Greener Journal of Agricultural Sciences
Vol. 10(2), pp. 95-102, 2020
ISSN: 2276-7770

https://gjournals.org/GJAS

Effect of *Stictococcus vayssierei* Richard (Hemiptera: Stictococcidea) on growth and yield of cassava (*Manihot esculenta* Crantz)

Patrice Zemko Ngatsi[1]*, Bekolo Ndongo[1], Désiré Anaba Manga[1], Eric Biyo'a Ndongo[1], Champlain Djieto-Lordon[2]

[1]Department of Plant Biology, Plant Pathology Laboratory, University of Yaoundé 1, Yaoundé, Cameroon
[2] Department of Plant Animals, University of Yaoundé 1, Yaoundé, Cameroon

ARTICLE INFO

Article No.: *031020048*
***Type*:** *Research*

Accepted: *15/03/2020*
Published: *22/06/2020*

Corresponding Author
Ngatsi PZ
E-mail: *ngatsipatrice@gmail.com*
Phone: *(237) 675974551*

Keywords: *Scale insect; Manihot esculenta; growth; yield*

ABSTRACT

Cassava cultivation faces many constraints including various pathogens and pests. Among the pests of cassava, the African Root and Tuber Scale (ARTS) *Stictococcus vayssierei* (Hemiptera: Stictococcidea) is a sap-sucking insect that colonizes tubers and roots of cassava plants in humid Central Africa. Infestation by this pest affects plant physiology and severely reduces the productivity, causing 60 to100% yield losses in the field. The objective of this study is to evaluate the harmful effect of *S. vayssierei* on cassava yield in the field. The experiment was carried out using a completely randomized Fisher's blocs design with four replicate on six cassava varieties, four of which were improved and two local. During 12 months with a sampling interval of three months, the number of scale insects per plant, growth parameters, incidence and severity of the most important diseases, as well as yield were evaluated. As result, at 12 months after planting (MAP), the highest fresh shoot weight (2.69 ± 0.43 kg) as well as of fresh tuber yield (23.8 t ha^{-1}) were obtained with the local variety Douma; at opposite, the Excel variety produces the lowest fresh shoot weight (1.69 ± 0.15 kg) and yield (14.1 $t.ha^{-1}$). The average number of scale insects per plant (ARTS/P) was greater with the Excel variety (90.12 ARTS/P) and lowest on the 96/0023 variety (58.14 ARTS/P). In addition to ARTS infestation, two biotic constraints, namely cassava mosaic disease (CMD) and cassava anthracnose disease (CAD), appeared in the plots, with varying incidence and severity. Finally, it appeared that *S. vayssierei* through damage to cassava plants leads to a decrease in the productivity of cassava varieties, especially on improved varieties.

List of Abbreviations:

ARTS: African Root and Tuber Scale
MAP: months after planting
CMD: cassava mosaic disease
CAD: cassava anthracnose disease
ARTS/P: number of scale insects per plant

INTRODUCTION

The African Root and Tuber Scale (ARTS), *Stictococcus vayssierei* Richard, is one of the most harmful arthropod pests in cassava agro-systems in semi-humid forest regions in the Congo Basin (CNRCIP, 1989; Hanna et *al*., 2004). Probably because of its underground habitat, *S. vayssierei* is a cryptic polyphagous agricultural pest first reported in the early 1980 (Nonveiller, 1984; Dejean and Matile-Ferrero, 1996; Ambe et *al*., 1999; Ngeve, 2003; Tata Hangy et *al*., 2006). There are 16 plant species belonging to 13 families from which it draws sap from the roots to feed (Tindo et *al*., 2009).

Cassava (*Manihot esculenta* Crantz) is a shrub of the family Euphorbiaceae (Westphal, 1985). It is an important source of carbohydrates for more than 800 million humans across the African, American and Asian continents (Liu et *al*., 2011). Cassava is grown mainly for its starchy tuberous roots (20-40%), which represent an important part of industrial starch and daily food for many human and animal populations worldwide (Jose et *al*., 2008; Graziosi and Wyckhuys, 2017). However, its cultivation is constraint by the infestation of root scales in Central Africa. In case of severe infestations, heavy starvation of sap can lead to leaf drop, wilting, tip dieback, and eventually death of seedlings (Ngeve, 2003; Williams et *al*., 2010) reducing both biomass and yield, resulting in losses ranging from 60% to 100% in plantations and posing a major threat to cassava production in Central Africa (Ngeve, 2003; Hanna et *al*., 2004; Lema et *al*., 2004; Tata-Hangy et *al*., 2006). Yield reduction is often the result of damage caused during the vegetative phase of the plants. It injects toxic saliva into the plant tissue when removing its food resource; this saliva affects plant tissues and can sometimes transmit various pathogens including viruses and fungi in many economically important root and tuber plants (Richard, 1971; Mutsaers et *al*., 1981; Tindo et *al*., 2006). In addition, large sap collections can increase the plant's susceptibility to disease. Therefore, the objective of this work was to evaluate the harmful effect of *S. vayssierei* on cassava yield in the field.

MATERIALS AND METHODS

Plant material

The cassava cuttings used in the study belong to six varieties (Table 1). Four improved (TMS 96/0023 and TMS 92/0057) and (8034 and Excel) obtained from the International Institute of Tropical Agriculture and Institute of Agricultural Research for Development of Nkolbisson collections respectively and known as tolerant to cassava mosaic and two local varieties named Douma and Miboutou susceptible to cassava mosaic based on field observations and locally grown by the farmers.

Table 1. Characteristics of cassava varieties used in this study

Varieties	Root Color	Maturity (months)	Behaviour against diseases and pests	Yield (t ha^{-1})	Origin
TMS 96/0023	White	12	Resistance to : cassava mosaic, Anthracnose tolerance to green mite	18-27	IITA-Nkolbison
Excel	Brown	12	Resistance to : cassava mosaic, Anthracnose tolerance to green mite	25-30	IRAD-Ekona
TMS 92/0057	Red	12	Resistance to : cassava mosaic, Anthracnose tolerance to green mite	21-30	IITA-Nkolbison
8034	White	12	Resistance to : cassava mosaic, Anthracnose tolerance to green mite	18-30	IRAD-Ekona
Miboutou	White	12	Sensitive to mosaic	nd	Local
Douma	Red	12	Sensitive to mosaic	nd	Local

IITA: International Institute of Tropical Agriculture; IRAD: Institute of Agricultural Research for Development; nd: not determined

Experimental design and cultural practices

The trial was conducted in a 3 year old fallow land naturally infested by the scale insect in the locality of Akonolinga (N 03°48.136' and E 012°15.518', altitude 671 m) in the Central region of Cameroon from March 2018. The fallow vegetation was cut and burnt in places when dry. This locality belongs to the agro-ecological zone V known as the bimodal rainfall zone with rainfall ranging from 1500 to 2000 mm per year. The cuttings (about 30 cm) of the six varieties of cassava were planted obliquely by pushing 2/3 into the soil using a completely randomized Fisher block design with four repetitions. Each block consisted of six sub-plots measuring 3 m x 4 m each, 1 m apart. The sub-plots have 15 cuttings at 1 m x 0.8 m spacing (12,500 plants ha^{-1}) (IITA, 2000). Weeding was carried out at 2, 3, 5 and 9 months after planting (MAP). No chemical pesticides or fertilizers were applied during the growth of the cassava plants.

Parameters measured

Evaluation of agronomic parameters

Agronomic parameters were assessed at 3, 6, 9 and 12 months after planting (MAP). Stem diameter was measured using a caliper on three labelled plants.

Fresh shoot weight (aerial biomass of stems, leaves) and tuber weight were measured on three randomly uprooting plants and weighed using a 200 and 250 precision balance with double graduation trademark Pesola. Tuber weights were extrapolated in tons per hectare to estimate the fresh tuber yield of the six cassava varieties using the formula of Kamau et *al*. (2011).

$$\text{Yield (t ha}^{-1}\text{)} = \text{tuber weight (kg/m}^2\text{)} \times 10\,000\ \text{m}^2\text{/ha} \times 1\ \text{t/1000 kg.}$$

Evaluation of ARTS density

Cassava root scales were counted on three plants randomly sampled in the subplots by uprooting plants. All life stages (first-instar nymphs L1, second-instar nymphs L2, adults, dead individuals) of the scale were counted on cassava stem, mother cuttings, tuberous and feeder roots of cassava at 3, 6, 9 and 12 MAP according to Ambe et *al*., 1999 and Ndengo et *al.*, 2016a. Subsequently, the level of infestation was determined (Table 2) by visual estimation with a ranking on a scale index (Tertuliano, 1993).

Table 2. Scale insect infestation index

Index	Number of scale insects per plant	Description
1	1-25	Very low infestation
2	26-50	Low infestation
3	51-75	Average infestation
4	76-100	Heavy infestation
5	>100	Very heavy infestation

Diagnosis, evaluation of the incidence and severity of diseases identified in the field

By removing nutrients, ARTS injects toxic saliva into the plant tissue, which can weaken the plant's defense system and promote the development of diseases. The visual diagnosis method through observations, precise comparisons of symptoms and their evolution in time and space (Renard and Foucart, 2008) has made it possible to follow the evolution of diseases in the field. Epidemiological parameters, i.e. disease incidence and severity, were assessed on plants in the field.

Evaluation of the incidence of identified diseases

Disease incidence was estimated from the frequencies of occurrence on plants in the experimental units and was calculated by the formula proposed by Tchumakov and Zaharova (1990):

$$I\ (\%) = (n / N) \times 100$$

I: incidence of disease; n: number of diseased plants; N: total number of plants

Evaluation of the severity of diseases

Disease severity was assessed on cassava plants in the experimental units according to the Rwegasira and Rey (2012) visual rating scale of 1-5 where 1=0; 2=1-5%; 3=5-30%; 4=30-60% and 5=60-100%. Thus the severity during development was given by the formula of Tchoumakov & Zaharova (1990) which is expressed as follows:

$$S\ (\%) = \sum (a.b)/N$$

S (%): severity of the disease; ∑(a.b): sum of the multiplication of the number of diseased plants (a) by the corresponding degree of infection (b) given as a percentage; N: total number of diseased plants.

Statistical analyses

The data collected for the various parameters studied were subjected to a one-way analysis of variance (ANOVA) using R software version 3.5.1. The multiple comparison tests of Tukey means at the 5% threshold followed the ANOVA when significant differences ($p < 0.05$) were detected. The data are represented as means ± standard deviation of a minimum of three replicates (n = 3).

RESULTS

Agronomic parameters

Data for agronomic parameters measured at 3, 6, 9 and 12 MAP show that there is no significant difference ($P > 0.05$) between varieties in mean stem diameter (

Table 3). On the other hand, fresh shoot weight and number of tubers per plant are highly significant ($P < 0.001$) between varieties. The local variety Douma 2.69±0.43 kg produces the highest fresh shoot weight than the improved variety Excel 1.69±0.15 kg. The highest number of tubers 6.08±0.43 tubers is produced by the local variety Douma. A significant effect ($P < 0.05$) was recorded between varieties with regard to yield. The highest yield was observed with the local variety Douma (23.8 t ha^{-1}) followed by the improved variety 96/0023 (21.8 t ha^{-1}). The Excel variety has the lowest yield (14.1 t ha^{-1}).

Table 3. Agronomic growth and yield parameters of cassava varieties grown under the influence of *Stictococcus vayssierrei*

Varieties	Stem diameter average (cm)	Fresh shoot average (kg)	Number of tubers average	Yield (t ha^{-1})
92/0057	2.45±0.36a	2.01±0.11bc	4.67±0.52b	18.7±4.5ab
96/0023	2.39±0.29a	2.19±0.38abc	4.50±0.55b	21.8±5.9ab
Excel	2.09±0.22a	1.69±0.15c	4.17±0.98b	14.1±2.8b
8034	2.38±0.35a	2.46±0.25ab	5.17±0.75ab	17.7±5.7ab
Douma	2.55±0.17a	2.69±0.43a	6.08±0.49a	23.8±2.9a
Miboutou	2.29±0.24a	2.30±0.30ab	5.00±0.63ab	20.5±3.7ab
Pr(>F)	0.138ns	<0.001***	0.0006***	0.0139*

P: 0 '***' 0.001 '**' 0.01 '*' 0.05; ns: not significant. Means followed by the same letter in the columns are not significantly different in the Tukey test (*P < 0.05*).

Variation in the number of scale insects on the cassava varieties tested.

The number of root scales (ARTS) on cassava varieties as a function of time is recorded in Table 4. It can be seen that varieties 96/0023, 92/0057 and 8034 have an average number of scale insects between 50 and 75. On the other hand, the local's varieties Miboutou, Douma and Excel have an average number of scale insects between 75 and 100. A very highly significant difference (*P < 0.001*) is observed at 3, 6, 9 and 12 MAP. Overall, the improved variety Excel (90.12 ARTS/P) has the highest average number of scale insects, followed by the local variety Douma (83.27 ARTS/P). The improved varieties 92/0057 (65.54 ARTS/P) and 96/0023 (58.14 ARTS/P) have the lowest average number of scale insects.

Table 4. Number of root scale insect on six cassava varieties

Varieties	3 MAP	6 MAP	9 MAP	12 MAP	Means±SD
92/0057	52.67±8.82cd	92.00±7.94bc	70.92±5.92cd	46.58±3.42c	65.54±2.34d
96/0023	47.50±3.49d	66.79±3.47e	68.13±4.28d	50.13±5.17c	58.14±1.93e
Excel	78.21±8.28a	113.67±7.63a	102.83±4.14a	65.75±4.58ab	90.12±3.84a
8034	66.17±7.19ab	82.25±9.42cd	74.39±6.70cd	59.56±4.70b	70.59±1.88cd
Douma	72.83±6.21ab	104.54±9.38ab	87.21±4.76b	68.49±2.91a	83.27±3.03b
Miboutou	62.33±6.46bc	73.71±7.36de	78.75±5.18bc	70.63±5.57a	71.36±3.96c
Pr(>F)	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

P: 0 '***' 0.001 '**' 0.01 '*' 0.05; ns: not significant. Means followed by the same letter in the columns are not significantly different in the Tukey test (*P < 0.05*).

Diseases observed during the experiment

Throughout the experiment, two diseases were recorded with varying incidence and severity following root scale infestation. These include cassava mosaic disease (CMD) observed only on local varieties and cassava anthracnose disease (CAD) causal agent (*Colletotrichum gloeosporioides* f. sp. *manihotis*) observed on the six cassava varieties tested.

Incidence and severity of cassava anthracnose

Observations of the evolution of cassava anthracnose during the experiment on a site naturally infested with ARTS allowed measuring the incidence and severity of the disease (Fig. 1).

The variation of these two parameters as a function of time shows that they differ from one variety to another with very highly significant differences (*P < 0.001*). The incidence of anthracnose increases up to 6 MAP and no longer varies up to 12 MAP. At 3 MAP, the lowest incidence of 35.24% is observed on variety 96/0023 than on variety 92/0057 (68.56%). As regards severity at this period, the variety Miboutou recorded the highest value (9.14%). At 6 and 12 MAP, all cassava plants are attacked by the disease with an incidence of 100%. However, the severity during these periods varies from one variety to another. At 6 MAP, the Excel variety had the lowest severity (11.14%). At 9 and 12 MAP, variety 96/0023 recorded the lowest severity (19.28 and 29.38% respectively) than variety Miboutou (49.87 and 62.37% respectively).

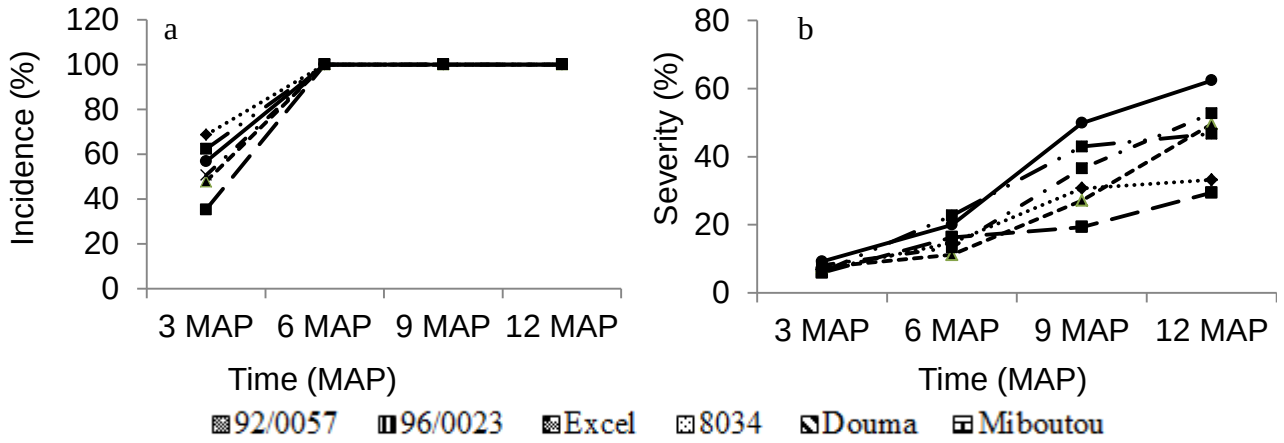

Fig. 1. Evolution of anthracnose as a function of time; a: Incidence; b: Severity.

Incidence and severity of cassava mosaic

The disease in the field was observed on two varieties, namely the Douma variety and the Miboutou variety (Table 5). The evolution of the incidence shows that it no longer varies from 6 MAP onwards. At 3 MAP, the Douma variety recorded an incidence of 36.65% against 41.87% for the Miboutou variety. The severity is higher in the Miboutou variety (32.93%, 67.44%, 77.45% and 83.68%) than the Douma variety (25.54%, 63.63%, 71.13% and 74.82%) at 3, 6, 9 and 12 MAP respectively.

Table 5. Evolution of incidence and severity of cassava mosaic disease as a function of time

Variétés	Incidence (%)				Severity (%)			
	3 MAP	6 MAP	9 MAP	12 MAP	3 MAP	6 MAP	9 MAP	12 MAP
92/0057	0 b	0 b	0 b	0 b	0 c	0 c	0 b	0 c
96/0023	0 b	0 b	0 b	0 b	0 c	0 c	0 b	0 c
Excel	0 b	0 b	0 b	0 b	0 c	0 c	0 b	0 c
8034	0 b	0 b	0 b	0 b	0 c	0 c	0 b	0 c
Douma	36.65 a	100 a	100 a	100 a	25.54 b	63.63 b	71.13 a	74.82 b
Miboutou	41.87 a	100 a	100 a	100 a	32.93 a	67.44 a	77.45 a	83.68 a
Pr(>F)	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

P: 0 '***' 0.001 '**' 0.01 '*' 0.05; ns: not significant. Means followed by the same letter in the columns are not significantly different in the Tukey test (*P < 0.05*).

DISCUSSION

The cassava root scale is a biting-sucking insect that feeds on the resources available in cassava roots, causing loss of vigour and weakening of the plant (Johnson, 2009). Damage caused during its feeding is not limited to specific tissues near feeding sites, but affects the entire plant causing yield losses ranging from 60 to 100% in the field (Lema et *al*., 2004; Tata-Hangy et *al*., 2006).

Results show that cassava varieties were infested differently by scale insects with variation in growth. The highest average shoot fresh weight was produced by the local variety Douma (2.69 ± 0.43 kg) compared to the improved Excel variety which produced the lowest shoot fresh weight (1.69 ± 0.15 kg). It could be hypothesized that infestation of the plants by scale insects feeding on the roots would reduce their growth. Prüter and Zebitz (1991) show that field infestation by sucking biting insect's results in a reduction in leaf area, weight and average growth rate. The reduction in growth parameters is probably caused by the removal of carbohydrates. There are two other factors that are discussed as other possible causes of this reduction. One is a change in the well-source ratio in favour of sucking biting insects (Mallot and Davy, 1978), and the other is the excretion, with the saliva of sucking biting insects, of toxic or phytohormone-like compounds (Miles, 1987). In addition, damage caused by the scale insect at the root can impair the uptake of energy-dependent minerals and lead to a reduction in nutrient supply, thus indirectly affecting plant growth (Hawkins et *al*., 1986; Prüter and Zebitz 1991).

The average tuber number and yield are better for the local variety Douma 6.08±0.49 tubers and 23.8 t ha^{-1} respectively. In general, the improved varieties showed a low yield compared to the local varieties regardless of the damage observed. In addition, the yield of these varieties was not close to the yields expected from the experimental stations. This could be justified by the presence of scale insects that feed at the roots of the plants. Ndengo et *al*. (2016a) obtained similar results in the study on the influence of the population density of ARTS on the yield of cassava varieties in the Democratic Republic of Congo. These authors showed that local varieties were more tolerant to root scale attacks than improved varieties, resulting

in higher yields. According to Schulthess et *al*. (1991), high densities of biting sap-sucking insects generally show adverse effects on crop yields.

The number of root scale insects on cassava varieties varies with time. This number is high at 6 and 9 MAP compared to 3 and 12 MAP. Indeed, Ndengo et *al.* (2016a,b) showed in their work that a high number of ARTS is observed at 6 MAP. On the other hand Lema et *al*. (2004) show that a peak of ARTS infestation on the different cassava genotypes is observed at 9 and 12 MAP. The improved variety Excel and the local variety Douma recorded the highest average number of scale insects than the improved variety 96/0023. This could be explained by the fact that the screened varieties do not have the same genetic heritage and therefore do not develop the same defense mechanisms influencing the root scale fixing behaviour.

All varieties were infested with varying incidence and a ranking according to the level of infestation in ARTS was established. Screening did not reveal any cassava varieties that were fully resistant to *S. vayssierei*. Infested varieties (TMS 96/0023 and TMS 92/0057), moderately infested varieties (Miboutou and 8034) and heavily infested varieties (Excel and Douma) were found. Le Rü et *al*. (1991); Tertuliano (1993) showed that not all cassava varieties sifted in the field against the cassava mealybug (*Phenacoccus manihoti*) are fully resistant, but earlier partially resistant.

By removing its nutritive resource, ARTS injects into the plant tissues toxic saliva that can weaken the plant's defense system, hence the observation of certain diseases with variable incidence and severity. During the experiment, two of the most important diseases (Cassava Mosaic Disease and Cassava Anthracnose Disease) were observed at the site. The importance of CMD attack is related to the susceptibility of the local variety. According to the results of Fokunang et *al.* (2000), in field trials, the severity of Anthracnose and cassava mosaic disease depends on the susceptibility or resistance of the host plant. The incidence and severity of Cassava Anthracnose Disease on all screened cassava varieties ranged from 3 to 9 MAP. Maho (2017) shows in his work that improved and local varieties of cassava were severely attacked by Anthracnose.

CONCLUSION

The damage caused by *S. vayssierei* is observable on the growth and yield of the cassava varieties used. In addition to feeding on the underground parts of the cassava plants, it causes loss of vigour, hence the low yields obtained. The improved Excel variety is the least productive and relatively more infested (90.12 ARTS/P). In addition to root scale infestation, two diseases were observed in the plots, with varying incidence and severity. These are cassava anthracnose observed on all varieties and cassava mosaic observed only on local varieties.

ACKNOWLEDGEMENTS

The authors are sincerely thankful to the International Institute of Tropical Agriculture and Institute of Agricultural Research for Development for planting material provision.

COMPETING INTERESTS

The authors declare that they have no competing interest.

REFERENCES

Ambe JT, Ntonifor NN, Awah ET, Yanine JS (1999). The effect of planting dates on the incidence and population dynamics of the cassava root scale, *Stictococcus vayssierei*, in Cameroon', International Journal of Pest Management. 45: 125-130.

CNRCIP. (1989). Annual report for 1989 of the CAMEROON NATIONAL ROOT CROP IMPROVEMENT PROGRAM (CNRCIP). Annual Report (BP 13, Njombe, Cameroon: IRAD Njombe).

Dejean A and Matile-Ferrero D (1996). How a ground-dwelling forest ant species favors the proliferation of an endemic scale insect (Hymenoptera: Formicidae; Homoptera: Stictococcidae). Sociobiology. 28: 183-195 Biology 56: 481-501.

Fokunang C.N, Dixan AGO and Akem CN (2000). Field reaction of cassava genotypes toanthracnose, facterial bligtht, cassava mosaic disease and their effets on yield. Africa Crop Science Journal, 8 (2): 179-186.

Graziosi I and Wyckhuys KAG (2017). Integrated management of arthropod pests of cassava: the case of Southeast Asia. In Hershey C (ed.), Achieving Sustainable Cultivation of Cassava, vol II. Cambridge: Burleigh Dodds, pp. 1–26.

Hanna R, Tindo M, Wijnans L, Goergen G, Tata Hangy K, Lema K, Toko M, Ngeve JM, Dixon A, Gockowski J (2004). The African root and tuber scale problem in Central Africa: the nature of the problem and the search for control options. In: Book of Abstracts of the 9th Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch, 31 October–5 November 2004, Mombasa, Kenya. 57 p.

Hawkins CDB, Whitecross MI and Aston MJ (1986). Interactions between aphid infestation and plant growth and uptake of nitrogen and phosphorous by three leguminous host plants. Canadian Journal of Botany 64, 2362-2367.

International Institute of Tropical Agriculture, (2000). How to start a cassava field, a guide to IPM practice for extension workers.IITA, Ibadan, Nigeria. 24 p.

Johnson PJ 2009. Mealybugs on orchids. American Orchid Society, Available online at https://www.aos.org/Default. aspx?id=511

Jose A, Makeshkumar T and Edison S (2008). Host Range of Sri Lankan Cassava Mosaic Virus. Journal of Root Crops, 2008, Vol. 34 No, 1, PP, 21-25, (34 1): 21-25.

Kamau J, Melis R, Mark-Laing, Derera J, Shanahan P, Ngugi CKE (2011). Farmers 'participatory selection for early Bulking Cassava genotypes in semi-arid Eastern Kenya. Journal of Plant Breeding and crop sciences. 3: 44-52.

Le Rü B, Tertuliano M, et Calatayud PA (1991). Les différentes catégories de résistance des plantes-hôtes de la cochenille du manioc *Phenacoccus manihoti* (Hom. Pseudococcidae): Perspectives d'études. Résume du 4ème Atelier du Réseau CORAF Manioc : Biocénose des principaux ravageurs du manioc et lutte biologique. IITA Bénin- Cotonou, 4-9 mars 1991. (Sous presse).

Lema KM, Tata-Hangy K, Bidiaka M (2004). Management of African root and tuber scale using improved cassava genotypes and mineral fertilisers African Crop Science Journal. 12: 217-221.

Liu J, Zheng Q, Ma Q, Gadidasu KK. and Zhang P (2011). Cassava genetic transformation and its application in breeding. Journal of Integrative Plant Biology. 53 (7): 552–569.

Maho YEJ (2017). Epidémiologie de l'anthracnose sur quelques variétés de manioc (*Manihot esculenta* Crantz) et caractérisation de *collectotrichum gloeosporioides* agent causal de la maladie au Cameroun. Thèse Ph.D. Université de Yaoundé I. 162 p.

Mallot PG, and Davy AJ (1978). Analysis of effects of the bird cherry-oat aphid on the growth of barley. Unrestricted infestation. New Phytologist 80: 209-218.

Miles PW (1987). Feeding process of Aphidoidea in relation to effects on their food plants. In Aphids: their biology, natural enemies, and control, pp. 321-339. Eds A. K. Minks and P. Harrewijn. Amsterdam : Elsevier Science Publishers B.V.

Mutsaers H, Mbouémboué P, Mouzong B (1981). Traditional food crop growing in the Yaoundé area (Cameroon). Part I. Synopsis of the system Agro-Ecosystems. 6: 87-273.

Ndengo NE, Ki-Munsek, AL, Hanna R, Mahungu NM, Ngbolua K (2016a). Influence of the population density of the African root and tuber scale insect (*Stictococcus vayssierei* Richard) on the yields of Cassava (*Manihot esculenta* CRANTZ) improved in different Agro-ecological zones of Beni (North Kivu, DR Congo). International Journal of Innovation and Applied Studies 16: 247-259.

Ndengo NE, Ki-Munsek, AL, Hanna R, Mahungu NM, Ngbolua K (2016b). Screening cassava (*Manihot esculenta* CRANTZ) genotypes for resistance to African root and tuber scale (*Stictococcus vayssierei* Richard) in different Agro-ecological zones of Beni (North Kivu, DR Congo). International Journal of Innovation and Applied Studies 16: 247-259.

Ngeve JM (2003). The cassava root mealybug (*Stictococcus vayssierei* Richard) (Homoptera: Stictococcidae): a threat to cassava production and utilization in Cameroon, International Journal of Pest Management 49: 327-333.

Nonveiller G (1984). Catalogue des insectes du Cameroun d'intérêt agricole. Beograd: Institut pour la Protection des Plantes, Mémoires XV.

Prüter C and Zebitz CPW (1991). Effects of *Aphis fabae* and Urumyces viciae-fabaeon the growth of a susceptible and an aphid resistant cultivar of *Vicia faba*. Ann. appl. Biol., 119: 215-226.

Rwegasira GM. and Rey CME (2012). Response of selected cassava varieties to incidence and severity of cassava brown streak disease in Tanzania. Journal of Agricultural Science, 4 (7): 237-245.

Renard F et Foucart G (2008). Les maladies foliaires de la fin de végétation en culture de maïs. CIPF-Centre pilote en culture de maïs. Laboratoire d'Ecophysiologie et d'Amélioration Végétale. UCL-Louvain-la-Neuve. 6 p.

Richard C (1971). Contribution à l'étude morphologique et biologique des Stictococcinae [Hom. Coccoidea]. Annales de la Société Entomologique de France 7: 571–609.

Schulthess F, Baumgartner JU Delucchi V and Gutierrez AP (1991). The influence of the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr. (Hom., Pseudococcidae) on yield formation of cassava, *Manihot esculenta* Crantz. Journal of Applied Entomology 111: 155-165.

Tata-Hangy K, Hanna R, Toko M, Lema KM, Solo M (2006). Changes in population abundance of the African root and tuber scale *Stictococcus vayssierei* Richard (Homoptera; Stictococcidae) on cassava in the bas-fleuve district in the Democratic Republic of Congo. In: Mahungu N.M., Manyong V.M., editors. Advances in Root and Tuber Crops Technologies for Sustainable Food Security, Improved Nutrition, Wealth and Environmental Conservation in Africa. Proceedings of 9th ISTRC-AB Symposium Mombassa, Kenya. 574-582.

Tchumakov EE et Zaharova I.I (1990). Influence et statistique du développement des maladies. In : *dommages causées par les maladies aux cultures agricoles*. Edition Agroprome, Moscou, pp 5-60.

Tertuliano M, (1993). Résistance du manioc à la cochenille farineuse *Phenacoccus manihoti* (Homoptera : Pseudococcidae) : rôles de quelques composés chimiques foliaires. Thèse de doctorat. Université de Rennes 1. 85 p.

Tindo M, Hanna R, Goergen G, Zapfack L, Tata-Hangy K, Attey A (2009). Host plants of *Stictococcus vayssierei* Richard (Stictococcidae) in non-crop vegetation in the Congo Basin and implications for developing scale management options, International Journal of Pest Management, 55 (4): 339-345.

Tindo M, Doumtsop A, Goergen G and Hanna R (2006). Morphological description and illustration of female developmental stages of *Stictococcus vayssierei* (Homoptera: Stictococcidae). International Journal of Tropical Insect Science. 26 (2): 126-133.

Westphal E (1985). Cultures vivrières tropicales avec référence spéciale au Cameroun. Ed PUDOC, Wageningen-Nertherlands. pp. 119-163

Williams DJ, Matile-Ferrero D and Miller DR (2010). A study of some species of the genus *Stictococcus* Cockerell (Hemiptera: Sternorryncha: Coccoidea: Stictococcidae), and a discussion on *Stictococcus vayssierei* Richard a species injurious cassava in Equatorial Africa with a description of a new species from Nigeria. Zootaxa. 2527: 1-27.

Cite this Article: Ngatsi PZ; Ndongo B; Manga DA; Ndongo EB; Djieto-Lordon C (2020). Effect of *Stictococcus vayssierei* Richard (Hemiptera: Stictococcidea) on growth and yield of cassava (*Manihot esculenta Crantz*). *Greener Journal of Agricultural Sciences* 10(2): 95-102.
.