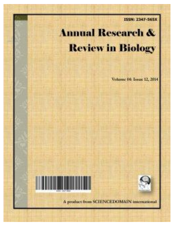

Annual Research & Review in Biology

25(4): 1-12, 2018; Article no.ARRB.35074
ISSN: 2347-565X, NLM ID: 101632869

Assessment of Tolerance Potential of Cassava (*Manihot esculenta* Crantz) Genotypes to Whiteflies (*Bemisia tabaci*) in East Cameroon

A. Mogo[1*], M. W. C. Tagong[2], E. L. Ngonkeu Mangaptche[2,3], J. N. Fomekong[2], Fotso[4] and N. Woin[3]

[1]Ministry of Scientific Research and Innovation, P.O.Box 1457, Yaoundé, Cameroon.
[2]University of Yaoundé I, P.O.Box 812, Yaoundé, Cameroon.
[3]Institute of Agricultural Research for Development (IRAD), P.O.Box 2067, Yaoundé, Cameroon.
[4]University of Bamenda, P.O.Box 39, Bambili, Cameroon.

Authors' contributions

This work was carried out in collaboration between all authors. Author AM designed the study, performed the statistical analysis and wrote the protocol and first draft of the manuscript. Authors MWCT and JNF collected field data and managed the literature searches. Authors ELF and NW conceived the project and ensured the overall supervision of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2018/35074
Editor(s):
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Complete Peer review History: http://www.sciencedomain.org/review-history/23999

Original Research Article

Received 26th June 2017
Accepted 19th March 2018
Published 5th April 2018

ABSTRACT

Cassava is a basic staple in Cameroon whose industrialization faces major constraints especially those related to the management of whiteflies (*Bemisia tabaci*), a vector of the African cassava mosaic virus (ACMV). This work has as main objective to identify the tolerance of some cassava genotypes to whiteflies and to undertake an agro-morphological characterization of infected cultivars to the ACMV. Data were collected from September to November 2015 on six cultivars: Five improved (TMS92/0057, TMS92/0067, TMS92/0326, TMS96/1414 and TME419) and one local

**Corresponding author: E-mail: mogoamos@yahoo.fr;*

(NTOLO), on a young plot (three months old) and mature plot (six months age). Adult whiteflies were counted on the underside of the last leaves of one apex and for nymphs; they were counted randomly between the ninth and fourteenth leaves. Three cultivars (TMS96/1414; TMS92/0057 and TMS92/0067) ramified early with a large number of apices. For the younger plants (three months old), three cultivars (NTOLO, TMS96/1414 and TMS92/0326) harbored the largest number of adult whiteflies, whereas two others (TMS92/0326 and TME 419) were the most attacked by the ACMD. Younger plants (3 Months old) were most vulnerable to ACMV attack (r = 0,307** with whiteflies population), while the older ones (at 6 Months), represent early senescence period for short-cycle genotypes.

Keywords: Cassava; tolerant cultivars; whiteflies; African cassava mosaic disease; severity; incidence; East-Cameroon.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is largely cultivated as an annual crop in tropical and subtropical regions [1]. It is consumed by more than 800 Million people, mainly for its rich carbohydrate content [2]. Cassava roots occupy the 4th position in the world food production ranking after maize, rice and wheat [3] and its leaves are rich in Vitamin C [4]. It is a better energy reserve food source with about 250 x 10^3 cal/ha/day as compare to maize 200 x 10^3 cal/ha/day, rice (176 x 10^3 cal/ha/day), sorghum (114 x 10^3 cal/ha/day) and wheat 110 x 10^3 cal/ha/day [5]. It is therefore a strategic food crop used to overcome hunger in developing countries. In Cameroon, it constitutes a basic food crop for more than multiple uses; in breweries, bakeries, cosmetics, clothing, as staple food source, etc.

Cameroon is one of the world's most important cassava producers (19th position) and its production in the country is the best of all root and tubers crop. Indeed, it is cropped in all of Cameroon's five agro-ecological zones, with the highest concentrations in the humid forests and high Guinean savanna zones covering seven of the country's ten administrative regions. Cassava production in Cameroon oscillates around 31 Million tons while the demand is about 50 Million tons [6].

However, a shift from small to large scale production, expected to meet up with the national and sub-regional demands, is hindered by major constraints, such as high soil acidity [7] as well as pathogen and insects invasion [8,9,10] with the most important in the tropical and sub-tropical regions, being whiteflies (*Bemisia tabaci* Genn). Whiteflies cause direct damage to cassava by sucking sap [11] and indirectly by facilitating the propagation of the *Begomovirus,* responsible for the African cassava mosaic disease (ACMD) [12,13,14].

In Cameroon, multi-locational studies [15,16] reveal the presence of Whiteflies in the mono-modal and bi-modal humid forest agro-ecological zones, which are the principal cassava production zones of Cameroon. Based on this situation, the government of Cameroon engaged several initiatives to reduce the effect of whiteflies in cassava farms [17,18]. The use of insecticides [19,20], have to date been unable to eliminate whiteflies in a relatively short periods, in order to avoid transmission of the virus [21]. Parasitoids (*Encarcia* spp and *Erecmocerus* spp) and acarian predators are generally used for biological control [22,10]. However, this approach has been found unsuitable owing to its cost and relative long action time. It is generally agreed that the genetic approach is most plausible for long lasting solutions to this natural cassava enemy. Physiological studies on this line show interesting results. In Kenya, [23] reported that some cultivars (N1 and Kibanda-meno) harbor greater number of whiteflies as compared to other genotypes (E-mariakani, Fe1O-30,08 /363, Shibe and Tajirike). In Cameroon, agronomic farm management has been found to influence both the population of whiteflies as well as the pathogenic strength of cassava mosaic virus [18].

Therefore, the main objective of this study was to identify cassava genotypes resistant or tolerant to whitefly invasion, and to undertake an agro-morphological characterization of infected cultivars to African cassava mosaic virus. This study could help to efficiently fight against whiteflies in the Tropics with the resistant cassava cultivars.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The study took place in eight farmers' plots (four from a 3-months aged plot and four from a 6-months aged plot) in Andom village (5º35' N; 13º16' E), a locality situated in the Lom and Djerem Division in the East Region of Cameroon. In this locality, the rainy season spans from April to October including a short dry season from July to August and with a main dry season from December to March [24]. Andom is situated in a transition ecological zone with bimodal rainfall (average annual rainfall of 1500 mm), an altitude of 650 m above sea level and an average temperature of 25ºC. The period from December to February is the driest with a relative humidity of 60% [24,25].

2.2 Data Collected

Biological materials were five improved cultivars namely, TME419, TMS92/0057, TMS92/0067, TMS92/0326 and TMS96/1414 (TME= tropical manihot esculenta, TMS= tropical manihot series); and one local cultivar (NTOLO). The materials were freely provided by the International Institute of Tropical Agriculture (IITA) and the Institute of Agricultural Research for Development of Cameroon (IRAD). Data collection was done following an « X » pattern as described by [26]. For each field (plot), evaluations were done thrice on a sample of twenty (20) randomly selected plants. Data were collected in the months of October and November 2015 during the rainy season.

Agro-morphological characteristics were done by evaluating the number of stems per plant, stem diameter, branching height and the number of apices, using a method described elsewhere [27].

The count of adult whiteflies was done *in situ* on the undersize of the leaves at leaf apex [18]. This operation was done every morning between 6:30 am and11:00 am local time (GMT+1) when the low insolation reduces the mobility of whiteflies.

Nymph count was done on the lower surface of leaves, randomly chosen between the 9th and 14th leaves [28].

Pathogenic virulence or strength was done by determining the incidence and the severity. The former was estimated as the percentage ratio of the number of attacked plants to the total number of considered plants in each plot [9] and the latter as the percentage ratio of the attacked surface area of the cassava leaves to the total surface area considered for each plant [7] using a scale from1 to 5 as follows:

1: no symptoms or no disease
2: 1-25% severity
3: 25-50% severity
4: 50-75% severity
5: 75-100% severity

2.3 Statistical Analyses

Data collected on the incidence of ACMD were treated using the SPSS software (version 20.0) while analyses of variance (ANOVA) were done using the Statistical Analysis System software package (SAS version 9.2). Mean values were compared using the Student T-test and Newman-Keuls test at 5% confidence threshold. Correlation between data was done using the Pearson correlation at 1% and 5% level of probability.

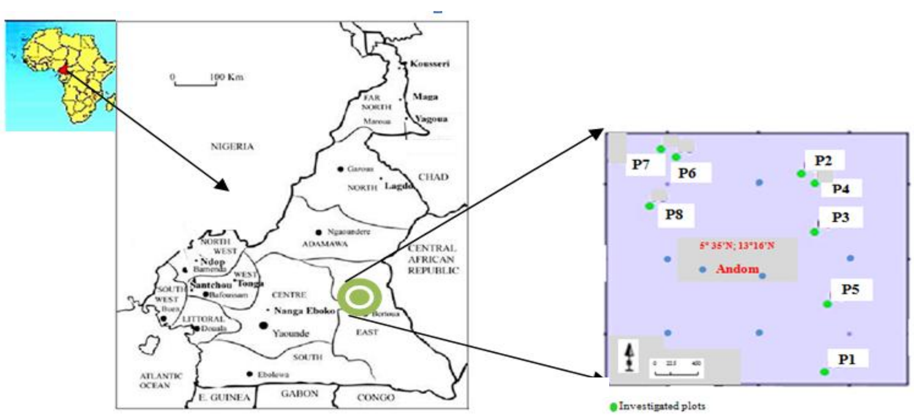

Fig. 1. Position of Cameroon in Africa and location of the experimental site

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Agro-morphological characterization

With respect to the number of stems per plant, it was generally observed that with time, 3-month old and 6-month old cultivars did not perform differently. However, the local cultivar (NTOLO) had the lowest number of stems in 3-month old plots but recorded the highest value in 6-month old plots. However, the differences with the improved cultivars were not significant (Table 1).

The stem diameter showed a wide variability between cultivars and plot ages. as the variation of this trait is a function of the growth phase and genotype related factors. The most developed cultivars at on 3-month old plots (TMS96/1414; TMS92/0326 and TMS92/0067) appeared performed best on 6-month old plots.

As concerns the height of cassava branches, cultivar TMS96/1414 performed best in 3 Months old plots with an average height of 1.86 cm. The other cultivars (TMS92/0057 and TMS96/1414) which could be considered as tolerant gave average results.

Generally, the number of apices increased with age and these were significantly different for all cultivars at different cassava growth phases except for cultivarTMS96/1414 which remained significantly constant but scored the highest values irrespective of the plant age.

3.1.2 Population of whiteflies (*Bemisia tabaci*)

Results in Table 3 show that for adult whiteflies in 3 Months farms, the lowest value recorded included TME419, TMS92/0057 and TMS92/0067; While the cultivars with the greatest number includes TMS92/0326, TMS92/1414 and local cultivars (NTOLO). In contrast to nymphs at 3 Months, the number of nymphs recorded in TMS92/0326, TMS92/0067and TMS92/1414 was low compared to others.

In 6-month old farms, there was a great variability in the number of adult and nymph whitefly (Table 2). Fig. 4 (a) and (b) shows the infested leaves by adult whiteflies and by nymphs, respectively.

3.1.3 Pathogenic strength of African cassava mosaic disease

Pathogenic strength modalities (incidence and severity) were all more than1 in both 3 Months and 6 Months old farms in all the tested cultivars. However, the local cultivar (NTOLO) recorded the highest score irrespective of the modality under investigation and the plot age. Cultivar TME419 gave a similar pathogenic strength irrespective of the plant age whereas cultivars TMS92/0057 and TMS92/0326 experienced an increase in the severity and incidence of the ACMD. In contrast, the cultivars NTOLO, TMS92/0067 and TMS92/1414 gave a decrease in severity and incidence in the older 6-Month old farms, where the lowest severity scores were recorded on cultivars TMS92/0067 (1.28) and TMS92/1414 (1.36).

For the younger farms (3-Month old), the cultivars with the lowest pathogenic strength were TMS92/1414 (1.39); TMS92/0057 (1.38) and TMS92/0067 (1.40) whereas those with the highest were the local NTOLO (2.00) and TMS92/0326 (1.67).

3.1.4 Correlations between agro-morphological traits in whitefly populations and Pathogenic strength of ACMD

The pathogenic strength modalities (incidence and severity) correlated strongly and positively with the population of whiteflies in young 3-months old plants. Here, the nymph counts were significantly correlated with incidence ($r = 0.205^{**}$) and with a severity ($r = 0.202^{**}$), while the adult populations were equally significantly correlated with incidence ($r = 0.342^{**}$) and with severity ($r = 0.307^{**}$).

However, in older plants (6-month old farms), the population of adult and nymph whiteflies were non-significantly but negatively correlated with incidence and positively with severity.

In the same vain, the population of adult whiteflies in in the younger farms (3-month old) were positively correlated to cassava's agro-morphological traits (stem diameter, branch height and number of apices) as shown in Table 4.

Table 1. Agro-morphological characterization of some cassava genotypes

Parameter / Genotypes	Number of stems		Stem diameter (cm)		Branch height (cm)		Number of apices	
	3 Months	6 Months	3 Months	6 Months	3 Months	6 Months	3 Months	6 Months
NTOLO	1.00±0.00b	2.48±0.85a	1.44±0.21b	1.58±0.36b	1.33±0.50b	2.11±0.32a	1.44±0.72c	3.96±2.12a
TME419	1.83±0.81a	2.11±0.42a	1.38±0.19bc	2.07±0.35a	1.19±0.40b	2.26±0.45ab	1.19±0.40c	5.78±2.38a
TMS92/0057	1.93±0.78a	2.06±0.64a	1.28 ±0.25b	1.60±0.26b	1.49±0.50b	1.78±0.43bc	2.33±2.02b	5.22±3.10a
TMS92/0067	1.60±0.50a	2.06±0.42a	1.44±0.198ab	1.76±0.25b	1.40±0.49b	1.67±0.69d	1.58±0.89c	3.94±3.47a
TMS92/0326	1.85±0.53a	2.41±0.10a	1.49±0.188ab	1.66±0.19b	1.22±0.42b	1.72±0.57cd	1.26±0.53c	2.00±1.00b
TMS96/1414	1.92±0.28a	1.97±0.45a	1.56±0.21a	1.73±0.24b	1.86±0.35a	2.06±0.58abc	3.08±1.54a	4.58±3.43a

Treatments followed by the same letter were not significantly different at the 5% probability threshold

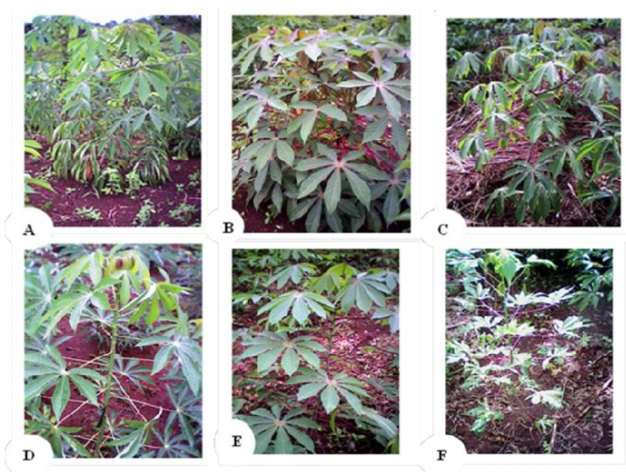

Fig.2. Three (3) Months aged farm [A]: TMS92/0067; [B]: TMS92/0057; [C]: TMS96/1414; [D]: TME419; [E]: TMS92/0326; [F]: NTOLO

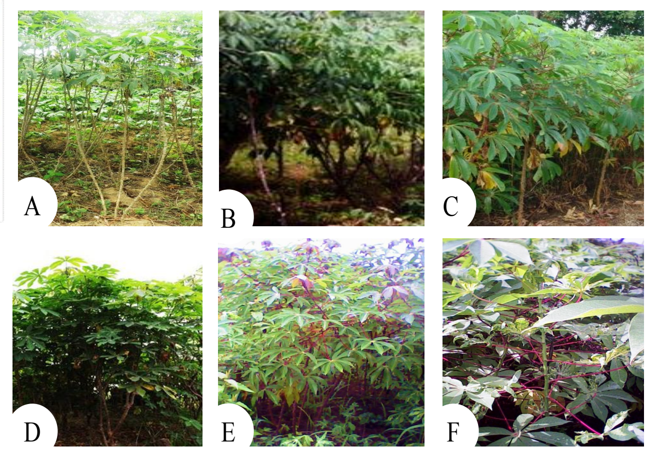

Fig.3. Six (6) Months aged farm [A]: TME419; [B]: TMS92/0067; [C]: TMS92/0326; [D]: TMS96/1414; [E]: TMS92/0057; [F]: NTOLO

Table2. Whiteflies (*B. tabaci*) population on cassava (*Manihot esculenta* Crantz) cultivars of different ages

Parameter / Cultivars	Adults		Nymphs	
	3 Months	**6 Months**	**3 Months**	**6 Months**
NTOLO	126.78±130.75a	11.40±11.43bc	218.67±199.33a	33.37±47.54bc
TME419	48.17±52.21b	2.63±2.78c	118.83±112.61b	6.26±4.40c
TMS92/0057	66.07±80.60b	9.11±8.42c	142.00±105.46b	15,50±14,82bc
TMS92/0067	57.00±52.86b	22.28±16.79a	94.38±67.04b	93.28±79.21a
TMS92/0326	83.00 ± 56.33a	18.30±18.56ab	160.44±87.25b	45.64±58.45b
TMS96/1414	80.36±108.69a	6.58±8.77c	133.11±83.35b	22.08±32.98bc

Figures followed by the same letters were not significantly different at the 5% probability threshold.

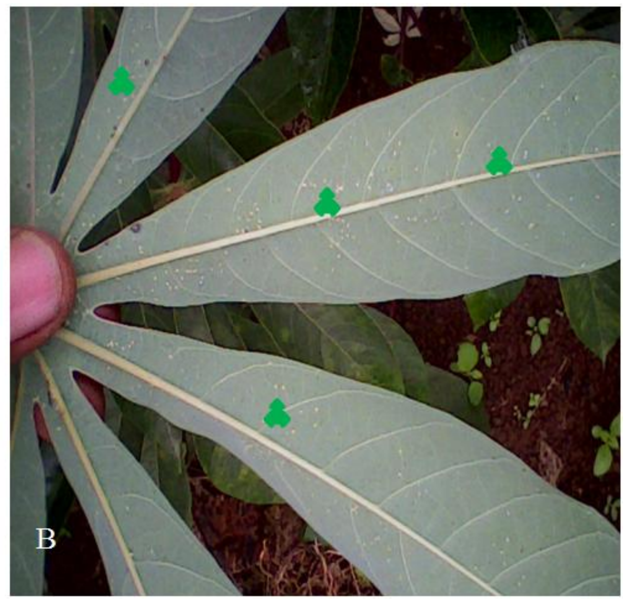

Fig. 4. Whiteflies (*Bemisia tabaci*) on the undersize of cassava leaf

A: adult whiteflies ( ) and B:nymphs ( )

Table 3. Pathogenic strength of ACMD on plants of different ages

Cultivars \ Parameter	Incidence(%)		Severity	
	3 Months	6 Months	3 Months	6 Months
NTOLO	100,00a	100,00a	2.00±0.00a	1.93±0.27a
TME419	55,56bc	70,37ab	1.56±0.50b	1.56±0.50bc
TMS92/0057	37,78cd	66,67bc	1.38±0.49b	1.67±0.49ab
TMS92/0067	40,00c	27,78d	1.40±0.49b	1.28±0.46d
TMS92/0326	66.67b	72,22ab	1.67±0.48b	1.72±0.45ab
TMS96/1414	38,89cd	36,11cd	1.39±0.49b	1.36±0.49cd

The same letters are not significantly different; ns: no significant different.

Table 4. Correlation coefficients between agro-morphological traits, population density of Whiteflies (*B. tabaci*) and pathogenic strength of ACMD

	Number of stems per plant	Stem diameter	Branch height	Number of apices	Incidence	Severity
3 Months						
Number of whitefly nymphs	-0.083ns	0.189**	0.052**	0.054*	0.205**	0.202**
Number of adult whiteflies	-0.121ns	0.245**	0.202**	0.150*	0.342**	0.307**
6 Months						
Number of whitefly nymphs	-0.165*	-0.142ns	-0.379**	-0.339**	-0.085ns	0.008ns
Number of adult whiteflies	-0.019*	-0.123ns	-0.334**	-0.279**	-0.085ns	0.007ns

***. Correlation is significant at 0.01 levels (2-tailed); * Correlation is significant at 0.05 level (2-tailed). ns: non-significant*

However, the same traits were negatively and non-significantly correlated with the population of nymph and adult whiteflies in older farms (6-month old).

3.2 Discussion

Field agro-morphological evaluations of cassava cultivars are crucial for the estimation of yield potential, and for influence of whiteflies population. The agro-morphological diversity observed in cassava in the different plots is partially due to the instinctive properties (genetic-related traits), which is specific to a particular cultivar [29] as well as growth phase (3 Months and 6 Months aged plots) of each cultivar. In this respect, cultivars from plots of 6 Months aged plots show agronomic phenotypic traits more elaborated as compared to 3 Months aged plots, taken as a whole (Figs. 2 and 3). This could suggest that at six Months aged farm, cassava crop have fully developed its organs that permit it to withstand most adverse attacks efficiently.

Generally, the average numbers of stems was much in the improved cultivar TMS92/0057 in 3 months farms and in the local cultivar (NTOLO) in 6 Months farms. Similarly, with respect to the stem diameter, branch height and number of apices, TMS96/1414 in 3 months plots and the cultivar TME 419 in 6 Months plots gave higher values. In the same vein [29] shown that, during growth phase of cassava crop, the cultivar with low number of ramification had a small height (189-199 cm) and with a diameter of between (2.4-3cm). Whereas the cultivar with early ramification had a small height (147-171cm), with a large number of ramifications (36-45) and with a small stem diameter (2-2.2cm). These results could somehow implied that, relative to the trait (number of stems), the genotype TMS92/0057 may respond faster than the local cultivar (NTOLO) which seems to have a longer life cycle than the other improves cultivars. In the same line, improved cultivars, in a general view elaborated their agro-morphological traits faster than the local genotype. In that respect, cultivar TMS96/1414 seems a suitable candidate to withstand environmental constrains. Similarly, [7] in his work at Andom (East-Cameroon) revealed that, cultivar TMS96/1414 gave interesting agro-morphological results in acidic conditioned soils. In the same report, cultivars TMS92/0326 and NTOLO are classified as tolerant to soil acidity and this could explain why cultivar TMS92/0326 though it had an increase in the number of apices from 3 Months (1.26) to 6 Months (2.00) aged plot it remains the lowest value at this growth phase. This could imply that the acidity of the soil may have a negative influenced in the number of apices at maturity. The response of cultivar TME 419 to the traits under study approaches those of the local genotype at 6 Months aged farm. These observations are in partial synergy with those of [30] in which, it is observed that improved cultivars of cassava genotypes generally have a high yield potential as compared to locals genotypes.

In addition, the heterogeneous agro-morphological traits observed between different plots could be due to the rhythm and manner of crop management practices by different peasant farmers. Competitive of adventives plants exerted on cropped plants for hydro mineral substances, light and space. These adventives prevent the normal development of cropped plants [31]. Also, the response to soil biodiversity is an addition fact that can support our observations. In fact, the work of [32] at Bityili and Andom in Cameroon revealed that different cultivars of cassava gave varied beneficial response to mycorrhizia inoculums.

The sanitary nature of the plants are not to be neglected or ignored, indeed, agro-morphological characterizations of plants are equally influenced by health statue of the initial seeds or stumps. In fact, according to [9,33] the degree of plant attacked by diseases significantly affects the plant yield as well as the expression of agro-morphological traits.

Cassava plants of 3 months aged harbors a quit number of whiteflies as compared to six months aged plants. This result corroborates with those of [23] carried out in Kenya and shown that the age of plant has a negative influenced on the abundance of whiteflies. The following cultivars NTOLO, TMS96/1414 and TMS92/0326 harbors large number of whiteflies, but this difference could be justified partially by a preference of this insect to the cassava cultivars which presented with small hairs on young leaves (pubescent cultivar) [34]. [22] proof that, whiteflies induces in the host plant on which they feed on, a high level of proteins PR such as β-1, 3-glucanase, peroxydases and chitinases as compared to non-infected. These proteins are known as substances that inhibit insect attack (bio-control measures). This results permit to understand the preference of some cassava cultivars by whiteflies. Owning to the fact that, data were collected during the short rainy season, the preference of this whitefly on cassava cultivars could be also due to a means to hide away from rain since the plant leaf architecture offer them a suitable niche [1].

It was equally demonstrated by [23] that, the number of whiteflies varies based on the period when the estimation of the population was done. Similarly, [35] indicates that, the number of whiteflies is relative to humidity and temperature. Field results show that, the maximum number of whiteflies was (126.78). This number is largely superior as compared to that found by [18] at Buea-Cameroun (4.07) and that from [23] in Kenya (4.58). Unfortunately this work was not repeated in dry season because the study was carried out in farm peasant who cultivated different crop at next cropping season. This differences could be due to the different cultivars used, [18] worked on the cultivars: 8061, AA and a local cultivar; while [23] worked on the cultivars: 08/363, F10-30-R2, NI, Tajirika, E-Mariakani, Kibandameno and Shibe. This differences in the results may also be due to geographical differences with varies parameters such as altitude, temperature and precipitation density of the zone [36]. In Zambia, following the work carries out by [26] adult whiteflies were more abundant in the West province (2.71) and less abundant in Luapula province (0.02). Furthermore, studies carried out by [37] shown that, the period within the day is crucial for the estimation of the population of whiteflies as well as the number of stem on which estimation are made.

The pathogenic virulence of African cassava mosaic disease was high in NTOLO cultivar and on TMS92/0326. This result goes hand in hand with those obtained by [7] who found that, these two cultivars are susceptible to African cassava mosaic disease. This susceptibility could be solely genetically related or due to sanitary oriented that is the original stumps could have been initially infected. According to [38] an approach that seeks to fight and obtain free mosaic virus plants is rarely used. On the other hand, [38] show that some cassava cultivars have an acceptable resistance to Mosaic virus that is experienced no or less destruction when affected. [9] Shown that *Manihot glaziovii* develop weak mosaic as compare to cultivars Alot-Bikon, IITA 8034 and IITA 8061. [20] Show that the cultivars TMS 92/0326 and TMS 96/1414 are more resistant than the cultivars 8034, Ekobele and Ngonkribi. These results partially confirm our results which show that the cultivar TMS 96/1414 is resistant as compared to TMS92/0326 which is sensible. [23] Shown that, geographical distances influences pathogenic strength of mosaic virus. [5] Shown that, improved cassava cultivars can synthesis more substances such as cyanide compounds that permit it to be resistant as compare to local cultivars. [37,39], show that fertilizers application increases significantly the incidence and severity to African cassava mosaic disease as compare to the control [1]. On the other hand show that, intercropping cassava with other legume crops specifically *Vigna radiate* (L) R. Wilewekvar Upenda have an positive influence on the severity of African cassava mosaic disease as compare to monoculture with or without NPK.

Severity and incidence of African cassava mosaic disease are positively influenced by the age of the plants. In fact, the more the plant is aged, the more it is affected by the disease [1]. This result contrast with our results which rather show that plant aged 3 months are more in fected by the African cassava mosaic disease as compare to plant of aged 6 months. This result is similar to the abundance of whiteflies on plant leaves on 3 months aged plant more than those of aged 6 months. [18] shows that, African cassava mosaic disease is positively influenced by the number of whiteflies. The decrease of incidence of cassava mosaic disease on TMS96/1414 and TMS92/0067 from 3 months to 6 months can be justified by the fall of severe infested leaves.

In 3 Months plant farms, the pathogenic strength modalities (incidence and severity) of the *Begomovirus* responsible agent of African cassava mosaic diseases strongly correlates with the adult as well as nymph population of whiteflies (*Bemisia tabaci*). The attack of the virus is more pronounced in 3 Months farm than 6 Months farms and this certainly suggests that, in 6 Months aged farm, cassava plant had enhanced anti viral mechanisms to impair the virulence of the virus. Also we could attribute this observation due to the fact that at 3 Months aged farms, cassava plant organs are not yet fully established such that, the nutrients intake are more tailored to satisfied the demand in the elaboration of organs (organogenesis).

Increase in the adult and nymph population of whiteflies (*Bemisia tabaci*) with increased in the agro-morphological traits, reveals that the plant architecture of cassava crop creates a favorable microclimate which influenced positively on the number of whiteflies. In 3 months farm, the more the plant grows taller, the more adult whiteflies are attracted. Whereas the population of whiteflies drop significantly in 6 Months aged farms could be due to the fact that, during that period, some cassava leaves are shading and fall down. These results could equally be supported by the observation made by [37,39] based on the application of NPK fertilizers and those of [1] which was based on the association cropping system with leguminous crop which is an appropriate source of Nitrogen to the companion non leguminous crop. These results show that the application of these cropping systems leads to a significant increase in the growth and increase in the abundance of whiteflies. In fact, Nitrogen supply to the plant favors the emergence of new plant leaves. Whereas at 6 months aged plants immobilized much nutrients at the level of plant roots.

Correlation on the number of whiteflies and the pathogenic strength to African mosaic is positive. This result is in complete accord with those of [40] in Uganda and those of [18] at Buea-Cameroun which show that the number of whiteflies and the pathogenic strength to African mosaic is positive. This result confirms that, the growth phases as well as the nutrients statue of the soil significantly affect the pattern of pathogenic attack on a given crop.

4. CONCLUSION

In this study, the tolerance of some cassava genotypes to whiteflies and an agro-morphological characterization of infected cultivars to the African cassava mosaic disease (ACMD) were evaluated.

Generally, the plant's architecture seemed to highly influence the population of whiteflies and all the tested cultivars gave early ramification. Two of them (NTOLO and TMS92/0326) harbored the largest number of whiteflies and were most sensitive to the ACMD. Two other cultivars (TMS96/1414 and TME419) could be classified as resistant. The whitefly population influenced positively the incidence and severity of ACMD. Thus, high-yielding plants of medium height, average number of apices and medium-sized branches (such as TMS96/1414and TMS92/0067cultivars) could be selected and recommended to reduce the impact of whiteflies on cassava in the East Region of Cameroon Future work could therefore be undertaken to identify the inherent differences accounting for the preferred attraction to whiteflies and their resistance to the ACMD.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge logistic and other support received in the framework of the Forest Savanna Sustainability Project – Cameroon (FOSAS) funded by the Japanese Agency for International Cooperation (JICA) and its Coordinator, Dr. Foahom B. The editorial support of Mr Mballa T.A.N. and Dr. Ehabe E.E. are equally acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Uzokwe VNE, Mlay DP, Masunga HR, Kanju E, Odeh IOA, Onyeka J. Combating viral mosaic disease of cassava in the Lake Zone of Tanzania by intercropping with legumes. Crop Protection. 2016;84: 69-80.
2. Blagbrough IS, Bayoumi SAL, Rowan MG, Beeching JR. Cassava: An appraisal of its phytochemistry and its bio-technological prospects. Phytochemistry. 2010;71:1940-1951.
3. Krabi ER, Assamoi AA, Ehon AF, Bréhima D, Niamké LS, Thonart P. Production of attiéké (couscous made from fermented manioc) in the city of Abidjan. European Scientific Journal. 2015;11(15):277-292.
4. Cassava factsheet, Nutritional composition of foods table, Ciqual, Anses; 2016.
5. Afoakwa EO, Asiedu C, Budu AS, Chiwona-Karltun L, Nyirendah DB. Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties. International Food Research Journal. 2012;19(1):175-181.
6. FAO. FAOSTAT statistical database; 2013. Available:http://faostat.fao.org.
7. Sarr SP, Araki S, Njukwe E. Interactions between cassava varieties and soil characteristics in crop production in eastern Cameroon. African Study Monographs. 2013;34(4):187–202.
8. James B, Yaninek J, Neuenschwander P, Cudjoe A, Modder W, Echendu N, Toko M. Control of cassava pests: A guide to IPM practice for extension workers. 2000;21.
9. Ambang Z, Akoa A, Bekolo N, Nantia J, Nyobe L, Ongono BSY. Tolerance of cassava (*Manihot esculenta* Crantz) and wild species (*Manihot glaziovii*) to African viral mosaic and cassava Cercospora. Tropicultura. 2007;25(3):140-145.
10. Omara T, Ocitti P, Wamani S, Opio SM, Okao-Okuja G, Katono K, Kalyebi A, Omongo CA, Otim M. Population dynamics of the whitefly (*Bemisia tabaci*) and associated natural enemies on different cassava genotypes in Uganda; 2016. Available:Institute:http://www.nacrri.go.ug.
11. Earrnet. Ecologically sustainable plant protection; 2015.
12. legg JP, Fauquet CM. Cassava mosaic geminiviruses in Africa. Plant Mol. Biol. 2004;56:585–599.
13. Legg JP, Owor B, Sseruwagi P, Ndunguru J. Cassava mosaic virus disease in East and Central Africa: Epidemiology and management of a regional pandemic, Adv. Vir. Res. 2006;67:355-418.
14. Fondong VN, Pita JS, Rey C, Beachy RN, Fauquet CM. Evidence of synergism between African cassava mosaic virus and the new double recombinant *Geminivirus* infecting cassava in Cameroon, J. Gen. Virol. 2000;81:287-297.
15. Fomekong NJ, Tene TM, Mogo A, Rachid H, Yemefack M. Abundance of whitefly populations on a few cassava cultivars according to soil fertilization in Bityili (Ebolowa South Cameroon). FOSAS. 2015;11.
16. Akinbade SA, Hanna R, Nguenkam A, Njukwe E, Fotso A, Doumtsop A, Ngeve J, Tenku STN, et al. Kumar PL. First report of the East African cassava mosaic virus-Uganda (EACMV-UG) infecting cassava (*Manihot esculenta*) in Cameroon. New Disease Reports; 2010.
    Available:http://dx.doi.org/10.5197/j.2044-0588.2010.021.022
17. Maruthi MN, Seal S, Colvin J, Briddon RW, Bull SE. East African cassava mosaic Zanzibar virus a recombinant *begomovirus* species with a mild phenotype, Arch. Virol. 2004;149:2365-2377.
18. Berrie LC, Rybicki EP, Rey MEC. Complete nucleotide sequence and host range of South African cassava mosaic virus: Further evidence for recombination amongst begomoviruses, J. Gen. Virol. 2001;82:53-58.

19. Adjata KD, Muller E, Peterschmitt M, Aziadekey M, Gumedzoe YMD. Incidence of cassava viral diseases and first identification of East African cassava mosaic virus an Indian cassava mosaic virus by PCR in Cassava (*Manihot esculenta* Crantz) fields in Togo, Am. J. Plant Physiol. 2008;3:73-80.
20. Njock T, et al. Sama V. Quantification and correlation of African cassava mosaic disease parameters on cassava genotypes (*Manihot esculenta* Crantz) in Buea, Cameroon. Global Advanced Research Journal of Agricultural Science. 2015;4(3): 166-172.
21. Perring TM. The *Bemisia tabaci* species complex. Crop Protection. 2001;20:725–737.
22. Antony B, Palaniswami MS. *Bemisia tabaci* feeding induces pathogenesis-related proteins in cassave (*Manihot esculenta* Crantz). Indian Journal of Biochemistry & Biophysics. 2006;43:182-185.
23. Sing'ombe G, Ateka E, Miano D, Githiri S, Munga T, Mwaura S. Assessment of the responses of cassava (*Manihot esculenta*) breeder's germplasm to cassava mosaic virus (CMD) infection in Kenya. International Journal of Agronomy and Agricultural Research. 2015;6(4):120-129.
24. Araki S, Saito H. Monitoring soil erosion and water run-off by different soil conservation methods: Results of Andom experiments 2010–2012. In Progress report 2012, Forest-Savanna Sustainability Project Cameroon, Eds. Woin N, Foahom B, Araki S, FOSAS Project, IRAD, Yaoundé, Cameroon. 2013;86–91.
25. Johannes TA, Vabi MB, Malaa DK. Adoption of maize and cassava production technologies in the forest-savannah zone of Cameroon: Implications for poverty reduction. World Appl. Sci. J. 2010;11(2): 96–209.
26. Chikoti PC, Tembo M, Chisola M, Ntawuruhungu P, Ndunguru J. Status of cassava mosaic disease and whitefly population in Zambia. African journal of Biotechnology. 2015;14(33):2539-2546.
27. Bakayoko S, Soro D, Be N, Kouadio KKH, Tschannen A, Nindjin C, Girardin O. Study of the plant architecture of 14 improved varieties of manioc (*Manihot esculenta* Crantz) Côte d 'Ivoir e. 2013;7:4471-4477.
28. Van Halder L, Van Helden M. Mechanisms of resistance of cassava to *Bemisia tabaci* (*Gennadius*) vector of the African Mosaic of Manioc. 1986;55.
29. Maroya NG. Morphological characterization of cassava clones grown in West and Central Africa (Benin, Cameroon, Ghana and Nigeria). Agricultural Research Bulletin. 1997;23.
30. Khonje M, Mkandawire P, Manda J, Alene AD. Analysis of adoption and impacts of improved cassava varieties in Zambia. In: 29th Triennial Conference of the International Association of Agricultural Economists (IAAE). Milan Italy. 2015;28.
31. Melifonwu A, James B, Aihou K, Weise S, Awah E, Gbaguidi B. Weed control in cassava fields. A guide to IPM practice for extension workers. 2000;16.
32. Begoude BDA, Sarr PS, Mpon YTL, Owona DA, Kapeua NM, Araki S. Composition of arbuscular mycorrhizal fungi associated with cassava (*Manihot esculenta* Crantz) cultivars as influenced by chemical fertilization and tillage in Cameroon. Journal of Applied Biosciences. 2016;98:9270–9283.
33. Ambang Z, Amougou A, Ndongo B, Nantia J, Chewachong GM. Resistance to the viral mosaic of *Manihot glaziovii* par grafting on *M. esculenta*. Tropicultura. 2009;27(1):8-14.
34. Akanza KP, YAO-Kouamé A. Organo-mineral fertilization of manioc (*Manihot esculenta* Crantz) and diagnosis of soil deficiency. Journal of Applied Biosciences. 2011;46:3163-3172.
35. Seif AA. Transmission of cassava mosaic virus by *Bemisia tabaci.* Plant Disease. 1981;65:606-610.
36. Zinga I, Chiroleu F, Zango AV, Ballot CSA, Harimalala M, Komba EK, Yandia PS, Semballa S, Reynaud B, Lefeuvre P, Lett JM, Dintinger J. Evaluation of cassava cultivars for resistance to cassava mosaic disease and yield potential in Central African republic. J Phytopathol. 2016;11.
37. Seruwagi P, Serubombwe WS, JP, Legg JP, Ndunguru J, Thresh JM. Methods of surveying the incidence and severity of cassava mosaic disease and whitefly vector populations on cassava in Africa: A review. Virus Research. 2004;100:129–142.

38. Hillocks RJ, Thresh JM. Viruses of the mosaic and brown streak of cassava in Africa: A comparative guide to symptoms and etiology. ROOTS. 2000;7.
39. Nkongolo KK, et al. Bragard C. Effect of NPK fertilization on cassava mosaic disease (CMD) expression in a Sub-Saharan African region. Am. J. Exp. Agric. 2012;2(3):336–350.
40. Otim-Nape GW. Epidemiology of African cassava mosaic *geminivirus* disease (ACMD) in Uganda. Ph. D. thesis, University of Reading, UK. 1993;256.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/23999