Entomology

Potential of chemical, natural materials and insect predators for controlling olive black scale insect, *Saissetia oleae* (Olivier) (Coccidae: Hemiptera) infesting olive trees

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Abstract

The population fluctuaionand control efficiency of the olive black scale insect, *Saissetia oleae* (Olivier) (Coccidae: Hemiptera), on olive trees were investigated over two consecutive seasons (September 2023 to August 2024 and September 2024 to August 2025). Populations exhibited clear annual fluctuations, with winter declines followed by pronounced spring and summer peaks. Immatures were more occurring throughout both seasons than adult females, which discloses continuous Two predatory coccinellids; *Coccinella undecimpunctata* and *Exochomus flavipes*, were recorded associated with *S. oleae* during both seasons. Their populations showed positive correlations with the total scale population, indicating a numerical response of the predators to host abundance. Among control treatments, pyriproxyfen was most effective, achieving 88–91% reduction, followed by sulfoxaflor and acetamiprid, while natural materials showed moderate to low efficacy; neem oil and agricultural soap produced moderate reductions, and the soap–vinegar mixture had the lowest effect with a limited residual activity. Spring and early summer peaks indicate critical windows for targeted management. Overall, the findings highlight the nearly year-round activity of *S. oleae*, and the superior performance of pyriproxyfen and sulfoxaflor.

Keywords: *Saissetia oleae*, Olive trees, Seasonal abundance, Pesticides, Insect predators

Introduction

For thousands of years, olive trees (*Olea europaea* L.) and olive oil have been essential to human life, particularly in the Mediterranean region. They are closely related both biologically and culturally. Egypt is one of the leading producers of both olive oil and table olives, with regions extending from Nile Delta up to Upper Egypt (FAO, 2022) [8]. Because olive trees are perennial, they are vulnerable to infestations of various insect pests throughout the year, making ongoing monitoring essential to protect these valued trees from insect damage.

As a result, effective management of insect pests is crucial to the health and productivity of olive orchards since they can significantly reduce fruit yield and quality (Abd-Rabou and Abbassi, 2009) [2].

The black wax scale, *Saissetia oleae* (Olivier) (Hemiptera: Co ccidae), is one of the most damaging insect pests that adversel y affect olive trees. This soft-cale insect has been found to be a major global limiting factor in olive yield and is widely dispersed throughout Mediterranean olive-growing regions (González *et al*., 2018) [9].

While adult females are sessile and have an oval body covere d in a thick layer of wax that shields them from predators and environmental stresses, adult males are small, winged, and sh ort-lived.

Both nymphal and adult stages affect the phloem sap of leave, stems, and fruits, leading to serious physiological disorders.

Additionally, *S. oleae*'s honeydew secretion encourages the development of sooty mold fungus, which further reduces the fruit's photosynthetic efficiency and marketability (Tena *et al*., 2007) [20]. Scale insect populations in olive habitats are frequently impacted by the actions of natural enemies, including parasitoids and predatory coccinellids, which help to naturally control pest populations in field settings.

Implementing successful management measures requires an understanding of *S. oleae's* population fluctuaionand population dynamics.

Growers can maximize control effectiveness and reduce environmental impact by anticipating peak infestations and implementing interventions at the most vulnerable stages of the insect's life cycle when they are aware of the temporal patterns of population increase (Soulsby and Thomas, 2012) [18].

In order to coordinate chemical and biological management strategies, seasonal monitoring also sheds light on the pest's phenology, including times of crawler emergence, oviposition, and adult development. Additionally, recording the presence and population fluctuaionof related natural enemies might yield important data for bolstering biological control elements in IPM plans.

Chemical insecticides have traditionally been the primary tool for managing *S. oleae* populations due to their rapid knockdown effect and ease of application. The applications of neonicotinoids, organophosphates, and insect growth regulators have demonstrated varying degrees of efficacy depending on the timing and mode of application (Ouguas, and Chemseddine, 2011) [15]. However, excessive and repeated use of chemical insecticides can lead to undesirable consequences, including the development of pest resistance, negative impacts on beneficial arthropods, environmental contamination, and residues in harvested olive fruits. These challenges have underscored the need to explore safer and more sustainable alternatives, such as plant-derived products, mineral oils, and compatible biological agents, which can contribute to a holistic, environmentally friendly approach to pest management while maintaining orchard productivity (Abd Alaziz, *et al*., 2012; Ibraheem *et al*., 2012) [1, 11].

The goal of this study was to monitor the population fluctuations of *Saissetia oleae* and two associated predators; *Coccinella undecimpunctata* and *Exochomus flavipes* across two consecutive years. Additionally, the study assessed the efficacy of three natural materials (neem oil, agricultural soap, and a soap-vinegar mixture) and three chemical insecticides (acetamiprid, sulfoxaflor, and pyriproxyfen) against the adults and immatures of olive black scale insect, *Saissetia oleae*.

Based on obtained data, timing of insecticidal treatments, against this insect pest, could be adjusted and then, involved into integrated pest management (IPM) programs.

Material and Methods

1. Experimental site

This investigation was undertaken at a private olive (*Olea europaea* L.) orchard at El Hammam district, Matrouh Governorate, Egypt, 28.84 N latitude, and 30.52 E longitude with an area of about six feddans. The olive trees were 7- year old (about 2.5 m height), with a drip irrigation system, receiving recommended agricultural practices, except for the insecticidal applications (the target of this study).

2. Population fluctuations of olive black scale insect, *Saissetia oleae* (Olivier) on olive trees

Population fluctuations of *S. olea*e were monitored for two whole years; from September 2023 to August 2024, and from September 2024 to August 2025 on 10 trees. From each tree, 7 branches (20 cm length), representing four cardinal directions and three heights of the tree, were weekly cut, giving a total of 70 branches with their leaves per sampling date. All immature stages (crawlers and nymphs) and adult females were separately counted.

3. Sampling of predatory coccinellids

Observations indicated the occurrence of two coccinellids, *Coccinella undecimpunctata* L and *Exochomus flavipes* (Thunberg) as associated with *S.olea*e. The same sample size (70 branches) was examined for recording number of coccilnellid individuals. All immature and adult stages of both predators were counted during each inspection. The counts of coccinellids were expressed as the total number of larvae and adults/ sample.

4. Efficacy of chemical and natural materials against *Saissetia olea*e

The efficacy of chemical and natural materials against olive scale insect was evaluated under orchard conditions. The evaluation included seven treatments (six insecticidal treatments plus an untreated check). Each treatment was applied to five trees, with each tree considered as an independent replicate. Appropriate buffer zones were established between treatments to avoid spray drift. The treatments and their application rates were as follows:

- **Chemical insecticides-**
  - **Acetamiprid** (Mospilan 20% SP – Neonicotinoid) **:** 20 g a.i. per 100 L of water
  - **Sulfoxaflor** (Closer 24% SC – Sulfoximine)**:** 30 g a.i. per 100 L of water
  - **Pyriproxyfen** (Admiral 10% EC – Insect Growth Regulator, Juvenile Hormone Analogue) **:** 25 g a.i. per 100 L of water
- **Natural materials-**
  - **Neem oil:** (2 L/ 100 L of water)
  - **Agricultural soap:** 1 % solution (1.5 kg/100 L of water)
  - **Soap plus vinegar mixture:** 1 % soap + 5 % acetic acid solution (adapted from organic control studies)

Treatments were applied as foliar sprays using a hand-held sprayer, ensuring homogenous coverage of tree foliage. Each treatment was applied once per year (mid-March) to assess the initial reaction and comparative efficacy of the evaluated compounds. Immatures and adult females of *S.olea*e were counted just before treatments, and one, two, three, and four weeks after treatments. Twelve braches per tree were sampled at each assessment, and total population of insects was counted. Dead insects were identified by falling from the plant, shriveling in place, changes in body color, or absence of honeydew excretion. The reduction in pest populations was calculated using Henderson and Tilton's formula (1955) [10], and data were analyzed statistically as described below.

Henderson and Tilton's (1955) [10] formula:

Mortality (%) = [1− (Number alive in control before treatment × Number alive in treatment after treatment) / (Number alive in control after × Number alive in control before)] × 100

Statistical analysis

Collected data were subjected to analysis of variance (ANOVA) using CoStat software. Mean differences among treatments were separated by the Least Significant Difference (LSD) test at a probability level of $p \leq 0.05$ to detect statistically significant differences in pest reduction among treatments. Standard errors and standard deviations were computed for *Saissetia olea*e immatures, adult females and their total, as well as for two insect predators. In addition, correlations between populations of *Saissetia olea*e and populations of each of *Coccinella undecimpunctata* and *Exochomus flavipes* were calculated.

Results and discussion

1. Population fluctuation of *Saissetia oleae*

Saissetia oleae immatures and adult females clearly fluctuated, on olive trees, across two whole years. Immature individuals predominated most of the year, indicating continuous reproduction and extended crawler activity (Tables 1 and 2).

1.1. First season (from September, 2023 to August, 2024)

At the beginning of September, *S. oleae* populations appeared at a moderate level (196 immatures and 160 adult females/per 70 olive branches) and declined through November, December and January, which may be attributed to cooler weather (Table 1). Population recovery started by mid-February with 344 immatures and 203 adult females/per 70 olive branches, and slightly increased two weeks later (on March 1st) with 563 (total of immatures and adult females) which represents the first peak of *S. oleae*. This peak was followed by a second and higher peak wit 646 individuals (420 immatures and 226 adult females/per 70 olive branches) on mid-June.

Table 1: Population fluctuation of immature stages, adult females, and total population (per 70 olive branches) of *Saissetia oleae* and its predators on olive trees, from September 2023 to August 2024

Investigation date	*Saissetia oleae*			Predator	
	Immature stages	Adult females	Total population	*Coccinella undecimpunctata*	*Exochomus flavipes*
Sept 1, 2023	196	160	356	2	0
Sept 15	244	124	368	4	0
Oct 1	224	128	352	2	0
Oct 15	152	103	255	5	0
Nov 1	131	100	231	6	1
Nov 15	126	112	238	2	0
Dec 1	207	140	347	0	0
Dec 15, 2023	196	120	312	4	0
Jan 1, 2024	274	153	427	0	0
Jan 15	212	164	376	7	2
Feb 1	239	203	442	12	7
Feb 15	344	203	537	9	5
Mar 1	365	198	563	11	6
Mar 15	220	127	347	13	6
Apr 1	320	194	514	10	10
Apr 15	297	207	504	12	5
May 1	224	152	376	14	3
May15	325	148	473	16	2
Jun 1	441	190	631	11	0
Jun 15	420	226	646	15	0
Jul 1	361	235	596	11	0
Jul 15	277	128	405	9	0
Aug 1	320	167	487	5	0
Aug 15, 2024	328	161	489	4	0
Mean±S.E.	368.46±17.41	160.13±8.00	428.00±24.14	7.67±0.99	1.96±0.60
Mean±S.D.	368.46±85.28	160.13±39.17	428.00±118.24	7.67±4.86	1.95±2.93
r				0.5475	0.2312

1.2. Second season (from September, 2024 to August, 2025)

Population fluctuations in the second season took a trend similar to that of the first one (Table 2), but in general with relatively higher population densities. The numbers of *S. oleae* started high on September 18th (291 immatures and 113 adults, total 404/70 olive branches) and declined up to November 18th (total 245). However, *S. oleae* seasonal populations exhibited three peaks throughout this season, with 442, 573 and 673 total individuals/70 olive branches on January 3rd, March 3rd and June 18th, respectively.

It could be concluded that both seasons were of a regular yearly pattern; winter decline succeeded by population growth in spring and summer. Insect population reductions in winter (December–January) were noticeable in both seasons, indicating the influence of low temperatures and low olive tree sap availability, aligning with *S. oleae* biology (Darwish, 2021) [6]. The prevalence of immatures in overall population trends was evident, which is an indication of continuous insect population growth and consequently, economic threat (Abd Alaziz, *et al*., 2012; Mesbah, *et al*., 2020; Ilias, and Hammadi, 2017) [1, 14, 12].

In a conclusion, *S. oleae* proved to be active almost throughout the year, showing slight reductions in winter and significant peaks in summer. Temperature-induced developmental patterns regulate seasonal population levels, and thus, effective chemical control measures should be implemented in summer (Souza *et al*. 2015; Abou-Ghadir, 2025) [19, 3].

Table 2: Population fluctuations of immature stages, adult females, and total population (per 70 olive branches) of *Saissetia oleae* and its predators on olive trees, from September 2024 to August 2025

Investigation date	*Saissetia oleae*			Predator	
	Immature Stages	Adult Females	Total population	*Coccinella undecimpunctata*	*Exochomus flavipes*
Sept3, 2024	216	160	356	0	0
Sept 18	291	124	368	0	0
Oct 3	247	102	349	2	0
Oct 18	155	102	257	4	0
Nov 3	140	99	239	3	1
Nov 18	131	114	245	2	2
Dec 3	230	150	370	0	0
Dec 18,2024	199	123	322	0	3
Jan 3, 2025	280	162	442	0	2
Jan 18	223	165	388	4	2
Feb 3	251	200	451	7	3
Feb 18	345	205	554	7	3
Mar 3	372	201	573	10	4
Mar18	232	150	382	8	5
Apr 3	341	205	546	5	0
Apr 18	312	200	512	6	2
May 3	230	156	386	1	1
May 18	341	152	493	8	3
Jun 3	455	208	663	15	0
Jun 18	443	230	673	15	0
Jul 3	318	240	558	10	3
Jul 18	302	135	437	9	4
Aug 3	333	172	505	5	0
Aug 18, 2025	341	180	521	4	0
Mean ± S.E.	280.33 ± 17.42	163.96 ± 8.39	441.25 ± 24.78	5.21 ± 0.91	1.58 ± 0.33
Mean ± S.D.	280.33 ± 85.34	163.96 ± 41.11	441.25 ± 121.40	5.21 ± 4.46	1.58 ± 1.61
r				0.7580	0.0257

2. Population fluctuations of predatory coccinellids associated with the olive black scale insect

In 2023–2024 season, two predatory coccinellids; *Coccinella undecimpunctata* (Coleoptera: coccinellidae) and *Exochomus flavipes* (Coleoptera: coccinellidae) were observed on olive branches infested by the black olive scale, *S. oleae*. *C. undecimpunctata* population was first observed in few numbers, throughout the period from first of September up to mid-January. The populations evidently increased from the first of February (12 adults and larvae/70 olive branches) up to first of July (11 individuals), with three small peaks on mid-March, mid-May and mid-June with 13, 16 and 15 adults and larvae/70 olive branches, respectively. Insignificant positive correlation (r = 0.5475) was calculated between the predator population and the overall population of the scale insect, suggesting that the predator density tended to rise as the host abundance increased.

In comparison, *E. flavipes* was seen at lower densities throughout the majority of the season, appearing sporadically in autumn and winter, and gradually increasing starting from February and reaching a maximum of 10 individuals by the first of April. The correlation between this predator and the scale population was positive (r = 0.2312) but not significant, suggesting that the predator's numbers rose in reaction to the presence of its prey.

In 2024–2025 season, the same predatory species were recorded with relatively higher densities compared to the previous season. The predator *C. undecimpunctata* was detected on October 3rd with 2 individuals and showed a slight increase during spring and early summer, reaching the highest population level of 15 individuals on June 3rd before declining slightly towards the end of the season. The correlation analysis revealed a highly significant positive correlation between the predator abundance and the total population of the scale insect (r = 0.7580**). On the other hand, *E. flavipes* showed relatively low numbers during autumn and winter but slightly increased during summer.

3. Efficacy of chemical insecticides and selected natural materials for the control of *Saissetia oleae* on olive trees

3.1. 2023/2024 Season

Data in Table (3) show the reduction percentage of *S. oleae* populations on olive trees one, two, three, and four weeks after treatments, as well as the overall mean of reduction through the four-week period. Pyriproxyfen exhibited the highest and most consistent efficacy, achieving 88.46% ± 2.42 after one week,

rising to 93.20% ± 0.94 after two weeks, and maintaining values above 91% in subsequent weeks, with an overall mean of 91.12% ± 2.23, significantly higher than all other treatments (LSD = 6.86, $p \leq 0.05$). Sulfoxaflor also showed high efficiency, with an overall mean of 86.49% ± 4.25, while acetamiprid provided moderate control (77.71% ± 3.82), significantly lower than pyriproxyfen but higher than natural materials. Among the natural treatments, neem oil and agricultural soap achieved moderate reductions, with overall means of 68.76% ± 9.64 and 65.32% ± 11.46, respectively. The soap plus vinegar mixture showed the lowest overall efficacy, with a general mean of 53.43% ± 17.59, demonstrating a steep decline by the fourth week (30.72% ± 3.42), likely due to the limited residual effect of soap plus vinegar mixture and its efficacy against only early instars of *S. oleae*.

Table 3: Reduction percentage of *Saissetia oleae* on olive trees due to applications of chemical insecticides and selected natural materials, 2023/2024 season

Treatment	Weeks after treatment				Overall mean
	One week	Two weeks	Three weeks	Four weeks	
Pyriproxyfen	88.46 ±2.42 a	93.20 ± 0.94 a	91.71 ± 1.17a	91.12±1a	91.12±2.23a
Sulfoxaflor	84.55 ±5.57 ab	86.91 ± 5.26 a	85.37 ± 3.31ab	89.13±2.09ab	86.49±4.25a
Acetamiprid	75.29 ± 4.34 b	78.16 ± 2.86 b	75.64 ± 1.49 bc	81.76±2.85b	77.71±3.82b
Neem oil	59.75 ± 8.09 c	76 ± 4.33 bc	77.79 ± 4.47 bc	61.48±1.84c	68.76±9.64c
Agricultural soap	54.13 ± 13.11 c	69.83 ± 4.88 c	67.88 ± 7.83 c	69.42±13.22c	65.32±11.46c
Soap + vinegar mixture	55.7 ± 9.04 c	71.63 ± 8.76 bc	55.67±15.32d	30.72±3.42d	53.43±17.59d
F values	14.61	12.67	11.855	60.499	33.214
LSD	11.74	7.57	11.02584	8.64973	6.8554

Means followed by the same letter are not significantly different from each other ($p \leq 0.05$, LSD test)

These results are in agreement with previous studies. Pyriproxyfen, as an insect growth regulator, is known to disrupt molting and adult emergence, leading to high suppression rates in soft-scale populations when applied during crawler activity (Ishaaya and Horowitz, 1992) [13]. Mode of action of sulfoxaflor sulfoximine has been documented to rapidly reduce hemipteran pests, including soft-scale crawlers (Babcock *et al*., 2011) [4]. Acetamiprid, a systemic neonicotinoid, provides a good control but may be slightly less effective against early nymphal stages due to limited contact activity (Darwish *et al*., 2021) [6]. Natural materials, particularly neem oil, exhibited a moderate efficacy due to their antifeedant and growth-regulating properties (Schmutterer, 1990) [17], while soap-based treatment was less effective on older nymphs and adults because of the dense wax layer that limits pesticide penetration, as consistent with reports of Copping and Menn (2000) [5] and Quesada and Sadof (2017) [16]. The observed decline in efficacy of the soap plus vinegar mixture by the fourth week emphasizes the importance of timing of applications with the emergence of the crawler stage for optimal control. Overall, the results confirm that chemical insecticides, especially pyriproxyfen and sulfoxaflor, provide a superior control of *S. oleae* during the first season, while natural materials can serve as supplementary or environmentally friendly alternatives, particularly when integrated into an IPM program targeting early developmental stages.

3.2. 2024/2025 Season

Table (4) shows the reduction percentage of *S. oleae* populations on olive trees one, two, three, and four weeks after treatments, as well as the overall mean reduction during 2024/2025 Season. The results were similar to those of the first season. Pyriproxyfen achieved the highest and most consistent control, with reductions of 87.21% ± 1.78 after one week, slightly increased to 88.77% ± 2.32 after two weeks, and settled above 88% in subsequent weeks, with an overall mean of 88.2% ± 2.1, significantly higher than all other treatments (LSD = 2.87, $p \leq 0.05$). Sulfoxaflor and acetamiprid induced moderate to high reductions, with overall means of 81.92% ± 2.27 and 79.13% ± 2.57, respectively, showing slightly lower efficacy than pyriproxyfen but still significantly more effective against *S. oloeae* populations compared to natural materials.

Table 4: Reduction percentage of *Saissetia oleae* on olive trees due to applications of chemical insecticides and selected natural materials, 2024/2025 season

Treatment	Weeks after Treatment				Overall mean
	One week	Two weeks	Three weeks	Four weeks	
Pyriproxyfen	87.21±1.78a	88.77±2.32a	88.40±2.69a	88.41±2.12a	88.20±2.10a
Sulfoxaflor	80.53±0.88b	82.31±2.34b	81.96±2.31ab	82.89±2.15b	81.92±2.27b
Acetamiprid	77.21±1.34b	79.93±3.05b	79.87±2.98bc	79.51±2.51b	79.13±2.57b
Neem oil	67.99±4.10c	73.18±2.60c	73.82±6.01cd	69.25±2.72c	71.06±4.48c
Agricultural soap	62.56±5.39d	72.89±3.96c	71.97±3.31d	64.78±4.16c	68.05±5.98d
Soap + vinegar mixture	52.16±3.40e	56.07±4.55d	59.08±6.33e	58.32±5.32d	56.41±5.27e
F values	62.834	47.906	21.498	47.068	123.8117
LSD	4.81949	4.826117	6.481008	5.014	2.865759

Means followed by the same letter are not significantly different from each other ($p \leq 0.05$, LSD test)

Neem oil achieved an overall mean reduction of 71.06% ± 4.48, while agricultural soap reduced *S. oleae* populations by 68.05% ± 5.98. The soap plus vinegar mixture again showed the lowest overall efficacy (56.41% ± 5.27) despite slight increases in three and four weeks after treatments, indicating limited residual activity and effectiveness primarily on the crawler and early nymphal stages.

These results align with previous findings and the first season's observations. Pyriproxyfen maintained superior efficacy due to its mode of action as a juvenile hormone analogue, preventing molting and adult emergence (Ishaaya and Horowitz, 1992) [13]. Sulfoxaflor continued to demonstrate rapid activity against hemipteran pests including soft-scale nymphs (Babcock *et al*., 2011) [4], while acetamiprid showed a moderate systemic action against concealed feeding stages (Darwish *et al*., 2020) [7]. The performance of natural products was consistent with expectations; neem oil's antifeedant and growth-regulatory effects provided moderate control (Schmutterer, 1990) [17], whereas soap-based treatments were less effective on older nymphs and adult females due to their protective wax layer (Copping and Menn, 2000) [5]. The limited residual activity of the soap plus vinegar mixture reinforces the importance of timing applications with crawler emergence for optimal impact.

Overall, chemical insecticides particularly pyriproxyfen and sulfoxaflor proved highly effective in the second season, while natural materials may be employed as complementary, environmentally friendly options targeting early developmental stages.

Conclusion

The current study demonstrates that *Saissetia oleae* maintains active populations throughout the year, with pronounced peaks during spring and early summer. Two predatory coccinellids, *Coccinella undecimpunctata* and *Exochomus flavipes,* were recorded in association with the pest and showed positive correlations with its population density, indicating their potential contribution to natural biological control. Chemical treatments, particularly pyriproxyfen, showed the highest and most consistent efficacy, followed by sulfoxaflor and acetamiprid. Meanwhile, natural products such as neem oil and agricultural soap provided moderate suppression to the pest, whereas the soap–vinegar mixture offered limited control. These findings emphasize the need for accurate monitoring with timely applications of effective insecticides to achieve a sustainable management of *S. oleae* in olive orchards.

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