diarrassouba	20.67^{a}	21.33^{c}	36.67^{a}	27.33^{b}	29.78^{a}	24.22^{a}	22.00^{ab}	21.78^{ab}	21.56^{ab}
	Yavo	20.22^{a}	21.56^{c}	24.67^{c}	22.22^{c}	21.77^{c}	20.67^{b}	20.67^{b}	20.88^{b}	20.22^{b}
	Bocou 1	20.67^{a}	26.44^{ab}	28.00^{b}	28.00^{ab}	27.56^{ab}	23.11^{ab}	22.22^{ab}	20.44^{b}	20.22^{b}
	Bocou 2	20.44^{a}	24.67^{b}	25.33^{bc}	27.33^{b}	27.11^{ab}	22.44^{ab}	22.67^{ab}	21.11^{ab}	20.67^{b}
	Bocou 3	20.44^{a}	22.22^{bc}	26.88^{bc}	25.56^{bc}	25.56^{b}	23.33^{ab}	22.22^{ab}	20.89^{b}	21.11^{ab}
Overall average		20.50	24.31	28.78	26.81	25.72	22.44	22.25	21.05	21.06
CV (%)		1.51	10.90	14.13	10.12	10.96	5.84	3.83	3.13	5.78
Ferkéssédougou	Yacé	21.11^{a}	32.00^{ab}	34.89^{b}	33.78^{a}	30.22^{a}	23.56^{ab}	21.33^{bc}	21.11^{b}	20.67^{b}
	Akama	20.22^{b}	30.44^{b}	27.56^{c}	30.89^{ab}	26.00^{b}	22.00^{b}	21.78^{b}	21.11^{b}	21.33^{a}
	Dankwa	20.67^{b}	26.44^{bc}	29.33^{bc}	27.33^{bc}	23.33^{bc}	21.56^{bc}	21.56^{bc}	22.00^{ab}	21.33^{a}
	Diarrassouba	20.44^{b}	31.56^{ab}	48.67^{a}	33.11^{a}	28.44^{a}	22.00^{b}	24.00^{a}	24.44^{a}	21.33^{a}
	Yavo	20.22^{b}	23.78^{c}	26.22^{c}	24.22^{c}	22.22^{c}	20.89^{c}	20.89^{bc}	20.44^{c}	20.22^{b}
	Bocou 1	21.78^{a}	36.00^{a}	32.89^{ab}	31.78^{ab}	27.56^{ab}	24.44^{a}	22.44^{b}	21.33^{b}	21.11^{a}
	Bocou 2	20.44^{b}	25.78^{bc}	26.67^{c}	28.22^{b}	26.67^{ab}	21.11^{bc}	20.44^{c}	20.67^{c}	20.44^{b}
	Bocou 3	21.33^{a}	23.11^{c}	28.89^{bc}	29.33^{b}	27.56^{ab}	24.22^{a}	23.78^{ab}	20.67^{c}	20.44^{b}
Overall average	20.78	28.64	31.89	29.83	26.5	22.47	22.03	21.47	20.86	
CV (%)	2.75	15.86	23.26	10.74	9.93	6.24	5.87	6.03	2.24	

For the same city and in the same column, the averages followed by the same letter are not statistically different at 5% threshold of the Newman-Keuls test

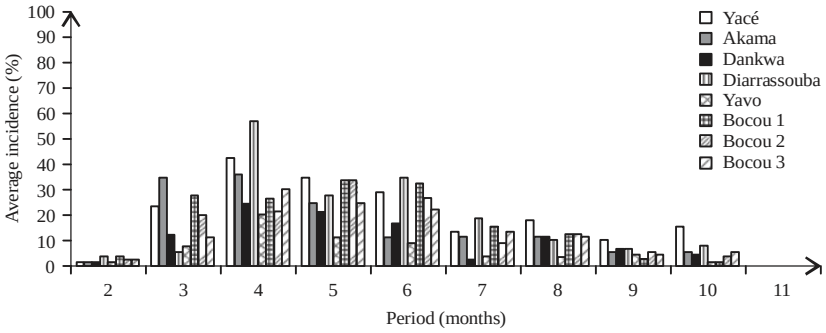

Fig. 4: Incidence of cassava bacterial blight in Yamoussoukro depending on cassava varieties

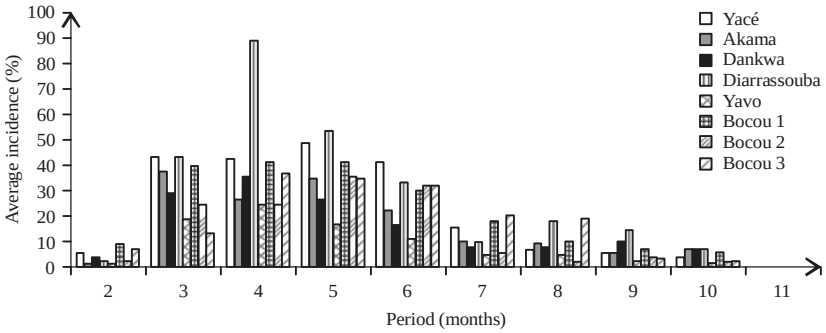

Fig. 5: Incidence of cassava bacterial blight in Ferkéssédougou depending on cassava varieties

highest values of average incidences of 88.89 and 48.89% respectively. In contrast, the lowest values were observed on improved varieties Yavo and Bocou 2 by 24.44%, respectively.

Like the incidence of cassava bacterial blight, regardless of the phenological stage of the plants, the statistical analyses showed a significant to very significant difference between the level of average severity of symptoms in all varieties studied (Table 2). The most significant damage was observed in Ferkéssédougou with die-back effect on variety Diarrassouba. In Yamoussoukro, the levels of average severity of symptoms ranged from 20.22-36.67% with peaks in the 4th month (Table 2). The degrees of severity observed in that period were 36.67, 32.22 and 30.22% respectively for traditional varieties (Diarrassouba, Yacé and Akama). The disease was more severe on all the traditional varieties expressed by angular spots with leaf wilt.

Regarding the city of Ferkessédougou, bacterial blight severity levels ranged from 20.22-48.67%. Four months after planting cuttings, corresponding to the period of higher severity of the disease (Table 2), the level of severity of symptoms varied from 26.22-48.67%. The disease was more severe on local varieties Diarrassouba (48.67%) and Yacé (34.89%) as well as the improved variety Bocou 1 (32.89%). Bacterial blight was stronger in this city with attacks on stems as well as leaves and young small branches.

DISCUSSION

The results of this study reveal the presence of cassava bacterial blight caused by *Xanthomonas axonopodis* pv. *manihotis* in all the agro-ecological zones visited in Côte d'Ivoire with varying incidence. The symptoms observed on the leaves and stems were similar to those described in the literature in other African and Latin American countries[25]. Indeed, the symptoms observed during these surveys were expressed in the aspect of translucent spots characteristic of bacterial attacks described in the aspect of angular spots and leaf burn. The endemic nature of bacterial blight as vascular disease has already been noted in other countries such as South Africa, with no mention of neither the areas of prevalence nor the varieties attacked[26]. This observation could be related to the presence of different strains of the parasite having variable aggressiveness levels. The disease attacks improved varieties as well as traditional (local) varieties with attack levels. Indeed, in the same AEZ several cassava varieties were encountered, some were more sensitive and others were less sensitive. This could cause a change in the incidence of disease from one variety to another[26]. This disease is more rampant in agro-ecological zone VI (AEZ VI), which is a Savannah zone, in the departments of Korhogo and Ferkéssédougou with an incidence of 66.67%. It is less present

in AEZ I (2.17%), which is a forest zone. These observations corroborate those of Banito *et al.*[27] which in the ecological conditions of Togo found that bacterial blight was absent in the forest zone and more severe in the Savannah zone and the forest-Savannah transition area. Several studies in various African countries confirm this assertion with generally highest incidences in the Savannah than in the transition forest zones and rarely in forest zones[28-30]. According to the study of Boher and Agbobli[22], some improved varieties express few symptoms and thus escape the visual health check. However, according to these researchers, such varieties can thereafter be an important source of inoculum. In Côte d'Ivoire, cassava bacterial blight has been increasing significantly in recent years. This situation might be the result of the intervention of several factors: Increased cassava cultivation, seed exchange, lack of resistant varieties, poor agricultural practices and inadequate control measures. Indeed, the climatic conditions of the country are very favorable to the emergence of bacterial blight. In Côte d'Ivoire, there is an alternation of rainy and dry season, maximum moisture and significant daytime and night temperature differences. Now, according to Lozano[31], the variation in temperature between day and night helps favoring the disease. The high incidence observed in the AEZ VI would thus be linked to the subsistence of high humidity and a significant daytime and night temperature difference. These results confirm those obtained by Lamouroux[32] in Central African Republic in 1979, indicating that the equatorial or transition climate is conducive to the development of cassava bacterial blight. Our surveys were conducted in the rainy season and confirm the detection of diseases in this period, namely bacterial blight which parasitic phase process is characterized by epiphytic multiplication of the bacteria, its penetration and proliferation in tissues of the host, unlike the dry season, which is a phase of survival. However, the almost continuous presence of the plant in the landscape could encourage rapid dissemination of the parasite either naturally or with rain runoff and certain insects, without omitting soil depletion[22]. For the establishment of a new plot, cassava producers tend to exchange plant material (cuttings) each other. According to Verdier *et al.*[33], the low availability of plant material explains the frequent exchanges of cuttings between farmers. Indeed, the use of contaminated cuttings is usually the cause of the occurrence of the disease in new plantations where it was initially absent[10,22]. A deep analysis is needed to see if there is morphotype variability of the causative agent of the disease observed. This analysis shall begin with the isolation of the pathogen associated with brown spots of cassava from infected tissues.

This study in natural conditions of infection by *Xanthomonas axonopodis* pv. *manihotis*, which took place in two distinct agro-ecological zones (AEZ V and AEZ VI) with 8 cassava varieties of which four improved varieties and four other local ones has helped highlight the sensitivity or tolerance of these varieties.

In these experimental conditions, different types of symptoms of bacterial blight were observed on improved varieties as well as local varieties in the cities of Ferkéssédougou and Yamoussoukro and whatever the phenological stage of the plant. These symptoms varied depending on the varieties tested and the city. Local varieties were more sensitive to bacterial blight in both cities with incidences ranging from 1-89%. Indeed, 2 months after the planting of cuttings, the plants of local varieties already showed a high level of infection. This could be due to the fact that these cuttings were contaminated before they had been planted. As for improved varieties, symptoms were less expressed on them. The change in sensitivity observed among varieties can be explained by the genetic characteristics of each variety and the existence of Xam races[34]. Also, the sensitivity of varieties to bacterial diseases would depend on environmental conditions and especially their genetic heritage. The level of infection of improved varieties disseminated is lower compared to that of local varieties, which is consistent with the results of Zinsou *et al.*[34] where the 7 varieties of cotton showed different levels of symptoms with 3 isolates of *Xanthomonas axonopodis* pv. *malvacearum*. This spatial variation in the incidence of bacterial blight could be explained by the difference in vegetation, which is denser in Yamoussoukro (forest-Savannah transition zone), which would contribute less to the development of bacterial blight, than in Ferkéssédougou which is located in the Savannah zone. According to Onyeka *et al.*[30], the incidence of bacterial blight may depend on various environmental conditions influencing more or less the success of transmissions. The results of this study highlight the climate parameters that influence the evolution of the disease. Indeed, the period from the third to the 6th month corresponding respectively to the months from August-November is the period of the rainy season in the study areas and it would favor the development of the disease in the different varieties.

CONCLUSION

This study has highlighted the existence of cassava bacterial blight in all the agro-ecological zones of

Côte d'Ivoire. This disease attacks traditional (local) varieties as well as improved varieties but with a higher incidence in traditional varieties. The disease is more rampant in the Savannah zone than in the forest zone.

In natural condition, the varieties of cassava studied are sensitive to bacterial blight with variations from one city to another. Local varieties Akama and Dankwa were less tolerant to the disease than the improved variety Bocou 1. The most important bacterial attack occurred during the rainy season and resulted in mortalities in the most sensitive varieties. The data reveal an interest for the use of traditional varieties Akama and Dankwa and improved varieties Yavo, Bocou 2 and Bocou 3 in the areas of high pressure by cassava bacterial blight.

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