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INTEGRATING CASSAVA VARIETIES AND *Typhlodramulus aripo* TO SUSTAIN BIOLOGICAL CONTROL OF CASSAVA GREEN MITE

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ABSTRACT

The cassava green mite (CGM), *Mononychellus tanajoa*, is a pest that reduces root yield of cassava (*Manihot esculenta* Crantz) by 30-80% in the cassava belts of Africa. The objective of this study was to identify cassava varieties that enhance abundance and persistence of *Typhlodramulus aripo* on cassava and increase its efficiency in controlling CGM. Nine cassava (*Manihot esculenta* Crantz) varieties were evaluated in Kenya based on CGM abundance and HCN of leaves for their ability to sustain low CGM populations to enhance biocontrol of *T. aripo*. Cassava fields were surveyed in five agro-ecological zones in Uganda and samples of cassava apices were analysed for cassava varieties to sustain high population of *T. aripo*. In the screening study of CGM abundance and HCN content of leaves and the lowest cumulative CGM population densities (<1200 mites/leaf) were recorded on MM97/3567, Tajirika and MM96/9308, with the lowest cyanide content of leaves, 8.5 ± 4.9 , 12.5 ± 3.2 and 12.3 ± 2.5 mg kg⁻¹, respectively. Cassava varieties with hairy and non-hairy tips sustained *T. aripo* with highest densities (0.96 actives per tip) on hairy TME14. High *T. aripo* population densities corresponded to high densities of hairs on cassava tips. There were significant inverse linear relationships between CGM densities and *T. aripo* on TME14 at moderate CGM population densities (CGM damage level 2).

Key Words: Cyanide, *Manihot esculenta*, *Mononychellus tanajoa*

RÉSUMÉ

Le tantinet vert de la cassave (CGM), *Mononychellus tanajoa*, est un insecte nuisible qui réduit la production de racine de cassave (*Manihot esculenta* Crantz) de 30-80 % dans les ceintures de cassave de l'Afrique. L'objectif de cette étude était d'identifier des variétés de cassave qui améliorent l'abondance et la persistance de *Typhlodramulus aripo* sur la cassave et augmentent son efficacité dans le contrôle de CGM. Neuf cassave (*Manihot esculenta* Crantz) les variétés ont été évaluées au Kenya basé sur l'abondance CGM et HCN de part pour leur capacité de soutenir bas des populations de CGM pour améliorer biocontrol de *T. aripo*. Les champs de cassave ont été étudiés dans cinq zones agro-écologiques en Ouganda et les échantillons de sommets de cassave ont été analysés pour les variétés de cassave pour soutenir la haute population de *T. aripo*. Dans l'étude de projection d'abondance CGM et de contenu de HCN de congés et des densités démographiques CGM cumulatives les plus basses (<1200 tantinets/feuille) ont été enregistrés sur MM97/3567, Tajirika et MM96/9308, avec le contenu de cyanure le plus bas de congés, 8.5 ± 4.9 , 12.5 ± 3.2 et 12.3 kg de 2.5 mgs ± 1 , respectivement. Les variétés de cassave avec les bouts poilus et non-poilus ont soutenu *T. aripo* avec les plus hautes densités (0.96 actives par bout) sur TME14 poilu. Haut *T. aripo* les densités démographiques a correspondu à de hautes densités de hairs sur les bouts de cassave. Il y avait des rapports linéaires inverses significatifs entre les densités CGM et *T. aripo* sur TME14 aux densités démographiques CGM modérées (le niveau de dommage de CGM 2).

Mots Clés: le Cyanure, *Manihot esculenta*, *Mononychellus tanajoa*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is attacked by cassava green mite (CGM), *Mononychellus tanajoa* (Acari: Tetranychidae), an introduced pest in Africa, in 1970s (Nyiira, 1972). Since its first appearance in East Africa, the pest has expanded its distribution to the entire cassava growing belts, where it causes estimated yield losses ranging between 30-80 % (Yaninek *et al.*, 1989). Climatic and soil factors influence the population dynamics of CGM with positive or negative effects. To date, control of CGM in Africa has relied mainly on predatory mite species, of the family Phytoseiidae. Initial biological control efforts involved evaluation of over 11 phytoseiid mite species, of Colombian and Brazilian origin, during 1986-1993 (Yaninek *et al.*, 1993). But none of these species became successfully established in Africa. However, in the later years of evaluation, one predatory mite species, *Typhlodramulus aripo*, was introduced from Brazil (Yaninek and Hanna, 2003). Through field releases, the species was identified as the most successful biological control agent and since then, it has been considered as the key predator of CGM in the cassava belts of Africa (Yaninek *et al.*, 1991; Yaninek *et al.*, 1993; Hanna and Toko, 2003).

Typhlodramulus aripo was imported by the International Institute of Tropical Agriculture (IITA), under CGM Biological Control Regional project, and released in East Africa in 1994. Following its establishment, subsequent studies demonstrated the potential of *T. aripo* in increasing cassava production in both local and improved cassava varieties (Karuiiki *et al.*, 2004; Molo, 2006, unpublished). This predator has unique ecological requirements, that improve its efficiency in controlling CGM. It inhabits the apex of cassava and all its reproduction occurs in the apex (Onzo *et al.*, 2003). It is a nocturnal predator and encounters CGM prey as it migrates from cassava tips to the leaves during feeding. Studies by Zundel (2006) indicate that drought causes *T. aripo* to migrate from cassava apices to wild plants, leading to reduction in predation of CGM prey on cassava.

The East African region suffers frequent drought, thus facilitating proliferation of CGM

populations (Skovgard *et al.*, 1993). Gnanvossou *et al.* (2001) and Magalhaes *et al.* (2002) found that *T. aripo* has a high searching ability for CGM, at very low prey densities, which increases its efficiency as a biocontrol agent. Cassava varieties that sustain relatively low CGM population will facilitate biological control by *T. aripo* at a fast rate. Appropriate cassava varieties that support low CGM populations and increase persistence of *T. aripo* on cassava are needed to facilitate biological control of CGM. The objective of this study was to identify cassava varieties to aid abundance and persistence of *T. aripo* on cassava and increase its efficiency in controlling CGM.

MATERIALS AND METHODS

Cassava varietal screening. Nine cassava varieties, including MM99005, MM990183 and X-Mariakani from the eastern, Kaleso, Karibuni, Tajirika from coastal and MM97/3567, MM96/2480 and MM96/9308 from western Kenya were planted in the eastern lowlands, western midlands and the humid coastal lowlands of Kenya. The experiment was carried in screen houses to exclude white fly vectors of cassava mosaic and brown streak diseases that affect cassava leaves. Cassava green mites were collected from the coastal Kenya lowlands, and 10 individuals of CGM adult motiles were released on each cassava variety. On day five, after mite introduction, the number of CGM per leaf on each cassava variety was determined, by counting CGM actives, according to Yaninek *et al.* (1989), every three days for up to 55 days. Leaf samples representing CGM damage scores on a scale 1-5 where, 1 = no damage and 5 severe damage, were picked in paper bags. They were brittle oven-dried at 60 °C for 4 days, and weighed.

The loss in leaf biomass was determined as weight difference between damaged and undamaged leaves. Cassava leaf cyanide (HCN mgkg⁻¹) content of CGM damage leaves at damage score 1-5, was determined by Picric Acid method.

Persistence and impact. A follow up of previous field releases (1994-98) of *T. aripo* in Uganda was conducted in April and December 2013, during

the rainy and dry season, respectively, basing on the knowledge of *T. aripo* ecological characteristics that they reside entirely in bracts of cassava apices. Cassava fields were sampled at intervals of 5-10 Km, along major roads, and in each field, 20 cassava plants were examined. The CGM population was counted on the first fully opened leaf of each cassava plant. CGM leaf damage was assessed on a scale 1-3; where 1 = clean plants, 2= less than 75% of leaves showing chlorosis, and 3= over 75 % of leaves showing chlorosis. One cassava tip on each of the 20 plants was examined for *T. aripo* and recorded as present or absent to determine the total number of *T. aripo* infested plants. Five cassava tips were randomly decapitated from each field and put in vials containing 70% alcohol. They were dissected under a binocular microscope, and *T. aripo* actives were counted. One outer bract on each cassava tip was removed and placed under a dissecting microscope, and the total number of hairs on it was recorded. A total of 5 agro-ecological zones, each comprising of 4-5 districts, were randomly selected and surveyed.

Statistical analysis. Cumulative CGM numbers were calculated from CGM population data in the screening trial. Numbers of hairs on cassava tips,

CGM and *T. aripo* were log x+1 transformed and the number of *T. aripo* infested plants were converted into percentages and arcsine square root transformed. Data on CGM, HCN, *T. aripo*, and percentage *T. aripo* infested plants were analysed by ANOVA, using *Stata Statistical Software, Release 13*, and means separated using Tukey test.

RESULTS

CGM abundance and hydrocyanic content. The CGM population increased with time (Fig. 1), and cassava varieties MM97/3567 sustained the lowest cumulative CGM population (300 mites per leaf), over a period of 55 days. Varieties Tajirika (1146 mites per leaf) and MM96/9308 (1186 mites per leaf) sustained intermediate CGM population densities. The highest cumulative CGM population (1665.7 actives per tip) was on Mariakani.

Cassava varieties; Kaleso, Karibuni and MM96/2480, showed the highest level of HCN in correspondence with high CGM densities. On the other hand, varieties MM97/3567, Tajirika and MM99005 showed the lowest cyanogenic potential of 8.5 ± 4.9 , 12.5 ± 3.2 and 12.3 ± 2.5 mgkg⁻¹, respectively (Fig. 2). High leaf cyanide

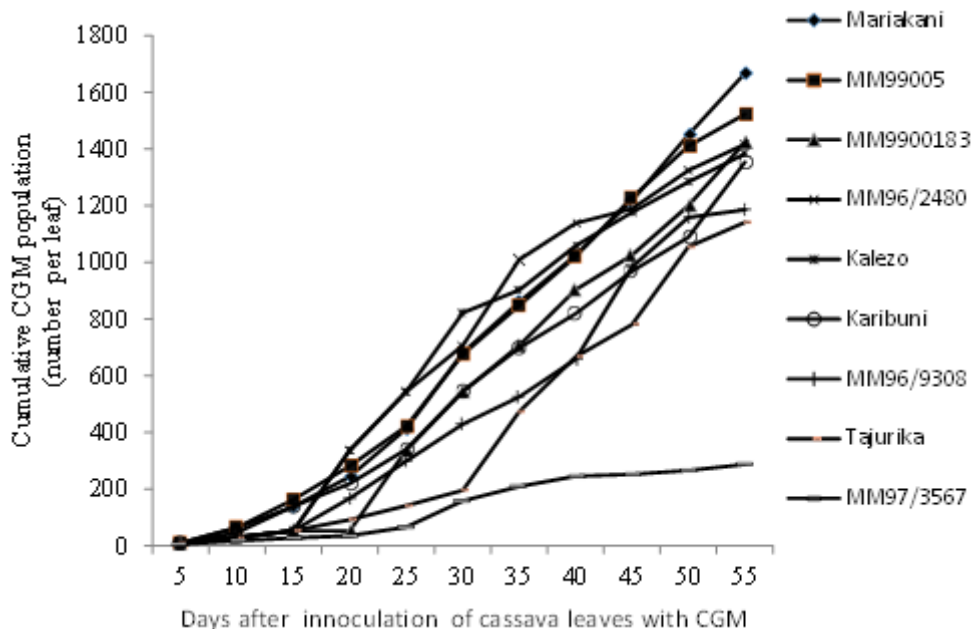


Figure 1. Cumulative numbers of CGM on cassava varieties in Kenya.

(HCN) content corresponded with higher leaf biomass loss (%).

Hairiness of cassava varieties. Hairiness of tips of several cassava varieties contributed to the abundance of *T. aripo* (Fig. 3). The cassava varieties with hairy and non-hairy tips, sustained *T. aripo* with population densities ranging between 0.08-1.0 actives per tip. The hairy cassava varieties included TME2961, NASE3,

Akena, NASE12, NASE14 and TME14. Hair densities ranged from 1.02-1.67 hairs per bract, with the highest on TME14 and the lowest on TME2961. There were no hairs on the tips of Bao, NASE4 and TME204.

Persistence and impact on CGM of *T. aripo*. Low to moderate CGM population densities were considered in assessing *T. aripo* persistence, as the impact of the predator can be easily

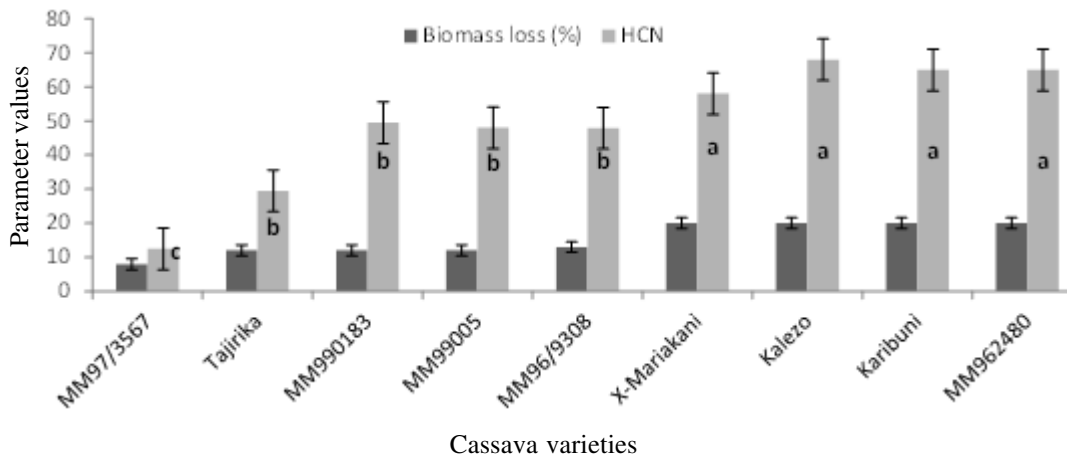


Figure 2. Cyanide content (HCN mgkg⁻¹) and leaf biomass loss (%) for cassava varieties. Case letters denote significance (P< 0.05) levels.

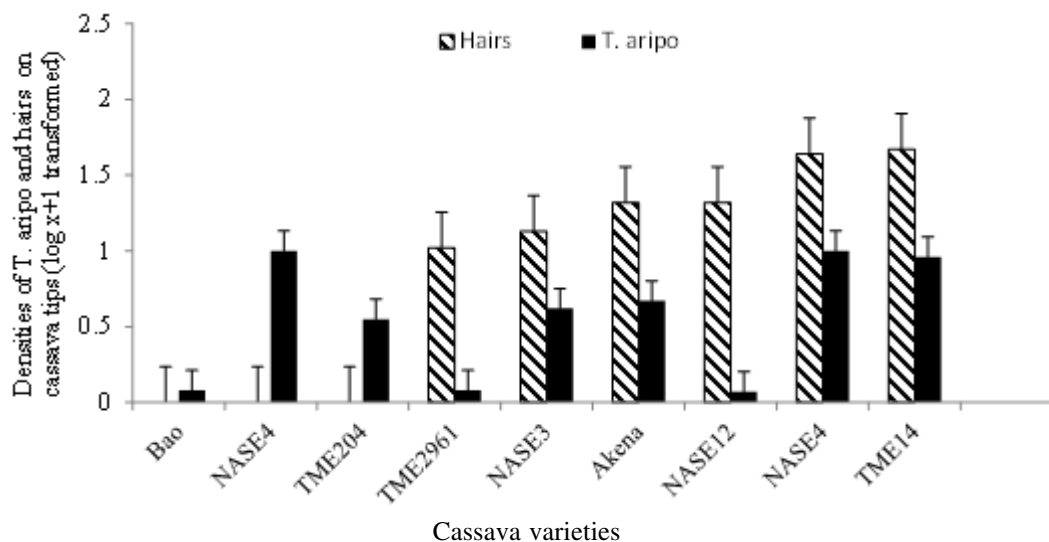


Figure 3. Relationship between tip hairiness and abundance of *T. aripo* on cassava varieties in Uganda. Vertical bars indicate standard errors.

demonstrated on cassava at these densities. Table 1 shows variability of CGM and *T. aripo* infestation on cassava varieties in various agro-ecological zones of Uganda at different dates. During April 2013, low to moderate CGM population densities (0-0.82 mites per leaf) were found on TME2961, Bao, TME14 and TME204 in

Northern Moist Farmlands, NASE3 in Southern and Eastern Lake Kyoga basin and TME14 in Western Medium High Farmlands. In December 2013, low to moderate CGM densities were found on TME 204 in Northwestern and West Nile Farmlands and TME14 in Southern and Eastern Lake Kyoga basin. In April, *T. aripo* was found

TABLE 1. Population densities of *T. aripo* on cassava varieties in various agro ecological zones during first rains in April and dry season in December 2013

Agro ecological zone	Variety	CGM density leaf ⁻¹	<i>T. aripo</i> density tip ⁻¹	<i>T. aripo</i> infested plants (%)
First rains April 2013				
Northern moist farmlands	TME2961	0.00 ^d (0.00)	0.06 ^a (0.15)	0.00 ^e (0.00)
	Bao	0.00 ^d (0.00)	0.03 ^a (0.08)	0.00 ^e (0.00)
	NASE12	1.05 ^{abcd} (63.02)	0.05 ^a (0.15)	7.78 ^{de} (6.68)
	NASE3	1.83 ^a (68.67)	0.15 ^a (0.47)	25.00 ^b (31.10)
	TME14	0.27 ^d (1.63)	0.05 ^a (0.14)	1.23 ^e (0.24)
	TME204	0.23 ^d (0.70)	0.00 ^a (0.00)	7.50 ^{de} ()
	Akena	1.39 ^{abcd} (25.27)	0.00 ^a (0.00)	17.50 ^{cde} (6.6)
Southern and Eastern Lake Kyoga basin	NASE3	0.63 ^{bc} (13.32)	0.18 ^a (0.74)	18.79 ^{bc} (14.71)
	TME14	1.58 ^{abc} (36.82)	0.42 ^a (2.76)	34.06 ^{bc} (37.32)
	TME204	1.04 ^{abcd} (0.51)	0.00 ^a (0.00)	20.72 ^{cd} (35.00)
	Akena	1.98 ^a (261.09)	0.23 ^a (0.75)	0.00 ^e (0.00)
Western Medium High Farmlands	TME14	0.34 ^{cd} (3.00)	0.17 ^a (0.63)	49.50 ^{ab} (56.26)
	NASE14	1.27 ^{abcd} (18.70)	0.00 ^a (0.00)	50.75 ^{ab} (59.97)
Dry season December 2013				
Northern moist farmlands	TME14	1.18 ^{abcd} (17.17)	0.14 ^a (0.59)	20.36 ^{cd} (20.53)
	NASE3	1.18 ^{abcd} (49.17)	0.05 ^a (0.10)	38.91 ^{bc} (39.99)
	TME204	1.31 ^{abcd} (119.52)	0.27 ^a (1.22)	6.37 ^{de} (2.50)
	NASE12	1.21 ^{abcd} (15.40)	0.00 ^a (0.00)	0.00 ^e (0.00)
Northwestern farmlands	TME204	0.19 ^d (0.53)	0.03 ^a (0.07)	15.00 ^{cde} (16.67)
Southern and Eastern Lake Kyoga basin	NASE3	1.80 ^{ab} (62.13)	0.14 ^a (0.49)	23.67 ^{bcd} (19.96)
	TME14	0.82 ^{bcd} (9.64)	0.30 ^a (1.34)	31.03 ^{bc} (9.64)
	NASE14	1.25 ^a (16.70)	0.48 ^a (2.03)	75.50 ^a (93.33)
West Nile farmlands	TME204	0.21 ^d (0.63)	0.17 ^a (1.00)	40.61 ^{bc} (42.50)
Western Medium High Farmlands	TME14	1.36 ^a (23.36)	0.27 ^a (1.83)	33.75 ^{bc} (39.99)
	TME2961	1.32 ^a (20.00)	0.00 ^a (0.00)	0.00 ^e (0.00)
	Akena	1.32 ^a (20.00)	0.00 ^a (0.00)	0.00 ^e (0.00)

Figures in parentheses are actual mean numbers of CGM and *T. aripo* for log x+1 transformed values and actual percentages for arcsine transformed values for percentage *T. aripo* infested plants; Figures with same superscript letters within a column are not significantly different (Tukey test)

on TME2961 and Bao in Northern Moist Farmlands in the absence of CGM; but at moderate CGM population densities, *T. aripo* was found on TME14 in Northern Moist and Western Medium High Farmlands and on TME204 in the Northwestern and West Nile Farmlands in December 2013. Moderate *T. aripo* infested plants (18.79-49.50%) were at moderate CGM infestations on NASE3 and TME14 in Southern and Eastern Lake Kyoga basin and TME14 in Western Medium High Farmlands in April, TME14 in Southern and Eastern Lake Kyoga basin and TME204 in West Nile Farmlands in December 2013.

The criterion for selection of optimal cassava variety for persistence of *T. aripo* was based on consistency in presence of *T. aripo* on cassava at different dates and agro-ecological zones. At various CGM leaf damage levels, *T. aripo* and CGM population densities varied among cassava varieties, in agro-ecological zones, at different sampling dates (Table 2). At CGM leaf damage score 1, Bao, TME2961, NASE12, TME14 and NASE3 sustained *T. aripo* without CGM. Population densities of *T. aripo* on the varieties ranged from 0.03-0.43 actives per tip, and differed significantly ($P=0.002$) among cassava varieties. At the CGM leaf damage score 2, population densities of CGM were low, moderate and high; and differed significantly ($P= 0.007$) among cassava varieties.

Variety TME204 did not support *T. aripo* in the Northern Moist Farmlands and Southern and Eastern Lake Kyoga basin during April; and in December in Northern Moist and Northwestern Farmlands at low CGM densities (0.18-0.23 mites per leaf). At moderate CGM population densities (0.73-0.91 mites per leaf), TME14 supported *T. aripo* populations in Northern Moist and Western Medium High Farmlands during April; and Southern and Eastern Lake Kyoga basin in December 2013, with the highest *T. aripo* population density (0.54 actives per tip) in Western Medium High Farmlands in December 2013. At moderate CGM population densities, NASE3 also supported *T. aripo*, but only in Southern and Eastern Lake Kyoga basin during April 2013.

A linear regression of abundance of CGM and *T. aripo* showed the importance of cassava

varieties on abundance of CGM and *T. aripo* (Table 3). At the CGM leaf damage score of 2, TME14 demonstrated significant inverse relationships of abundance of CGM and *T. aripo* in the Northern Moist Farmlands, during April 2013. Positive significant relationships for TME14 were obtained in Western Medium High Farmlands in April and December. Similarly, at the leaf damage score 2, significant positive relationships of abundance of CGM and *T. aripo* were found on NASE12 in Southern and Eastern Lake Kyoga basin during December. In other varieties, increasing CGM population densities were linked to increasing *T. aripo* population and *vice versa* but these were not significant at different dates and agro-ecological zones.

DISCUSSION

Cassava varieties showed tolerance to CGM as evidenced by the low cumulative mite densities on MM97/3567 and Tajirika (Fig. 1). Resistance of cassava varieties was inversely related to cyanide levels in their leaves; the most susceptible varieties showing the highest cyanide levels. Chemical plant attributes have been shown to influence the abundance, fecundity and survival rate of insect herbivores in various crops (Cortesero *et al.*, 2000). In studies elsewhere (Riis *et al.*, 2003), high cyanide levels were shown to predispose plants to insect attack through increased feeding, but reduced multiplication rates of insect herbivores.

Basing on the results from this study, the cassava varieties with low cyanide levels have been found to harbour low CGM population densities. Therefore, one way to improve the effectiveness of *T. aripo* is to use cassava varieties with low cyanide levels, such as MM97/3567 to reduce the multiplication rate of CGM. Under low CGM population densities, *T. aripo* can adequately bring CGM population under control.

Persistence of *T. aripo* was demonstrated on cassava varieties based on the hairiness of cassava tips (Fig. 3). Several hairy and non-hairy cassava varieties encouraged high population of *T. aripo*. Based on tip characteristics, it was clear that hairiness contributes immensely to abundance of *T. aripo* on the cassava varieties.

TABLE 2. Population densities of *T. aripo* and CGM on cassava varieties at various CGM leaf damage scores in agro ecological zones during April and December 2013

Sampling date	Agro ecological zone	Cassava variety	Score 1		Score 2		Score 3	
			CGM	<i>T. aripo</i>	CGM	<i>T. aripo</i>	CGM	<i>T. aripo</i>
Rainy season April 2013	Northern moist farmlands	Bao	0.00	0.03±0.02 ^b	-	-	-	-
		TME2961	0.00	0.06±0.04 ^b	-	-	-	-
		NASE12	0.00	0.10±0.06 ^{ab}	-	-	2.10±0.06 ^{bc}	0.00±0.00 ^b
		TME14	0.00	0.06±0.04 ^b	0.73±0.02 ^{cd}	0.04 ^c ±0.02	-	-
		TME204	-	-	0.23±0.00 ^e	0.00 ^c ±0.00	-	-
		Akena	-	-	1.42±0.03 ^a	0.00 ^c ±0.00	-	-
		NASE3	-	-	-	-	1.83±0.04 ^{bcd}	0.15±0.01 ^{ab}
	Northwestern farmlands	TME204	-	-	-	-	-	-
	Southern and Eastern Lake Kyoga basin	NASE3	0.00	0.24±0.21 ^{ab}	0.32±0.04 ^e	0.19 ^{ab} ±0.11	1.66±0.28 ^{cde}	0.11±0.04 ^{ab}
		TME204	-	-	0.18±0.00 ^f	0.00 ^c ±0.00	2.19±0.23 ^{ab}	0.08±0.01 ^{ab}
		Akena	-	-	1.40±0.00 ^a	0.15 ^{ab} ±0.01	2.76±0.2 ^a	0.34±0.01 ^{ab}
		TME14	-	-	-	-	1.58±0.05 ^{cde}	0.42±0.20 ^{ab}
	Western Medium High farmlands	TME14	0.00	0.08±0.07 ^{ab}	0.91±0.12 ^{cd}	0.33 ^{ab} ±0.07	-	-
NASE14		-	-	1.29±0.00 ^{ab}	0.00 ^c ±0.00	-	-	
Dry season December 2013	Northern Moist farmlands	TME14	-	-	1.01±0.07 ^{cd}	0.20 ^{ab} ±0.10	1.51±0.08 ^{cde}	0.04±0.00 ^{ab}
		NASE3	-	-	0.34±0.23 ^e	0.00 ^c ±0.00	1.99±0.03 ^{bcd}	0.10±0.00 ^{ab}
		TME204	-	-	0.23±0.03 ^f	0.03 ^c ±0.00	2.38±0.02 ^b	0.53±0.02 ^a
		NASE12	-	-	1.21±0.06 ^{ab}	0.00 ^c ±0.00	-	-
	Northwestern farmlands	TME204	-	-	0.19±0.01 ^f	0.03 ^c ±0.03	-	-
	Southern and Eastern Lake Kyoga basin	NASE3	-	-	-	-	1.80±0.05 ^{bcd}	0.14±0.03 ^{ab}
		TME14	0.00	0.43±0.21 ^a	0.85±0.04 ^{cd}	0.31 ^{ab} ±0.07	1.52±0.03 ^{cde}	0.08±0.02 ^{ab}
		NASE12	-	-	1.25±0.03 ^{abc}	0.48 ^a ±0.05	-	-
	West Nile farmlands	TME204	-	-	0.21±0.01 ^f	0.18 ^{ab} ±0.18	-	-
	Western Medium High farmlands	TME14	-	-	1.19±0.01 ^{abc}	0.54 ^a ±0.27	1.52±0.05 ^{cde}	0.00±0.00 ^b
		TME2961	-	-	1.32±0.01 ^{ab}	0.00 ^c ±0.00	-	-
		Akena	-	-	1.32±0.05 ^{ab}	0.00 ^c ±0.00	-	-

Integrating cassava and *Typhlodromus aripo* to sustain biological control

(-) not applicable for the CGM damage score; Scores: 1= less than 25 % of leaf surface with chlorosis; 2= more than 25% but less than 75 % of leaf surface with chlorosis, and 3= over 75 % of leaf surface with chlorosis; Figures with same superscript letters within a column are not significantly different.(Tukey test)

TABLE 3. Linear regression statistics of abundance of CGM on *T. aripo* on cassava varieties at CGM leaf damage score two in various agro-ecological zones during April and December 2013

Cassava variety	Agro-ecological zone	Regression coefficients	t- value	Probability
	Rainy season April 2013			
TME14	Northern Moist farmlands	-1.382	17.25	0.037*
	Western Medium High farmlands	0.610	111.00	0.006*
	Dry season December 2013			
	Northern Moist farmlands	0.398	0.64	0.558
	Southern and Eastern Lake Kyoga basin	-0.047	0.30	0.769
	Western Medium High farmlands	16.300	13.40	0.047*
	Rainy season April 2013			
NASE3	Southern and Eastern Lake Kyoga basin	-0.469	0.71	0.50
	Rainy season April 2013			
Akena	Southern and Eastern Lake Kyoga basin	1.333	2.00	0.184
	Dry season December 2013			
NASE12	Southern and Eastern Lake Kyoga basin	1.451	19.05	0.033*
	Dry season December 2013			
TME204	Northwestern farmlands	4.000	-	-
	West Nile farmlands	-3.889	0.40	0.728

*indicates values were significant for the cassava varieties at $P < 0.05$

Hairy cassava tips were probably preferred by *T. aripo* because they offer several advantages. Hairs on plant tips have been associated with maintenance of high humidity levels (Johnson, 1975) and preference of hairy cassava tips by *T. aripo* may be due high humidity levels inside the cassava tips, which shield *T. aripo* from dehydration, which is an adaptation to climatic extremes (Onzo *et al.*, 2003; Yaninek and Hanna, 2003). During encounters with preys, insect predators also use hairs on the leaves for support (MacRae and Croft, 1997) and hairy cassava tips found in the present study may provide suitable habitats for *T. aripo* to adequately exploit CGM prey.

It has been reported that *T. aripo* survives, develops and oviposits on pollen diet (Gnanvossou *et al.*, 2005), and probably the hairy apices of some cassava varieties contribute to better trapping of pollen grains (Roda *et al.*, 2003) from wild plants. This provide alternative food sources with commensurate effects on survival, longevity and fecundity of *T. aripo*. The

influence of hairs on phytoseiids has been reported in other plant species, apart from cassava (Romero and Benson, 2005). There was evidence in this study that cassava varieties with non-hairy tips (glabrous) such as Bao, NASE4 and TME204 also sustained high population of *T. aripo*. Naturally, some cassava varieties produce exudates and these have been found to be important food for *T. aripo* (Onzo *et al.*, 2003).

Among the several cassava varieties, *T. aripo* was consistently present on TME14 in April and December 2013 in Southern and Eastern Lake Kyoga basin at low to moderate CGM densities, but in Northern Moist Farmlands, it was present on TME14 only during April (Tables 1 and 2). The lack of TME14 to support *T. aripo* in the Northern Moist Farmlands may be due to variability in nutritional quality of cassava plants, caused by several factors that include stresses (Showler, 2004) and drought (Gzik, 1996) that influence the host selection behavior of insects. In very attractive host plants, higher levels of free amino acids that are essential for insect

herbivore development and population growth, have been reported (Reay-Jones, 2007). It is further reported that where the preferred host plants co-occur, varieties with substantially higher biomass supports greater oviposition of insects suggesting there may be marked differences in plant characteristics in TME14 and other cassava varieties.

CONCLUSION

This study has shown that *T. aripo* released in Uganda from 1994-98 has persisted and could still be recovered on cassava in 2013. At the leaf damage score of 2 (moderate CGM population densities), there are inverse significant linear relationships between CGM and *T. aripo* population densities on TME14. These relationships indicate that the CGM densities at leaf damage score of 2 are sufficiently low for *T. aripo* to deplete CGM, demonstrating the impact of *T. aripo*. These linear relationships are applicable under a range of low host densities as occur for CGM on cassava during the rainy season in the cassava belts of Africa (Hopper and King, 1986; Yanninek *et al*, 1989; Wiedenmann and Smith, 1993). However, there are increasing trend in *T. aripo* and CGM population densities in Western Medium High Farmlands in April and December. This observation depicts high CGM population densities that occur particularly during the dry season that overwhelms *T. aripo*. From the results of our finding in this study, TME14 can be suggested as a promising cassava variety to sustain *T. aripo* in Southern and Eastern Lake Kyoga basin and its use in other agro-ecological zones need validation.

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