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Seasonal Dynamics and Damages of *Mononychellus tanajoa* Bondar (Acari: Tetranychidae) on Commercial Cassava Varieties in Mwanza Region, Lake Zone,Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author BSW designed the study, wrote the protocol and the first draft of the manuscript. Author GMR made conceptual contributions, corrections and objective criticisms; he was assisted by author ABK. While author SJ coordinated the fields work with close supervision. All authors read and approved the final manuscript.

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ABSTRACT

Two-year studies were conducted to determine the responses of 9 commercial and local cassava varieties to *M. tanajoa* and the environment during the 2014/2015 and 2015/2016 wet and dry seasons at Ukiriguru in Mwanza region of the Lake Zone, Tanzania. The experiments were conducted at Lake Zone Agricultural Research and Development Institute, Ukiriguru. These were laid out in a Randomized Complete Block Design (RCBD) with three replications, making a total of twenty-seven plots allocated to a plot size of $36m^2$ with a 1m path between plots and 2m between blocks. One stem cutting (30cm long) was planted at a spacing of 1x1m within and between rows giving a total of 10,000 plant population ha^{-1}. This was allowed under natural infestation by the

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mites. Results revealed that the population and damage were higher in 2016 while leaf malformation and mites incidence were statistically greater in 2015. Cassava varieties were heavily infested and damaged at lower age range (3 and 6 months) within and between the two seasons. Among the crop varieties, Liongo Kwimba recorded higher infestation and suffered most in leaf damage and malformation. Kyaka cassava variety was found to performed better in yield despite the attack by the mites while Liongo Kwimba recorded the lowest yield. The regression analysis predicted mostly negative relationships among the weather variables and the population, damage and incidence of *M. tanajoa*. Therefore, farmers at Ukiriguru could be encouraged to plant Kyaka variety for increased yield while Liongo Kwimba should be improved especially by breeding and molecular researches. More so, there is need to manipulate planting season by early planting before the favourable period of growth and perpetuation of *M. tanajoa.*

Keywords: Occurrence; Kyaka cassava variety; Liongo Kwimba; cassava green mite; incidence and Tanzania.

1. INTRODUCTION

In Tanzania, East African region and Africa in general, cassava *Manihot esculenta* Crantz (Euphorbiaceae) is grown for local consumption of its root tubers which are swellings of the adventitious roots of the stem. The roots are rich in starch, calcium and vitamin C [1,2]. The East African countries are increasingly producing more cassava both as a cash crop and security foodstuff [3,4,5]. Several previous studies have revealed the economic advantage of cassava root where high root yield has the potential for processing into many industrial and food products [6,7]. The central and West African countries have more established industries for cassava products than the east African region [8].

Cassava green mite, *Mononychellus tanajoa* Bondar. (Acari: Tetranychidae) is the most important among pests that attack cassava in Tanzania [9,10]. *Mononychellus sp.* was first reported in the country in 1972 at Ukerewe Islands [11]. It attacks mainly shoots and leaves of cassava reducing both photosynthetic rate and root dry matter [10]. In the Lake zone, the pest is more devastating that losses a ranging from 20% to 80% tuber yield loss if left uncontrolled [12]. At present, the mites have spread throughout the country, although at varied incidences among agro-ecological zones. It is not known that if such variations are related to seasonal changes or the varied responses of the cassava varieties that are commonly grown.

Several commercial cassava varieties have been developed and released in Tanzania (especially in 2010) targeting the yield and major diseases, but limited information exists on their responses to *M. tanajoa*. Researchers that are geared towards understanding the ecology and the importance of the pest are scarce. The dynamics of pest population across seasons has not been established in Mwanza region of the Lake Zone, Tanzania. The current study aims at bridging the research gaps on *M. tanajoa* and the outcome(s) could be useful in the management of *M. tanajoa* to its minimum damage threshold level and subsequent losses in the Lake Zone and Tanzania in general.

2. MATERIALS AND METHODS

Mwanza region of the Lake Zone (020 45’S 320 45’E) Tanzania is the leading cassava producing zone that accounts for about 37.43% of the total cassava in the country [13]. Two experiments were conducted during 2015 and 2016 rainy and dry seasons to determine the seasonal changes and damages of *M. tanajoa* on some selected commercial and local cassava varieties. The site, Ukiriguru is located at 02°43.156’S, 033°01.43’E and 1400 m above sea level in Misungwi district of Mwanza region of the Lake Zone, Tanzania. Nine commercial and local cassava varieties Naliendele (NLD), Kiroba (KRB), Meremeta (MRM), Belinde (BLD), Liongo Kwimba (LNG), Suma (SUM), Mkombozi (MKZ), Kyaka (KYK) and Namikonga (NMK) were selected from three different zones; Lake, Eastern and Southern zones. These were planted and randomized into nine plots using Randomized Complete Block Design (RCBD) and replicated three times making a total of twenty-seven plots. The treatments were allocated to a plot size of 36m^2 with the 1 m path (boarder) between plots and 2 m between blocks, respectively. One stem cutting (30 cm long) was planted at a spacing of 1x1 m within and between rows giving a total of 10,000 plant population ha^{-1} in a 1, 924m^2 plot. This was allowed under natural infestation by the mites.

2.1 Population Assessment of *M. tanajoa*

Cassava green mite population was monitored on monthly basis after three months of planting i.e from March and ending in September 2015 and 2016 respectively. This was taken by the physical counting of the mites from the top fully open five leaves using a hand lens (Model No. YT1045/50 mm). In each plot, eighteen cassava plants were selected randomly and leaving 1 cassava to stand out from the habitat boundaries to avoid border effects modified from [9].

2.2 Assessment of the Mites' Incidence

The incidence was assessed by carefully opening the leaves from the top fully open five leaves using a hand lens (Model No. YT1045/50 mm). In each plot, eighteen out of the 36 cassava plants were selected randomly along the diagonals and recording presence or absence of the mites. One cassava stand was left out from the habitat boundaries to avoid border effects modified from [9].

2.3 Leaf Damage Assessment

The leaf damage was recorded using a scale of 1 to 5 (i.e. 1 means no obvious symptom, 2 = less than 5% of leaf chlorosis, 3 = more than 5% but less than 50% of leaf chlorosis, 4 = more than 50% of leaf chlorosis with significant reduction in leaf area and 5 = leaf is dead and has dropped) a result of the damage by the mites as adopted from [14].

2.4 Leaf Malformation Assessment

The leaf malformation was taken from the 1 to 5 damage scale above modified from [14]. A scale of 2 to 5 was used to distinguish between leaf malformations as follows. 2 = leaf not malformed, 3 = more than 5% but less than 50% malformed, 4 = more than 50% malformed with significant reduction in shape and 5 = the leaf is 100% distorted or died.

2.5 Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) in a RCBD using the GenStat software 15th edition [15]. Two sample t-test was used to compare seasons and multiple linear regression analysis was also run to predict the effects of the weather variables on the population and damage by *M. tanajoa*. Treatment means were compared using the least significant difference (LSD) at 5% level of significance *(P = .05)*. While all the numerical data with low counts or zero values were transformed into log y+1 [16]. Yield data were taken in kilograms ha^{-1}.

3. RESULTS AND DISCUSSION

Results of the study shows that there were significant *(P = .05)* differences on the population, damage, leaf malformation and incidence of *M. tanajoa* between the seasons (2015 and 2016). The population and damage were higher in 2016 compared to 2015 (Fig. 2). The differences between the two seasons as per the population and damage by *M. tanajoa* could be attributed to so many factors inclusive of weather variables such as rainfall, relative humidity and temperatures. Moreover, as higher amount of rainfall was received in 2015, the population of *M. tanajoa* was found to be lower compared to 2016. Therefore, these environmental factors dictated about the differences. Several authors [9,17,18,19] have reported that high cassava green mite's mortalities due to rain drop could serve as its natural population control. More so, all the mite's developmental stages are affected by environmental factors (rainfall, relative humidity and temperatures). However, the damage was also slightly different between the seasons which might be due to the differences in the cassava varieties used as each variety might respond differently. Several researchers [9,20] have reported that seasonal variations in arthropods in the tropics have been related to several studies and these were due to the temporal variation in local environmental factors such as rainfall, temperatures and humidity. The incidence might be a function of the population number which could be attributed to the preference of the mites on the different cassava varieties planted while the leaf malformation could be dictated also by the extent of damage caused by the mites.

The population and damage by *M. tanajoa* were significant *(P = .05)* among the cassava varieties in both seasons (Fig. 3). Liongo Kwimba recorded the highest mite's number compared to all other cassava varieties while Kyaka was found to have the lowest population number in both years. Similarly, Kyaka cassava variety recorded the lowest damage in both seasons. However, Liongo Kwimba was proved to have recorded higher damage followed by Kiroba in 2016. All other varieties were found to be similar on *M. tanajoa* number in 2015 while Mkombozi and Kiroba were found to be the least.

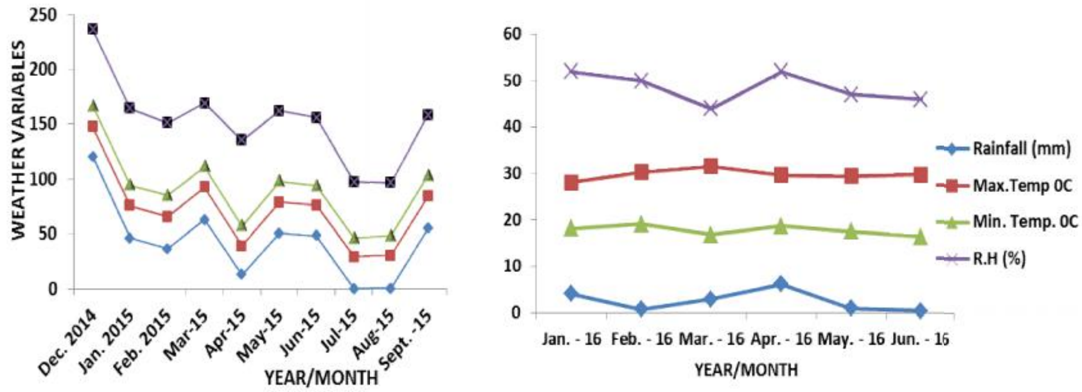

Fig. 1. Mean monthly rainfall, maximum and minimum temperatures and relative humidity for the Lake Zone, Tanzania from December 2014 to June 2016

Table 1. Cassava varieties used for the experiments and their history

Variety	Type	Maturity[1]	Pest Status	Year Released	Yield Potential
Kyaka	Improved	Early	Tolerant	2010	Medium
Meremeta	Improved	Early	Tolerant	2010	Medium
L/Kwimba	Local	Early	Susceptible	None	Medium
Namikonga	*B/Line	Medium	M/ tolerant	None	Medium
Mkombozi	Improved	Early	Susceptible	2010	High
Naliendele	Improved	-	M/ tolerant	-	-
Kiroba	Improved	Early	Tolerant	-	High
Suma	Improved	Early	Tolerant	2010	Medium
Belinde	Improved	Early	S/tolerant	2010	Medium

Source: (Personal communication, 2016)

*Note: *It is thought to be an Amani hybrid from the Amani cassava breeding program by British in 1930s (Hillocks and Jennings 2003, Jennings 1957)*

[1]Early means 8-12 months while late is 15 months and above

*Key: *B/Line = *Breeding line; M/tolerant = Moderately tolerant; S/tolerant = Slightly tolerant*

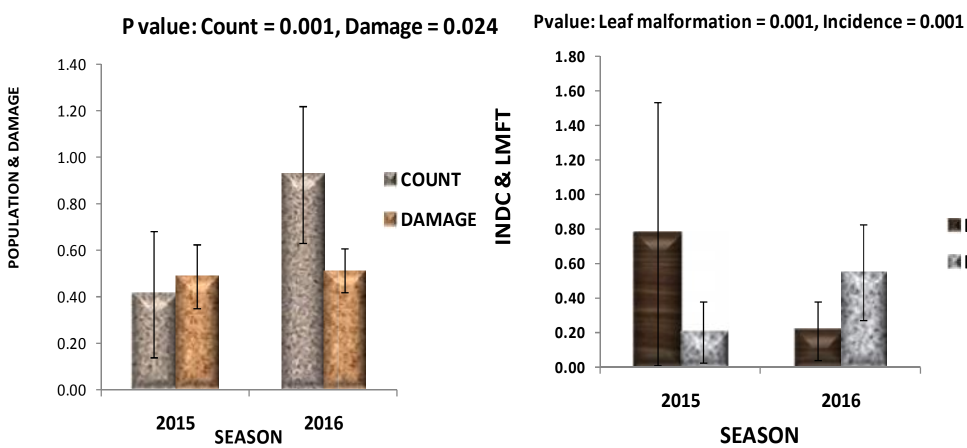

Fig. 2. The effects of the population, damage, leaf malformation and incidence of cassava green mite at Ukiriguru, Lake zone of Tanzania

Key: LMFT = Leaf malformation; INDC = Incidence

The responses of the cassava varieties to *M. tanajoa* population and damage were probably due to their inherent resistant and/susceptibilities to the mites. These varieties moreover were a mixture of local and commercial varieties thus could respond in different ways as per mite's number, damage and incidence. Liongo Kwimba was found to have recorded higher number and damage of *M. tanajoa* while Kyaka has been performing better in terms of mites' population, damage and subsequently the yield. All of the above could be attributed to the fact that Liongo Kwimba is a local and susceptible variety while Kyaka is commercial and improved variety. Similar findings have been reported by several authors including [21] that varietal differences could be attributed to their inherent resistance/ tolerance and/or susceptibility to the mites' damage. Similar result was reported that the variation in *M. tanajoa* population density among the genotype might be associated with factors inherent in the different genotypes. The resistant cassava varieties might have high leaf pubescence and high canopy retention ability during the dry season [22].

Results on the influence of time interval (months) has indicated a highly significant *(P = .05)* effect on the population and damage of *M. tanajoa*. Highest number of *M. tanajoa* was recorded in June with the least in July in 2015. However in 2016, higher population number was recorded in July and August which are similar while the lowest number was observed in September. Similarly, the damage by cassava green mite in 2015 was higher in June and July with the least in April and September which are found to be similar. Moreover, in 2016, the damage was higher in July and August however; the lowest damage by *M. tanajoa* was recorded in June.

The differences in the population number, damage, incidence as well as the leaf malformation across months could be attributed to the variations in the weather variables especially rainfall, temperatures and relative humidity. In 2015, the population of *M. tanajoa* was higher probably due to the low amount of rains received in the year compared to 2016. While there was a little higher damage in 2016 which might affirmed that different varieties were used thus they responded differently based on the environmental conditions which might have dictated the growth, development and perpetuation of the mite. It was reported by several authors that Tetranychid mites are known for rapid reproductive rates in hot dry weather [23] for example June to September at Ukiriguru. Several authors have also indicated that infestations are heaviest and/or population density increases in the dry season which also corresponds to June to September periods at which the mites' number and damage were higher at Ukiriguru [24,25].

Fig. 5 shows that effects of the cassava crop age (months) on the population and damage of *M. tanajoa* was highly significant *(P = .05)* among the crop ages. Crops at 3 and 6 months of age recorded higher infestation and damage compared to older ones (9 months). Generally, the higher population and damage were recorded most in 2016 except the damage at 6 months of age in 2015. The lowest mites' counts were recorded by crops at the age of 3 months in 2015 and 9 months in 2016. However on the damage by *M. tanajoa*, higher damages were observed on older crops of 9 months in 2015 and 6 months old in 2016.

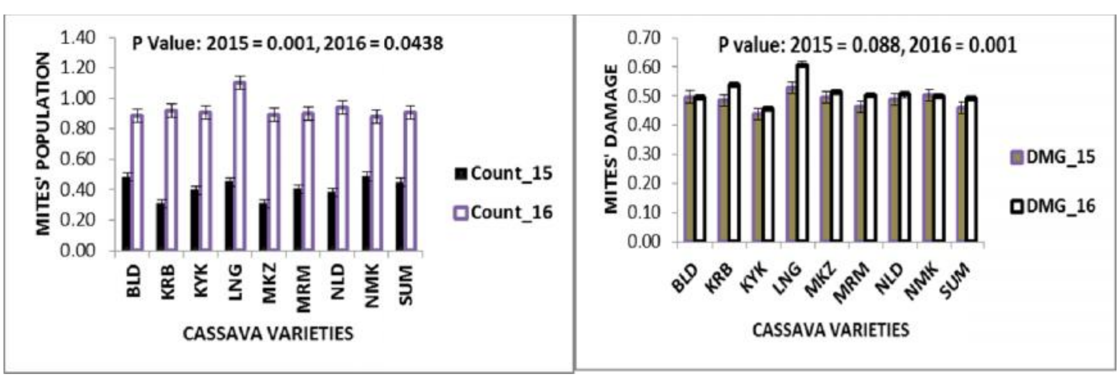

Fig. 3. Responses of some cassava varieties to *M. tanajoa* population and damage at Ukiriguru of the lake zone, Tanzania

Key: Count_15 & 16 = Count in 2015 and 2016; DMG_15 & 16 = Damage in 2015 & 2016

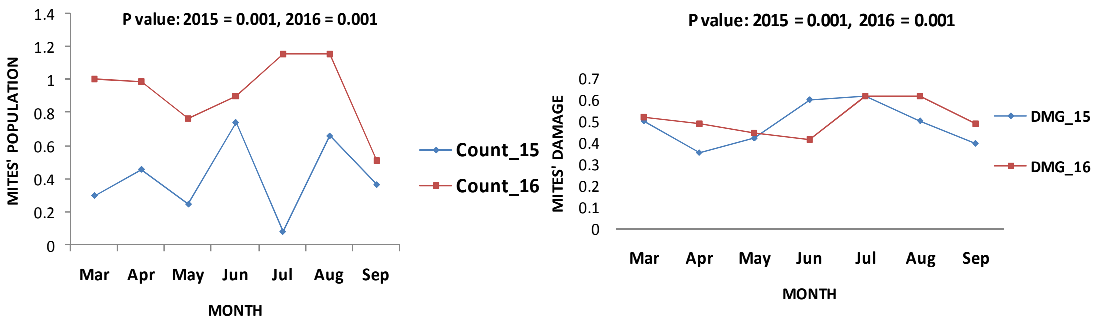

Fig. 4. Influence of time interval (months) on the population and damage of *M. tanajoa* at Ukiriguru, of the Lake zone, Tanzania

Results of the studies at Ukiriguru revealed that the incidence and leaf malformation of cassava green mite on cassava crop age were highly significant *(P = .05)* in both seasons (Fig. 6). Generally, the incidences were higher at 3 and 6 months of age with the least at 9 months in 2016. However, crops at 6 months of age recorded higher mites' incidence in 2015 while it was the least at 3 months. Similarly, the highest leaf malformation scores were recorded by most crops at the age of 6 and 9 months in 2015 and 2016 while the least were recorded on crops at 3 months of age respectively.

Table 2 shows that in both seasons, the incidence of *M. tanajoa* on cassava varieties was significant *(P = .05)*. Cassava variety Liongo Kwimba recoded higher incidence (0.2381) followed by Naliendele (0.2350) while Mkombozi was found to have the lowest incidence in 2015. Similarly in 2016, Liongo Kwimba (0.6209) appeared to have higher mites incidence which was followed by Kiroba variety (0.5719), however the lowest mites' incidence was recorded by Belinde variety (0.4898). Moreover, the leaf malformation was only significant *(P = .05)* in 2016 while Liongo Kwimba recorded the highest leaf malformation compared to all other varieties; this was followed by Kiroba and Kyaka varieties which appeared to have recorded the least leaf malformation. In 2015 however, there was no significant difference among the cassava varieties although Namikonga and Liongo Kwimba recorded higher leaf malformation.

Fig. 7 shows that the interaction effects of varieties and time interval on crop age of some cassava varieties was highly significant *(P = .05)* in 2015. The highest population number was recorded by Kyaka, Suma and Belinde at 6 months of age across all varieties while at 3 months of age Kyaka variety however recorded the lowest population number of *M. tanajoa*. However, it was not significant in 2016 although, Kiroba variety recorded higher mites number at the age of 3 months while Namikonga was found to have the least mites number at 9 months of cassava growth.

The interaction of varieties and time interval (months) on the damage by *M. tanajoa* was not significant in 2015 (Fig. 8). However, in 2016 there were significant *(P = .05)* differences among the cassava varieties and time interval. Cassava variety, Liongo Kwimba recorded the highest crop damage at the ages of 3 and 9 months while across the varieties, Meremeta was found to have the lowest crop damage at 6 months of age. All other varieties were either similar or slightly different compared across the ages.

Fig. 9 shows the effects of time interval (months) on the incidence and leaf malformation of *M. tanajoa* in 2015 and 2016. The incidence of *M. tanajoa* was highly significant *(P = .05)* among the time intervals (months). In 2015, the highest mites' incidence was recorded in June and August with the lowest in July. Moreover in 2016, the mites' incidence was found to be higher in the month of August with the least in September. The effects of the leaf malformation by cassava green mite was also significant *(P = .05)* whereby the highest leaf malformation was recorded in July and June in 2015 while the months of April and March having the least. In 2016 however, the highest leaf malformation was observed in June and September with the lowest in July and August.

Results in Fig. 10 shows that there are significant *(P = .05)* differences between the two seasons in root weight and root number. The season of 2015 recorded the highest root weight compared to 2016 while root number was higher in 2016.

The results indicated that the differences among cassava varieties on root number were significant (P = .0) only in 2015 (Fig. 11). Kyaka recorded the highest root number (5.50) and followed by Meremeta (5.41) in 2015 while least was found with Namikonga (2.56). However in 2016, there were no significant differences among the cassava varieties although, Suma (8.35) and Mkombozi (8.34) recorded the highest number of roots and the least was recorded by Kyaka (6.41) and Liongo Kwimba (6.41). Moreover, there were no significant differences among the cassava varieties on root weight in both seasons. However, in both seasons, Kyaka recorded the heaviest roots (92.00 kg n 2015) and (19.17 kg in 2016) compared to others with Liongo Kwimba having the lowest root weight (6.6 kg in 2015) and (13.5 in 2016) respectively.

Generally, the population, incidence, leaf malformation and damage were found to be higher on crops at 3 and 6 months of age compared to the older ones. More so, the responses of the cassava varieties at different ages have been mostly higher on younger plants compared to the older ones (9months) and this has been sometimes fluctuating over time. These indicated that cassava green mites prefer young and tender plants which are succulent and nutritious compared to the fibrous older ones. These have been reported by other researchers such as [26] cassava plants aged 2-9 months are the most vulnerable to infestation.

The regression analysis explained that with an increase in unit of the rainfall and relative humidity, there will be decrease in the mites' counts in 2016 vice versa in the case of maximum and minimum temperatures. The variation in either positive or negative relationship between the two seasons could be attributed to the differences in amount of rainfall, relative humidity and temperatures received in each year thus, in 2016 there was higher amount of rainfall which if increased that will negatively affects the mites count. This indicated that with increase in a unit in rainfall in 2015 will subsequently increase mites' damage and vice versa in 2016. This also applied to the incidence and leaf malformation by *M. tanajoa*. These have been reported by [27,28,29]. Environmental abiotic factors such as temperature, relative humidity and rainfall are important mechanisms mediating the population dynamics of arthropods in agro-ecosystems. Other environmental variables especially rainfall, temperature and relative humidity might sometimes differ based on seasons and these factors dictate the perpetuation and survival of cassava green mites, similar result was reported that the differences in population and damage between seasons could be due to the fact that the population build-up of the pest started at the onset of the dry season or end of the rainy season which is May, while July to August were the peak periods and thus, the damage was subsequently higher [18].

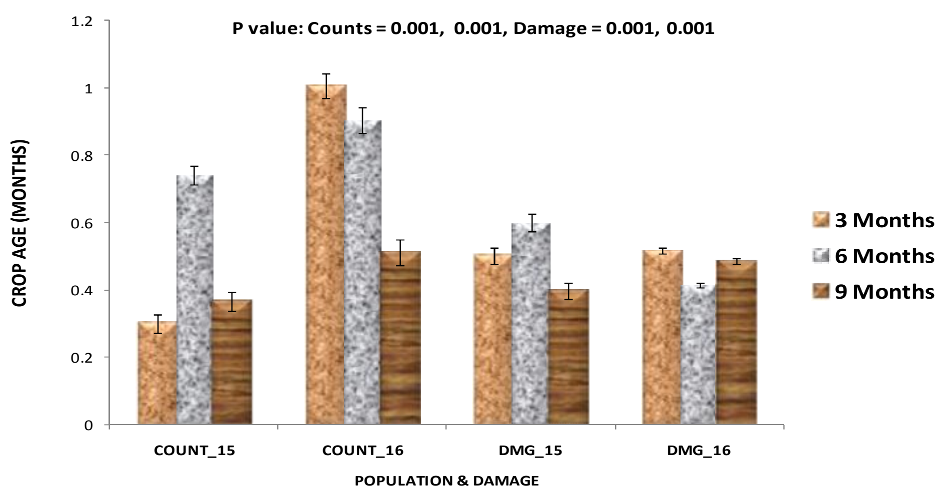

Fig. 5. Effects of the cassava crop age (months) on the population and damage by *M. tanajoa* on at Ukiriguru, Lake zone of Tanzania

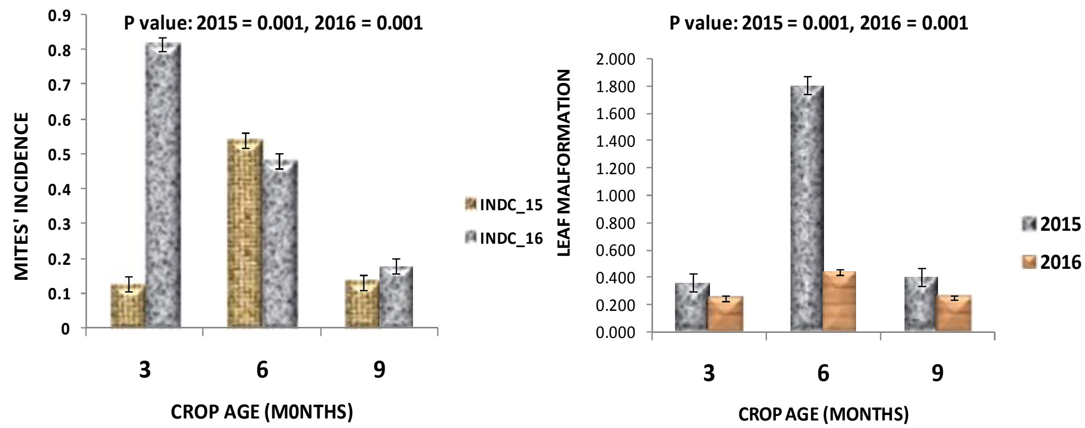

Fig. 6. Effects of the cassava crop age (months) on the incidence and leaf malformation by *M. tanajoa* on at Ukiriguru, Lake zone of Tanzania

Key: INDC_15; INDC_16 = Incidence in 2015 and Incidence in 2016

Table 2. Incidence and leaf malformation by *M. tanajoa* on some cassava varieties at Ukiriguru, Lake Zone Tanzania

Variety	Mites' incidence		Leaf malformation	
	(2015)	(2016)	(2015)	(2016)
Balinde	0.2219	0.4898	0.777	0.1512
Kiroba	0.1768	0.5719	0.795	0.2691
Kyaka	0.1937	0.5637	0.673	0.1182
Liongo	0.2381	0.6209	0.848	0.3893
Mkombozi	0.1561	0.5672	0.813	0.2073
Meremeta	0.1799	0.5097	0.739	0.1775
Naliendele	0.235	0.5528	0.676	0.2074
Namikonga	0.1952	0.4971	0.875	0.1662
Suma	0.2068	0.5483	0.742	0.1663
SE±	**0.01857**	**0.02979**	**0.0612**	**0.0195**
P Value:	**0.030**	**0.056**	**0.236**	**0.001**

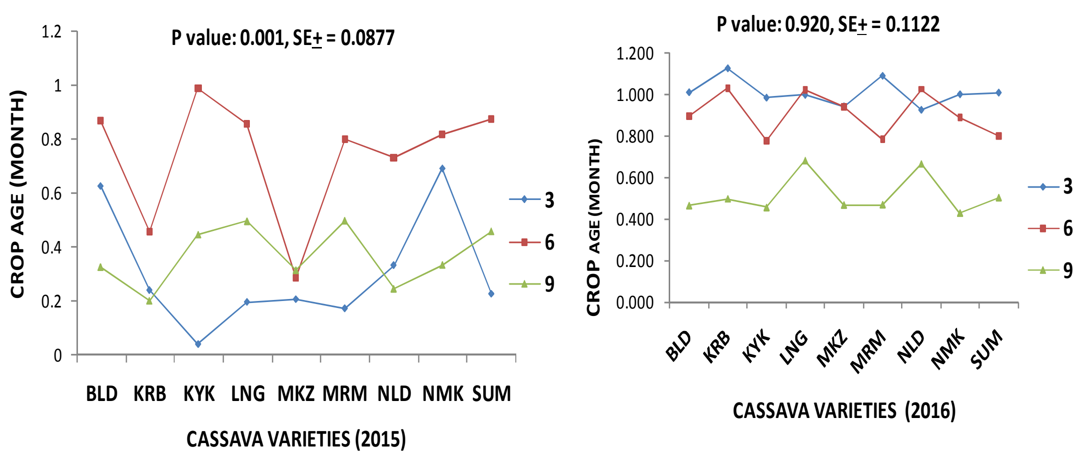

Fig. 7. Interaction effects of varieties and time interval (Months) on population of *M. tanajoa* on some cassava varieties at Ukiriguru of Lake zone, Tanzania

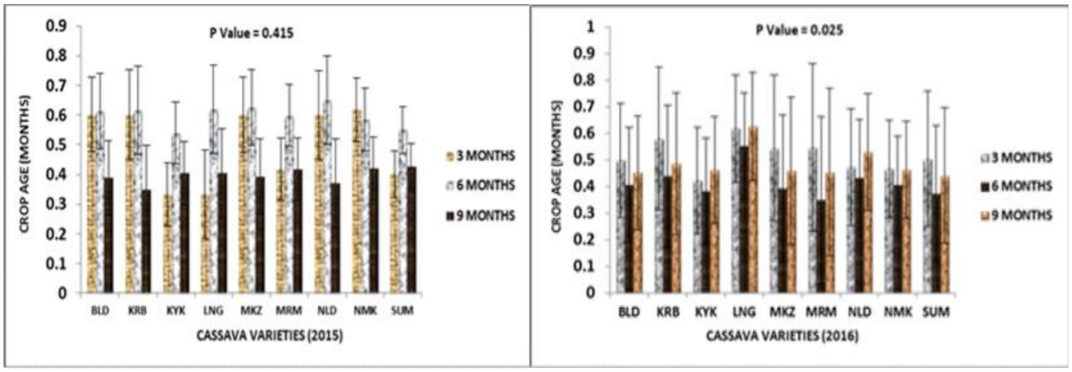

Fig. 8. Interaction effects of varieties and time interval (Months) on damage by *M. tanajoa* on some cassava varieties at Ukiriguru of Lake Zone, Tanzania

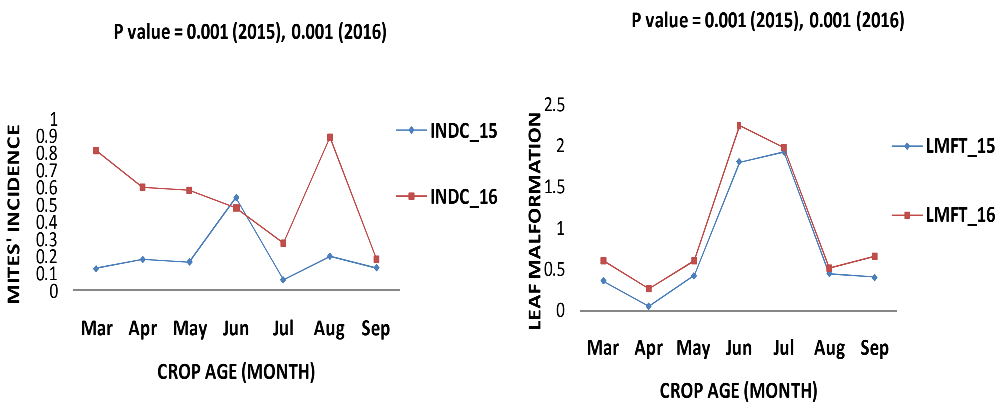

Fig. 9. Effects of the time interval (months) on the incidence and leaf malformation of *M. tanajoa* at Ukiriguru of Lake zone, Tanzania

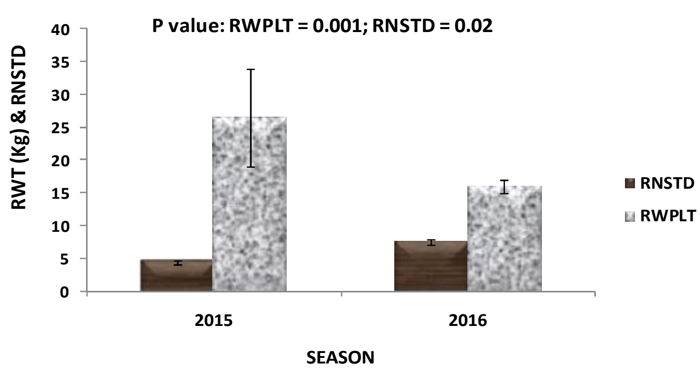

Fig. 10. Effects of seasons on root weight per plot (kg^{-1}) and root number per stand at Ukiriguru of Lake Zone, Tanzania

Multiple regression analysis was made to predict the influence of some weather variables on the population, damage, incidence and leaf malformation of *M. tanajoa* at Ukiriguru of the Lake zone, Tanzania in 2015 and 2016 rainy and dry seasons (Tables 3 to 5). Four weather variables (rainfall, relative humidity, and maximum and minimum temperatures) were simultaneously entered into the model and to find out the percentage contribution of each of the dependent variables to the population and damage of *M. tanajoa*. Rainfall and minimum temperature were not significant and have positively correlated to the mites' population while relative humidity and maximum temperature were have significant *(P = .05)* negative relationship to the population number of *M. tanajoa* in 2015 such as rainfall (β = 0.00066, p = 0.182), relative humidity (β = -0.0367, p = 0.080), maximum temperature (β = -0.217, p = 0.044), and minimum temperature (β = 0.1396, p = 0.159) this explains that with increase in a unit of each variable (relative humidity and maximum temperature) will decrease the population number of *M. tanajoa*. However in 2016, the relationships between rainfall and relative humidity were highly significant *(P = .05)* and negative while it was positive with the maximum and minimum temperature (Table 3).

Table 4 shows that the relationships among all the weather variables predicted were highly significant *(P = .05)*. Rainfall was found to be negatively correlated to *M. tanajoa* damage in 2015 rainfall (β = -0.001454, p = 0.001), relative humidity (β = 0.04011, p = 0.001), maximum temperature (β = 0.1615, p = 0.001), and minimum temperature (β = -0.2473, p = 0.001) this explains that with continuous increase in a unit of each variable (rainfall and minimum temperature) will decrease the damage by *M. tanajoa*. Nonetheless, with continuous increase by a unit in relative humidity and maximum temperature will subsequently decrease mites' damage negatively. However in 2016, both relative humidity and rainfall were negatively correlated with damage while maximum and minimum temperatures were positive.

The regression analysis of some weather variables had predicted that the relationships among the mites' incidence and the variables were significant *(P = .05)* on rainfall, maximum and minimum temperatures (table 5). All the variables except relative humidity were negatively correlated with mites' incidence in 2015. However, rainfall and relative humidity were negative although, only rainfall was significant *(P = .05)* in 2016 while maximum and minimum temperatures were positively correlated with mites' incidence.

Table 3. Regression analysis of some weather variables against *M. tanajoa* count during 2015 and 2016 rainy and dry seasons in Ukiriguru, Mwanza region, Tanzania

	2015 COUNT		2016 COUNT		
Parameter	**Estimate**	**SE+(P Value)**	**Estimate**	**SE+**	**(P Value)**
Rainfall	0.00066	0.00049 (0.182)	-0.0914	0.0153	(0.001)**
RH	-0.0367	0.0208 (0.080)*	-0.02074	0.00526	(0.001)**
Max. Temp.	-0.217	0.107 (0.044)*	0.1117	0.0439	(0.012)*
Min. Temp.	0.1396	0.0987 (0.159)	0.2672	0.0683	(0.001)**

Table 4. Regression analysis of some weather variables against *M. tanajoa* damage during 2015 and 2016 rainy and dry seasons in Ukiriguru, Mwanza region, Tanzania

Parameter	**2015 damage**		**2016 damage**	
	Estimate	**SE+(P Value)**	**Estimate**	**SE+ (P Value)**
Rainfall	-0.001454	0.000191 (0.001)**	-0.02814	0.00413 (0.001)**
RH	0.04011	0.00807 (0.001)**	-0.01490	0.00142 (0.001)**
Max. Temp.	0.1615	0.0414 (0.001)**	0.0504	0.0118 (0.001)**
Min. Temp.	-0.2473	0.0382 (0.001)**	0.1303	0.0184 (0.001)**

Table 5. Regression analysis of some weather variables against *M. tanajoa* incidence during 2015 and 2016 rainy and dry seasons in Ukiriguru, Mwanza region, Tanzania

Parameter	**2015 incidence**		**2016 incidence**	
	Estimate	**SE± (P Value)**	**Estimate**	**SE± (P Value)**
Rainfall	-0.001069	0.000284 (0.001)**	-0.1063	0.0146 (0.001)**
RH	0.0061	0.0120 (0.611)	-0.00524	0.00501 (0.298)
Max. Temp.	-0.0980	0.0616 (0.113)	0.2890	0.0418 (0.001)**
Min. Temp.	-0.0097	0.0568 (0.865)	0.3570	0.0650 (0.001)**

Table 6. Regression analysis of some weather variables against *M. tanajoa* leaf malformation during 2015 and 2016 rainy and dry seasons in Ukiriguru, Mwanza region, Tanzania

Parameter	Leaf malformation (2015)		Leaf malformation (2016)	
	Estimate	SE± (P Value)	Estimate	SE±(P Value)
Rainfall	-0.008317	0.000700 (0.001)**	0.06269	0.00730 (0.001)**
RH	0.1173	0.0296 (0.001)**	0.03233	0.00250 (0.001)**
Max. Temp.	0.036	0.152 (0.812)	-0.0830	0.0209 (0.001)**
Min. Temp.	-0.993	0.140 (0.001)**	-0.3439	0.0325 (0.001)**

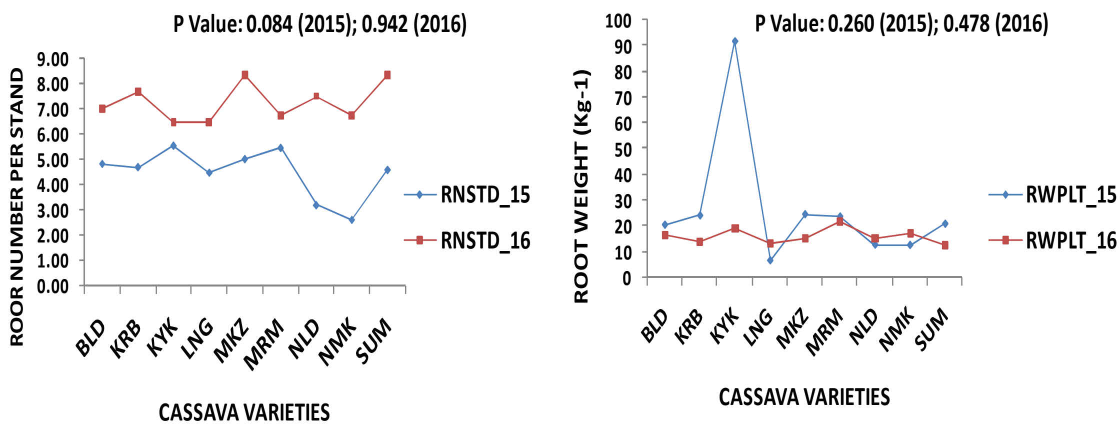

Fig. 11. Root weight and root number as influenced by *M. tanajoa* number and damage at Ukiriguru, Lake zone Tanzania

The relationships among the weather variables predicted were highly significant *(P = .05)* except maximum temperature (table 5). Rainfall was found to be negatively correlated to *M. tanajoa* leaf malformation in 2015 rainfall (β = -0.008317, p = 0.001), relative humidity (β = 0.1173, p = 0.001), maximum temperature (β = 0.036, p = 0.812), and minimum temperature (β = -0.993, p = 0.001) this explains that with continuous increase in a unit of each variable (rainfall and minimum temperature) will lead to a decrease in leaf malformation by *M. tanajoa*. Nonetheless, with continuous increase by a unit in relative humidity and maximum temperature will subsequently decrease mites' leaf malformation. However in 2016, both relative humidity and rainfall were positively correlated with leaf malformation while maximum and minimum temperatures were negative (Table 6).

The regression analysis of incidence and leaf malformation has shown that leaf malformation has a negative relationship with root weight in 2016 which indicated that with an increase in leaf malformation by a unit, the root weight will decrease by the same unit. This could be possible because the leaf malformation is a component of damage reduces the photosynthetic ability of the cassava plant which subsequently affected the dry matter production capacity of the crop thus reduced weight. However, other components in both seasons were not significant probably due to similarities that exists among the cassava varieties and that environmental factors have more impacts on the population and damage of *M. tanajoa*. This has been reported by Mutisya et al. [3] that the regression of *M. tanajoa* density to root yield did not indicate any negative effect of the mite pest as other environmental factors influenced more the final yield. Moreover, several authors including 27, 28 and 29 have reported on the reduction of photosynthetic ability of the plant. More so, it attacks mainly shoots and leaves of cassava reducing both photosynthetic rate and root dry matter [17]. The visual damage led to high loss of the cassava leaves and subsequent reduction in the photosynthetic ability of the cassava and the yield, especially on the susceptible varieties. This has been reported by researchers that the damage has been equated to the loss of biomass and is an indicative of loss of the leaf photosynthetic area [30].

4. CONCLUSION

Results of the studies have revealed that mites' population, incidence and damage were higher in 2016 while leaf malformation was statistically greater in 2015. More so, the cassava varieties were heavily infested and damaged at lower ages (3 and 6 months) within and between the two seasons. Among the crop varieties, Liongo Kwimba recorded higher infestation and suffered most in damage and leaf malformation. The regression analysis had predicted negative relationships among the weather variables and the population, damage and incidence of *M. tanajoa*. Kyaka cassava variety was found to performed better in yield despite the attack by the mites while Liongo Kwimba recorded the highest damage and lowest yield, thus farmers at Ukiriguru could be encouraged to plant Kyaka variety for increased cassava yield while Liongo Kwimba should be improved especially through breeding and molecular researches. More so, there is need to manipulate planting season by early planting before the favorable period of growth and perpetuation of *M. tanajoa* at Ukiriguru, Lake Zone Tanzania.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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