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RESEARCH ARTICLE
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Grasshopper *(Zonocerus variegatus* L) Infestation and Root Dry Matter Content of Cassava as Influenced by Planting Date and Cassava Genotypes

Infestación de Saltamontes (*Zonocerus variegatus* L) y Contenido de Materia Seca en Raíces de Yuca Influenciados por la Fecha de Siembra y los Genotipos de Yuca

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Abstract

Dearth of information exists on the effects of planting dates and genotypes on grasshopper (*Zonocerus variegatus* L.) infestation and dry matter accumulation in the root organ of cassava. An experiment was conducted at the School of Agriculture and Food Sciences Experimental site of Njala University during 2007/2008 and 2015/2016 cropping seasons. This study assessed the effects of planting date and cassava genotypes on grasshopper infestation and root dry matter accumulation in cassava. The experiment utilized four cassava genotypes (Cocoa, SLICASS 1, SLICASS 4 and SLICASS 6) and three planting dates (June, September and December) laid out in a Randomized Complete Block Design (RCBD) with three replications. Findings showed that the incidence and severity of grasshopper attacks, as well as root dry matter contents were significantly ($p<0.05$) different between variety and planting dates. The grasshopper severity scores increased from 3 months after planting (MAP) (1.6) to 9 MAP (2.6). Similarly, the incidence increased from 3 MAP (23.0 %) to 9 MAP (29.7 %). The lowest percent incidence of grasshoppers was observed in June (24.8%), followed by September (26.0 %), whilst December recorded the highest (30.7 %). Similar trends were exhibited for severity score for June (1.5), September (2.2) and December (2.5) planting dates. Genotype SLICASS 6 (42.21 %) had the highest root dry matter content, followed by SLICASS 1 (42.17 %), while Cocoa and SLICASS 4 had the lowest of 41.90 %. The protected plots recorded higher root dry matter content (44.0 %) than the unprotected plots (40.9 %). Identification of tolerant cassava variety, protection of cassava field from grasshopper infestation and harvesting cassava in December could be exploited for selection and production of tolerant cassava variety with desired processing traits such as high root dry matter content.
Key word: *Grasshoppers, Planting dates, Management, Root dry matter, Cassava*

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Resumen

Existe poca información sobre los efectos de las fechas de siembra y los genotipos sobre la infestación de saltamontes (*Zonocerus variegatus* L.) y la acumulación de materia seca en el *órgano* radicular de la yuca. Se realizó un experimento en el sitio experimental de la Escuela de Agricultura y Ciencias de la Alimentación, de la Universidad de Njala durante las temporadas de cultivo 2007/2008 y 2015/2016. Este estudio evaluó los efectos de la fecha de siembra y los genotipos de yuca sobre la infestación de saltamontes y la acumulación de materia seca en la raíz de la yuca. El experimento utilizó cuatro genotipos de mandioca (Cacao, SLICASS 1, SLICASS 4 y SLICASS 6) y tres fechas de siembra (junio, septiembre y diciembre) dispuestos en un diseño de bloques completos aleatorizados (RCBD) con tres repeticiones. Los resultados mostraron que la incidencia y la gravedad de los ataques de saltamontes, así como el contenido de materia seca radicular, fueron significativamente diferentes ($p<0.05$) entre la variedad y las fechas de plantación. Las puntuaciones de severidad del saltamontes aumentaron 3 meses después de la plantación (MAP) (1.6) a 9 MAP (2.6). Del mismo modo, la incidencia aumentó de 3 MAP (23 %) a 9 MAP (29.7 %). El porcentaje más bajo de incidencia de saltamontes se observó en junio (24.8 %), seguido de septiembre (26 %), mientras que diciembre registró el más alto (30.7 %). Se observaron tendencias similares para la puntuación de severidad en las fechas de plantación de junio (1.5), septiembre (2.2) y diciembre (2.5). El genotipo SLICASS 6 (42.21 %) tuvo el mayor contenido de materia seca radicular, seguido de SLICASS 1 (42.17 %), mientras que Cacao y SLICASS 4 tuvieron el más bajo de 41.90 %. Las parcelas protegidas registraron un mayor contenido de materia seca radicular (44 %) que las parcelas no protegidas (40.9 %). La identificación de la variedad de yuca tolerante, la protección del campo de yuca contra la infestación de saltamontes y la cosecha de yuca en diciembre podrían aprovecharse para la selección y producción de la variedad de yuca tolerante con rasgos de procesamiento deseados, tales como un alto contenido de materia seca de la raíz.

Palabras clave: *Saltamontes, fechas de plantación, manejo, materia seca radicular, yuca*

Introduction

Cassava (*Manihot esculenta* Crantz) is an important staple food security crop consumed by over 800 million individuals of the global populace (Esuma et al., 2019). The crop is utilized as food, feed and different industrial applications that support many livelihoods globally. In Sierra Leone, cassava is ranked as the second staple food after rice. The fresh storage roots contain mainly starch and other food nutrients such as calcium (0.16 g/kg), phosphorus (0.27 g/kg), vitamin C (0.206 g/kg), and minute quantities of protein and other nutrients (United States Department of Agriculture [USDA], 2016). Moreover, the leaves of cassava are consumed as vegetables since they contain protein such as lysine, but lack the amino acid methionine and possibly tryptophan (Nweke et al., 2002; Chipeta et al., 2013). Other cassava products utilized in the country are cassava pellets for animal feed, cassava starch for sweeteners, thickeners and textile paper industry (Chipeta et al., 2013).

Despite the enormous importance of the crop, a number of biotic and abiotic factors (Kintché et al., 2017) limits increased cassava productivity. Among biotic factors, some of the key insect pests that affect the economic yield of the crop include variegated grasshopper (*Zonocerus variegatus* L.), cassava green mite, and cassava mealy bug. The variegated grasshopper belongs to the same order (Orthoptera) as locusts (Britton, 2020). This insect defoliates and destroys the stem bark of food crops at the end of the dry season. The feeding behaviour of this pest also results in the reduction in cassava tuber yield and quality and the destruction of cassava cuttings (Brima et al., 2000). Although often viewed as a polyphagous pest, grasshoppers are selective to some degree, exhibiting definite plant preferences (Mansaray et al., 2012). Studies carried out by Song (2010) have shown that grasshoppers could be conveniently classified as grass-feeders (Graminivorous), forb–feeders (Forbivorous) or a mixture of the two (Ambivorous or mixed feeders). Also, Picaud et al. (2003) have attributed the chemical composition of plants as the main factor in the food selection behaviour of grasshoppers. The pest defoliates and destroys the stem bark of food crops at the end of the dry season (Mansaray et al., 2012). Moreover, the feeding behaviour of the pest reduces the storage root quality and destroys the cassava stem cutting planting materials (Mansaray et al., 2012). The cassava green mite infestation was reported to cause about 15 % and 73 % storage root yield losses in resistant and susceptible genotypes of cassava, respectively (Bellotti, 2002). Cassava mealy bug infestation causes about 88 % root yield loss in susceptible genotypes of cassava (Bellotti et al., 1987). Low storage root yields of cassava are opined to be caused by low yielding genotypes, environmental variability and poor environmental management or utilization of elite agronomic packages (Karim et al., 2020).

Research has shown that early nymphs of grasshoppers are deterred from feeding on cassava due to the presence of cyanogenic glucosides (Brima et al., 2000). The concentration of this plant secondary compound varies among cassava clones ranging from 80 mg to 167 mg CN per 100 g of fresh leaf (Isley, 1944). Control of the variegated grasshopper has generally involved knock off chemical pesticides. However, because of the increasing concern of its effect on non-target organisms, prohibitive cost and persistence in the environment, there is the need for environmentally friendly alternative. In this regard, host plant resistance is strongly advocated for the control of pests and diseases than the continual utilization of pesticides due to its adverse environmental effects on the ecosystem and unsustainability for low-income small-scale farmers (Bellotti, 2002). Host plant resistance can be described as any reduction in the population growth of a target pest as influenced by inheritable characteristic of the host plant compared to a standard variety (Bellotti & Arias, 2001). Host plant resistance is as a result of the presence of secondary compounds found in plants; the nature and concentration of these compounds varies in time and space and also among and within plant varieties (Erb & Kliebenstein, 2020).

End-use quality traits significantly affect the acceptance of cassava genotypes by producers, processors and consumers (Fomba et al., 2012). In effect, the success of newly developed cassava genotypes depends not only on their agronomic attributes but also on their acceptability by targeted end-users. Cassava genotypes with good food qualities possess high dry matter as one of the key traits. The research questions of the present study included the following: (i) is the effect of planting date on grasshopper infestation and root dry matter content in cassava significant? and (ii) is the effect of cassava genotypes on grasshopper infestation and root dry matter content in cassava significant? The aim of the present study was to assess the effects of planting date and cassava genotypes on grasshopper infestation and root dry matter accumulation in cassava. The results of the study will contribute to solving in-field grasshopper infestation through identification of appropriate planting date, selection and production of tolerant cassava variety with desired processing traits such as high root dry matter content.

Materials and Methods

Description of Field Trials

The trial was carried out at the School of Agriculture farm site, Njala University, Njala, Kori Chiefdom, Moyamba District, Southern-Sierra Leone. Njala is located at an elevation of approximately 54 m above sea level on latitudes 8 °06′ N and on longitude 12 °06′ W. The trial site has vegetation that is mostly of elephant grass (*Andropogon sp*.) and Spear grass (*Imperata cylindrica*). The experiment was conducted both in rainy and dry seasons. During the dry season, overhead irrigation was done.

There are two distinct seasons, the wet season (May-October) and the dry season (November –April). The mean annual rainfall at Njala is 2 525 mm with a mean monthly maximum air temperature ranging from 29 °C to 33 °C. Relative humidity is very high often close to 100 % for the greater part of the day and at night especially during the rainy season.

During the dry season potential evapotranspiration exceeds rainfall, while during the rainy season precipitation exceeds evapotranspiration. The predominant vegetation at Njala is secondary bush and the soil belongs to the Njala series (*Orthoxic palihumult*). Textures are usually gravelly clay loam in the surface and gravelly clay loam to gravelly clay in the sub-soil. The soils are low in soil moisture and have a very low nutrient status and are slightly acidic with pH ranging from 5.5 to 6.0.

Experimental Materials and Design

The trial was laid out in a 3 × 4 factorial arrangement in a Randomized Complete Block Design (RCBD) with 3 replications. The two factors included three levels of planting date: June, September and December and four genotypes: Cocoa cassava (local check variety), Sierra Leone Improved Cassava (SLICASS) 1, SLICASS 4 and SLICASS 6. The origins, potential yields and disease tolerance attributes of the four genotypes are presented in Table 1. Stem cuttings of each genotype measuring 30 cm in length each were planted on the crest of ridges at 1 m × 1 m spatial arrangement giving a plant population of 10 000 plants ha^{-1}. A total of 40 cuttings were planted per plot. The treatments were established in protected and unprotected experimental blocks**.** Block A (protected plots) was located in an area that was less prone to grasshoppers, whereas Block B (unprotected plots) was located closer to the source of grasshopper infestation. The distance between the two blocks was 200 m and the sites were separated by a small stream. The protected block was sprayed periodically with Chlorpyrifos to prevent grasshoppers' infestation. Hand picking was also done throughout the growing season to remove any hoppers that entered the protected plots. No fertilizer was applied in both the unprotected and protected plots or sites. Hand weeding was done when necessary.

Data Collection and Analysis

Evaluation of the genotypes for susceptibility to grasshopper in the field was based on the injury done to each genotype by the pest. Severity was expressed as the total area of the cassava plant tissue affected over the total area of the plant tissue. Grasshopper severity was estimated using the visual rating scale of 1 to 5 per individual plant; where: 1 = 0 % to 20% of foliage damaged, 2 = 21 % to 40% of foliage damaged, 3 = 41 % to 60% of foliage damaged, 4 = 61 % to 80% of foliage damaged and 5 = 81 % to 100% of foliage damaged following the procedure by Capinera (1993). Pest assessments were done at 3, 6, 9 and 12 months after planting (MAP) which coincided with the rainy season, dry season and dry-rainy season transition periods. Percentage incidence was expressed, as the number of infected cassava plants over the total number of cassava stands planted expressed as percentage. Data on plant damage was collected on the two middle rows per plot, which at maturity was used for yield estimation.

Root dry matter content (RDMC) determination was done at harvest (12 MAP) by selecting three representative roots from the bulk of roots harvested from 5 plants. Cassava roots were washed and shredded into pieces. A standard measure of 100 g weight of the fresh samples was taken and oven dried with forced drought oven. Samples were reweighed again to obtain a constant weight after 72 h at 65 °C –70 °C (Fukuda et al., 2010).

All data collected were pooled and subjected to factorial ANOVA and means were separated using the Student Newman Keuls Test (SNK) at 0.05 level of significance.

Results and Discussion

Percent Incidence

Analysis of the data using ANOVA shows significant differences ($p<0.05$) in the percent incidences of grasshoppers with respect to the planting time. The percent incidence of

Table 1. Origin, status and attributes of *Manihot esculenta* genotypes used in the study

Genotype	**Origin**	**Status**	**Attributes**
Cocoa	Sierra Leone	Landrace	Susceptible to cassava mosaic disease (CMD), low root yielding (7 t.ha^{-1})
SLICASS 1	Nigeria	Improved	Resistant to CMD, medium yielding (15 t.ha^{-1}-20 t.ha^{-1})
SLICASS 4	Nigeria	Improved	Resistant to CMD, high yielding (20 t.ha^{-1}-30 t.ha^{-1})
SLICASS 6	Nigeria	Improved	Resistant to CMD, high yielding (20 t.ha^{-1}-30 t.ha^{-1})

grasshoppers was observed to be lowest in June (24.8 %), followed by September (26.0 %), whilst December recorded the highest (30.7 %) across the four cassava varieties (Table 2). These findings show that grasshopper attack increases with time from the rainy season to the dry season. The lowest incidence of the pest observed on the field in June could probably be attributed to the heavy rains that serves as a mortality factor of grasshoppers. As the intensity of rainfall decreased between September and December, the mean incidence of grasshoppers significantly increased. This observation concurs with Mansaray et al. (2012) who reported that grasshoppers cannot withstand heavy rains, as rain is one of the natural factors responsible for the high mortality rate of the pest in the field.

With regards the time of observation, mean incidence was significantly different (p=0.05) during the observation periods. The highest grasshopper incidence was observed at 9 MAP (29.7 %), closely followed by 6 MAP (23.9 %), 3 MAP (23.0 %) and the least was recorded by 12 MAP (18.6 %), respectively across the four cassava varieties (Table 3).

The higher incidence at 6 MAP and 9 MAP could probably be related to the life cycle of the grasshoppers. This observation is in agreement with the findings of Brima et al. (2000) who reported that grasshoppers damage is more common in older than younger cassava plants, and is more severe in the dry season than in the wet season. Mansaray et al. (2012) reported similar findings on grasshopper incidence in cassava fields at Njala Agricultural Research Centre (NARC) experimental site, Njala, southern Sierra Leone.

Severity Score

Significant (P<0.05) differences were also recorded for grasshopper severity scores with respect to planting time. The highest score was observed in December (2.5), followed by September (2.2) and the least severity score in June (1.5) (Table 4). The increased severity score for December and September planting time compared to June could probably be due to the stage of plant growth at the time of infestation by grasshoppers. International Institute of Tropical Agriculture (IITA, 2000) reported that young cassava plants suffer more from pest attack than older plants. At 3 - 4 months after planting, the roots of the cassava plants start to heave as a result of photosynthate translocation from the leaves to storage root organ development. At 7 months after planting, the total number of storage roots could have been formed. Beyond this time, the storage root number does not increase, but the storage roots continue to grow in size until they are harvested. Therefore, cassava farms attacked by pests at lesser than or 7 months after planting, incur more yield losses than if older plants are attacked.

Table 2. Mean percentage incidence of grasshoppers with respect to planting time

Time of planting	Incidence score (%)	F	P
June	24.8 c	5.0	0.014
September	26.0 b		
December	30.8 a		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

Table 3. Mean percent incidence of grasshoppers with respect to observation time

Sampling regime (MAP)	Incidence score (%)	F	P
3	23.0 c	518.84	0.0001
6	23.9 b		
9	29.7 a		
12	18.6 d		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

Table 4. Mean severity score of grasshoppers with respect to planting time

Time of planting	Severity score	F	P
June	1.5 c	18.95	0.0001
September	2.2 b		
December	2.5 a		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

With respect to observation time, significant (p < 0.05) differences were also recorded in severity scores across the four cassava varieties. The highest severity score was recorded at 9 MAP (2.6), followed by 6 MAP (2.5), 3 MAP (1.6), while the lowest severity score was recorded at 12 MAP (1.5) (Table 5).

The reason for the slightly high severity at 6 MAP and 9 MAP could be related to the fact that at this stage of development of the plant; the grasshoppers would have developed to the late instars or adult stage which causes most destruction on cassava plants in the field compared to when the cassava plant is young (Bernays et al., 1975). At the younger stage lesser than 4 months after planting, the cassava plants possess higher HCN compound that deters the young instars (1 - 3) from feeding on the crop, rather they will prefer to die. The above observation is in accordance with Brima et al. (2000) who reported that the older nymphs and adults cause more damage to cassava than the young nymphs. Moreover, the authors opined that cassava plants that are 3 - 4 months or lesser than 7 months old are not fed on by nymphs of grasshopper. The low severity impact reported at 3 MAP could be due to the same observation. These findings also support the view that the first and second instars of grasshoppers prefer to die rather than feed on cassava (Bernays et al., 1977). In addition, most of the early nymphs were found on green vegetables known as alternate hosts within or outside the cassava field.

The root dry matter contents with respect to variety and planting dates were significantly (p<0.05) different (Tables 6 and 7). The highest root dry matter content was recorded in SLICASS 6 (42.21 %), followed by SLICASS 1 (42.17 %), while Cocoa (41.9 0%) and SLICASS 4 (41.90 %) had the least root dry matter content (Table 6). The slight differences in root dry matter content among the varieties could probably be due to their inherent genetic variation. The highest root dry matter content was recorded in December (43.7 %), followed by September (40.1 %) and the least of 39.8 % was recorded in June (Table 7). The variation in dry matter accumulation in the cassava root organ could be attributable to the dry matter reversion in the cassava physiology caused by seasonal variation. The results indicate that harvesting of cassava roots in December or in the dry season exhibits the highest dry matter accumulation useful for processing of the crop compared to harvesting done in the wet season period such as June and September. Findings are consistent with Sagrilo et al. (2008) who assessed the performance of cassava cultivars in the Northwest Paraná at different harvest times and concluded that, for those conditions, the physiological rest period at the end of the second crop cycle was more indicated for harvest, due to the higher production of the fresh storage root dry matter content and starch.

The root dry matter content significantly (p<0.05) differed with management (Table 8). The protected plots recorded higher mean root dry matter content of 44.0 %, while the

Table 5. Mean severity score of grasshoppers with respect to sampling time

Sampling time (MAP)	Severity score	F	P
3	1.6 c	21.37	0.0001
6	2.5 b		
9	2.6 a		
12	1.5 d		

Means in column with the same letter are not significantly different at p< 0.05 (SNK); Severity score: 1= 0 %-20 % of foliage consumed, 2= 21 % - 40 % of foliage consumed, 3= 41 %-60 % of foliage consumed, 4= 61 %-80 % of foliage consumed and 5= 81 % - 100 % of foliage consumed (Capinera, 1993).

Table 6. Mean root dry matter content with respect to variety

Variety	Root dry matter content (%)	F	P
Cocoa	41.90 c	38.5	0.000418
SLICASS 1	42.17 b		
SLICASS 4	41.90 c		
SLICASS 6	42.21 a		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

Table 7. Mean root dry matter content with respect to planting time

Time of planting	Root dry matter content (%)	F	P
June	39.8 c	547	0.0001
September	40.1 b		
December	43.7 a		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

unprotected plots had mean root dry matter of 40.9 %. The difference in mean root dry matter contents between the protected and the unprotected management strategies could probably be due to high degree of feeding of grasshoppers on the cassava varieties on the unprotected plots compared to the protected plots. This is in agreement with the findings of Mansaray et al. (2012) who opined that cassava plants in unprotected plots are more vulnerable to grasshoppers than those in protected plots and thus account for dry matter differences.

Conclusion

This study demonstrates that increasing root dry matter content and reducing grasshopper infestation require use of improved farming practices such as protected production environment, adequate planting date and cassava genotypes by farmers. Findings established a significant influence of planting date and cassava genotypes on selected agronomic traits and root dry matter content in cassava that could be exploited for increased productivity of the crop in protected and non-protected cropping systems. Identification of tolerant cassava variety, protection of cassava field from grasshopper infestation and harvesting cassava in December could be exploited for selection and production of tolerant cassava variety with desired processing traits such as high root dry matter content. The protection of cassava field from grasshopper infestation, early planting in June and harvesting in December contribute to high root dry matter content and invariably the production of good quality planting material that is resistant to grasshopper attack.

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Authors' contributions

TSJ, FSN: Conceptualization of the work, experimental design and revision of the manuscript. TSJ, AES, AJS, DDQ, FSN, KSA, MDP, PEN: Discussion of results, support and supervision of the study. TSJ, AES, AJS,

Table 8. Mean root dry matter content with respect to treatment

Treatment	Root dry matter content (%)	F	P
Protected	44.0 a	94.08	0.0003
Unprotected	40.9 b		

Means in column with the same letter are not significantly different at p< 0.05 (SNK)

DDQ, FSN, KSA, MDP, PEN: Fieldwork supervision, manuscript review. TSJ, AES, MDP, FSN: Support and supervision in field work, manuscript revision. TSJ, AJS, FSN, KSA, MDP, PEN: Experimental design, statistical analysis of results. TSJ, AJS, PEN: Field work carried out, review of statistical analysis of results. TSJ, FSN, AES: Logistics management, execution of field work.

Conflict of interests

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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