The Spatio-Temporal Distribution Patterns of the Spider Mite, *Oligonychus afrasiaticus*, on Date Palm (Deglet Nour Cultivar) in a Pesticide Free Tunisian Oasis

Sameh Ben Chaaban, Centre Régional des Recherches en Agriculture Oasienne à Degache, Tozeur, Tunisia ; Département de Protection des Plantes, Institut Supérieur Agronomique de Chott-Mariam, Université de Sousse, 4042 Chott-Mariam, Sousse, Tunisia, Brahim Chermiti, Département de Protection des Plantes, Institut Supérieur Agronomique de Chott-Mariam, Université de Sousse, 4042 Chott-Mariam, Sousse, Tunisia, and Serge Kreiter, UMR CBGP, Montpellier SupAgro, Bâtiment 16, 2 Place Pierre Viala, 34060 Montpellier cedex 01, France

ABSTRACT


Seasonal abundance of the date palm spider mite *Oligonychus afrasiaticus* on date palm (Deglet Nour cultivar), was studied between 2004 and 2006 in a pesticide-free oasis. The objectives of this study were to (i) inventory mite species present around date palm trees, (ii) quantify abundance of *O. afrasiaticus* in trees and in ground cover and (iii) to monitor *O. afrasiaticus* population dynamics and its dispersal. The first infestations of *O. afrasiaticus* on fruits varied between years, ranging from the first to the third week of July. Spider mite density increased rapidly throughout July and August during the fruit’s Kimri stage, characterized by greenness. At the end of August, higher rates of *O. afrasiaticus* migrated to the palm crown. Overwintering *O. afrasiaticus* individuals were found on the pinnaes, but no overwintering individuals were found on the ground cover. Phytoseiids were very scarce, only two phytoseiid species were collected on the ground cover. During the years of observation no phytoseiid mites able to reduce the populations of *O. afrasiaticus* were found on Deglet Nour dates. Pest dispersion starts from a palm tree located at far away from the well of water. Causes of *O. afrasiaticus* outbreaks on fruits included (1) absence of predators (2) dry weather (3) no application of pesticides that suppress *O.afrasiaticus*.

Keywords: Acari, dynamic populations, oasis pesticide-free, Phytoseiidae, Tetranychidae

Corresponding author: Sameh Ben Chaaban
Email: samah_bchaaban@yahoo.fr

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Date palm *Phoenix dactylifera* is widely cultivated in the southern oases of Tunisia with about 250 current varieties (Rhouma 1994; 2005). More than 4 million date palm trees are spread along 32,000 ha; almost 55% of this area was recently planted with Deglet Nour, the major commercially desirable date variety in the country. However, a serious threat encountered by the date harvest is the
spider mite, *Oligonychus afrasiaticus* (Prostigmata : Tetranychidae), one of the four major pests of date palms (Dhouibi 1991; Khoualdia et al. 1997). Among the different cultivated varieties in Tunisia, the most severe damage was reported on the Deglet Nour cultivar (Ben Chaaban and Chermiti 2010; Dhouibi 1991).

Immediately after fruit set, mites start their oviposition activity, laid eggs hatch into larvae, which feed on the fruits that are later covered with a web retaining fine particles (Hussain 1974). Feeding on the immature green dates causes severe fruit scarring, and dates can turn brown and get scabbed. The skin of infested fruits becomes hard, then cracked, and shriveled, reducing the quality of the fruit and thus resulting in subsequent economic loss. In several areas, *O. afrasiaticus* is mainly controlled using sulfur (Coudin and Galvez 1976; Dhouibi 1991; Djerbi 1993; Guessoum 1986; Palevsky 2004). Similar programs have been conducted in California for many years for the control of the new world date mite *Oligonychus pratensis* (Carpenter and Elmer 1978). However, the efficacy of sulfur treatments for both of these closely related pests, is limited (Ben Chaaban et al. 2011; Gispert et al. 2001) and the development of alternative mite control methods is required. For this, understanding the life cycle and behavior of *O. afrasiaticus* is essential. It is necessary to establish a precise sequential sampling scheme (Margolies and Kennedy 1985), detect pest levels for assisting decisions for control measures (Arnaldo and Torres 2005) and assess crop loss (Haughes 1996). Investigating the population dispersion behavior is prerequisite for ecological and behavioral studies (Faleiro et al. 2002; Jarosik et al. 2003). Dispersal can be considered an essential factor in the understanding of the natural regulation of pest mites at different spatial levels in agro-ecosystems (Croft and Jung 2001).

Despite the economic importance of dates in Tunisian agriculture and the damage caused by mites, the role of predatory mites in Tunisian oases is not well known (Kreiter et al. 2010). Obtaining information about spatial distribution of prey and predator is critical for evaluating natural enemy potential to reduce its prey density and system persistence (Slone and Croft 1998).

Thus, this work aims to (1) study the occurrence and fluctuation of *O. afrasiaticus*; (2) determine its dispersal ability and overwintering habitat; (3) survey mites that are present around the trees, and (4) identify natural enemy species associated to this pest.

**MATERIALS AND METHODS**

**Study area and production systems.**

The study was carried out between 2004 and 2006 in a commercial oasis of 2 ha with mixed varieties of date palm trees. This area is located in Segdoud, from the region of Tozeur (Djerid), in southwest Tunisia. It belongs to the superior bioclimatic Saharan zone with a temperate winter. The annual mean temperature is about 21.6°C, while 44°C in August and 2.5°C in January are the absolute maximum and minimum temperatures, respectively. The annual average rainfall is about 96 mm.

The oases in this area are continental and of a modern type with a mean planting spacing of 10 × 10 m. The principal vegetation is composed of date palm trees with a predominance of the Deglet Nour variety and very few market-gardening or fodder practices for farmer consumption. The plot under investigation, which was previously farmed and then abandoned, had very frequent outbreaks of *O. afrasiaticus*. 

Palms were pesticide-free, and rarely pruned or watered during the experiment.

Sampling mites on fruit and pinnae.

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Sampling mites on fruit and pinnae. Samples were collected weekly from 27 July to 10 October in 2004, from 30 April to 25 October in 2005 and from 15 April to 4 November in 2006. Mite populations were monitored twice a month during the rest of the study period. Ten trees were tagged for subsequent sampling. Two trees located in the North, the South, the West, the East and the middle of the oasis were sampled at random.

Samples of 10 fruits and 10 pinnae were taken per palm tree. From the beginning of the fructification until harvest, fruits were taken from bunches in four locations (NSWE). The ten pinnaes were sampled as follows: five in the central crown (less than 1 year old) and five in the base (the oldest fronds). Fruits and pinnae were individually placed in plastic bags, kept in an insulated cooler ice, and stored at 4°C in the laboratory. Mites were collected directly from the fruits and pinnae, and then counted under a stereomicroscope. We determined the mean number of eggs and motile forms of *O. afrasiaticus* and its predators for 100 fruits and pinnae, per sampling date.

At each sampling date, the percentage of fruits with mite damage was calculated as number of infested fruits (at least by 1 tetranychid) divided by the total number of fruits sampled (n = 100). Weekly, all trees were observed for general appearance and presence of webbing. The frequency of total date palm infestation was calculated as number of total infested trees divided by the total number of date palm trees of the Deglet Nour variety (n = 113).

Sampling mites in ground cover vegetation.

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Sampling mites in ground cover vegetation. To determine plant species serving as hosts for phytophagous mites and refuge for natural enemies, a volume of approximately 1 liter of leaves or 100 leaves of other plant species collected randomly under sampling trees were carefully clipped. Samples were individually placed in plastic bags, kept in an insulated ice cooler, and stored at 4°C in the laboratory. Plants were identified and mites were directly collected from leaves with a fine paint brush using a stereoscope or by using the leaves dipping-shaking-washing method, mites being collected on a filter at the end of the process. Mites were then transferred with a fine paint brush into small plastic vials containing 70° alcohol for later identification. Sampling dates in 2004-2006 were synchronized with those for date palm fruits and pinnae.

Identification of mites leaving or migrating to bunches.

Identification of mites leaving or migrating to bunches. Date bunches extend from the tree on stalks, allowing each bunch to stand alone. The mite that wants to reach a bunch would have to walk up this stalk. To determine the migration of *O. afrasiaticus* to the bunches, 5 cm-wide bands of masking tape coated with Tangle trap® were applied to the base of the fruit stalks.

Five trees (other than those used to monitor seasonal abundance) were randomly selected. Two bunches were treated with glue barriers on each sampling tree. In 2004, sticky bands were placed on July 20th and replaced at approximately 2-week intervals until October 25th. In 2005, bands were fastened on April 27th and replaced at 2-week intervals until October 15th. In 2006, bands were setup on April 15th and replaced at 2-week intervals until October
Bands being transferred to and from orchards were temporarily covered with plastic food wrap to prevent them from sticking to other objects. Bands were then removed, and brought to the laboratory where mites were counted under a stereomicroscope.

Separate records were kept for mites caught near the bottom margin of bands (crawling up the tree) and those caught along the top margin (crawling downwards). Because mites were never seen further than a few millimeters from either edge of the bands, there was no overlap between upward and downward crawling individuals.

At each sampling date, up to 30 mites per band were removed and placed in Hoyer’s medium on microscopic slides for later identification under a phase contrasted microscope. To extract mite from sticky support, it was first necessary to cut out a small piece of plastic food wrap covering the portion of the sticky band housing each mite. Then, one or two drops of commercial organic solvent, Varsol®, was placed on the band to wash away Tangle trap® embedding the mite. Afterwards, the mite was transferred by a single-hair paintbrush to a glass slide and washed again in Varsol® to remove any remaining Tangle trap® so that the mounting medium could penetrate and clear the mite for identification.

Identification of spider and phytoseiid mites.

Samples of extracted mites, from all habitats (sticky bands, fruits and pinnae) were mounted in Hoyer’s medium on microscopic slides and identified using a phase and interferential contrast microscope. The species were identified and morphologically characterized using publications (Chant and McMurtry 1994; 2007; Lindquist 1985) and with the help of specialists from INRA and Montpellier SupAgro (France).

Diagram of O. afrasiaticus dispersion.

In 2004 and 2005, we observed a variation in the degree of infestation of trees according to the location in the oasis. To explore the dispersion of O. afrasiaticus in 2006, we counted weekly the number of distorted date palms and their location.

Data analysis.

The cumulative mite days (CMDs) were used to assess the effect of mite density over time on fruit damage. Mite days were defined according to Beers and Hull (1990) as one mite per fruit strand for 1 day and calculated as the mean of both successive motile form counts multiplied by the number of intervening days. The fortnight values were summed over the season to give the CMDs. Data were analyzed by a paired t-test or ANOVA followed by pair wise comparisons according to LSD test by using SPSS 10.0 (SPSS, 1999).

RESULTS

Seasonal abundance of O. afrasiaticus.

In 2004 (Fig. 1a), spider mite density increased rapidly throughout July and August during the fruit’s Kimri stage, characterized by greenness. O. afrasiaticus density peaked at 81.6 ± 8 /date on 15 August. This caused severe fruit scarring.

Starting from late August, the color of fruit changed to yellow, numbers of O. afrasiaticus on fruits decreased gradually and remained relatively low for the rest of the season. Densities of downward mites caught per bunch sticky band exceeded 1700 motile forms at the end of August (Fig. 1b). However, no O. afrasiaticus were detected on the ground cover. Low densities of O. afrasiaticus
were detected on pinnae from mid-August till late November (< 6 per leaf) (Fig. 1a).

![Graph showing mite numbers](image)

**Fig. 1.** Mean numbers (± 95% CL) of *Oligonychus afrasiaticus* in 2004 per fruit and per pinnae (a) upward and (b) downward crawling *O. afrasiaticus* on bunch.

In 2005, the active period of *O. afrasiaticus* on fruits occurred from the third week of July until mid-October (Fig. 2a). This persistence was due to the presence of green dates. The mean number of mites reached its maximum on 11 of August with 22.8 motile forms per fruit.

Low densities of mites crawling up bunches were detected. Densities of *O. afrasiaticus* leaving bunch peaked at 18.2/bunch (Fig. 2b). Mite populations (Fig. 2a) on pinnae were present from
April to December. Overwintered females were first found on pinnae shortly before colonizing dates. Densities were similar, not exceeding 2 motile forms per 100 pinnae.

In 2006 (Fig. 3a), infestations occurred in the beginning of July. Motile form densities reached up to 24.2 on 13 August. Numbers of *O. afrasiaticus* on pinnae were low during May and June, but they increased by early September (Fig. 3a). Concerning mite migration (Fig. 3b), we noted trends similar to 2005.
Densities of *O. afrasiaticus* decreased from 2004 to 2006, mean seasonal CMDs ($F = 5.18; \text{df} = 2, 31; P < 0.05$) (Table 1) and the rate of damaged fruit were significantly different. Damage caused by *O. afrasiaticus* was noted in 71.86, 58.4, and 47.78% trees in 2004, 2005 and 2006, respectively. Mean monthly temperatures of July and August in 2005 (35.3°C) were approximately 2°C above the long-term mean in 2004 (33.3°C) and in 2006 (33.7°C).
Table 1. Mean seasonal cumulative mite days CMDs (mobile forms/date) and percent of date fruit collected with mite damage (n = 10 fruits per tree) on the cv. Deglet Nour in 2004, 2005 and 2006.

<table>
<thead>
<tr>
<th>Year</th>
<th>CMDs</th>
<th>Fruit with mite damage (%)</th>
<th>Infested trees (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>2165.8 a</td>
<td>29.5 a</td>
<td>71.68</td>
</tr>
<tr>
<td>2005</td>
<td>773.17 b</td>
<td>23 a</td>
<td>58.4</td>
</tr>
<tr>
<td>2006</td>
<td>437.31 b</td>
<td>11.6 b</td>
<td>47.78</td>
</tr>
</tbody>
</table>

Within each column, values followed by the same letter are not significantly different according to LSD test at $P < 0.05$.

Seasonal fluctuations of *O. afrasiaticus* densities on oldest and latest fronds of Deglet Nour pinnae.

In 2004, mites found during August were mainly located on the base leaflet of the crown, while the central leaflets of the crown were not infested (Fig. 4). On the latest fronds, the presence of *O. afrasiaticus* was recorded at the beginning of September where its development culminated in the last week of the month with 93 motile forms per 50 pinnae. From mid-September, low densities of *O. afrasiaticus* were detected on oldest pinnae throughout the remainder of the season. Outbreaks of mites were encountered even in December and January on latest fronds. Therefore, there was a movement of the date palm crown infestation depending on the year period.

![Seasonal fluctuations of Oligonychus afrasiaticus on oldest and youngest fronds of Deglet Nour pinnae at the Segdoud plot during 2004.](image-url)
Distribution of *O. afrasiaticus* on oasis ground cover vegetation.

The ground cover under date palms was scarce and limited to *Cynodon dactylon* and other species such as *Urtica dioica*, *Convulvulus* sp., *Malva* sp., *Rubia* sp., *Setaria* sp., *Salsola tetrandra*, *Aeloropus littoralis*, *Erigeron* sp., *Daucus* sp., *Polygonum equisetiforme*, *Suaeda fruticosa*, *Anagallis* sp., *Medicago sativa*. *O. afrasiaticus* individuals were found on *C. dactylon* (6 individuals) in August 2006, in August 2005 (13 individuals) and in August 2004 (4 individuals), but no overwintering *O. afrasiaticus* was recorded on *C. dactylon*.

Phytoseiid mites.

Two phytoseiid species were found: *Neoseiulus cucumeris* on *Setaria* sp., June 2006 (4 individuals) and *Phytoseius finitimus* collected on *Urtica dioica* on July (7 individuals). During the years of observation, no specialized spider mite predators for *O. afrasiaticus* were found on Deglet Nour fruits.

**Temporal and spatial distributions of *O. afrasiaticus* in oases.**

In 2006, the diagram of spider mite dispersion (Fig. 5) was established. The pest dispersion started from a palm tree located far from the water well, where there was a dry microclimate. The number of infested palm trees increased with the propagation of *O. afrasiaticus*. Places not invaded by the pest are generally located near wells where the humidity remains at a relatively high level. We suppose that propagation was affected by microclimatic factors.

![Diagram](attachment:fig_5.png)

**Fig. 5.** Diagrammatic illustration of the spatial distribution of date palm infestation (Deglet Nour cultivar) at the non-treated plot in Segdoud, South of Tunisia during the 2006 season. (A) July 23, (B) August 5 and (C) September 4. Well of water, κ Uninfested tree, □Infested tree, ■ First infested tree on July 2.
DISCUSSION
This study is a preliminary survey of the spatio-temporal distribution patterns of *O. afrasiaticus* in Segdoud, South of Tunisia. According to the obtained results, we could confirm that the only serious mite pest of date fruit is *O. afrasiaticus*. However, a detailed understanding of the behavior of this species in the oases is necessary for the design and implementation of control strategies.

Many physical and environmental factors influence the likelihood of spider mite outbreaks. Huffaker et al. (1969) listed the following elements that contribute to spider mite dynamics: (1) features of the life cycle, particularly with regard to movement phases and potentials, reproduction, and diapause; (2) meteorological conditions, including photoperiod effects; (3) the nutrition afforded by the host plant and its relative susceptibility or resistance to mites; and (4) action of enemies, particularly predators.

Some researchers have speculated that the dynamics of *O. afrasiaticus* is affected by climate exchanges (Ben Chaaban 2011; De Montaigne and Fall 1986; Dhouibi 1991; Lepesme 1947; Palevsky 2004). Our research supports these results. Fruit infestation started during the first three weeks of July. Greater heat and a mid-summer drought caused *O. afrasiaticus* population growth in fruits. Mean temperatures of 32°C in July and August in Tozeur seemed to be suitable for an increase in the pest mite population. The mite was active on fruits from July until September monthly mean temperatures.

The temperature of 27°C corresponds to the monthly mean temperature of September and October. Although this temperature was still favorable to the development of the mite on date fruits (Chaaban et al. 2011), mobile forms of mites started leaving date bunches and migrated to the palm crown. The lowest densities were found in the beginning of September. At this time, fruit ripening occurred and the fruit reached the phonological date stage. Consequently, not only climatic conditions seem to be the cause for the distribution of tetranychid mites.

Food shortage can also be assumed to be an important factor (Flexner 1991; Helle and Sabelis 1985; Margolies 1995). Previous results have revealed that performance of *O. afrasiaticus* varied greatly depending on the chemical composition of date fruits (Ali and Aldosari 2007; Ben Chaaban and Chermiti 2009; Palevsky et al. 2005). In fact, the fruit infestation begins and increases during the Kimri stage, characterized by the green color of fruit, rapid increase in size, weight, and reducing sugars. At this stage, moisture content and acid activity are at the highest level (Ali and Aldosari 2007; Barreveld 1993; Ben Chaaban and Chermiti 2009; Palevsky et al. 2005). Mite populations begin to decline with color change of fruit to yellow or red at the Khalal stage. The decrease in water content with elevated sugar contents at this stage makes the date extremely repellent to *O. afrasiaticus* (Ali and Aldosari 2007; Ben Chaaban and Chermiti 2009; Palevsky et al. 2005).

One of the most outstanding characteristics of the population dynamics of spider mites is their ability to colonize and develop on host plants before dispersal to new plants when nutritional resources were exhausted (Helle and Sabelis 1985; Margolies and Kennedy 1985). The results reported here show that between September and March, *O. afrasiaticus* was found on pinnae but no mite was detected on the ground cover. Literature reported that *O. afrasiaticus*
migrates to rejections, fibers, palms, inflorescence, male date palms and infertile date palms, on grasses as *Cynodondactylon*, *Lolium* sp., sorghum, cucumber, watermelon, fig, grapevine (Ben Chaaban et al. 2011; Dhouibi 1991; Guessoum 1986; Lepesme 1947; Palevsky et al. 2003). Hussain (1974) reported overwintering *O. afrasiaticus* on fibers and the frond bases, but no overwintering mites were observed on the pinnae, offshoots, or the ground cover. In two out of our three study years, *O. afrasiaticus* was found on pinnae in the spring (April-May) before being seen on the fruit.

*O. afrasiaticus* was absent or in very low numbers in ground cover. During May and June, no motile forms were detected crawling towards bunches. But despite this, there were infestations of fruits. Mites infest dates by not reaching stalks coming from fronds but by airborne infestation. Yet, *O. afrasiaticus* is well known for its ability to disperse by crawling or by aerial transport (Ben Chaaban et al. 2011; Palevsky et al. 2005). Gispertet al. (2001) showed fruit bunch infestation to be generally clumped, with heavily infested bunches being adjacent to non-infested ones, and suggested that infestation resulted from random arrivals of individual mites. In the case of *O. afrasiaticus*, even one mated and unmated female, was enough to establish a colony that rapidly infested an entire bunch (Coudin and Galvez 1976; Gispert et al. 2001; Palevsky et al. 2004).

We found that the leaflet positions inside the tree crown had a substantial effect on the distribution of *O. afrasiaticus*. Contrasting results were documented by Palevsky et al. (2003) who reported no preference to mature leaves over young leaves for *O. afrasiaticus*.

In a previous study conducted on sulfur treated oasis (Ben Chaaban et al. 2011), two factors were the most likely causes of the scarcity of phytoseiids on date fruits: dry conditions and application of sulfur. But in this study, predators were never found in association with *O. afrasiaticus*, even in the absence of pesticides. Therefore, it is likely that dry conditions prevented phytoseiids to establish. Helle and Sabelis (1985) mentioned that among factors determining the effectiveness of phytoseiids, humidity appears to be of major importance. The egg stage is especially sensitive to low humidity. Palevsky et al. (2004) found that Phytoseiids were very scarce and their role as a potential predator of *O. afrasiaticus* remains uncertain. Excessively dry seasons favor *O. afrasiaticus* population growth (De Montaigne and Fall 1986; Dhouibi 1991; Lepesme 1947). The propagation of *O. afrasiaticus* populations was affected by microclimatic factors such as the changes in drought in one plot. It contributed to the observed higher densities of *O. afrasiaticus* in palm trees located far from the water well. Sparingly irrigated isolated and vegetate evil palms are the most attacked by *O. afrasiaticus* (Djerbi 1993; Guessoum 1986; Lepesme 1947).

In Tunisia, outbreaks of *O. afrasiaticus* began in the late 1990s. No economic threshold for spider mite on fruit dates has been established ever since. Understanding the contribution of abiotic factors, such as soil nutrient and moisture stress, toward plant tolerance to spider mite injury may be a viable approach to reducing yield loss due to spider mite injury.
RESUME


Mots clés: Dynamique des populations, oasis non traité, Oligonychus afrasiaticus, phytoseiidae, Tetranychidae

ملخص


أجريت دراسة حلم الغبار (صنف دقلة نور) على نخيل التمر (صنف دقلة نور) كأن الهدف من هذا العمل (i) جرد الأكارات المرتبطة بغرسات النخيل (ii) وقياس وفرة الاضاءة (iii) وتحديد ديناميكية حلم الغبار وفترات انتشاره على النخيل والأعشاب الضارة. بنت الدراسات خلال شهر يوليو/يوليو. أثناء الفترة الملائمة لتلامسها على بالغة اعداد التمر الخضراء التي تعرف بطور القمري. يتداخل وتدفق أجيال الألفة مما يؤدي إلى تكاثر تصادفي خلال شهر يوليو/يوليو. اعتبارا من نهاية شهر أوت عندما يبدأ التمر بالنضج، تبدأ الأكارات في النخيل في تزايد أعدادها على التマー. يتضمن هذا النتائج البحثية في شكل أثري بالغة اعداد التمر الخضراء غير الملفحة ووربيات الجريدة. نجد الأكارات المرتبطة بغرسات النخيل توجد نوعان على الأعشاب الضارة. خلال سنوات من المراقبة لم يتم العثور على أكارات متفرسة عند تواجد O. afrasiaticus على اعداد ضعيفة. ونظرًا إلى أن هذه الآفة تفضل المناطق الجافة ذات الرطوبة المنخفضة والحرارة المرتفعة، تتواجد الأجزاء غير المتضررة عموما قرب الأبار أو برك الري، حيث تكون الرطوبة مرتفعة نسبيا.
LITERATURE CITED


