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# Season- and fruit age-dependent population dynamics of *Aceria guerreronis* and its associated predatory mite *Neoseiulus paspalivorus* on coconut in Benin

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ABSTRACT

The coconut mite *Aceria guerreronis* Keifer resides beneath the perianth of coconut fruits where it feeds on the tender meristematic tissue. *A. guerreronis* is one of the most important coconut pests but knowledge of its population dynamics is scant. We quantified seasonal and fruit age-related population fluctuations of *A. guerreronis* and its predator *Neoseiulus paspalivorus* DeLeon in Benin. *N. paspalivorus* was the most common and abundant beneath the bracts compared with other predators, which were very scarce and were largely found outside the bracts. Both percent fruit occupation and abundance of *A. guerreronis* and *N. paspalivorus* varied across sampling months as well as among coconut plantations and fruit age classes. Both parameters peaked in the middle of the rainy season and at the end of the dry season. Fruit age at which *A. guerreronis* and *N. paspalivorus* started to colonize the fruits was 0.9 and 1.2 months, respectively. The two species reached their peak abundance (1512 *A. guerreronis* and 2.3 *N. paspalivorus* per fruit) on 3 months-old fruits. Peak percent fruit occupation by *A. guerreronis* (~70%) occurred after 4.3 months, which was ~0.7 months earlier than that by *N. paspalivorus* (~22%). Difficulties encountered by the predators in accessing the area beneath the perianth on the very young fruits allowed *A. guerreronis* a head-start in population build-up leading to strongly diverging population curves as a function of fruit age (higher population increase compared to *N. paspalivorus*). Protecting the very young fruits from *A. guerreronis* colonization should be a key issue for developing successful control strategies of this pest.

## 1. Introduction

Knowledge of seasonal population dynamics and within-plant distribution of phytophagous pests and their natural enemies is essential for understanding predator–prey dynamics that are critical for natural enemy conservation and the development of sustainable pest management strategies. Spider mites (Acari: Tetranychidae) and eriophyoid mites (Acari: Eriophyoidae) are the most important pests among phytophagous mites (Helle and Sabelis, 1985; Lindquist and Oldfield, 1996; Oldfield, 1996). Due to their small size and wormlike body shape eriophyoid mites have limited mobility and are highly vulnerable to predation. To escape from predation, many eriophyoid species have adapted to living in spatial refuges on their host plants. Such refuges may be constitutively present or induced by the mites (Sabelis and Bruin, 1996). It is well established that refuge use has important consequences for predator–prey dynamics (e.g., Hawkins et al., 1993; Berrymann and Hawkins, 2006). Pest populations protected from predation may temporarily grow exponentially, interfere with the growth and development of the attacked plant part and cause enormous economic damage.

The refuge-bound predator–prey system investigated in the present study is composed of a phytophagous pest, the coconut mite *Aceria guerreronis* Keifer (Acari: Eriophidae), and its most common predator, *Neoseiulus paspalivorus* DeLeon (Acari: Phytoseiidae), on fruits of coconut *Cocos nucifera* L. (Arecaceae) in southern Benin. *A. guerreronis* had been first recorded from coconut in the 1960s in the state of Guerrero, Mexico, and was first described by Keifer in 1965. It is presently widespread in the tropics and subtropics causing important damage to coconut fruits (e.g. Mariau, 1969, 1986; Ramaraju et al., 2002; Fernando et al., 2002). It was also reported to cause significant damage to young queen palm seedlings, *Syagrus romanzoffiana* (Cham) Glassman in southern California (Ansolini, 2002 cited by Ansolini and Perring (2004)). *A. guerreronis* was reported from other Arecaceae (Flechtmann, 1989; Ramaraju et al., 2002; Navia et al., 2005) but damage and/or yield loss on those plants were not as important or widespread

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compared with those on coconut. The mite is likely native to Brazil and invasive in Africa and Asia (Navia et al., 2005). It lives beneath the perianth, i.e. the floral bracts, of coconut fruits where it feeds on the tender meristematic tissue, resulting in physical injuries that further develop into necrotic and suberized tissues on the fruit surface. The space beneath the perianth constitutes a spatial refuge for *A. guerreronis* and provides protection from environmental hazards and natural enemies and therefore interferes with natural, biological and chemical control (Hernandez, 1977; Mariau, 1977; Julia and Mariau, 1979; Howard and Abreu-Rodriguez, 1991; Aratchige et al., 2007; Lawson-Balagbo et al., 2007a, 2008a,b). Nonetheless, *A. guerreronis* has been found in association with a number of natural enemies, mainly predatory mites, in several countries in South America, Asia and Africa (Moraes and Zacarias, 2002; Fernando et al., 2003; Moraes et al., 2004; Lawson-Balagbo et al., 2007a, 2008a; Negloh et al., unpublished). Previous studies showed that *A. guerreronis* colonizes coconut fruits about four weeks after pollination (Julia and Mariau, 1979; Moore and Alexander, 1987; Fernando et al., 2003) but during this time the bracts adhere too tightly to the fruit surface to allow access for the predatory mites, which are much larger than *A. guerreronis* (Moore and Alexander, 1987; Howard and Abreu-Rodriguez, 1991; Aratchige et al., 2007; Lawson-Balagbo et al., 2007a). Aratchige et al. (2007) demonstrated that once *A. guerreronis* colonized the fruit, their injuries caused the space between the bracts and the fruit surface to increase leaving enough space for the predatory mite *Neoseiulus baraki* Athias-Henriot to move into the area under the bracts. As the fruits grow the degree of adherence decreases (Julia and Mariau, 1979; Mariau, 1986; Otterbein, 1988; Negloh et al. unpublished data). Information on the fruit age at first infestation by both *A. guerreronis* and its associated predatory mites (mainly *N. paspalivorus* and *N. baraki)* and their respective progression within the palm canopy is crucial to get more insight in their predator–prey relationship. Such knowledge constitutes a cornerstone for implementation of sustainable control strategies. Several studies addressed population dynamics of eriophyoid mites in tropical regions (e.g. Muraleedharan et al., 1988; Varadarajan and David, 2002; Fournier et al., 2004), but detailed studies on multi-location seasonal dynamics of both prey and predator are very scarce (Fernando et al., 2003; Reis et al., 2008).

Due to their tiny size and wormlike body shape eriophyoid species have limited ambulatory dispersal abilities and therefore disperse mostly passively on air currents (Sabelis and Bruin, 1996) or through phoresy on winged insects such as honey bees (Waite and McAlpine, 1992; Waite, 1999). Nevertheless, even in tropical and subtropical regions with only moderate climatic fluctuations, the distribution patterns of eriophyoid populations between infested plant parts are likely to be non-random and heterogeneous over the seasons. For example, Fournier et al. (2004) found that populations of the eriophyoid *Calacarus flagelliseta* Flechtmann, De Moraes and Barbosa peaked in summer and were more abundant in the middle and lower vertical strata of the papaya plant canopy and least abundant on the youngest leaves. Fernando et al. (2003) found that *A. guerreronis* and *N. baraki* had different temporal and spatial distribution patterns in Sri Lanka, with *N. baraki* being mostly present on more mature fruits. Lawson-Balagbo et al. (2008a) and Reis et al. (2008) observed highest densities of *A. guerreronis* during the dry seasons in eastern and northeastern regions of Brazil. Overall, previous studies showed variable seasonal fluctuation patterns of *A. guerreronis* populations but details on the relationships with the associated predator dynamics and their within-plant distributions are scarce. Moreover, the most recent studies on *A. guerreronis* and its predators in West Africa date back to the late 1980s (Mariau, 1986) while information on the spatial and seasonal dynamics of both prey and predators are presently needed as an important step towards implementation of sustainable control strategies.

In the framework of a multi-institutional project, with the ultimate objective to develop a sustainable control strategy against *A. guerreronis* in sub-Saharan Africa and elsewhere in the world, we investigated in the present study colonization patterns, population dynamics and within-plant distribution of *A. guerreronis* and its associated predatory mite *N. paspalivorus* in southern Benin.

## 2. Materials and methods

### 2.1. Study sites

The study was conducted in four coconut plantations in southern Benin, West Africa. Two of the plantations were located in the Atlantique Province (06°21′66 N; 02°09′76E and 06°23′33 N; 01°54’33E) while the other two were located in the Mono Province (06°21′73 N; 01°55′08E and 06°15′20 N; 01°42′54E). In each province, one plantation was inland (3.3 km and 8.5 km from the ocean in Atlantique and Mono, respectively) and one plantation was coastal (0.2 and 0.2 km from the ocean in both Atlantique and Mono). The two provinces are major coconut production areas in Benin and are located in the humid coastal Savannah Forest Mosaic (SFM) zone, which is characterized by a bimodal rainfall pattern in the rainy season that begins in late March and lasts until mid November. The rainy season is interrupted by a short dry spell from mid-July to late-August.

The two inland plantations – 7 and 9 years old – contained two hybrid coconut cultivars (PB121 and PB111), while the coastal plantations – 12 and 15 years old – were planted with the cultivar PB121 only. The latter is at present replacing the old West African Tall (WAT) variety in Benin. PB121 is produced by crossing WAT with Malayan Yellow Dwarf (MYD), while PB111 is obtained from crossing WAT and Cameroonian Red Dwarf (CRD) (Julia and Mariau, 1979). The two hybrids are smaller (2.5 m on average at the beginning of their productive life) and produce fruits earlier – at 2 years of age – than the WAT variety. Inland plantations were younger than coastal ones but all trees were fully grown and had a good productivity at the time of sampling. The height of palms varied only slightly between and within plantations (∼0.3 to 1 m).

### 2.2. Sampling protocol

In each plantation, 30 coconut palms were randomly selected, marked and assigned to three groups of 10 palms each. In inland plantations, each group of 10 palms consisted of five palms of each variety, while in costal plantations the groups consisted of a single palm variety. Each plantation was sampled at monthly intervals over a 12 months period. Within plantations, sampling was rotated among groups such that each group was sampled once every three months to avoid excessive removal of fruits.

Coconut palm canopy was divided into four strata, based on fruit-bunch age (hereafter referred to as $FBA_i$ where $i$ = 1–4 is the fruit age class). Coconut fruits grow in bunches with all fruits within a given bunch being of about the same age. In the area where the study was conducted, a new coconut fruit-bunch is produced approximately every month. Therefore, the position or the rank of a particular bunch on the palm corresponds to its age in months, the first just fertilized bunch being 1-month-old. The 12 fruit-bunch ages normally found on a coconut palm were placed into four FBA classes: $FBA_1$ – first bunch (just fertilized fruits) to third bunch; $FBA_2$ – fourth to sixth bunch; $FBA_3$ – seventh to ninth bunch; and $FBA_4$ – tenth to twelfth bunch (mature fruits). Inflorescences were not included in the sampling. $FBA_1$ had significantly