

Predatory phytoseiid mites associated with cassava in Kenya, identification key and molecular diagnosis (Acari: Phytoseiidae)

Daniel L. MUTISYA^{1,2}, El Sayed M. EL-BANHAWY², Victor VICENTE DOS SANTOS³, Charles W. KARIUKI¹, Cannute P.M. KHAMALA², Marie-Stéphane TIXIER³

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¹ KALRO-Katumani, P. O. Box 340-90100, Machakos, Kenya. dlmutisya@gmail.com / Daniel.Mutisya@kalro.org (✉), Charles.Kariuki@kalro.org

²University of Nairobi, P. O. Box 30197-00100, Nairobi, Kenya. banhawy@uonbi.ac.ke, khamala@uonbi.ac.ke

³Montpellier SupAgro, UMR CBGP, INRA/IRD/CIRAD/Montpellier SupAgro, 755 Avenue du Campus Agropolis, CS 30016, 34988 Montferrier-sur-Lez cedex, France. vicente@supagro.fr, marie-stephane.tixier@supagro.fr

ABSTRACT — The objective of this study was to carry out a large survey in order to characterize Phytoseiidae species diversity on cassava in Kenya. A total of 29 species from 10 genera were identified in diverse ecological zones in Kenya. The warm-to-hot low midlands of eastern and the warm-humid coastal strip yielded over 70 % of the species identified. The dominant species were *Euseius fustis* (Pritchard & Baker) and *Typhlodromalus aripi* De Leon present in 37 and 34 % of samples, respectively. *Typhlodromalus aripi* was found in coastal, eastern and western regions of Kenya while *E. fustis* was present in all sampled localities of the country. In addition to morphological diagnosis, molecular sequences for DNA fragments 12S, CytB, COI and ITS, were obtained for *T. aripi* and *E. fustis*. Molecular diagnosis has revealed the unexpected presence of *Neoseiulus idaeus* Denmark & Muma and indicated its misidentification as *Neoseiulus onzoi* (Zannou, Moraes & Oliveira) in a previous survey carried out in Kenya. Molecular sequences herein obtained will help further diagnosis of phytoseiid species and complement the international reference databases needed to assist molecular identification of Phytoseiidae species.

KEYWORDS — *Typhlodromalus aripi*; *Euseius fustis*; cassava; molecular diagnosis

ZOOBANK — [30D9F6BD-A542-448F-8C72-F3B772DB33CF](https://doi.org/10.15463/ZOOBANK.30D9F6BD-A542-448F-8C72-F3B772DB33CF)

INTRODUCTION

Predatory mites of the family Phytoseiidae are the major natural enemies of the cassava green mites (CGM): *Mononychellus tanajoa* Bondar and *M. progressivus* Doreste (Acari: Tetranychidae) in Africa (Yaninek *et al.* 1993; Mutisya *et al.* 2015). The wet humid geographical regions are usually the most suitable for phytoseiid mites in cassava fields (Shipp and van Houten 1997; Walzer *et al.* 2007), as long dry periods cause high mortality of most phytoseiid

species (De Courcy *et al.* 2004; Kariuki *et al.* 2005; Zundel *et al.* 2007). Bakker *et al.* (1993) reported that saturation deficit tolerance spectrum of phytoseiid species is an important factor for mite survival and breeding during periods of long drought. The phytoseiid mite *Typhlodromalus aripi* De Leon was introduced to Africa in the 1990's to control the CGM. Following its release, it quickly spread to most warm-humid regions of the continent (Hanna *et al.* 1998; Kariuki *et al.* 2002; Zannou *et al.* 2007a).

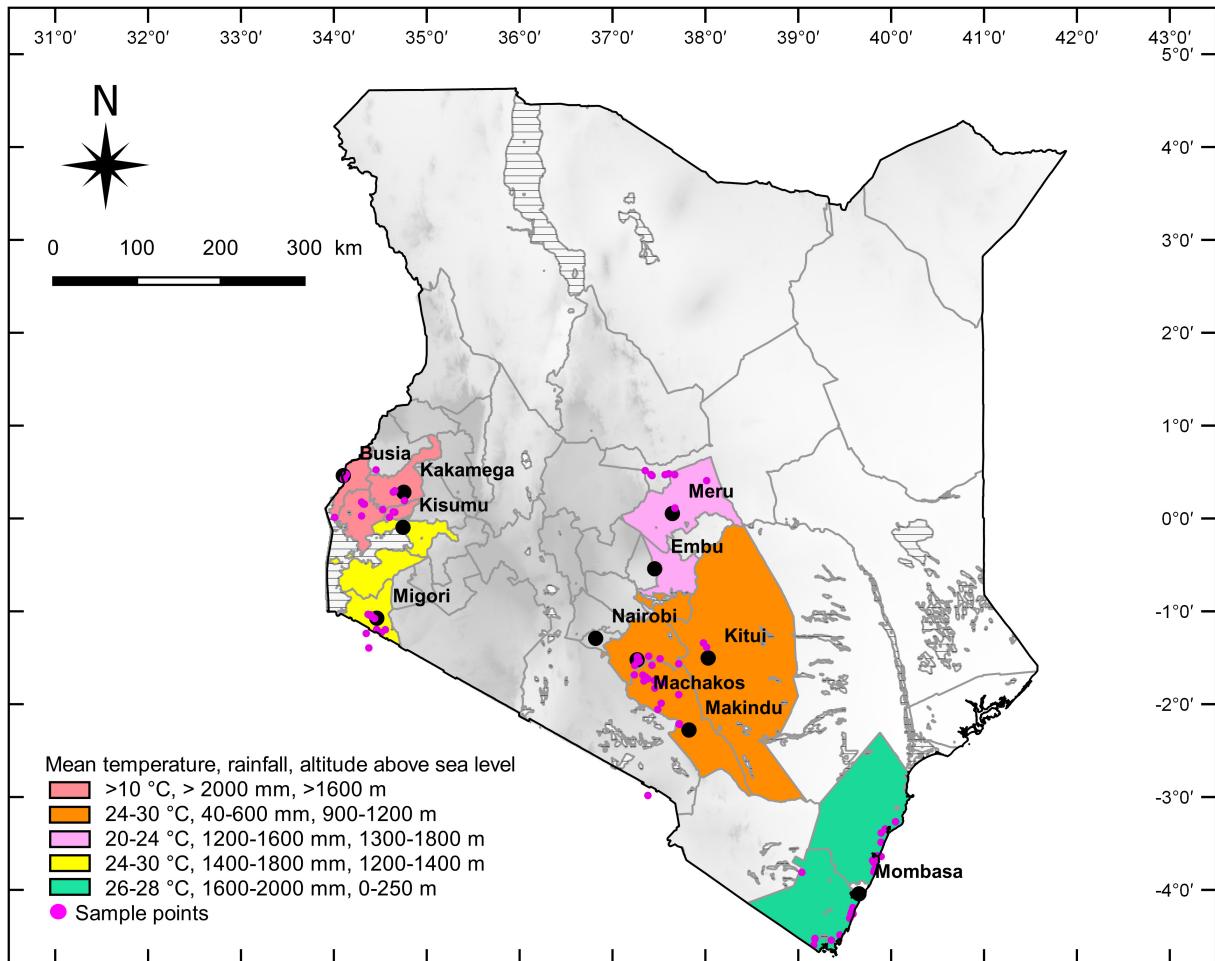


FIGURE 1: Zones in Kenya where phytoseiid species were sampled between 2011 and 2013.

Since the release of *T. aripi* in the mid-1990s in Kenya's coastal and western regions, full report on phytoseiid fauna on cassava was lacking in comparison to Malawi and Mozambique (Zannou *et al.* 2007a). *Typhlodromalus aripi* prefers inhabiting cassava apex and is reported to co-exist well with other native species present on leaves of the plant with no displacement impact of either species (Gnanvossou *et al.* 2005; Zannou *et al.* 2007a; Molo *et al.* 2016).

The objective of the present study was to explore phytoseiid diversity in different cassava production zones. Further, it offered an opportunity to carry out a molecular diagnosis study of two species common on cassava. Finally, an identification key to species found on cassava in Kenya based on works of Moraes *et al.* (2001, 2007), Zannou *et al.* (2006,

2007b) and Chant and McMurtry (2006) was provided.

MATERIALS AND METHODS

Survey and phytoseiid species identification

A survey was conducted (2011-2013) in 166 cassava fields of three geographical zones: the hot-dry low midlands (LM), the cool-wet upper midlands (UM) and the warm-wet coastal lowlands (CL) of Kenya (Table 1, Figure 1). In each field, 15 cassava plants were sampled at random. The phytoseiid specimens were collected by beating the plants with a wooden stick (60 cm long) over a blue plastic board for approximately two minutes. This technique was chosen as it allows collecting mites from both apices

TABLE 1: Cassava fields locality, altitude and respective climatic conditions.

| Zone | No. Plots | County (Locality) | Altitude range (m) | Annual temp (°C) | Annual rainfall (mm) |
|------|-----------|---|--------------------|------------------|----------------------|
| UM | 30 | Kakamega, Meru, Embu | > 1,400 | < 23 | > 1,800 |
| LM | 86 | Kisumu, Migori, Busia, Kitui, Machakos, Makindu | 1,100-1,400 | 24-30 | 600-1,600 |
| CL | 50 | Mombasa; North, south coastal strip | 0-250 | 26-28 | 1,600-2,000 |

LM=Lower midlands, UM= upper midlands and CL= coastal lowlands

and leaves. With the aid of a head loop lens (magnification 4 x). Mites were then identified using morphological identification keys according to El-Banhawy and Knapp (2011), Moraes *et al.* (2001, 2007), Chant and McMurtry (2005) using a phase contrast microscope (x 400).

Molecular characterization of phytoseiid mites

Specimens from plant apex in the coastal Kenya at Mtwapa (assumed to belong to *T. aripo*) and specimens from the middle canopy leaves at Embu (upper eastern region) were collected in 100 % alcohol vials for DNA analyses. Genomic DNA was individually extracted from four mite specimens using a Qiagen DNeasy tissue kit (Qiagen, Hilden, Germany), according to the DNA extraction protocol « Purification of Total DNA from Animal Blood or Cells » (Spin-Column Protocol) adapted for extracting total DNA from mites (Kanouh *et al.* 2010). After extraction, specimens were retrieved and mounted on slides according to the method developed by Tixier *et al.* (2010). A nuclear ribosomal gene section including ITS1-5.8S-ITS2 (reported as ITSS) and three mitochondrial markers (COI, 12S rRNA, Cytochrome B mtDNA) were used. For the COI mtDNA, two fragments were amplified, one using the former's primers and one using the primers proposed by Navajas *et al.* (1996, 2000) and used in Okassa *et al.* (2009) and Tixier *et al.* (2006). Primers and thermal cycling are those reported in Tixier *et al.* (2012) and in Okassa *et al.* (2009). PCR products were sequenced along both strands using *Dynamic ET Terminator Cycle Sequencing kit*, and puri-

fied using *ExoSAP-IT* (Amersham). Sequences were aligned and analysed with Geneious v3.5.4 (Drummond *et al.* 2007). The genetic distances were calculated using the Kimura 2-parameter model using Mega 6.0.6® (Tamura *et al.* 2013).

RESULTS AND DISCUSSION

1. Diversity of phytoseiid mites

Within the 166 cassava plots sampled, 528 mites belonging to 29 species and 10 genera were identified (Table 2). The highest number of species belonged to genus *Euseius* Wainstein (12). The most frequent and numerous species were: *E. fustis* and *T. aripo* (present in 37 and 34% of sampled fields, respectively). All species found are reported below with some comments on DNA sequences when obtained. Information on the known distribution of the species is taken from the online (<http://www.lea.esalq.usp.br/phytoseiidae/>) Phytoseiidae catalogue (Demite *et al.* 2014).

Amblyseiinae

Amblyseius ankaratrae Blommers, 1976

Specimens observed. 1 female: (01°21'50"S, 37°52'19"E, Alt. 1376 m Mwala Machakos, 31-V-2011). **Previous records.** Madagascar. **Remarks.** This is the first report of this species in the African continent.

Amblyseius herbicolus (Chant, 1959)

Specimens observed. 1 female: (04°08'56"S,

TABLE 2: Bio-geographical distribution of Phytoseiidae species in different cassava zones of Kenya.

| Species | Origin and distribution | No. species | % field presence | Warm-wet coastal lowlands (CL) | Hot dry low midlands (LM) | Cold-wet upper midlands (UM) |
|---------------------------------|--------------------------------|-------------|------------------|--------------------------------|---------------------------|------------------------------|
| <i>Euseius fustis</i> | Prevalent in Africa | 196 | 37 | X | X | X |
| <i>Typhlodromalus aripo</i> | Introduced from South America | 177 | 34 | X | X | |
| <i>Euseius neofustis</i> | Prevalent in Africa | 66 | 12.02 | X | X | |
| <i>Neoseiulus idaeus</i> | Introduced from South America | 19 | 3.6 | | X | |
| <i>Amblyseius largoensis</i> | Worldwide spread | 14 | 2.7 | X | | |
| <i>Euseius vandenberga</i> | Prevalent in Africa | 8 | 0.05 | | X | |
| <i>Euseius Africanus</i> | Prevalent in Africa | 7 | 1.3 | X | X | X |
| <i>Iphiseius degerans</i> | Mediterranean Basin and Africa | 6 | 3 | | X | X |
| <i>Moraesius papayana</i> | Prevalent in Africa | 5 | 2.4 | | X | X |
| <i>Euseius talinga</i> | Prevalent in Africa | 4 | 0.02 | X | X | |
| <i>Typhlodromips bunyorei</i> | Prevalent in Africa | 4 | 1.8 | | X | |
| <i>Amblyseius sundi</i> | Prevalent in Africa | 2 | 0.01 | | X | |
| <i>Amblyseius swirskii</i> | Mediterranean Basin and Africa | 2 | 0.01 | X | | |
| <i>Euseius lokele</i> | Prevalent in Africa | 2 | 0.01 | | X | X |
| <i>Euseius natalensis</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Amblyseius ankaratrae</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Amblyseius herbicolus</i> | Worldwide spread | 1 | 0.01 | X | | |
| <i>Euseius albissiae</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Euseius baetae</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Euseius bwende</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Euseius rhusi</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Kuzinellus kariuki</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Neoseiulus asperisetatus</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Neoseiulus scapilatus</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Neoseiulus teke</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Neoseiulus tekeleius</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Proprioseiopsis atrichos</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| <i>Transeius msabahaensis</i> | Prevalent in Africa | 1 | 0.01 | X | | |
| <i>Ueckermannius mangrovei</i> | Prevalent in Africa | 1 | 0.01 | | X | |
| Total | | | 14 | 20 | 5 | |
| No. plots sampled | | | 50 | 86 | 30 | |
| % plots occupied | | | 28% | 23% | 17% | |

39°31'48"E, Alt. 25 m Kwale South Coast, 17-I-2012). **Previous records.** A cosmopolitan species. **Remarks.** This species is worldwide spread though mainly found in the Southern Hemisphere. This is the first record of this species on cassava.

Amblyseius largoensis (Muma, 1955)

Specimens observed. 14 females: (04°36'32"S, 39°27'7"E, Alt. 41 m Vanga South Coast, 17-I-2012; 04°45'40"S, 39°5'50"E, Alt. 25 m, 17-I-2011, Coast Kwale; 03°45'00"S 39°26'06"E, Alt. 10 m Malindi North Coast, 17-I-2011). **Previous records.** A cosmopolitan species. **Remarks.** *Amblyseius largoensis* was recovered in the coastal lowlands but at low frequency (0.4 %) with a total number of 14 specimens. This species is worldwide distributed and usually found in tropical climates. This is the first record of *A. largoensis* on cassava in Kenya. Earlier

surveys have shown the presence of this species on mangrove trees in the same coastal region of Kenya (El-Banhawy and Knapp 2011).

Amblyseius sundi Pritchard & Baker, 1962

Specimens observed. 2 females: (03°42'36"S, 39°13'19" E Alt. 23 m Watamu North Coast, 17-I-2011). **Previous records.** Benin, Burundi, Cameroon, Cape Verde, Cuba, Democratic Republic of Congo, Ghana, Guadeloupe, Ivory Coast, Kenya, Madagascar Island, Malawi, Mozambique, Nigeria, Rwanda, Sierra Leone, Uganda, Zimbabwe. **Remarks.** This species has been mainly reported from the Ethiopian area and two areas in the Neotropical zone (Guadeloupe and Cuba). It has been reported once on cassava in Democratic Republic of Congo (Gutiérrez and Bonato 1994).

Amblyseius swirskii Athias-Henriot, 1962

Specimens observed. 2 females: (03°17'13"S, 39°02'38"E, Alt. 41 m Kilifi North Coast, 17-I-2011).

Previous records. Argentina, Azerbaijan, Benin, Burundi, Cape Verde, Cuba, Democratic Republic of Congo, Egypt, Gaza Strip, Georgia, Ghana, Israel, Italy, Kenya, Malawi, Nigeria, Reunion Island (Kreiter *et al.* 2016), Saudi Arabia, Senegal, Spain, Tanzania, Turkey, USA, Yemen, Zimbabwe. **Remarks.** This species has been described from Israel and mainly recorded from Mediterranean Basin and Africa. It is a very efficient natural enemy commercialized and released in greenhouses for controlling phytophagous mites and thrips (Buitenhuis *et al.* 2015). It has been recorded once on cassava in Ghana (Zannou *et al.* 2007b).

Euseius africanus (Evans, 1954)

Specimens observed. 7 females: (04°43'30"S, 39°05'59"E, Alt. 32 m South Coast Lunga Lunga, 17-I-2011; 01°54'53" S, 37°42'26"E, Alt. 1116 m Kialala Machakos, 20-I-2011). **Previous records.** Burundi, Kenya, Malawi, Tanzania. **Remarks.** *Euseius africanus* was observed in 0.1% of the fields sampled in the regions of upper eastern, western and coastal Kenya. This species is only reported from the Ethiopian region. In Kenya, it has been already observed on other plants in coastal and central regions (El-Banhawy and Knapp 2011). This is the first report of this species on cassava.

Euseius albizziae (Swirski & Ragusa, 1978)

Specimens observed. 1 female: (00°37'33"S, 34°56'02"E, Alt.1266 m Ugunja Kisumu, 21-I-2011). **Previous records.** Kenya. **Remarks.** This species is only reported from Kenya and it is the first report on cassava.

Euseius baetae (Meyer & Rodriguez, 1966)

Specimens observed. 1 female: (04°43'37"S, 39°11'31"E, Alt. 26 m Kwale-Kokotoni South Coast, 17-I-2012). **Previous records.** Congo, Kenya, Malawi, Mozambique, South Africa. **Remarks.** This species is only recorded from Africa. Rodrigues (1968) reported it on cassava plants in Mozambique. Zannou *et al.* (2005) showed that this species was abundant on cassava plants in that country.

Euseius bwende (Pritchard & Baker, 1962)

Specimens observed. 1 female: (04°08'41"S, 39°27'57"E, Alt. 30 m Msabweni South Coast, 17-

I-2012). **Previous records.** Democratic Republic of Congo, Kenya, Mozambique, Nigeria, South Africa, Zimbabwe. **Remarks.** This species is only reported from Africa. Zannou *et al.* (2005) reported this species as abundant in cassava plantations in Mozambique.

Euseius fustis (Pritchard & Baker, 1962)

Specimens observed. 196 females: (00°54'22"N, 34°26'60"E, Alt. 1689 m Kayenga Kakamega, 3-III-2013; 00°52'16"S, 37° 20'2"E, Embu, 19-II-2011; 00°25'01"S, 34°19'03"E, Alt. 1163 m Meru, 16-II-2011; 00°43'44"S, 37°23'46"E, Alt. 1407 m Rogo Migori 19-V-2011, 01°24'25"S, 37°29'46"E, Alt.1141 m Mukaa Machakos, 7-VII-2011; 03°10'48"S, 39°58'1"E, Alt. 43 m Mafueni North Coast, 18-I-2011; 04°36'32"S, 39°27'07" E, Alt. 41 m Vanga South Coast, 17-I-2012). **Previous records.** Benin, Burundi, Democratic Republic of Congo, Ghana, Kenya, Malawi, Nigeria, Rwanda, Tanzania, Uganda, Zimbabwe. **Molecular sequences.** Three to four sequences of this species were obtained for the DNA fragments 12S rRNA, COI (LCOHCO), CYB mtDNA and ITSS (Table 3). The genetic distances between the specimens of *E. fustis* are very low (12S rRNA: 0-0.002; CYTB mtDNA: 0-0.002; COI (LCOHCO): 0-0.032; ITSS: 0) and much lower than those previously reported from two species of a same genus (Tixier *et al.* 2006, 2008, 2011, 2012, 2014). Sequences of this species are not reported from Genbank. **Remarks.** *Euseius fustis* was collected in 62% of the cassava fields sampled in Kenya. This species was mostly observed in eastern, western and coastal areas covering most agro-ecological zones of upper and low midlands (UMs & LMs) as well as the coastal lowlands (CLs). This species was already reported from different plants in western Kenya including cassava (Moraes and McMurtry 1988; Moraes *et al.* 1989; El-Banhawy and Kapp 2011). It is only present in Africa and has been reported on cassava also in Benin (Moraes *et al.* 1989), Malawi and Democratic Republic of Congo (Gutierrez and Bonato 1994; Zannou *et al.* 2005). The high densities presently observed as well as its high frequency indicate this is the most common phytoseiid on cassava in Kenya, even after the introduction of *T. aripo* as suggested by Onzo *et al.* (2014) due to par-

tial niche separation among predator species (Onzo et al. 2010). Its ability to control *M. tanajoa* alone has been shown to be limited (Onzo et al. 2014; Mutisya et al. 2015).

Euseius lokele (Pritchard & Baker, 1962)

Specimens observed. 2 females: (00°42'18"S, 37°24'50"E, Alt. 1402 m Chuka Meru, 20-I-2011; 00°48'40"N, 34°42'36"E, Alt. 1219 m Teso Busia, 18-I-2012). **Previous records.** Benin, Burundi, Cameroon, Democratic Republic of Congo, Ghana, Kenya, Nigeria, Sierra Leone, Uganda. **Remarks.** This species is only recorded from Africa. It has been reported once on cassava in Democratic Republic of Congo.

Euseius natalensis (Van der Merwe, 1965)

Specimens observed. 2 females: (01°07'59"S, 037°27'50"E, Alt. 1141 m Kyanika Kitui, Date 27-I-2011). **Previous records.** Kenya, South Africa. **Remarks.** This species has only been recorded from Africa. It is its first report on cassava.

Euseius neofustis Moraes & McMurtry, 1988

Specimens observed. 66 females: (00°42'22"S, 37°15'50"E, Alt. 1401 m Egoji Meru, 19-V-2011; 00°27'47"S, 39°39'36"E, Alt. 28 m, Lunga Lunga, South Coast, 1-XII-2011; 03°17'06"S, 39°01'19"E, Alt. 23 m, Kilifi North Coast, 2-XII-2011). **Previous records.** Kenya, Tanzania, Thailand. **Remarks.** *Euseius neofustis* was observed in 20.2 % of the plots sampled. Sixty-six specimens were collected from eastern and coastal regions. El-Banhawy and Knapp (2011) reported the presence of this species on other plants in coastal region of Kenya and Moraes and McMurtry (1988) reported its occur-

rence on cassava in Kenya.

Euseius rhusi (Van der Merwe, 1965)

Specimens observed. 1 female: (03°02'10"S, 39°02'28"E, Alt. 29 m Kilifi North Coast, date 2-XII-2011). **Previous records.** Burundi, Colombia, Kenya, Mozambique, Reunion Islands, Rwanda, South Africa. **Remarks.** This species is mainly reported from Africa. Only one publication states its presence in Colombia. This is the first report of this species on cassava.

Euseius talunga (Pritchard & Baker, 1962)

Specimens observed. 4 females: (04°27'36"S, 39°14'44"E, Alt. 43 m Msabweni South Coast, 1-XII-2010; 00°52'16"S, 37°20'2"E, Alt. 1404m Embu, 19-II-2011). **Previous records.** Benin, Burundi, Democratic Republic of Congo, Ghana, Kenya, Malawi, Nigeria, Rwanda, Sierra Leone, Togo. **Remarks.** This species is prevalent in Africa, but it had never been reported on cassava before.

Euseius vandenbergae (Ueckermann & Loots, 1988)

Specimens observed. 8 females: (02°3'18"S, 37°19'11"E, Alt. 922 m Mwailu Makindu, 7-VII-2011) **Previous records.** Cameroon, Kenya, Rwanda, South Africa. **Remarks.** *Euseius vandenbergae* was rarely recovered in this study (8 specimens in 0.04 % of the fields sampled) in the coastal and western Kenya regions. It is the first time that *E. vandenbergae* is reported on cassava. This species was already observed in this country on other plants in coastal regions (El-Banhawy and Knapp 2011).

Iphiseius degenerans (Berlese, 1889)

Specimens observed. 6 females: (00°52'41"S,

TABLE 3: Characteristics of collection localities of the different species considered and accession numbers in Genbank database.

| Species | Collection date | Locality | 12S rNA | CYTB | COI | ITS |
|-----------------------------|-----------------|--------------------------------|----------|----------|----------|----------|
| <i>Euseius fustis</i> | 2015 | Embu on leaves | KX610072 | KX610076 | KX610062 | KX610058 |
| | | | KX610073 | KX610077 | KX610063 | KX610059 |
| | | | KX610074 | KX610078 | KX610064 | KX610060 |
| <i>Typhlodromalus aripo</i> | 2015 | Mtwapa in apex | KX610075 | KX610079 | | KX610066 |
| | | Embu on leaves | | | | KX610067 |
| <i>Neoseiulus idaeus</i> | 2011 | Mtwapa in apex | | | | KX610071 |
| | | Chile, La Paz on Citrus sp | | | | KX610065 |
| | 2007 | Argentina, Mercedes on Sida sp | | | | KX610070 |
| | | | | | | KX610068 |
| | | | | | | KX610069 |

37°20'06"E, Alt. 1402 m Embu, 20-V-2011; 02°29'22"S, 037°18'29"E, Alt. 1150m-Nzaui Makindu, 7-VII-2011). **Previous records.** Algeria, Benin, Brazil, Burundi, Cameroon, Canary Island, Cape Verde, Cyprus, Democratic Republic of Congo, Egypt, Georgia, Ghana, Greece, Israel, Italy, Kenya, Lebanon, Madagascar, Madeira Island, Malawi, Morocco, Nigeria, Portugal, Rwanda, Sierra Leone, South Africa, Sudan, Syria, Tanzania, Tunisia, Turkey, Uganda (Moraes *et al.* 2007), USA, Yemen, Zimbabwe. **Remarks.** This species is essentially reported from Africa, Middle East and southern Europe. It is used in greenhouses to control phytophagous mites and thrips (van Houten and van Stratum 1995; Vantornhout *et al.* 2004). This is the first report on cassava in Kenya; it has been already observed on this plant in Benin, Burundi, Malawi and Uganda (Zannou *et al.* 2005). Several studies report its low efficiency in controlling *M. tanajoa* because of the lack of spatial persistence in cassava fields (Nwilene and Nachman, 1996).

Moraeseius papayana (Van der Merwe, 1965)

Specimens observed. 5 females: (01°45'47"S, 37°05'20"E, Alt. 1316 m Machakos, 20-I-2011; 01°22'8"S, 37°30'43"E, Alt. 1587m-Nzaui Makindu, 00°42'16"S, 37°23'54"E, Alt. 1408 m Egoji Meru, 22-V-2011; 00°53'16"S, 37°18'02"E, Alt. 1404m Siakago-Embu, 19-II-2011). **Previous records.** Kenya, Mozambique, South Africa. **Remarks.** *Moraseius papayana* was rarely observed (only 5 specimens in 0.1% of the fields sampled). This is the first report of this species in Kenya and on cassava.

Neoseiulus asperisetatus Zannou, Moraes & Oliveira, 2006

Specimens observed. 1 female: (01°12'25"S, 38°05'13"E, Alt. 1642 m Kyanika Kitui, 21-I-2011). **Previous records.** Benin, Cameroon, Democratic Republic of Congo, Kenya, Zambia. **Remarks.** This species is prevalent in Africa and has been previously reported from cassava in Benin (Zannou *et al.* 2006).

Neoseiulus idaeus Denmark & Muma, 1973

Specimens observed. 19 females: (01°20'51"S, 37°16'56"E, Alt. 1606 m Katumani Machakos 21-IV-2013; 02°45'43"S, 37°19'2"E, Alt. 922 m Kiboko Makindu 7-VII-2011; 01°13'24"S, 38°06'17"E,

Alt. 1141 m Wikiliye Kitui, 21-I-2011; 00°10'55"S, 34°24'43"E, Alt. 1211 m Maseno Kisumu, 2-III-2011; 00°16'55"N, 37°00'50"E, Alt. 1402 m, Ishara Embu, 19-V-2011). **Previous records.** Argentina, Brazil, Colombia, Chile, Kenya, Paraguay, Peru, Venezuela. **Molecular sequences.** The COI sequences obtained matched with sequences of *N. idaeus* obtained by French researchers collected in Chile and Argentina (Table 3). DNA sequences of this species exist in Genbank but not for the fragment of COI herein sequenced. **Remarks.** This species was observed in 0.7 % of the cassava fields sampled, with a total of 19 specimens. Based on the morphological details given by El-Banhawy and Knapp (2011) for specimens from Kenya reported as *Neoseiulus onzoi* Zannou Moraes & Oliveira, we consider that those mites instead belong to *N. idaeus*. The latter species has been introduced to Africa between 1985 and 1993 to control *M. tanajoa* (Yaninek *et al.* 1992, 1993) without promising results (Yaninek *et al.* 1993; Karuki *et al.* 2005). During 1988-1992, *N. idaeus* was released in coastal, western and eastern Kenya to control CGM, but recovery efforts did not yield any specimens (Yaninek and Herren, 1988; Yaninek *et al.* 1993). The specimens herein reported have been collected less than 500 meters from where *N. idaeus* was released in 1992 at KALRO Katumani field plot.

Neoseiulus scapilatus (Van der Merwe, 1965)

Specimens observed. 1 female: (03°42'36"S, 39°13'19"E, Alt. 18 m Msabaha Malindi, 18-I-2011). **Previous records.** Benin, Burundi, Kenya, Malawi, Mozambique, Reunion Islands, Rwanda, South Africa, Uganda, Zimbabwe. **Remarks.** This species is widespread in Africa. It is the first record on cassava.

Neoseiulus teke (Pritchard & Baker 1962)

Specimens observed. 1 female: (03°17'06"S, 39°01'20"E, Alt. 29 m Kilifi North Coast, 2-II-2013). **Previous records.** Burundi, Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Reunion Islands, Rwanda, Sierra Leone, South Africa, Tanzania, Zimbabwe. **Remarks.** This species is widespread in Africa. It was reported on cassava in Kenya (Moraes *et al.* 1989), Mozambique (Rodrigues 1968) and Malawi (Zannou *et al.* 2006). Nwilene and Nachman (1996) studied the reproduction

characteristics of this species on *M. tanajoa*. It was more efficient than *I. degenerans*, but seems not efficient enough in field conditions (Nwilene and Nachman 1996).

Neoseiulus tekeleius El-Banhawy & Knapp, 2011

Specimens observed. 1 female: (04°21'04"S, 39°08'41"E, Alt. 36 m Ukunda South Coast, 17-I-2012). **Previous records.** Kenya. **Remarks.** This species has been only reported from Kenya on unknown plant.

Proprioseiopsis atrichos Moraes, Zannou & Oliveira, 2007

Specimens observed. 1 female: (01°10'41"S, 37°14'20"E, Alt. 1168 m Kilala Machakos, 20-II-2011). **Previous records.** Uganda. **Remarks.** It is the second record of this species after its description. This species is new for Kenyan fauna and has never been observed on cassava.

Transeius msabahaensis (Moraes & McMurtry, 1989)

Specimens observed. 1 female: (03°15'41"S, 39°32'10"E, Alt. 38m-Chumani Malindi, 16-XI-2011). **Previous records.** Kenya. **Remarks.** This species was described from Kenya and it is the third report after its description. It is the first report on cassava.

Typhlodromalus aripo De Leon, 1967

Specimens observed. 177 females: (04°27'46"S, 39°39'35"E, Alt. 44 m Lunga Lunga South Coast, 01°58'30"S, 37°45'57"E, Alt. 1584m- Kyambai Machakos, 12-II-2012; 03°11'22"S, 39°32'5"E, Alt. 34 m Gede Malindi North Coast, 12-IV-2013; 00°43'44"S, 37°23'46"E, Alt. 1407 m, Rogo Migori, 19-V-2011, 01°24'25"S, 37°29'46"E, Alt. 1141m, Mukaa Machakos, 7-VII-2011; 03°10'48"S, 39°58'01"E, Alt. 43 m, Mafueni North Coast, 2-II-2013; 02°45'43"S, 37°19'02"E, Alt. 922 m Kiboko Makindu 7-VII-2011). **Previous records.** Argentina, Benin, Brazil, Cameroon, Colombia, Democratic Republic of Congo, Costa Rica, El Salvador, Guadeloupe, Guyana, Jamaica, Malawi, Mexico, Mozambique, Paraguay, Peru, Trinidad, Uganda. **Molecular sequences.** One sequence of this species was obtained for the DNA fragments 12S rRNA and CYTB mtDNA (Table 3). The sequences of *T. aripo* match with those already in hand by French contributors

of the paper were collected at Kiboko: 02°07'52"S, 37°25'57"E and Mtwapa: 03°10'01"S, 40°12'55"E , south east lowlands and coastal region of Kenya respectively. **Remarks.** *Typhlodromalus aripo* occurs in western, eastern and coastal regions and was absent in the cool upper eastern midlands (UM). Kariuki *et al.* (2002, 2005) has reported its continued occurrence on cassava since its release in Africa in 1990's. Earlier reports have shown this species to be the most efficient in controlling CGM (Kariuki *et al.* 2005; Mutisya *et al.* 2014). This species was described from the Neotropical region and has been introduced to Africa for the control of the CGM where it suppresses pest populations to < 2 mites per leaf in most fields in optimum climatic conditions (Mutisya *et al.* 2015; Molo *et al.* 2016). In the absence of CGM, this species can survive on alternative preys such as whitefly and mealy bug nymphs (Gnanvossou *et al.* 2005; Mutisya *et al.* 2014).

Typhlodromips bunyorei El-Banhawy & Knapp, 2011

Specimens observed. 4 females: (00°07'19"S, 34°43'16", Alt. 1411 m Mjini Kakamega, 3-III-2011). **Previous records.** Kenya. **Remarks.** *Typhlodromips bunyorei* was found in western Kenya. This is the first report on cassava. El-Banhawy and Knapp (2011) reported this species on other plants in western Kenya.

Ueckermannseius mangrovei El-Banhawy & Knapp, 2011

Specimens observed. 1 female: (01°43'58"S, 37°30'04"E, Alt. 155 8 m Tendelyani Machakos, 8-VII-2011). **Previous records.** Kenya. **Remarks.** This species is known from its original description from Kenya. This is the first report on cassava.

Typhlodrominae

Kuzinellus kariuki El-Banhawy & Knapp, 2011

Specimens observed. 1 female: (01°59'31"S, 37°33'32"E, Alt. 1339m-Mwala Machakos, 31-V-2011). **Previous records.** Kenya. **Remarks.** This is the second report of this species from Kenya, the first one being on coffee (El-Banhawy and Knapp 2011).

2. Phytoseiid species distribution and abundance

The most frequent and numerous species in this study were *E. fustis* (indigenous species) and *T. aripo* (introduced species), accounting respectively for 37 and 34 % of the specimens collected. They were present in more than 70% of the fields sampled. *Euseius neofustis* followed as a numerous species (13 % of the specimens collected). Each of the other species corresponded to less than 4 % of the specimens collected, most of them represented by a single specimen. Most of the species reported in this paper are indigenous to Africa and some of them are being reported first time on cassava in the present work. This study shows the spread of *T. aripo* and success of its introduction throughout Kenya.

3. Geographical distribution and impact of climatic conditions

Phytoseiid mites were observed from all climatic areas sampled. The highest number of plots occupied by Phytoseiidae was observed in the CL and LM zones corresponding to the most humid areas. The percentage of plots where phytoseiids were found were highest for the warm-wet low midlands and coastal lands; in the warm-drier coastal lowlands, 28 % of the plots were occupied by Phytoseiidae species. This observation validates the hypothesis that phytoseiids are susceptible to dry conditions. Only two species among the 29 sampled are observed in all regions (*Euseius fustis* and *E. africanus*) whereas 19 species were only found in one region, nine in the warm-wet coastal lowlands (CL) and ten in the hot-dry low midlands (LM). Only *E. fustis* was observed in the cool-wet upper midlands (UM). *Typhlodromalus aripo* prevailed in the CL (warm-wet coastal lowlands) region whereas *E. fustis* prevailed in the UM (cool-wet upper midlands) region.

4. Identification key for phytoseiid females on cassava in Kenya

1. Podonotal region of the dorsal shield (anterior to setae *R1*) of the female with five or six pairs of "lateral" setae (*j3, z2, z3, z4, s4, s6*) *Kuzinellus kariuki*

- 1'. Podonotal region of the dorsal shield (anterior to setae *R1*) of the female with four pairs of "lateral" setae (*j3, z2, z4 and s4, z3 and s6 absent*) 2
- 2 (1'). Sternal shield with median posterior projection, some forward "migration" of preanal setae *ZV2* and/or *JV2* 3
- 2'. Sternal shield without posterior projection, without forward "migration" of preanal setae *ZV2* and/or *JV2* 17
- 3 (2). Chelicera of normal size and shape, with prominent teeth evenly distributed along fixed digit; peritreme usually extending to level of seta *j1* 4
- 3'. Chelicera reduced in size, stubby, with a group of small teeth clustered at the distal end of the fixed digit; peritreme usually not extending beyond seta *j3*, often much shorter 5
- 4 (3). Dorsal shield setae short/minute (except *Z5*), shorter than distances between their bases; *Z4* not as long as distance between its base and that of *S4*; dorsal shield smooth except for anterolateral striations *Ueckermannseius mangrovei*
- 4'. Dorsal shield setae of medium length, subequal; dorsal shield usually ornamented in addition to anterolateral striations; *Z4* longer than distance between its base and that of *S4* *Typhlodromalus aripo*
- 5(3'). Ventral and anal shields separated *Iphiseius degenerans*
- 5'. Ventral, and anal shields fused 6
- 6(5'). Seta *Z1* present 7
- 6'. Seta *Z1* absent *Moraeseius papayana*
- 7(6). Peritreme extending anteriorly to level of *j1* 8
- 7'. Peritreme extending anteriorly at most slightly beyond level of *j3* 10
- 8 (7). Calyx of spermatheca tubular 9
- 8'. Calyx of spermatheca bifurcate, with a long neck

Euseius rhusi

9 (8). Calyx of spermatheca tubular but inflating progressively toward atrium *Euseius lokele*
 9'. Calyx tubular, with same diameter throughout *Euseius baetae*

10 (7'). Peritreme extending anteriorly about to level of *j3* 11
 10'. Peritreme anteriorly reaching at most ca. half way between level of *j3* and *z2* 12

11(10). Some dorsal shield setae longer especially for setae *j3* (40 – 50), *S5* (24 – 27), *Z1* (13 – 18), *Z4* (18 – 21) *Euseius albizziae*
 11'. Some dorsal shield setae shorter, especially for setae *j3* (27 – 38), *S5* (8 – 13), *Z1* (6 – 11), *Z4* (8–11) *Euseius africanus*

12(10'). Seta *JV1* inserted on anterior margin of ventrianal shield 13
 12'. Seta *JV1* inserted distinctly posterior to anterior margin of ventrianal shield 14

13(12). Setae *j3*, *z2* and *z4* much less than half distances between their bases and bases of setae next behind *Euseius vandenbergae*
 13'. Setae *j3*, *z2* and *z4* ca. as long as distances between their bases and bases of setae next behind *Euseius natalensis*

14(12'). Genu, tibia and tarsus of leg IV with several knobbed setae, dorsal shield reticulate 15
 14'. Genu, tibia and tarsus of leg IV at most each with one knobbed seta 16

15(14'). Seta *R1* rarely on dorsal shield, seta *s4* ca. twice as long as distance between its base and pore immediately posterolaterad to it *Euseius fustis*
 15'. Seta *R1* always on dorsal shield, seta *s4* slightly longer than distance between its base and pore immediately posterolaterad to it *Euseius neofustis*

16(14'). Seta *j3* ca. half as long as seta *j1*, seta *Z5* slightly longer than seta *j1* *Euseius talinga*

16'. Seta *j3* ca. as long as seta *j1*, seta *Z5* slightly shorter than seta *j1* *Euseius bwende*

17(2'). Seta *J2* absent *Proprioseiopsis atrichos*
 17'. Seta *J2* present 18

18(17'). Macrosetae usually present only on leg IV (rarely missing on this leg) but sometimes also on leg III. Except for *Z5*, lateral dorsal setae subequal 19
 18'. Macrosetae usually present on legs II, III and IV, and sometimes also on leg I, lateral dorsal setae of quite different lengths 24

19(18). GeII without and GeIII rarely with a macroseta; fixed cheliceral digit usually with less than 6 teeth, rarely multidentate; never with these 2 character states together 20
 19'. GeII and GeIII rarely without macrosetae; fixed cheliceral digit of usually with more than 6 teeth; most species with both of these 2 character *Typhlodromips bonyorei*

20(19). Anterolateral setae (*j3*, *z2* and *z4*) at least as long as distance between their bases and bases of respective immediate posterior setae 21
 20'. Anterolateral setae (*j3*, *z2* and *z4*) shorter than distance between their bases and bases of respective immediate posterior setae 23

21 (20). Dorsal setae, except *j1* and *J5* serrate; calyx of spermatheca abruptly constricted toward atrium 22
 21'. Dorsal setae, except *Z4* and/or *Z5* smooth; calyx of spermatheca not abruptly constricted toward atrium *Neoseiulus idaeus*

22(21). Some dorsal setae shorter, especially *j3*=39, *z4*=48, *Z5*=58, seven teeth on fixed cheliceral digit *Neoseiulus teke*
 22'. Some dorsal setae longer, especially *j3*=55, *z4* =70, *Z5*=75, four teeth on fixed cheliceral digit *Neoseiulus tekeleius*

- 23 (20'). Seta Z_1 at least 0.6x as long as distance between its base and base of S_2 ; S_2 at least 0.8x as long as distance between its base and base of S_4 *Neoseiulus scapilatus*
 23'. Seta Z_1 at most 0.5x as long as distance between its base and base of S_2 ; S_2 at most 0.6x as long as distance between its base and base of S_4 *Neoseiulus asperisetatus*
- 24 (18'). Ratios $s_4: Z_1$ and $s_4: S_2 > 3.0$ 25
 24'. Ratio $s_4: Z_1 > 3.0$; ratio $s_4: S_2 < 2.7$ *Transeius msabahaensis*
- 25(24). Seta Z_1 absent *Amblyseius sundi*
 25'. Seta Z_1 present 26
- 26(25'). Female ventrianal shield vase-shaped 27
 26'. Female ventrianal shield not vase-shaped (pentagonal) *Amblyseius swirskii*
- 27(26). Ratio $s_4: Z_1$ ca. 2.0; Z_4 shorter *Amblyseius ankaratrae*
 27'. Ratio $s_4: Z_1 > 3.0$; Z_4 longer 28
- 28(27'). Calyx of spermatheca trumpet-shaped *Amblyseius herbicolus*
 28'. Calyx of spermatheca tubular, parallel sided *Amblyseius largoensis*

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