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Seasonal Occurrence, Abundance, and Within-Plant Distribution of the Citrus Rust Mite, *Phyllocoptruta oleivora* Ashmead (Acari: Eriophyidae), on Different Citrus Species in Southern Türkiye

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ABSTRACT

This study investigated the seasonal occurrence and abundance of the Citrus rust mite, *Phyllocoptruta oleivora* Ashmead (Acari: Eriophyidae), on leaves and fruits, and its directional preferences on different citrus species in Adana, Türkiye from 2019 to 2021. The research was conducted in two orchard types: a commercial, sprayed orchard with lemon (*Citrus limon* cv. Interdonato), orange (*C. sinensis* cv. W. Navel), mandarin (*C. reticulata* cv. W. Murcott), and grapefruit (*C. paradisi* cv. Riored), and a minimally sprayed experimental orchard with lemon (cv. Meyer), orange (cv. W. Navel), and mandarin (cv. Okitsu). Among the citrus species examined in both orchard types, lemon exhibited the highest mean population density of *P. oleivora*. The mean total density of *P. oleivora* on lemon leaves was 0.757 and 1.899 all stages/cm² in the commercial and experimental orchards, respectively. In the commercial orchards, no mite population development was observed on the fruits. However, in the experimental orchards, the mean population density reached 4.680 all stages/cm² on lemon. In the experimental orchards, *P. oleivora* was first observed in May on lemon and reached its peak in August on the same host. In contrast, in the commercial orchards, the mite was first detected in September on lemon, and peaked in November. Directional preferences varied between orchard types. In the commercial orchards, no directional differences were detected except on lemon, where *P. oleivora* densities were higher in the west and north. In the experimental orchards, *P. oleivora* densities were highest in the west and north across all citrus species.

Keywords: *Citrus* species, *Phyllocoptruta oleivora*, Population development.

INTRODUCTION

Plant-feeding mite species in the families Tetranychidae, Tenuipalpidae, Eriophyidae, and a single species within the Tarsonemidae, are responsible for significant economic losses in citrus cultivation worldwide (Jeppson *et al*., 1975; Gerson, 2003; Yalçın *et al*., 2022). These species are generally characterized by broad host ranges, except those in Eriophyidae.

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Phyllocoptruta oleivora Ashmead, commonly known as the citrus rust mite, belongs to Eriophyidae and is a frequent pest of *Citrus* and *Fortunella* species (Sarada *et al*., 2018). Believed to have originated in Southeast Asia as a citrus pest, it has since spread to all citrus-growing regions with high humidity worldwide (Yothers and Mason, 1930; Villanueva, 2002; Hoy, 2011). In certain regions, *P. oleivora* reportedly infests lemon, lime, citron, grapefruit, orange, and mandarin, in that order (Brussel, 1975; Sarada *et al*., 2018; Puspitarini and Endarto, 2021).

Phyllocoptruta oleivora is a sap-feeding pest that infests citrus leaves and fruit, often causing substantial declines in fruit quality and yield. Sarada *et al*. (2018) reported that citrus fruit affected by this pest show symptoms such as brown, shriveled skin, decreased juice volume, and elevated levels of acetaldehyde and ethanol. Infestations can lead to significant reductions in fruit yield, with losses reaching up to 40%, as well as a notable reduction in fruit size (Sarada *et al*., 2018). The mite's developmental period is temperature-dependent, with its life cycle taking approximately 10 days in summer and extending to 14 days in winter. Overall, *P. oleivora* may produce up to 30 generations annually (Vacante and Gerson, 2012).

The population abundance of *P. oleivora* varies regionally. In Egypt, *P. oleivora* persists year-round on Navel oranges, while in Florida, the mite is first observed on leaves in spring, peaks by mid-July, and later shifts to young fruit (Al-Azzazy, 2016; Demard and Qureshi, 2020). In Egypt's Valencia orange orchards, populations peak three times between April and October (Saad *et al*., 2018). Madanlar (1991) reported that in Turkey's Aegean Region, similar to Florida, pest population densities increase, particularly in August. These findings emphasize the need for region-specific studies to better understand *P. oleivora* population abundance.

Chemical control, typically involving acaricide applications, remains the primary management strategy for *P. oleivora* worldwide. Successful chemical control depends on detecting the pest before its population reaches damaging levels, requiring a robust sampling protocol (Athanassiou *et al*., 2005). An optimized mite sampling plan should minimize the number of samples required and reduce the time necessary for accurate infestation assessment, avoiding exhaustive orchard-wide scouting. This approach is particularly important given the minuscule size of the pest and the difficulty of visually detecting it on host plants (Southwood and Henderson, 2000). Delays in detection of *P. oleivora* often result in infestations becoming apparent only after irreversible damage has occurred, making subsequent control efforts more challenging.

The directional preferences of *P. oleivora* within trees have been inconsistently reported. Jeppson *et al*. (1975) observed higher densities of *P. oleivora* on green fruit and the undersides of leaves, with populations concentrated on the outer parts of the trees. Moreover, mite densities were highest on leaves and fruits located on the eastern side of the tree canopy, followed by the southern, northern, and western sides (Aghajanzadeh and Mallik, 2007). Yang (1994) additionally found that at low pest population densities, damage caused by the pest was greatest on the eastern side; however, as the population increased, damage shifted to the northern side, followed by the eastern, southern, and western sides. In contrast, Chen *et al*. (2018) reported that fruit position on the tree did not significantly influence the pest's preference. Shivarju (1990) found that citrus fruit on the northern canopy side had the highest mite populations, followed by the eastern, southern, and western sides.

Previous studies have shown that chemical control can reduce *P. oleivora* populations, thereby altering their spatial distribution within orchards (Stansly and Kostyk, 2015). These interventions often result in shifts in pest aggregation patterns, affecting both pest density and movement within crops (Hall *et al.,* 1991). Understanding how these interventions impact *P. oleivora* populations is crucial for assessing the differences between orchards with and without chemical management.

While prior research has examined the abundance and directional preferences of *P. oleivora* on leaves and fruit, further investigation is needed to understand these variations across different citrus species and cultivars. Therefore, the present study aims to investigate the population abundance and directional preferences of *P. oleivora* across distinct citrus species, with a particular focus on the impact of early-season infestations in orchards with or without chemical controls targeting the pest.

MATERIALS AND METHODS

Orchard sites

The seasonal occurrence and abundance of *P. oleivora* were monitored in lemon (*Citrus limon* cv. Interdonato), orange (*C. sinensis* cv. W. Navel), mandarin (*C. reticulata* cv. W. Murcott), and grapefruit (*C. paradisi* cv. Riored) in a sprayed commercial citrus orchard in Taşcı village, Yüreğir district, Adana - Türkiye, during 2019 – 2021 (Table 1). Leaf and fruit samples were collected from orchard sections of 0.1 hectare (ha), with orchard sizes varying and tree spacing ranging from 6 × 6 m (~ 28 trees per 0.1 ha) to 8 × 6 m (~ 21 trees per 0.1 ha). The trees were planted in 1998 (lemon), 2001 (grapefruit), 2003 (orange), and 2015 (mandarin). In addition to the commercial orchards, mite population abundance was monitored in lemon (*C. limon* cv. Meyer), mandarin (*C. reticulata* cv. Okitsu), and orange (*C. sinensis* cv. W. Navel) orchards located in the experimental fields of Çukurova University, Department of Plant Protection, Sarıçam district, Adana – Türkiye, during 2020 – 2021. The lemon, mandarin, and orange orchards were established in 1998, 1999, and 2003, respectively, and all trees were planted at a spacing of 6 × 6 m (Table 1). Sampling was conducted in orchard sections of 0.2, 0.1, and 0.1 ha, respectively, with total areas of 0.8, 0.4, and 0.4 ha. The acaricides and insecticides applied in the commercial orchards during the study are listed in Table 2, along with their application dates. Pesticides were uniformly applied to all citrus species on the specified dates. In the experimental orchards at Çukurova University, a single application of abamectin combined with petroleum oil was applied to the sampled citrus species in mid – May 2021. Other standard cultural practices were maintained at both study sites to support plant health throughout the experimental period.

Sampling

To evaluate the population abundance of *P. oleivora*, leaf and fruit samples were collected at weekly to ten - day intervals. At each sampling date, ten trees were randomly selected throughout the orchard by walking along diagonal transects and selecting trees at regular intervals while avoiding border rows. The same trees were not necessarily sampled on each date. From each selected tree, twelve mature leaves were collected, with three leaves taken from each of the four cardinal directions (i.e., north, south, east, and west) from the outer canopy at approximately 1.5 – 2.0 m above ground. One fruit from each cardinal direction was also collected from the outer canopy whenever available. Thus, a total of 120 leaves and 40 fruits were collected from each orchard during each sampling event. Citrus leaves and fruit were initially placed in paper bags and subsequently transferred to polyethylene bags. Samples were stored in an icebox and transported to the Acarology Laboratory at Çukurova University. Mite density was assessed by separately counting eggs and active stages within three areas of 1 cm^2 randomly selected on the abaxial leaf surface and within the central area of the fruit's surface under a stereo-binocular microscope.

Data Analysis

Phyllocoptruta oleivora population abundance on fruits and leaves was assessed in relation to citrus species in both chemically managed commercial orchards and experimental orchards. Individual leaves served as the experimental units in the statistical analyses. Data for mite density obtained from each leaf, based on counts within a standardized area of 1 cm^2, were used as independent observations in the analyses. To evaluate the effect of citrus species and directional preferences on *P. oleivora* populations, a two-way analysis of variance (ANOVA) was conducted on data from both commercial orchards and experimental sites. Citrus species and directional orientation were treated as independent factors, and their interactions were analyzed. A one-way ANOVA, followed by the Student-Newman-Keuls (SNK) test ($P < 0.05$), was applied to determine statistically significant differences between the factors examined (IBM Corp. 2015).

RESULTS

Population abundance and directional preferences of *Phyllocoptruta oleivora* on citrus leaves in commercial and minimally treated experimental orchards

Population abundance on leaves

Citrus species significantly affected the total mean number of *P. oleivora* in the sprayed commercial orchard ($F = 3.960$, $df = 3$, $P < 0.05$). Neither direction nor the interaction between citrus species and direction was statistically significant ($F = 0.236$, $df = 3$, $P > 0.05$; $F = 0.329$, $df = 9$, $P > 0.05$). The highest mean density of *P. oleivora* across all developmental stages was recorded in lemon (0.757 all stages/cm^2), followed by orange (0.599 all stages/cm^2) (Table 3). Grapefruit and mandarin had densities of 0.357 and 0.098 all stages/cm^2, respectively. The mean total number of *P. oleivora* on mandarin was significantly lower than on lemon and orange ($F = 4.010$, $df = 3$, $P < 0.01$) (Table 3).

The population abundance of *P. oleivora* in the commercial sprayed orchard from 2019 to 2020 is shown in Figure 1. In 2019, the pest was first detected on lemon in early September and reached its peak mean population density on 28 November (14.55 all stages/cm^2) (Figure 1a). The second highest density occurred on orange in the last week of November (11.24 all stages/cm^2) (Figure 1b). In grapefruit, the population peaked at 6.02 all stages/cm^2 by mid – December, while mandarin reached its highest density (2.24 all stages/cm^2) on 22 October (Figure 1c, d).

In 2020, *P. oleivora* was first observed on lemon in early August, similar to the previous year, reaching its highest density on 14 November (4.6 all stages/cm^2) (Figure 1a). The pest appeared on orange, mandarin, and grapefruit between 22 August and 1 September, with peak mean densities recorded on 4 November (2.24 all stages/cm^2) for orange, 12 October (1.62 all stages/cm^2) for grapefruit, and 24 October (2.14 all stages/cm^2) for mandarin (Figure 1b, c, d).

Similarly, in the experimental orchards, citrus species was the only factor significantly influencing *P. oleivora* population abundance in 2020 and 2021 ($F = 8.614$, $df = 2$, $P < 0.001$). Neither direction nor the interaction between citrus species and direction was statistically significant ($F = 0.574$, $df = 3$, $P > 0.05$; $F = 0.290$, $df = 6$, $P > 0.05$). The highest mean total density occurred on lemon (1.899 all stages/cm^2), followed by mandarin (1.423 all stages/cm^2) and orange (0.821 all stages/cm^2) (Table 4). Statistically significant differences were found only between the mean total populations on orange and lemon, and those on mandarin ($F = 8.718$, $df = 3$, $P < 0.001$).

Population development trends in the experimental orchards from 2020 to 2021 are shown in Figure 2. In 2020, *P. oleivora* was first detected on lemon on 29 May and peaked at 14.48 all stages/cm^2 on 22 August (Figure 2a). On orange, it was first detected on 18 August, peaked at 6.48 all stages/cm^2 on 11 October (Figure 2b), while on mandarin, the pest was first observed on 5 June at 0.89 all stages/cm^2, and reached a peak density of 9.86 all stages/cm^2 on 15 August (Figure 2c). Following these peaks, mite densities declined across all three citrus species. A secondary increase in populations occurred between 27 September and 11 October, but at lower densities than the initial peak (6.38 all stages/cm^2 for lemon and 5.35 all stages/cm^2 for mandarin). Populations declined thereafter, with the last observed individuals on orange recorded on 2 March 2021. In 2021, a resurgence began on lemon on 29 June, followed by orange on 7 August and mandarin on 17 August, stabilized at approximately 1 all stages/cm^2 until November (Figure 2a, b, c).

Directional preferences on leaves

In the commercial orchards, *P. oleivora* densities on the leaves were consistent across directional sampling for all species except lemon (Figure 3a, b, c, d). The highest densities on lemon occurred in the north (0.840 all stages/cm^2) and west (1.170 all stages/cm^2), whereas densities in the south and east ranged from 0.490 to 0.530 all stages/cm^2 (Figure 3a).

In the experimental orchards, densities were highest in the north and west for all citrus species, with lemon showing the highest density, similar to the commercial orchards. Mean densities in the north, south, east, and west were 2.079, 1.700, 1.788, and 2.030 all stages/cm^2, respectively for lemon (Figure 4a). A similar pattern was observed in orange and mandarin, where mean densities were 0.881, 0.759, 0.638, 1.000 all stages/cm^2 for orange and 1.502, 1.267, 1.308, and 1.614 all stages/cm^2 for mandarin (Figure 4b, c).

Population abundance and directional preferences of *Phyllocoptruta oleivora* on citrus fruit in commercial and experimental orchards

Population abundance on fruit

No infestation or population of *P. oleivora* was detected on the fruit of any citrus species in the commercial orchards during either year of the study. In the experimental orchards, *P. oleivora* population density on fruit was significantly influenced by citrus species, consistent with findings for leaf samples ($F = 3.206$, $df = 2$, $P < 0.05$). However, direction and the interaction between direction and citrus species were not statistically significant ($F = 1.591$, $df = 3$, $P > 0.05$; $F = 0.178$, $df = 6$, $P > 0.05$).

Among the citrus species studied, the highest mean density of *P. oleivora* was recorded on lemon (4.680 all stages/cm^2), followed by mandarin (3.600 all stages/cm^2) (Table 5). The mean total number of *P. oleivora* on orange fruit was lower, at 2.328 all stages/cm^2. Statistical analysis revealed a significant difference between the mean total number of *P. oleivora* on orange and lemon ($F = 3.220$, $df = 2$, $P < 0.05$) (Table 5).

The population abundance of *P. oleivora* on the fruit of the three citrus species in the experimental orchards in 2020 is shown in Figure 5. The timing of pest detection on fruit coincided with its appearance on the leaves. The highest population density was recorded on lemon, with the first detection occurring on 5 June, and peaking on 22 August, consistent with the leaf sampling data, when *P. oleivora* density reached 39.72 all stages/cm^2 on fruits. In contrast, on oranges, *P. oleivora* was first detected on 25 July, with a peak density of 34.38 all stages/cm^2 on 27 September (Figure 5).

Similar to leaf sampling, for mandarin fruit, *P. oleivora* was initially detected on 5 June at a density of 0.81 all stages/cm^2, peaking at 41.13 all stages/cm^2 on 15 August (Figure 5). From 22 November onwards, pest populations declined across all three citrus species, and no individuals were detected by 27 January. *P. oleivora* did not establish detectable populations on fruit after acaricide application at the end of mid – May 2021 (Figure 5). In 2021, *P. oleivora* was first detected on lemon fruit on 18 July and peaked at 0.75 all stages/cm^2 on 18 September. The mite was observed on orange fruit on 27 August and mandarin fruit on 2 October. Throughout the rest of the season, pest densities remained below 0.45 all stages/cm^2 on both citrus species, with no further detections in fruit samples after 20 October (Figure 5).

Directional preferences on fruit

No statistically significant differences in *P. oleivora* densities were observed based on sampling direction in the minimally treated experimental orchard. Nevertheless, the mean total number of *P. oleivora* was higher in the northern and western directions compared to the southern and eastern for all three citrus species. The highest pest densities were recorded in the north for lemon (6.269 all stages/cm^2), in the west for mandarin (5.064 all stages/cm^2), and in the north for orange (3.212 all stages/cm^2) (Figure 6a, b, c).

DISCUSSION

In the commercial orchard, *P. oleivora* was successfully controlled with chemical treatments in 2019. The pest was first detected on lemon in early September, followed by mandarin and grapefruit by the end of October, and orange by mid – November. Acaricide applications initiated upon pest's detection prevented fruit infestations and reduced population by the first week of December. In 2020, *P. oleivora* was first observed on lemon in the second week of August, earlier than the previous year. The pest was subsequently detected on mandarin and orange in late August and on grapefruit in the first week of September. However, *P. oleivora* did not establish a population on fruit during this period.

In the minimally treated experimental orchard, where no pest control were applied in 2020 and only one acaricide-petroleum oil application was conducted in mid – May 2021, *P. oleivora* was detected earlier in both years. In 2020, the pest was first observed on lemon in late May, on mandarin in early June, and on orange in mid – July. The population persisted on both leaves and fruit without interruption until the end of January 2021. In 2021, *P. oleivora* was first detected on lemon in late June, followed by orange and mandarin in the first and second weeks of August, respectively, with a 10-day gap between detections. After the acaricide application, population densities of *P. oleivora* on both leaves and fruits were significantly reduced.

Satar *et al*. (2020) reported that *P. oleivora* was first observed on Valencia orange leaves at the same study site on 22 June, with population peaks during the first week of August. The highest recorded density was 57.12 individuals per leaf, with the final mite observed on 20 January 2014. In the following growing season, *P. oleivora* was first detected on 5 May and peaked again in August, with the last individuals noted in January (Satar *et al*., 2020). A comparison of our findings and those of Satar *et al*. (2020) shows that the timing of the pest's initial appearance, population peaks, and final detections were generally consistent, even though population densities differed. Satar *et al*. (2020) recorded a maximum density of 57.12 mites per leaf, whereas the present study recorded densities of 13.24 all stages/cm^2 on lemon and 11.46 all stages/cm² on orange. Unlike the present study, Satar et al. (2020) considered only active stages of *P. oleivora*, whereas both eggs and active stages were included in the current study, which may partly explain differences in reported population densities. In addition, differences in citrus species and cultivar (Valencia orange vs. Washington navel) and pest management practices may have contributed to the observed variation between studies.

In the present study, *P. oleivora* densities were initially observed on lemon and mandarin fruits in early June, with populations peaking in August. On orange fruits, the mite was first detected in the latter half of July, reaching maximum densities in September. These findings are consistent with previous reports by Satar *et al*. (2020), who reported the first appearance of *P. oleivora* on Valencia orange on 22 July 2013 and 26 May 2014, with peak densities in July and August. The timing of the pest's appearance and peaks observed in the present study aligns with these earlier findings for oranges. Moreover, previous research has shown that *P. oleivora* densities are significantly higher on fruits than on leaves (Yang, 1994; Sarada *et al*., 2018), a trend also observed in the present study, in which the highest densities per unit sampling area (1 cm²) were recorded on fruits.

Phyllocoptruta oleivora was found to persist throughout the year on Washington Navel orange in Egypt, with peak population densities in August and September, after increasing from late July (Al-Azzazy, 2016). Saad *et al*. (2018) noted that *P. oleivora* population developments are influenced by multiple abiotic and biotic factors. In Egypt, populations were present on Valencia orange cultivars from April to October, with peaks in May, June, and September. In Florida, *P. oleivora* was observed on Valencia orange fruits from May to January, with an average density of 29.1 mites/cm² across all developmental stages under unsprayed conditions (McCoy *et al*., 1976).

In the present study, *P. oleivora* was detected on leaves later in the commercial orchard than in the minimally sprayed experimental orchard. This discrepancy likely reflects ecological differences between the sites, as well as the suppression of populations at low densities due to intensive spraying, which could have hindered detection during sampling. Furthermore, mite densities on leaves remained above 2 individuals/cm² across all developmental stages in both years, despite frequent spraying, which may suggest a potential shift in susceptibility that warrants further investigation (Kalkan and Satar, 2024). In both years, intermittent and abrupt declines in *P. oleivora* populations were observed on both leaves and fruits. Yang (1994) reported similar sudden decreases in fruit infestations, attributing them to high population densities, associated with mortality, mite migration, or reduced reproduction due to a malebiased sex ratio. Studies on the ecological requirements of *P. oleivora* showed that high humidity combined with elevated temperatures creates the most favorable conditions for the pest. Population densities increase rapidly when ambient humidity exceeds 70%, with significant surges following heavy rainfall (Sarada *et al*., 2018). Similar trends were observed by Satar *et al*. (2020) in the Adana province of the Çukurova region. In the present study, population development of *P. oleivora* was monitored in the Sarıçam and Yüreğir districts, where average maximum temperatures between May and September from 2019 to 2021 ranged from 31°C to 37°C. Concurrently, the highest recorded humidity reached 100%, with an average range of 59% to 75% (Figure 7) (Yalçın and Kazak, 2025).

Across all areas studied, *P. oleivora* showed the mean highest densities on both leaves and fruits of lemon. Lemon is highly susceptible to many mite species, and *P. oleivora* has been shown to exhibit a marked preference for this host. Based on feeding and damage assessments, Sarada *et al*. (2018) identified the host range of *P. oleivora* which includes lemon, lime, citron, grapefruit, orange, and mandarin. Puspitarini and Endarto (2021) reported that *P. oleivora* caused significantly more damage on orange fruit than on mandarin in Indonesian commercial citrus orchards. Similarly, Brussel (1975) observed higher *P. oleivora* populations in grapefruit orchards than in orange orchards in Suriname.

In the present study, pest population densities on mandarin leaves and fruits were higher than on orange in the minimally treated experimental orchard. This difference may be attributed to the proximity of lemon and mandarin sampling areas, potentially facilitating pest transfer from lemon to mandarin.

Host plant morphology and secondary metabolites can play critical roles in mite development and damage potential. For example, the presence of leaf oil sacs and higher tannic acid concentrations promote mite development, while increased cuticle thickness inhibits it feeding (Mohamed 1965). Additionally, higher protein densities in lemon have been associated with enhanced reproduction and development in certain mite species (Jyotika and Mandeep, 2003). Variations in host plant amino acid, carbohydrate, fat, and protein content can significantly impact mite development rates and reproductive success (Wermelinger *et al*. 1991; Puspitarini and Endarto, 2021). It should be noted that, despite the inclusion of multiple orchards, the observed variation in *P. oleivora* abundance among citrus species may still be partially influenced by cultivar-specific characteristics, as each species was represented by locally cultivated commercial varieties. These host-related physiological and biochemical traits may also contribute to differences in mite population abundances observed among citrus species in field conditions (Zanardi *et al*., 2015; Silva *et al*., 2017).

Studies on the spatial distribution of *P. oleivora* within trees have yielded conflicting results. Chen *et al*. (2018) reported that fruits direction did not significantly affect pest population levels. In contrast, Aghajanzadeh and Mallik (2007) found that, in mandarin trees in India, the highest pest densities occurred on fruits on the eastern side of trees, followed by the southern, northern, and western sides. Similarly, leaf infestations were highest on the eastern side. Shivarju (1990) observed higher mite populations on citrus fruit on the northern side of tree canopies, followed by the eastern, southern, and western orientations. Yang (1994) noted that, at low pest densities, damage was more pronounced on the eastern side, whereas at higher pest densities, the greatest fruit damage occurred on the northern side, followed by the eastern, southern, and western sides. This distribution pattern was attributed to the pest's tendency to avoid direct sunlight under high-temperature conditions. These results partially align with those of Shivarju (1990) and Chen *et al*. (2018).

In the present study, no statistically significant differences was found in *P. oleivora* densities based on direction alone or in combination with plant species interactions. However, significantly higher densities were observed in the northern and western directions of lemon trees in sprayed commercial orchards, and in all three citrus species in minimally treated experimental orchards. The overall results suggest that *P. oleivora* does not exhibit a clear directional preference for host plants. Spatial distribution patterns may vary depending on geographical location, sampling unit position within the orchard, and host plant light utilization. Therefore, consistently higher densities of *P. oleivora* on lemon indicate that this host may serve as a priority sampling target in citrus orchards, allowing earlier detection of population increases. Because no consistent directional preference was observed, representative sampling from different parts of the canopy should provide reliable estimates of mite abundance. This sampling strategy may support more timely acaricide applications, reduce unnecessary treatments, and improve the overall effectiveness of *P. oleivora* management.

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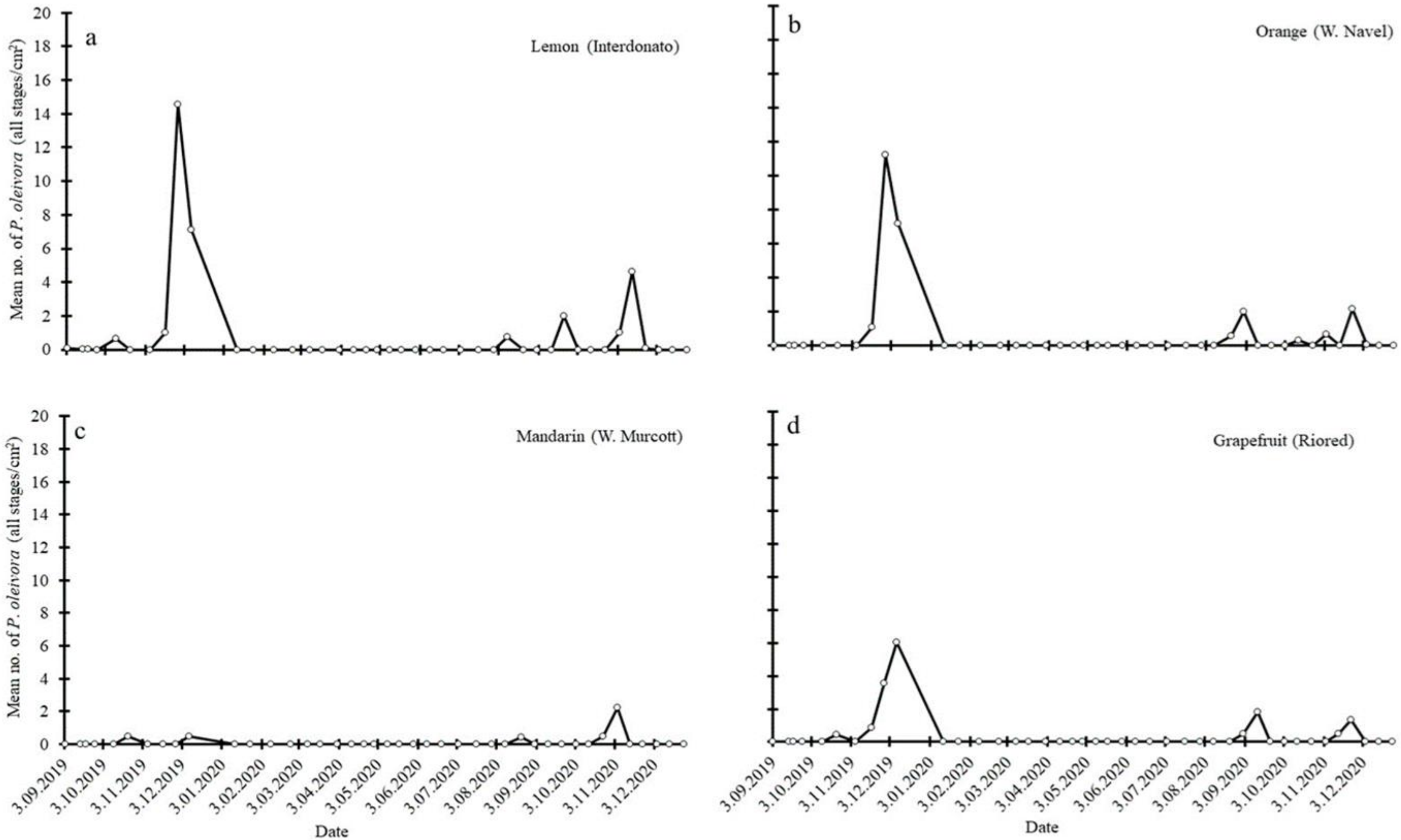


Figure 1. Population abundance of *Phyllocoptruta oleivora* on leaves of different citrus species in commercial orchards.

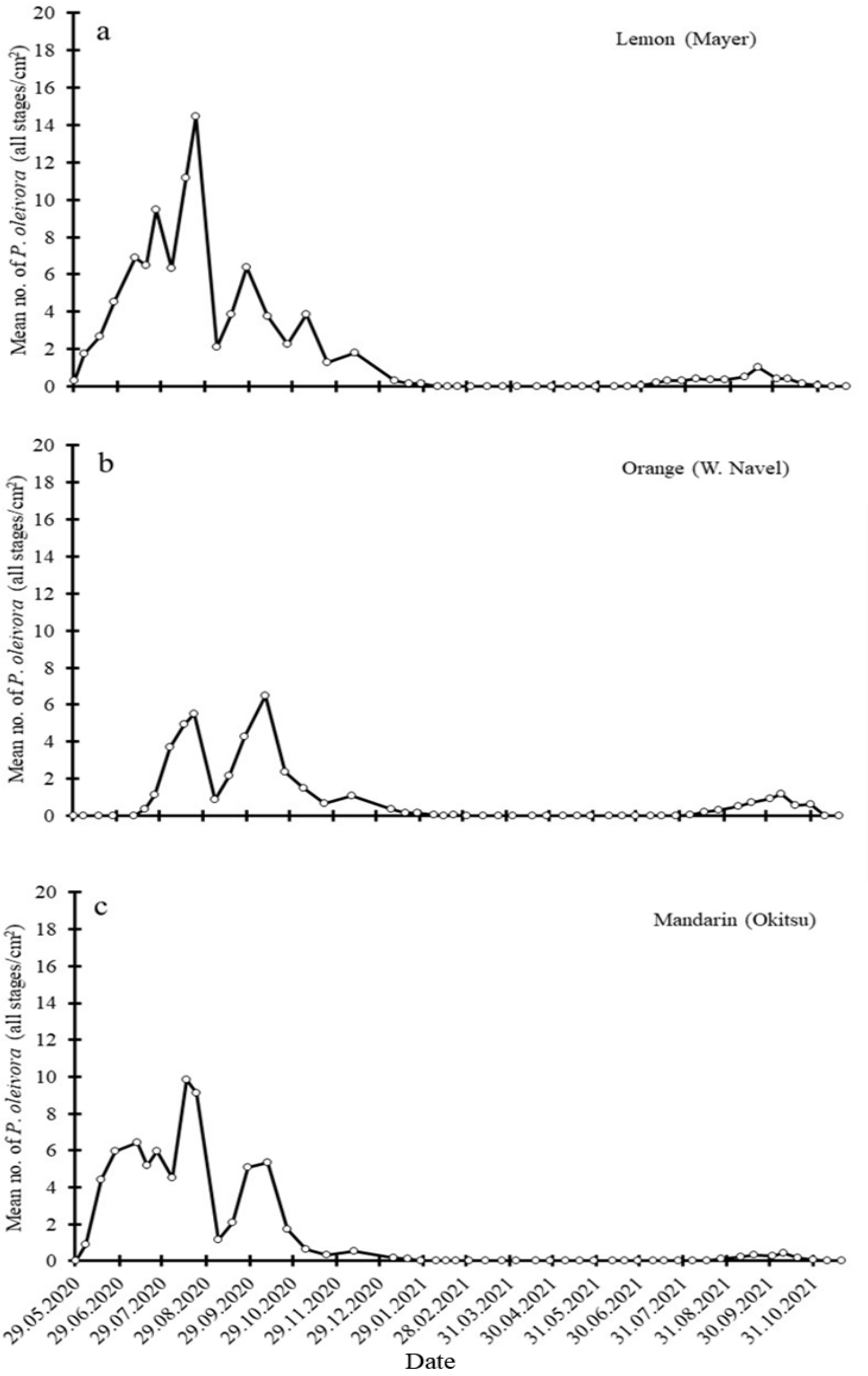
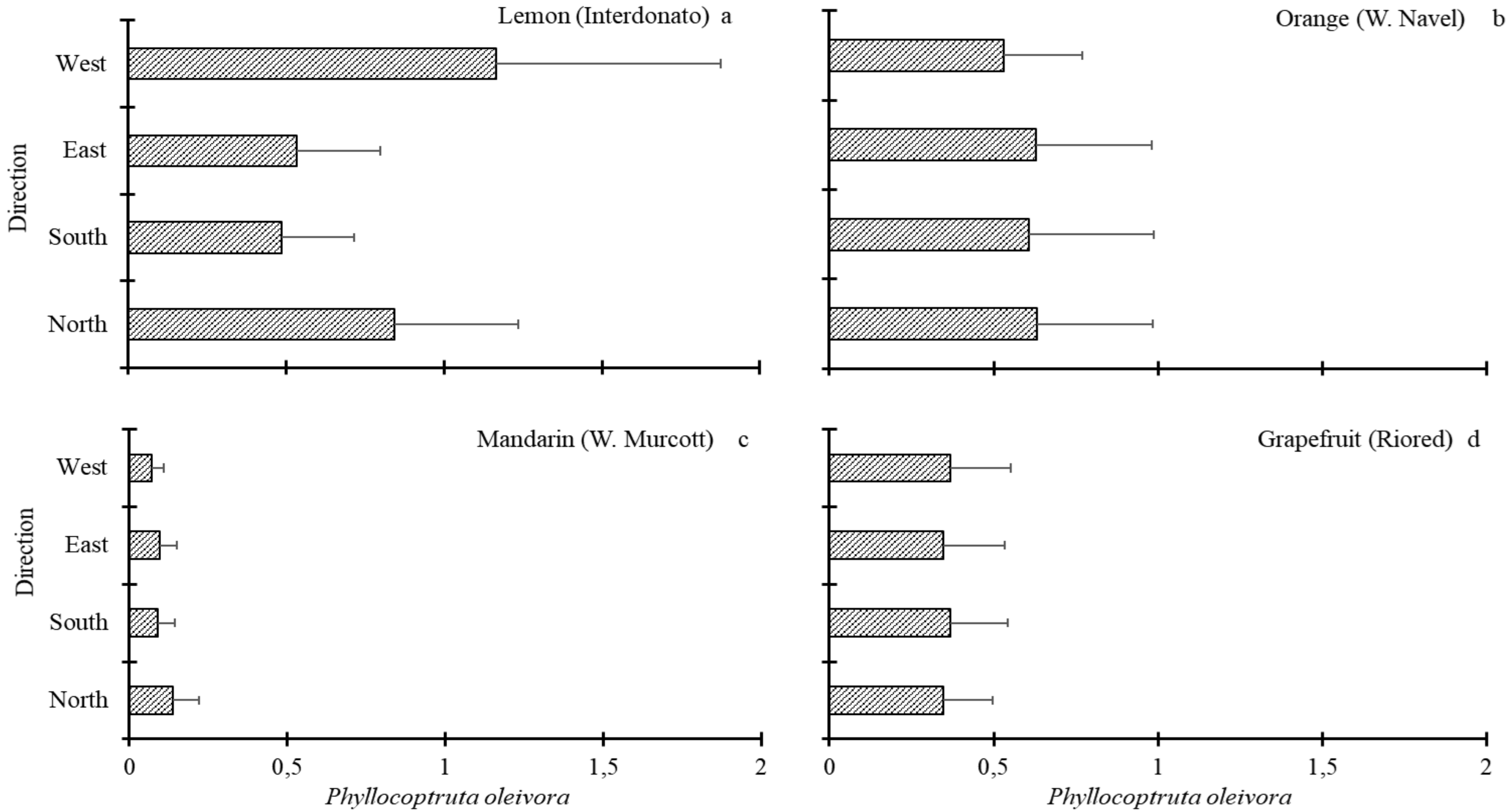


Figure 2. Population abundance of *Phyllocoptruta oleivora* on leaves of different citrus species in experimental orchards.



478 **Figure 3.** Mean total number of *Phyllocoptruta oleivora* in relation to cardinal directions on leaves of different citrus species in commercial
479 orchards (all stages/cm^2 ± SE).

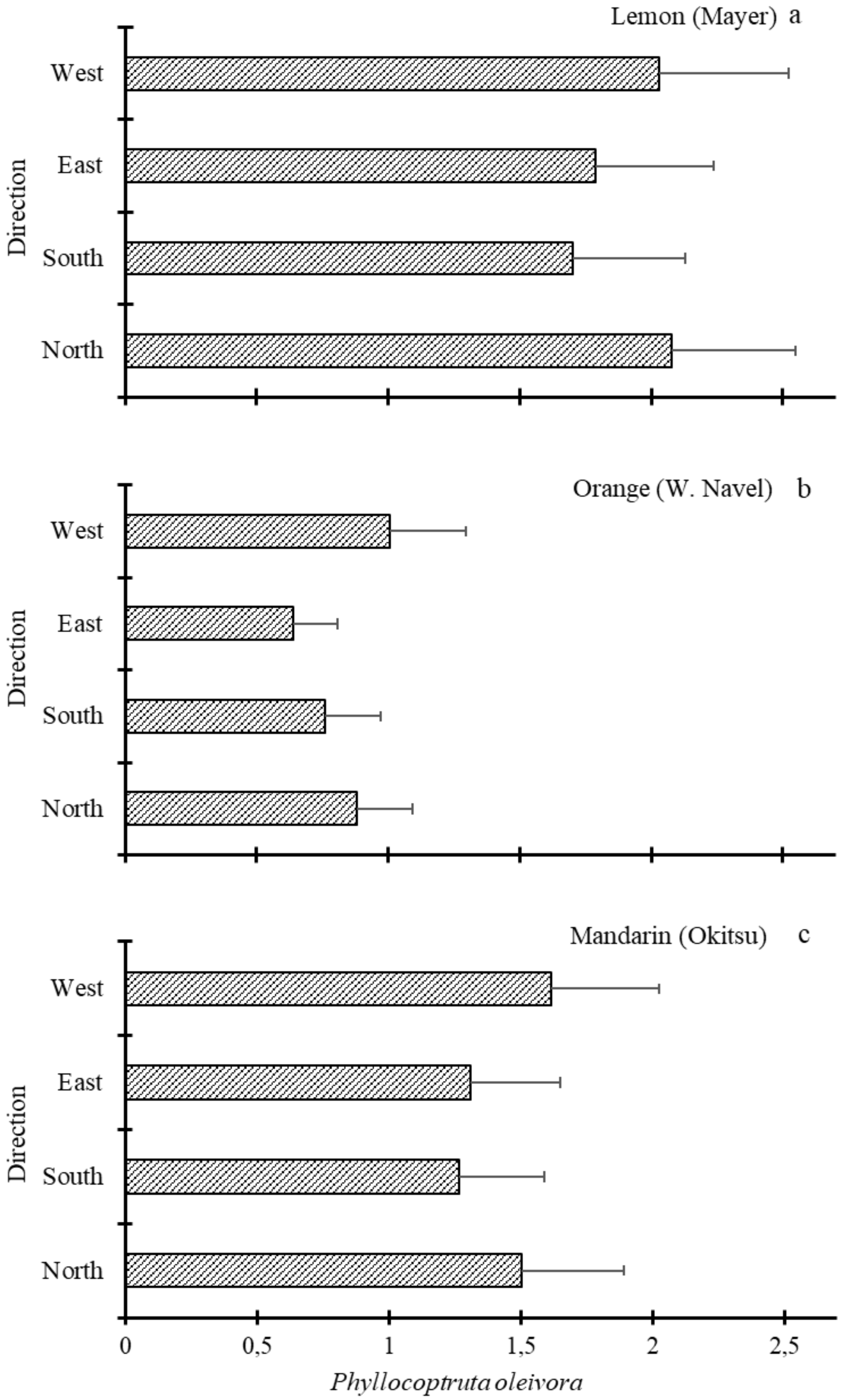


Figure 4. Mean total number of *Phyllocoptruta oleivora* in relation to directions on leaves of different citrus species in experimental orchards (all stages/cm^2±SE).

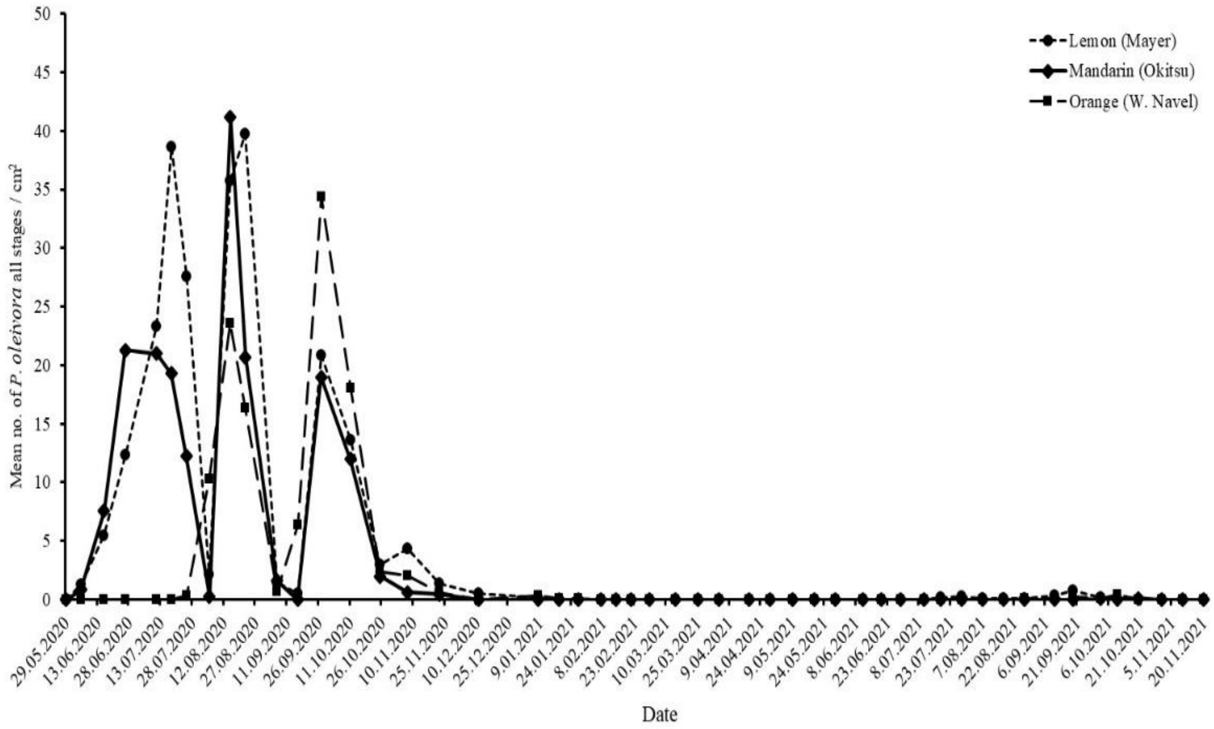


Figure 5. Population abundance of *Phyllocoptruta oleivora* on fruits of different citrus species in experimental orchards.

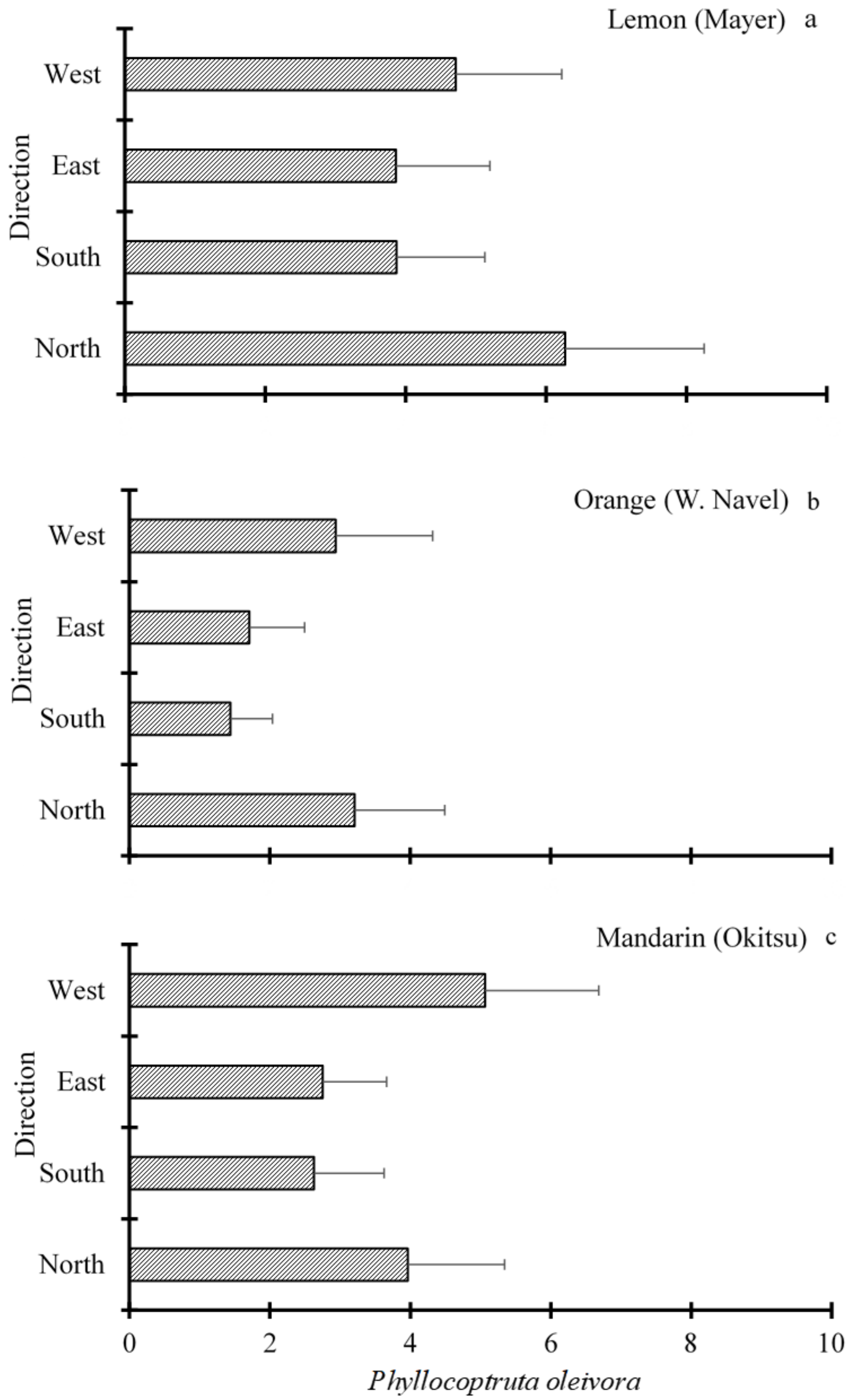


Figure 6. Mean total number of *Phyllocoptruta oleivora* in relation to directions on fruits of different citrus species in experimental orchards (all stages/$cm^2 \pm$ SE).

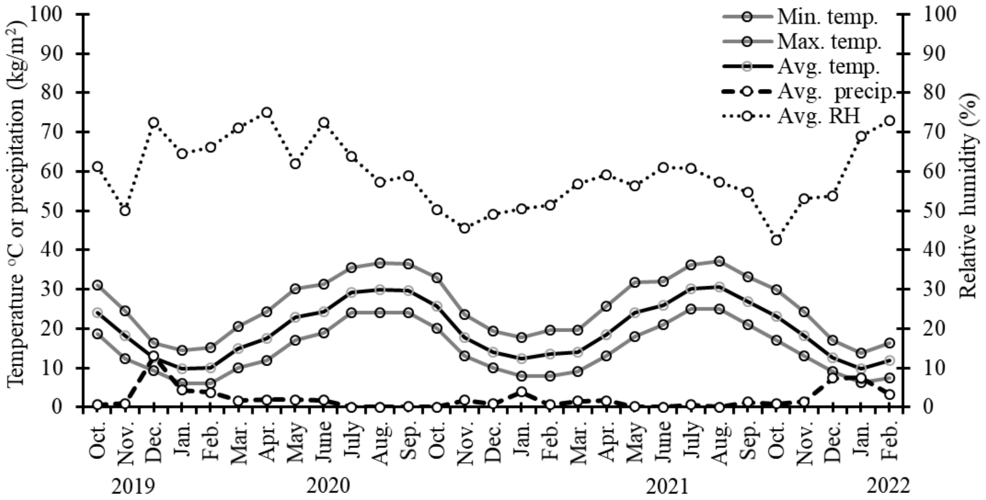


Figure 7. Climatic conditions in Adana province during the 2019 – 2021 study period.

Table 1. Orchard details (location, cultivar, size, spacing, and planting year) for the monitoring of *Phyllocoptruta oleivora* populations in commercial and experimental orchards in Adana, Turkey (2019 – 2021).

Orchard Location	Citrus Cultivar (cv.)	Orchard Size	Tree Spacing	Planting Year
1)Taşcı village, Yüreğir dist.,* (36°53'06.940"N, 35°17'59.287"E)	Lemon (*Citrus limon* cv. Interdonato)	0.1 ha	8 × 6 m	1998
2) Taşcı village, Yüreğir dist., (36°54'23.141"N, 35°21'22.213"E)	Orange (*C. sinensis* cv. W. Navel)	0.1 ha	8 × 4 m	2003
3) Taşcı village, Yüreğir dist., (36°51'50.265"N, 35°18'23.371"E)	Mandarin (*C. reticulata* cv. W. Murcott)	0.1 ha	6 × 6 m	2015
4) Taşcı village, Yüreğir dist., (36°51'49.221"N, 35°18'32.458"E)	Grapefruit (*C. paradisi* cv. Riored)	0.1 ha	8 × 6 m	2001
5) Sarıçam dist. (37°01'47.354"N, 35°21'46.326"E)	Lemon (*C. limon* cv. Meyer)	0.2 ha	6 × 6 m	1998
6) Sarıçam dist. (37°01'47.709"N, 35°21'37.971"E)	Orange (*C. sinensis* cv. W. Navel)	0.1 ha	6 × 6 m	2003
7) Sarıçam dist. (37°01'49.318"N, 35°21'44.821"E)	Mandarin (*C. reticulata* cv. Okitsu)	0.1 ha	6 × 6 m	1999

*Commercial orchards (1, 2, 3, and 4), experimental orchards (5, 6, and 7).

Table 2. Acaricides and insecticides applied in commercial orchards and their application times.

Treatment Date/Year	Year (2019)*	Treatment Date/Year	Year (2020)*
01 August, 2019	80% Sulfur	23 March, 2020	Petroleum oil + abamectin + tebufenpyrad
27 October, 2019	Abamectin+etoxazole+ spirodiclofen	29 April, 2020	Petroleum oil + abamectin + etoxazole + acetamiprid
		10 May, 2020	Cypermethrin + deltamethrin
		10 June, 2020	Fenbutatinoxide + pyriproxyfen
			Abamectin + pyridaben
			Abamectin + etoxazole + spirodiclofen
		25 August, 2020	Abamectin + pyridaben
		25 September, 2020	Abamectin + etoxazole + spirodiclofen

*Spray dosages: Abamectin 100 cc / 100 l water (w), acetamiprid 50 g /100 l w, cypermethrin 100 cc / 100 l w, etoxazole 30 cc / 100 l w, deltamethrin 100 cc / 100 l w, fenbutatin oxide 100 cc / 100 l w, petroleum oil 300 cc / 100 l w, pyridaben 100 cc / 100 l w, pyriproxyfen 50 cc / 100 l w, spirodiclofen 50 cc / 100 l w, Sulfur 500 g / 100 l w, tebufenpyrad 30 cc / 100 l w.

Table 3. Mean total number of *Phyllocoptruta oleivora* on leaves of different citrus species in commercial orchards (all stages/cm^2 ± SE).

Species	*Phyllocoptruta oleivora**
Lemon	0.757 ± 0.21 a
Orange	0.599 ± 0.16 a
Grapefruit	0.357 ± 0.08 ab
Mandarin	0.098 ± 0.02 b

* Means followed by the same letter within a column are not significantly different according to the SNK test ($P < 0.05$).

Table 4. Mean total number of *Phyllocoptruta oleivora* on leaves of different citrus species in experimental orchards (all stages/cm^2 ± SE).

Species	*Phyllocoptruta oleivora**
Lemon	1.899 ± 0.23 a
Mandarin	1.423 ± 0.18 a
Orange	0.821 ± 0.11 b

* Means followed by the same letter within a column are not significantly different according to the SNK test ($P < 0.05$).

Table 5. Mean total number of *Phyllocoptruta oleivora* on fruits of different citrus species in experimental orchards (all stages/cm^2 ± SE).

Species	*Phyllocoptruta oleivora**
Lemon	4.680 ± 0.75 a
Mandarin	3.600 ± 0.63 ab
Orange	2.328 ± 0.51 b

*Means followed by the same letter within a column are not significantly different according to the SNK test ($P < 0.05$).