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Population structure and dynamics of the cassava green mite *Mononychellus tanajoa* (Bondar) and the predator *Euseius ho* (DeLeon) (Acari: Tetranychidae, Phytoseiidae)

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Abstract
Population structure and dynamics of the cassava green mite *Mononychellus tanajoa* and the predator *Euseius ho* (Acari: Tetranychidae, Phytoseiidae). Cassava is attacked by several pests, among which the cassava green mite *Mononychellus tanajoa*. Predatory mites of the family Phytoseiidae are major natural enemies of pest mites and are naturally found inhabiting cassava plants in the field. We evaluated the temporal variation of the developmental stages of *M. tanajoa* and the most abundant predatory mite in cassava fields in the study region, the phytoseiid *Euseius ho*. Densities of all developmental stages of *M. tanajoa* were low during the rainy season, increasing over the cultivation cycle of cassava and peaking in the dry season. Overall, the larval stage of *M. tanajoa* presented the lowest densities throughout time. Densities of all developmental stages of *E. ho* were low and remained constant throughout the cultivation cycle of cassava. The number of eggs, nymphs and adults of *M. tanajoa* was higher in comparison to the larval stage whereas there were no differences in densities of the stages of *E. ho*. Densities of all developmental stages of *M. tanajoa* were negatively correlated with precipitation. Densities of the stages of egg, nymph and adult of *M. tanajoa* were positively related while the stage of larva was negatively related to temperature. We conclude that it is important to consider the population structure in studies of population dynamics of arthropods as each developmental stage experiences and responds uniquely to the local environment over time.

Keywords density; environmental factors; predatory mite; smallholders.

1 Introduction

Cassava *Manihot esculenta* Crantz is attacked by several pests, among which the cassava green mite *Mononychellus tanajoa* (Acari: Tetranychidae) (Moraes and Flechtmann, 2008). *Mononychellus tanajoa* attacks mainly shoots and leaves of cassava reducing both photosynthetic rate and root dry matter (Moraes and Flechtmann, 2008). In the Brazilian Northeast, cassava is usually cultivated in low input agricultural systems by smallholders which normally lack the resources to control pests such as the cassava green mite. Therefore, the natural biological control is an important strategy to regulate pest populations in such small farms.

Predatory mites of the family Phytoseiidae are major natural enemies of pest mites (McMurtry and Croft, 1997; Reis et al., 2000; Onzo et al., 2005; Oliveira et al., 2007; Sarmento et al., 2011) and are naturally found inhabiting cassava plants. Among the phytoseiids, species of the genus *Euseius* Wainstein are related as important natural enemies of pests in several crops (Reis and Alves, 1997; Melo et al., 2009; Sarmento et al., 2011). Phytoseiids of the genus *Euseius* belong to the group IV of Phytoseiidae (McMurtry and Croft, 1997; Croft et al., 2004), which includes generalist species that also feed on pollen besides preying on pest mites. The predatory mite *Euseius ho* is the most abundant species associated with *M. tanajoa* in cassava plantations located in the region where this study was conducted (Rêgo, 2010).

Although there are several studies on population dynamics of arthropods, little is known about the variation of densities of different developmental stages of arthropods over time (Teodoro et al., 2009a). Understanding the population structure of mites inhabiting cassava plants is key to assess the response of each developmental stage of such arthropods throughout time as some stages might be more sensible to environmental factors than others.

Environmental abiotic factors such as temperature, relative humidity and rainfall are important mechanisms mediating the population dynamics of arthropods in agroecosystems (Prischmann et al., 2005; Barbar et al., 2006; Teodoro et al., 2008). Therefore, studying the relationship between environmental factors and arthropod populations should help to determine how such mechanisms affect population patterns of arthropods over time in crops.

Here we determined densities of all developmental stages of both the cassava green mite *M. tanajoa* and the predatory mite *E. ho* throughout the cultivation cycle of cassava. We hypothesized that patterns of population dynamics of both *M. tanajoa* and *E. ho* are influenced by the developmental stage of each species.

2 Material and Methods

2.1 Study region

The experiments were carried out in small-scale farms located around the city of Miranda do Norte (3º36’45” S, 44º34’08” W, 44 m above sea level), Maranhão State, Brazil. This region has an average temperature of 27°C and is characterized by marked rainy (January to June) and dry (July to December) seasons. We chose four small farms with a minimum distance of ca. 1 km between them. At each farm, 10 cassava plants located at least 10 m away from habitat boundaries were randomly selected to avoid border effects.

Densities of each developmental stage of both *M. tanajoa* and *E. ho* were monthly surveyed during the cultivation cycle of cassava (11 months) in six leaves per plant (2 leaves from top, 2 leaves from medium, 2 leaves from bottom) to achieve a random sample on the whole-plant scale, totaling 60 leaves per farm per month. The number of eggs, larvae, nymphs and adults of both *M. tanajoa* and *E. ho* was recorded using a binocular microscope (Stemi DV4, Zeiss, Germany). The stages of protochrysalid, deutochrysalid and teliochrysalid of *M. tanajoa* were counted as nymphs. Rainfall data were obtained from the database of the National Institute for Space Research - INPE (http://www6.cptec.inpe.br/protoclima/). The environmental abiotic factors temperature (°C) and relative humidity (%) were monthly recorded over the cultivation cycle of cassava after placing a digital thermohygrometer (910.15 CHP, Alla, Brasil) on the ground for 10 minutes in each farm.

2.2 Densities of mites

Since cassava leaves vary in size and number of lobes over time, counts of all developmental stages of either *M. tanajoa* or *E. ho* on leaves were converted into number of mites per cm^2. Leaf area was estimated using the gravimetric method by randomly selecting 15 cassava leaves per farm per month and drawing their outlines on paper, cutting out and weighing. Pieces of paper of known area ($1cm^2$) were weighted using an analytic scale

(BL320H, Shimadzu, Brazil) to estimate the number of grams per cm^2. The area of the cut outs was calculated by dividing their weight by this value. Subsequently, the number of each developmental stage of either *M. tanajoa* or *E. ho* per leaf in each plant was divided by leaf area to estimate the number of mites per cm^2.

2.3 Statistical analyses

Analyses of Kruskal-Wallis were conducted to evaluate the population dynamics of *M. tanajoa* and *E. ho* within each month and densities of the different developmental stages of both mites. Pearson correlations were carried out between the environmental factors temperature, relative humidity and rainfall and densities of the different developmental stages of both the cassava green mite *M. tanajoa* and the predatory mite *E. ho*. To conduct Pearson correlations, densities of all developmental stages of *M. tanajoa* were Log (x+1) transformed to achieve assumptions of a normal distribution. All analyses were carried out using the software Statistica 7.0 (StatSoft Inc, 1984 - 2004).

3 Results

Densities of all developmental stages of *M. tanajoa* were low and remained constant during the rainy season (February to June), increasing over the cultivation cycle of cassava and reaching higher population levels in the dry season (July to December) (Fig. 1). The stage of larva of *M. tanajoa* had lower densities in comparison to adults, nymphs and eggs from July onwards (Fig. 1; Feb: P= 0.796; Mar: P= 0.635; Apr: P= 0.876; May: P= 0.531; Jun: P= 0.163; Jul: P= 0.008; Aug: P= 0.004 Sep: P= 0.021; Oct: P= 0.000; Nov: P= 0.000; Dec: P= 0.000). There was a trend of higher densities of eggs followed by the stages of adult and nymph over the cultivation cycle of cassava (Fig. 1).

Densities of all developmental stages of *E. ho* were low and remained constant throughout the cultivation cycle of cassava with medians equal to zero. No differences were found in the number of eggs, larvae, nymphs and adults of *E. ho* within each month (Fig. 2; Feb: P= 0.559; Mar: P= 0.292; Apr: P= 0.107; May: P= 0.874; Jun: P= 0.195; Jul: P= 0.198; Aug: P= 0.188; Sep: P= 0.569; Oct: P= 0.109; Nov: P= 0.109; Dec: P= 0.569).

The number of eggs, nymphs and adults of *M. tanajoa* was higher comparing with the number of larvae (Fig. 3; P= 0.000) whereas there were no differences in densities of the developmental stages of *E. ho* (Fig. 4; P= 0.105).

Densities of all developmental stages of *M. tanajoa* were negatively related to rainfall (egg: r_p= -0.618, P= 0.043; larva: r_p= -0.672, P= 0.023; nymph: r_p= -0.679, P= 0.021; adult: r_p= -0.681, P= 0.021). The stages of egg, nymph and adult of *M. tanajoa* were positively related whereas the stage of larva was negatively related to temperature (egg: r_p= 0.939, P= 0.000; larva: r_p= -0.964, P= 0.000; nymph: r_p= 0.953, P= 0.000; adult: r_p= 0.993, P= 0.000). Moreover, the developmental stages of *M. tanajoa* were not related to relative humidity (egg: r_p= -0.124, P= 0.716; larva: r_p= -0.214, P= 0.528; nymph: r_p= -0.188, P= 0.579; adult: r_p= -0.125, P= 0.713). Similarly, densities of all developmental stages of the predatory mite *E. ho* were not related to any environmental factor: rainfall (egg: r_p= -0.243, P= 0.472; larva: r_p= 0.227, P= 0.503; nymph: r_p= -0.011, P= 0.975; adult: r_p= -0.140, P= 0.681), temperature (egg: r_p= 0.281, P= 0.403; larva: r_p= 0.388, P= 0.238; nymph: r_p= 0.331, P= 0.320; adult: r_p= 0.221, P= 0.515), relative humidity (egg: r_p= -0.073, P= 0.831; larva: r_p= 0.013, P= 0.970; nymph: r_p= -0.037, P= 0.913; adult: r_p= 0.009, P= 0.979).

4 Discussion

The larval stage of the cassava green mite *M. tanajoa* had lower densities in comparison with the remaining stages from the beginning of the dry season onwards. No differences were found between densities of the developmental stages of the predatory mite *E. ho* over the cultivation cycle of cassava. Additionally, the developmental stages of *M. tanajoa* were related to rainfall and temperature (but not to relative humidity) whereas densities of *E. ho* were not related to any environmental factor.

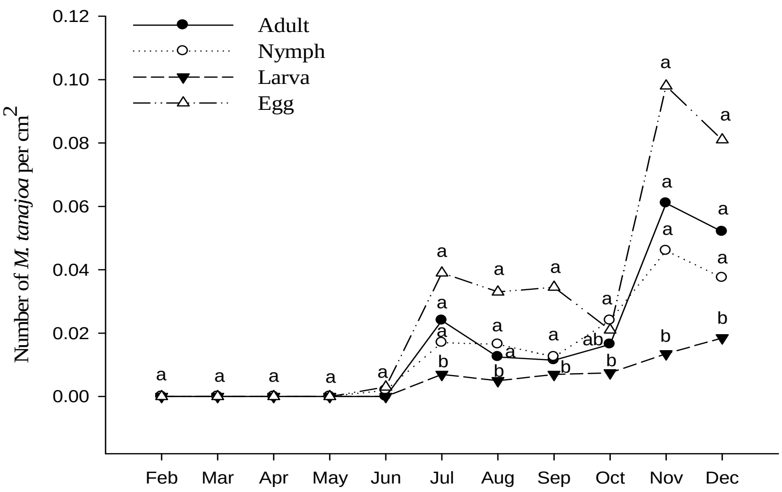

Fig. 1 Seasonal changes in densities of the developmental stages of adult, nymph, larva and egg of the cassava green mite *M. tanajoa* over the cultivation cycle of cassava. Medians are shown. Different letters within each month represent significant differences between developmental stages based on Kruskal-Wallis analyses (P< 0.05).

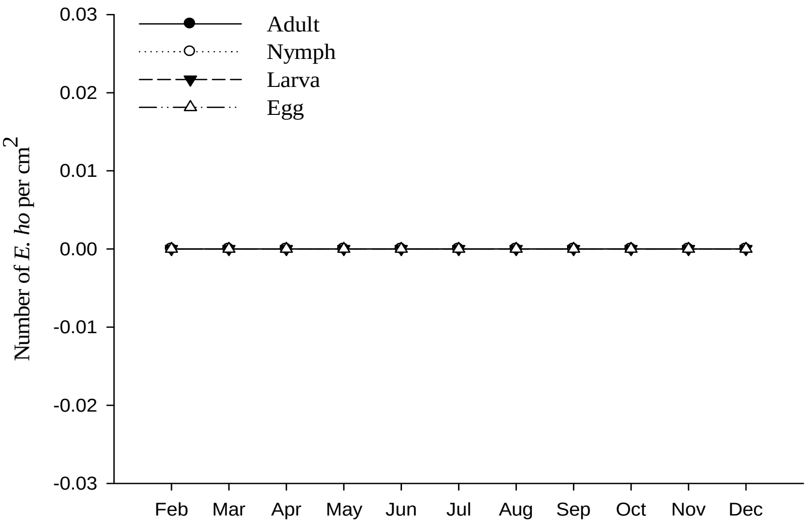

Fig. 2 Seasonal changes in densities of the developmental stages of adult, nymph, larva and egg of the predatory mite *E. ho* throughout the cultivation cycle of cassava. Medians are given. (Kruskal-Wallis, P> 0.05 for all months).

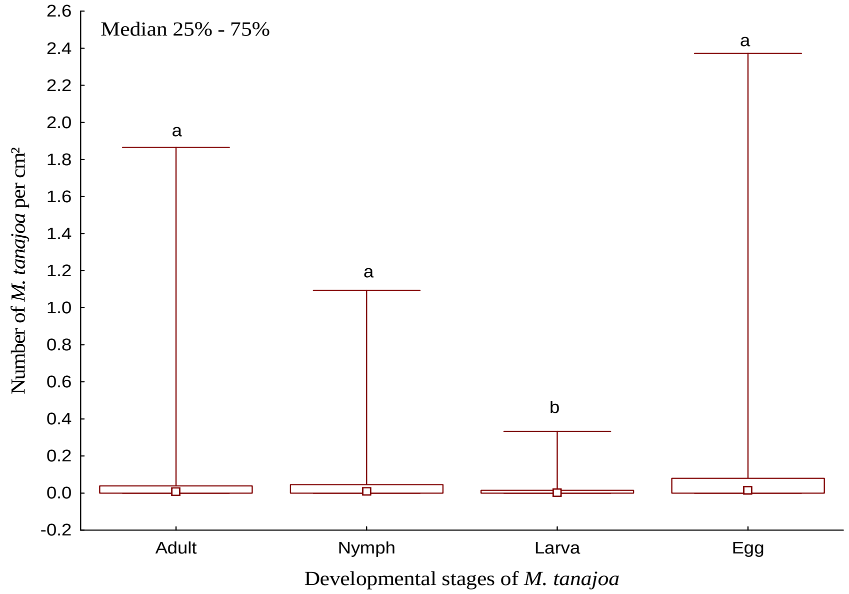

Fig. 3 Densities of the developmental stages of adult, nymph, larva and egg of the cassava green mite *M. tanajoa*. Medians, 25 and 75 percentiles are shown. Different letters denote significant differences between developmental stages based on Kruskal-Wallis analyses (P= 0.000).

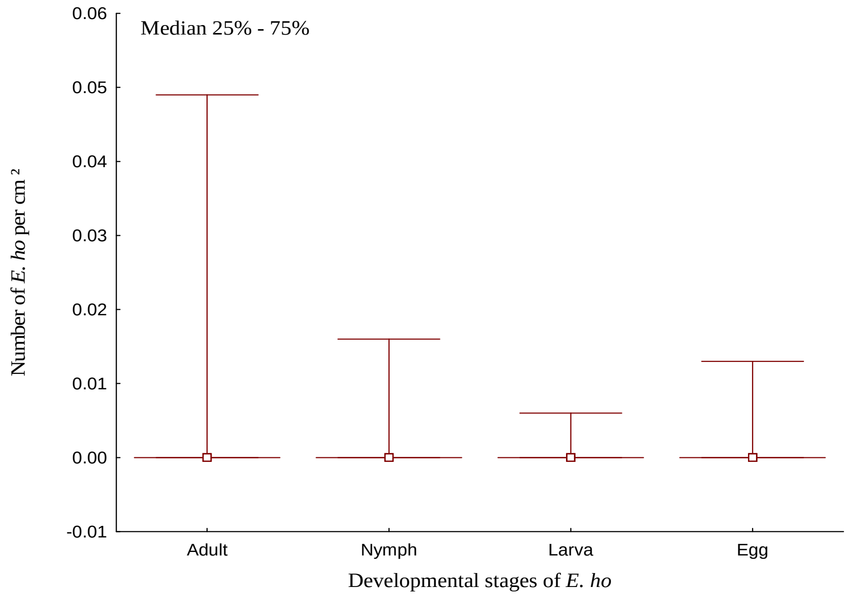

Fig. 4 Densities of the developmental stages of adult, nymph, larva and egg of the predatory mite *E. ho.* Medians, 25 and 75 percentiles are shown (Kruskal-Wallis, P= 0.105).

Seasonal changes in diversity and density of arthropods in tropical regions have been related in several studies and have been attributed to temporal variation in local environmental factors such as temperature, rainfall and relative humidity (Klein et al., 2002; Philpott et al., 2006; Teodoro et al., 2008). Spider mites are often positively influenced by temperature and negatively affected by rainfall (Bonato et al., 1995; Gotoh et al., 2004; Teodoro et al., 2008). Indeed, we found a negative correlation between rainfall and the developmental stages of *M. tanajoa* indicating that the population of the cassava green mite decreases with increasing rainfall.

Conversely, there was a positive correlation between temperature and densities of the developmental stages of egg, nymph and adult. The stage of larva, however, was negatively related to temperature. Temperatures over 30°C are common during the dry season in this region and it is well known that spider mites such as *M. tanajoa* build up larger populations during the dry season, which is characterized by high temperatures and low rainfall. During the rainy season, however, spider mites are substantially reduced as a result of rainfall washing off mite colonies on leaves (Onzo et al., 2005; Hanna et al., 2005; Teodoro et al., 2009a,b). Seasonal variations of environmental factors in tropical regions are generally extreme, which may affect the surviving ability of predatory mites (Zundel et al., 2007), however the population densities of the developmental stages of *E. ho* were surprisingly not related to temperature, relative humidity and rainfall.

Overall, densities of eggs, adults and nymphs of *M. tanajoa* were higher than densities of larvae throughout the cultivation cycle of cassava, suggesting that each developmental stage of the cassava green mite experiences and respond uniquely to environmental factors operating at local scale (Teodoro et al., 2009a). The high number of eggs of *M. tanajoa* is probably related to large densities of adults (Fig. 1) and high oviposition rate of cassava green mite females during its life cycle [ca. 5.3 ± 0.19 (SD) eggs/female/day] (Rêgo, 2010). The larval stage of *M. tanajoa* had the lowest population density over the cultivation cycle of cassava probably due to its short developmental time (1.0 ± 0.02 (SD) days) (Rêgo, 2010). Additionally, unlike the other developmental stages, larvae of *M. tanajoa* were negatively affected by temperature, indicating a greater sensitivity towards this environmental factor. Densities of the stage of nymph of *M. tanajoa* varied similarly to the stages of adult and egg from July onwards (Fig. 1).

Although all developmental stages of *E. ho* occurred at very low population levels throughout the cultivation cycle of cassava (Fig. 2), laboratory studies showed that this generalist predatory mite can help to regulate populations of the cassava green mite. *Euseius ho* feeds and completes its life cycle on *M. tanajoa* (Rêgo, 2010). Additionally, *E. ho* is considered a type VI predatory mite (McMurtry and Croft, 1997; Croft et al., 2004), specialized on pollen from several plant species as food source. Therefore, populations of *E. ho* could be preserved and augmented through conservation biological control programmes by supplying predators with alternative food like pollen (Ramakers, 1990). This alternative food may increase predator reproduction and promotes persistence of predators in the absence of prey. For example, the addition of pollen greatly promoted the impact of the predatory mite *Iphiseius degenerans* (Berlese) (Acari: Phytoseiidae) on its prey, the western flower thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (Van Rijn et al., 2002). This effect might also occur in the system studied here, however more studies are needed to elucidate the role of pollen-providing plants on the biological control potential of the predatory mite *E. ho*.

We conclude that it is important to consider the population structure in arthropod population dynamics studies as each developmental stage experiences and responds uniquely to the local environment over time.

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