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Seasonal and Spatial Distribution of Pest on Olive in District Killa Saifullah, Balochistan

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ABSTRACT

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The cultivation of Olive tree (*Olea europaea* L.) has gained significant importance across Pakistan owing to its nutritional and economic value. However, vegetative growth, fruit development and productivity of olive is affected by multiple insect pest infestations. The current study examined the seasonal population dynamics in the different stages of four insect pests, i.e. *Bactrocera oleae*, *Prays oleae*, *Euphyllura olivina*, and *Saissetia oleae*, and the changes in their population in relation to different physical environmental conditions and crop growth in Killa Saifullah district of Balochistan. Negative binomial regression was used to analyze the changes in the different stages of the insects. The changes in the insect infestation and climatic conditions were assessed by correlation analysis. The maximum populations of *B. oleae* and *P. oleae* were 14.0 flies and 7.2 moths per trap, respectively. The maximum populations of *E. olivina* and *S. oleae* were 9.0 nymphs and 9.5 scale per shoot, respectively. Among the abiotic variables, there were very weak and non-significant correlation with the insect infestation, and therefore the populations of insects were predominantly influenced by the biology of the insects, the phenology of the host plant and the conditions of the olive plantation. Insect infestation resulted in reduction in the plant growth attributes, including plant height and leaf area index. and crop yield. The highest infestation was observed in *E. olivina*, followed by *S. oleae*, *B. oleae* and *P. oleae*. The highest reduction in crop yield was caused by *E. olivina*. Therefore, climate-smart pest management strategies for olive production should be designed for insect pest management.

Introduction

The olive tree (*Olea europaea* L.) has a long history of agricultural development. Numerous sources provide evidence that the olive tree was domesticated approximately 6,000 to 7,000 years ago in the Eastern Mediterranean, in the Levant and Near East (Besnard et al., 2018). The wild olive tree, or oleaster (*O. europaea* subsp. *europaea* var. *sylvestris*), was the progenitor to the

cultivated olive tree (Besnard et al., 2018). The olive tree was domesticated through human selection of favorable traits over time. Archaeological and genetics sources of evidence suggest that many cultivated varieties of the olive tree were created through selection and vegetative propagation (Julca et al., 2020). Following the initial development of olive cultivation, the tree was widely propagated throughout the Mediterranean through migration and trade. As a result, there are numerous local varieties of olive trees (Díez et al., 2015; İpek et al., 2017). Extra virgin olive oil (EVOO) is high in monounsaturated fatty acids, particularly oleic acid, and contains vitamin E, phytosterols, carotenoids, and numerous bioactive compounds, such as hydroxytyrosol, tyrosol, oleuropein, and oleocanthal (Ghanbari et al., 2012; Servili et al., 2014). Consequently, the positive effects olive trees have on economy through their commercial value, is also positive on health and prevention of chronic diseases (Cicerale et al., 2012; Lu et al., 2024). In Pakistan also, it is expected that in the coming years, olive cultivation will be important to make Pakistan less dependent on importing edible oil, increase rural employment and use unproductive land productively. Climate and conditioned soil of Pakistan allow cultivation of olive tree. In parts of Punjab, Khyber Pakhtunkhwa, Baluchistan and Azad Jammu and Kashmir olive cultivation has a good potential. As part of the National Olive Program, and similar government initiatives, thousands of acres of land have been planted with olive plants, and hundreds of thousands of olive plants have been distributed (MNFSR, 2024; PHDEC, 2025). There are many different kinds of insects in olive groves. Some are beneficial, while others are harmful. Many of the harmful insects are economically important. Some of the economically important insects are: the olive fruit fly, olive moth, olive psyllid, and olive black scale. Each insect causes damages to the olive crop in a different way. The olive fruit fly is probably the most destructive of the group. It damages the fruit of the olive, while the olive moth damages the leaves and fruit of the plant. The olive psyllid and olive black scale cause damage to the plant, and in turn effect the developing fruit. The olive psyllid and black scale effect the plant the most during the growing season, while the olive moth is active during the flowering and early fruit development. The olive fruit fly is active during late fruit development. One of the most important aspects to develop a control strategy is to learn the biology of the pest, the seasonal activities of the pest, and its ecology (Daane & Johnson, 2010; Lantero et al., 2023). Since each insect affects the crops in different ways, an integrated pest management system is required to analyze the insect population, implement various pest control strategies and constantly monitor the system (Tzanakakis, 2003). Among the detrimental insects, the olive fruit fly, *Bactrocera oleae*, is the most detrimental insect of olive crops. The fly lays its eggs in the olive fruit. Upon hatching, the maggots feed on the olive fruit, resulting in the premature dropping of the fruit, and also adversely affects the quality of the olive oil. The fly's population increases in late summer and in the fall when the olives attain maturity and the flies lay eggs (Ordano et al., 2015). The second generation moths feed on the flower and affect the crop through sterile inflorescences. The last and third generation moths affect the crop through feeding on the fruit and adversely affecting the quality and yield of the olive crop. Like the olive fly, the olive moth is also affected by and synchronized with the environment and especially temperature (El Aalaoui & Sbaghi, 2026). The third important insect pest of olive crops is the olive psyllid *Euphyllura olivina*. The psyllid also adversely affects the vegetative growth of the olive plant, and reduces and affects the fruit set of the plant. Populations of herbivores generally increase in spring as a result of the growth of new tender plant tissues (Guessab et al., 2021; El Aalaoui et al., 2025). The seasonal variation of important olive tree pests was analyzed with the Negative Binomial regression model. This type of regression is commonly used in ecological and entomological studies, since olives and other crop pests are generally counted, and their population data often show over-dispersion. A Negative Binomial regression model may capture the uncertainty and variability in pest population data, which otherwise may not be captured with the conventional parametric regression models (Lindén & Mäntyniemi, 2011). Thus, seasonal variation and abiotic environmental factors may be incorporated in the model (Hilbe, 2011). Ultimately, incorporation of uncertainty and flexible modeling may provide a framework to answer important pest management and ecological questions (Lantero et al., 2023). Population dynamics of olive pest insects are influenced by many factors, including the biology of the insects, olive tree phenology, weather conditions, and availability of host tissues (Famiani et al., 2024; Papadopoulos, et al., 2026). Pest monitoring plays an important role in achieving a sustainable olive production system. It helps in detecting pest population build-ups, evaluating economic thresholds, and making management decisions. Integrated Pest Management (IPM) aims to control pest population levels so that the damage caused by the pest becomes economically unviable. In the case of olive production, IPM incorporates the use of pheromone and other traps, conservation of biological control agents, and integration of less harmful approaches to manage the olive fruit fly (*Prays oleae*), the olive leaf roller (*Saissetia oleae*) and other important pests of the olive ecosystem (Daane & Johnson, 2010; Lantero et al., 2023). Currently, large-scale olives production in Pakistan has not fully met industry demands, mainly due to limitations caused by insect pests that affect growth and yield of the crop. However, available data is not sufficient to adequately describe population dynamics of pests that attack olive trees, including the effect of different abiotic factors. This study evaluated some of the major insect pests of olives and other production constraints that are limiting sustainable production of olive crop in Pakistan. So, the Objectives of the Study was to understand seasonal population changes of the major insect pests in olive orchards and to assess the role of the abiotic factors including temperature and humidity and relative changes of rainfall in the seasonal fluctuations of the olive pests. Moreover, to study the effects of insect infestation on the growth and different physiological characteristics of olives including fruit production and yield attributes.

Materials And Methods

Experimental Study

The experimental locations within representative olive-growing orchards of Qilla Saifullah District, Balochistan, Pakistan, were selected to conduct field-based pest monitoring studies. Locations containing mature and productive olive trees were selected to evaluate insect pest population fluctuations. Uniform olive trees from each orchard site were selected and geographical position of each selected orchard by recording latitude, longitude, and elevation using a GPS device. The selected orchards were characterized by documenting important agronomic features, including olive varieties, tree age, planting arrangement, irrigation methods, and existing management practices.

Meteorological data collection

Monthly meteorological records of one year, including maximum temperature (°C), minimum temperature (°C), average temperature (°C), and total precipitation (mm), were obtained from the nearest weather monitoring station. Environmental data with field pest observations were integrated to analyze the effect of climatic conditions on the abundance and seasonal occurrence of olive insect pests.

Experimental Design and Sampling

The field experiment was designed to evaluate the infestation patterns and seasonal population dynamics of major olive insect pests. Representative olive trees were selected from each experimental orchard using a systematic sampling approach. The selected trees were marked for repeated observations throughout the experimental period to assess the abundance and occurrence of major olive insect pests, including *Bactrocera oleae*, *Prays oleae*, *Euphyllura olivina*, and *Saissetia oleae*. Pest population data based on their feeding behavior and infestation pattern were collected from distinct parts of olive plants such as shoots, leaves, branches and fruits based on their feeding behavior and infestation. Mature insect populations were monitored using appropriate trapping. Immature stages of each insect pest and infestation levels were assessed via visual observations and plant sampling. The number of each insect pest and infestation level was recorded from selected trees during sampling period. Proper field records such as orchard location, population density of each insect pest, sampling date, and damage observations were maintained, and samples were continuously collected from January–December, 2025, to determine seasonal variations in infestation intensity and abundance of each insect pest. The field observations were subjected for statistical analysis to determine relationships between environmental variables and pest occurrence, and seasonal population trends of olive insect pests.

Determination of Pest Infestation and Damage Intensity

The extent of insect pest infestation on fruits, shoots, branches and reproductive structures of olive plants was evaluated during each sampling visit. Each selected olive tree was observed to identify signs and symptoms of insect pests and determined the affected plant tissues. The number of healthy and infested plant units from selected trees was recorded to determine the pest infestation level of each insect pest. The fruit infestation induced by *Prays oleae* and *Bactrocera oleae* was assessed by recording affected fruits (%) and examining damaged fruits. Olive shoot infestation caused by *Euphyllura olivina* was assessed by estimating the proportion of damaged shoots and counting infested shoots. Olive branch infestation caused by *Saissetia oleae* was evaluated by recording the density and presence of scale insects on branches of olive trees. The infestation (%) was calculated using number of damaged plants and total observed plants. Separate observations were made for insect species, including affected plant parts, sampling date, pest types, and infestation level. The infestation intensity between distinct insect pest species were compared to assess their relative damage potential under field conditions. The infestation data was analyzed statistically to determine the influence of each insect pest over growth and yield attributes of olive plants.

Assessment of Physio-Morphological Traits

The **physio-morphological characteristics** of healthy and infested olive plants were recorded during experimental study. The plant height (cm) of each selected olive trees was determined by measuring vertical growth from the base of the plant to the highest growing point using a measuring tape. The Leaf Area Index (LAI) was measured by recording canopy characteristics and leaf development of each selected olive trees. The chlorophyll content was measured using a SPAD chlorophyll meter to determine the influence of infestation level of each insect pest on photosynthetic performance. Observation data from insect-infested plants and healthy control plants were recorded for comparative study.

Determination of yield attributes

Yield attributes at the harvesting stage of olive plants were recorded to determine the influence of insect pest infestation over olive production during experimental period. Number of fruits per tree was counted manually from each selected olive plant. The fruit yield was measured by harvesting fruits from each individual trees. The total yield was recorded using a digital weighing balance and expressed as kilograms per tree (kg tree^{-1}).

Statistical analysis

All the collected field observation, including pest population density, infestation percentage, climatic variables, plant growth parameters, physiological traits, and yield attributes were statistically analyzed. Data of each insect pest population was organized based on insect species and sampling dates to evaluate the seasonal fluctuations in olive pest abundance. Population dynamics of each insect pest was statistically analyzed using Negative Binomial regression (Hilbe, J. M. 2011). to determine temporal variations in insect abundance. The relationship between pest infestation levels and abiotic factors (temperature and precipitation) was determined by performing correlation analysis (Pearson's correlation coefficient) in RStudio (RStudio Team, 2024). Data of olive plant growth, physiological characteristics, and yield parameters were subjected for Analysis of Variance (ANOVA), and significant differences among mean values were using Tukey's Honest Significant Difference (HSD) test at probability value ($P \leq 0.05$). Graphs of representations of pest population trends, climatic relationships, infestation levels, and plant performance parameters were generated in Python (Python Software Foundation, 2026).

Results

Population Dynamics of Olive Insect Pests

Population Dynamics of *Bactrocera oleae* (Olive Fruit Fly)

The population of *Bactrocera oleae* significantly increased during the development and maturation of fruit (Figure. 1). Low populations were recorded from winter to early spring and trapped at densities of 0.3 to 1.8 flies per trap. These values suggest very little fly activity at a period of the year when immature fruits are not available. From July onward, the fly population started to increase. In August, population density was 3.5 flies per trap. The highest fly captures were recorded in September and October. During September, 9.5 flies per trap were caught and in October 14 flies per trap. The rest of the flies were caught at very low densities. During November the captures were 6 flies per trap. The Negative Binomial model, which was used to simulate fly population trends, indicated that fly population would increase during the summer. The model also indicated that the fly population would reach its peak in September at about 6 flies per trap. The model also underestimated the actual fly population in October. Factors such as the level of susceptibility of the fruits and the availability of the fruits may also contribute to the explosive increases of the fly population.

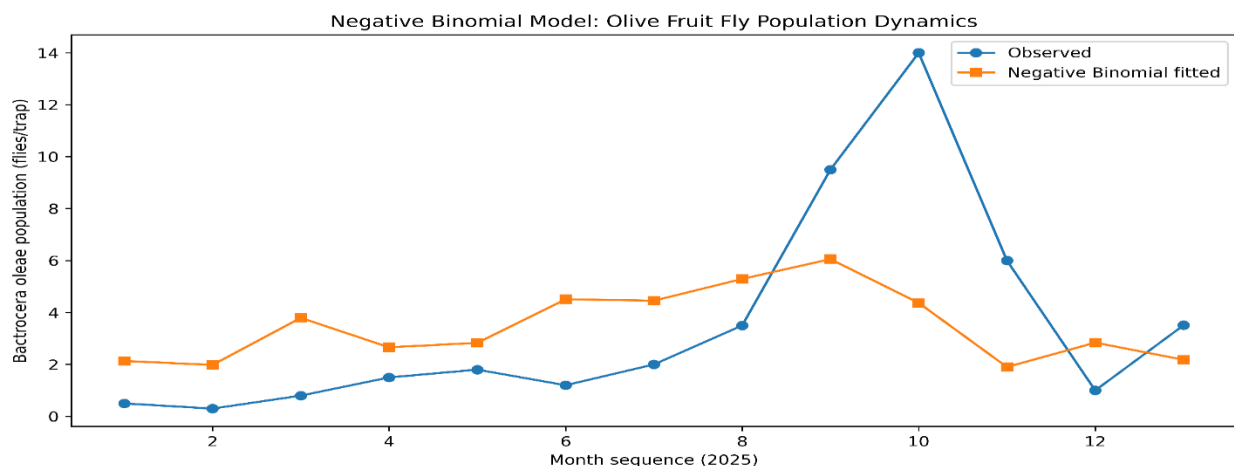


Figure 1. Seasonal population dynamics of *Bactrocera oleae* during the study period.

Population Dynamics of *Prays oleae* (Olive Moth)

The population of *Prays oleae* varied throughout the year and seasonally (Figure 2). The population during winter was low, ranging from 2.8 to 3.5 moths per trap. The population during spring (March) was high, with 5.5 moths per trap. The highest population during the year was in April, with 7.2 moths per trap. In May, the population was 6.0 moths per trap, and in June it

was 4.8 moths per trap. The population in July and August was low, with 1.5 and 1.8 moths per trap, respectively. In October and November, the population was 5.5 and 6.8 moths per trap, respectively.

Seasonal fluctuations in the population of moths was modeled using a Negative Binomial distribution. The model reflected seasonal population increase during the spring and later increase during the fall. The modeled population values were less variable compared to the field data. Naturally, field populations of insects exhibit high variability. The spring increase in moth population corresponds to the flowering period of the olives and early stage of olive fruit development. The larvae of the moth at this stage of development use the flowers and the fruits of the olive as food. The second increase in population during the fall may be due to the availability of the fruits of the olive. Generally, the management of the olive moth should focus on the periods of flowering and early stage of fruit set.

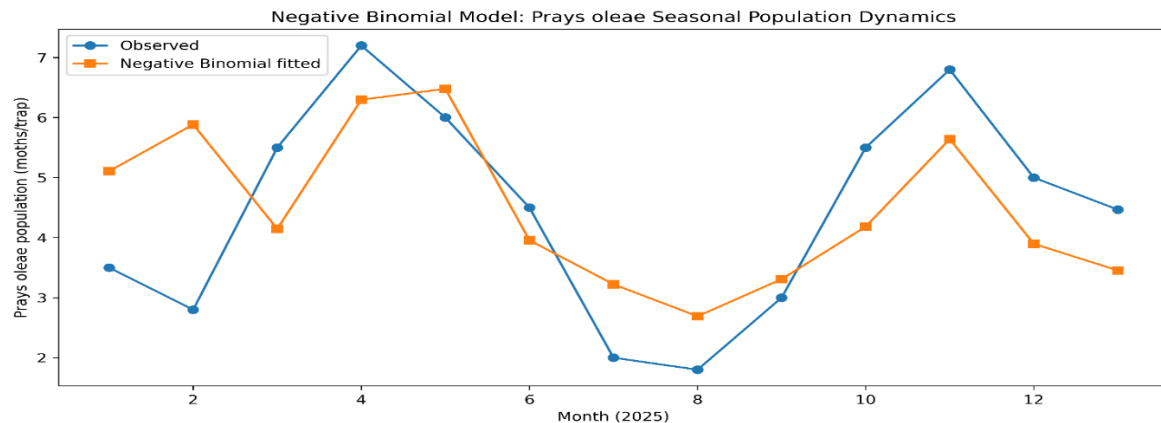


Figure 2. Seasonal population dynamics of *Prays oleae* (olive moth) during the study period.

Population Dynamics of *Euphyllura olivina* (Olive Psyllid)

Euphyllura olivina demonstrated a clear spring peak in population (Figure 3). The population mean increased from 2.0 nymphs per shoot in January to 5.5 in February, and further increased to 9.0 nymphs per shoot in March. Through April, the population was at a mean of 7.5 nymphs per shoot. Beyond April, the population declined, and was recorded at 1.5 nymphs per shoot in May. From June through the remainder of the year, the population remained very low at 1.5 to 2.5 nymphs per shoot.

In general, the Negative Binomial model captured the early spring increase in activity of the psyllid population and the subsequent seasonal decline. The model fit the psyllid data well, and was a reasonable prediction of the seasonal trend of the psyllid population. It is biologically appropriate to expect high psyllid populations to occur during the early growing season of the olive when inflorescences and young shoots are available for nymphal psyllid feeding and development. Psyllid management and monitoring should focus on the early spring period.

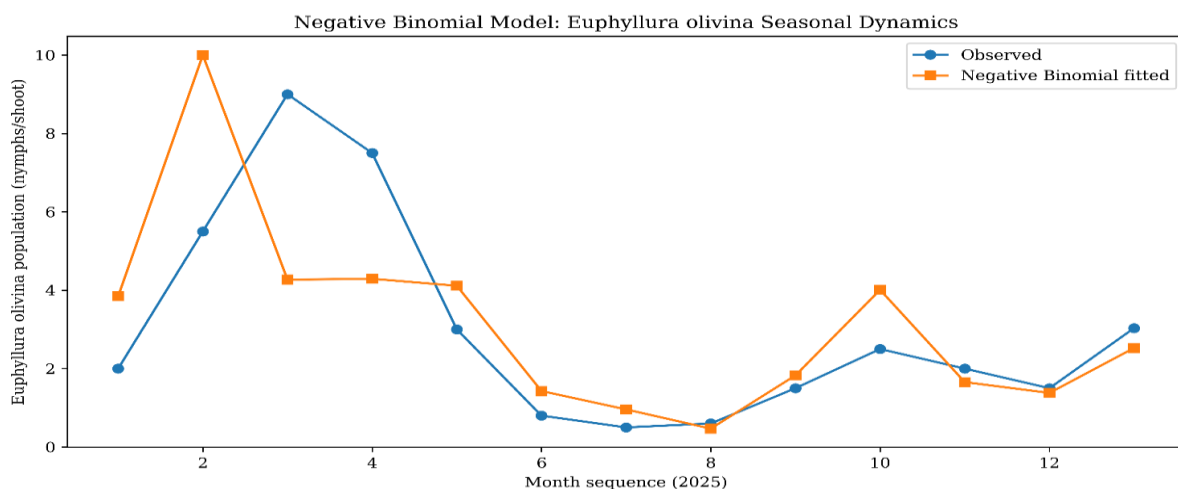


Figure 3. Seasonal population dynamics of *Euphyllura olivina* during the study period.

Population Dynamics of *Saissetia oleae* (Olive Black Scale)

Population dynamics of *Saissetia oleae* for the current study showed a gradual accumulation pattern (Figure 4). Population build-up during the early part of the season (between January and May) was low, ranging from 2.5 to 4.0 scales shoot⁻¹. In June, the population started increasing and reached 5.5 scales shoot⁻¹. Further build-up during the month of July caused the population to reach 7.0 scales shoot⁻¹, and in August it was 8.5 scales shoot⁻¹. The highest population (9.5 scales shoot⁻¹) of black scale was recorded in the month of September. A gradual decline from this date onwards resulted in a population of 5.0 scales shoot⁻¹ in December.

The Negative Binomial model captured trends in the olive fly population throughout the year, showing increases during the spring/summer and decreases during the fall/winter. For the most part, the model captured seasonal patterns and trends. When the olive fly population increases, it is assumed that the temperature and the availability of a host plant affect the process. Scale insects are not known to be rapid population builders the way other pests are. August and September were shown to be the most scale-infected months on olive trees and therefore the most critical for black scale monitoring.

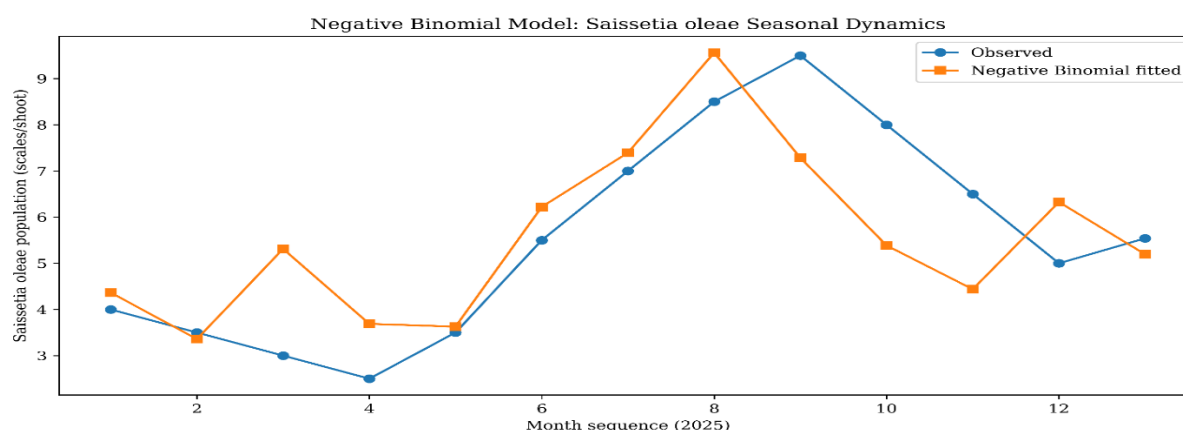


Figure 4. Seasonal population dynamics of *Saissetia oleae* (olive black scale) during the study period.

Comparative Seasonal Pattern of Olive Insect Pests

The comparative analysis showed that different species of pests showed particular seasonal patterns (Table 1). The most prevalent species of each pest group varied depending on the stage of olive fruit development. The results from the Negative Binomial Distribution suggested that olive pests had different seasonal activities and did not universally react to the change in environment. The fruit-feeding pests were active during the period of olive fruit development and maturation, while pests that fed on plant sap were active during the period of vegetative growth. The fruit fly, *Bactrocera oleae* exhibited maximum population (14) during Oct Month, while lowest population of Moths trap⁻¹(7.2) was evidenced during April month.

Table 1: Seasonal population peaks and maximum abundance of major olive insect pests.

Pest species	Maximum population	Peak period	Population unit
<i>Bactrocera oleae</i>	14.0	October	Flies trap ⁻¹
<i>Prays oleae</i>	7.2	April	Moths trap ⁻¹
<i>Euphyllura olivine</i>	9.0	March	Nymphs shoot ⁻¹
<i>Saissetia oleae</i>	9.5	September	Scales shoot ⁻¹

Correlation Analysis Between Olive Pest Damage and Abiotic Factors

The relationship between major olive pest damage parameters and selected abiotic factors were determined during the 2025 growing season in olive orchards of Qilla Saifullah, Balochistan, using Pearson correlation analysis (Figure 5). The aim of this analysis was to define the climatic variables influencing the behaviors of olive pests. The relationships defined above were interpreted by evaluating the corresponding correlation and p values (r , $p \leq 0.05$). Results of the correlation analysis demonstrated that most of the pest damage parameters were influenced by several climatic variables and the relationships defined were generally weak. While several biologically meaningful relationships were observed, the analysis demonstrated that in most cases, individual climatic variables were unable to explain variations in damage caused by olive pests.

Relationship Between *Bactrocera oleae* Damage and Abiotic Variables

Positive correlations between olive fruit fly (*Bactrocera oleae*) and temperature variables were weak (Figure 5). Damage from *B. oleae* was weakly positively correlated to maximum temperature ($r = 0.10$, $p = 0.748$). Minimum temperature ($r = 0.13$, $p = 0.694$) and average temperature ($r = 0.12$, $p = 0.718$) also showed weak positive correlations. On the other hand, fruit fly damage and precipitation showed a weak negative correlation ($r = -0.11$, $p = 0.728$). The temperature variables had a positive correlation with fruit fly damage. This could mean that rising temperatures may lead to an increase of fruit fly activity and/or survival. The positive temperature associations imply that the flies may be more active at higher temperatures, but the influence of temperature on fruit flies is likely weak. Higher temperatures also may accelerate insect metabolism, reproduction and movement. There may be other factors affecting the infestation level of *B. oleae*. The available and ripening olive fruits may affect the fly population. The fly population also may be affected by soil moisture and other factors.

Relationship Between *Euphyllura olivina* Damage and Abiotic Variables

The olive psyllid (*Euphyllura olivina*) showed no relationship with any abiotic factors (Figure 5). Minimum temperature was weakly negatively correlated with pest damage ($r = -0.28$, $p = 0.372$). Average temperature followed the same trend ($r = -0.27$, $p = 0.388$) as did maximum temperature ($r = -0.30$, $p = 0.343$). Precipitation also showed a weak negative association ($r = -0.14$, $p = 0.663$) with olive psyllid damage. The absence of significance of the above associations do not negate the fact that a decrease of temperature may reduce the Olive psyllid population, and an increase of temperature may produce stress, dehydration and reduces the survival of the immature psyllids. These data suggest that moderation of climate and *E. olivina* may be negatively correlated. Population establishment of olive psyllid may be limited to more moderate climatic conditions.

Relationship Between *Prays oleae* Damage and Abiotic Variables

The olive moth showed weak positive correlation with respect to selected variables of climate. Among the climatic variables, maximum and average temperatures showed positive correlation with olive moth ($r = 0.16$ and 0.14 , respectively) and minimum temperature showed weak positive correlation ($r = 0.09$). (Figure 5). Olive moth appears to be positively impacted with increasing temperatures. Of the variables considered, precipitation showed a weak negative impact ($r = -0.24$) on damage caused by the olive moth. Cool and dry conditions may lead to an increase in olive moth infestation. It is possible that rain may help suppress the olive moth population by affecting survival of olive moth eggs and larvae and/or by affecting the activity of olive moth adults. The presence of synchronous flowering in the olive tree, ensures that there are sufficient fruits in the following year. Other abiotic factors may help influence the population of olive moth.

Relationship Between *Saissetia oleae* Damage and Abiotic Variables

Saissetia oleae showed the most pronounced relationship with temperature. Maximum temperature and minimum temperature ($r = 0.44$, $p = 0.155$) showed a positive relationship with *S. oleae* ($r = 0.38$, $p = 0.222$). Positive relationships were shown by average temperature ($r = 0.40$, $p = 0.202$). Although the relationship between precipitation and *S. oleae* was positive ($r = 0.13$, $p = 0.697$), it is likely warmer conditions and/or higher temperatures foster the development of the scale insect. It has been shown that a higher minimum temperature will help offset mortality during overwintering. Therefore, it is reasonable to infer that low nighttime temperatures likely limit the development and/or population growth of *S. oleae* under the Qilla Saifullah climate conditions.

Relationship Between Total Pest Damage and Abiotic Variables

Total pest damage showed little relation to all measured abiotic factors. The positive relation with maximum temperature was weak ($r = 0.19$, $p = 0.55$) and similar relations were shown by minimum temperature ($r = 0.19$, $p = 0.554$) and mean temperature ($r = 0.20$, $p = 0.53$) (Table 2). A weak negative relation with total pest damage was shown by precipitation ($r = -0.21$, $p = 0.521$). The relations above indicate that the total pest damage is not controlled by the abiotic factors studied. Climatic conditions and other factors (like the phenology of the host and microclimatic conditions of the orchard) play a role in pest population dynamics and affect olive pest infestations. Relying on climatic conditions to forecast olive pest outbreaks may not always be adequate. Thus, biotic and agronomic factors should also be taken into consideration.

Table 2: Pearson correlation analysis between olive pest infestation and abiotic factors.

Pest/Damage	Abiotic Factor	Pearson r	p-value	Significance
<i>Bactrocera oleae</i>	Avg Temp (°C)	0.12	0.7	ns
<i>Bactrocera oleae</i>	Avg Min Temp (°C)	0.13	0.7	ns
<i>Bactrocera oleae</i>	Avg Max Temp (°C)	0.10	0.7	ns

<i>Bactrocera oleae</i>	Total Precipitation (mm)	-0.11	0.7	ns
<i>Prays oleae</i>	Avg Temp (°C)	0.14	0.7	ns
<i>Prays oleae</i>	Avg Min Temp (°C)	0.09	0.8	ns
<i>Prays oleae</i>	Avg Max Temp (°C)	0.16	0.6	ns
<i>Prays oleae</i>	Total Precipitation (mm)	-0.24	0.4	ns
<i>Euphyllura olivina</i>	Avg Temp (°C)	-0.27	0.4	ns
<i>Euphyllura olivina</i>	Avg Min Temp (°C)	-0.30	0.3	ns
<i>Euphyllura olivina</i>	Avg Max Temp (°C)	-0.28	0.4	ns
<i>Euphyllura olivina</i>	Total Precipitation (mm)	-0.14	0.7	ns
<i>Saissetia oleae</i>	Avg Temp (°C)	0.40	0.2	ns
<i>Saissetia oleae</i>	Avg Min Temp (°C)	0.44	0.2	ns
<i>Saissetia oleae</i>	Avg Max Temp (°C)	0.38	0.2	ns
<i>Saissetia oleae</i>	Total Precipitation (mm)	0.13	0.7	ns
Total Pest Damage	Avg Temp (°C)	0.20	0.5	ns
Total Pest Damage	Avg Min Temp (°C)	0.19	0.6	ns
Total Pest Damage	Avg Max Temp (°C)	0.19	0.5	ns
Total Pest Damage	Total Precipitation (mm)	-0.21	0.5	ns

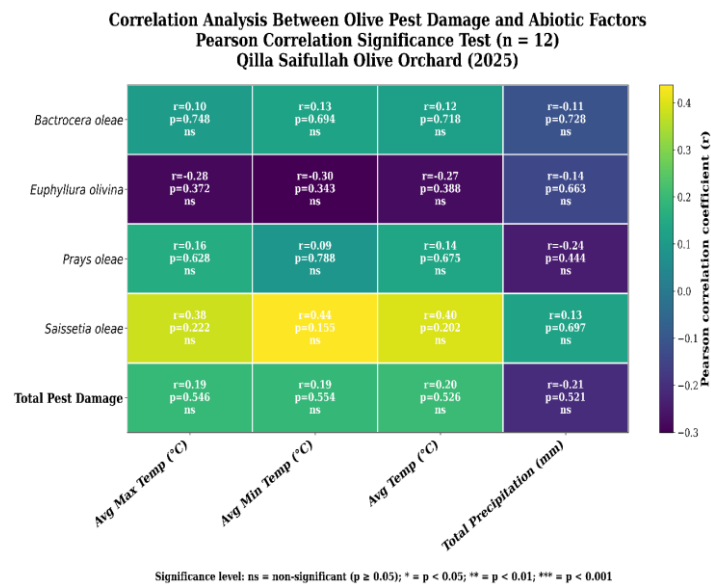


Figure 5. Relationship between abiotic factors and olive pest population dynamics.

Olive insect pest infestation (%) on different parts of olive tree

The level of infestation was different for each pest and plant part (see Table 3). Infestation of *Bactrocera oleae* on fruit was at the level of $15.8 \pm 0.7\%$. Damage caused by *Prays oleae* on the fruit and flowers was at the level of $10.5 \pm 0.9\%$. *Euphyllura olivina* infested shoots at the level of $21.0 \pm 1.7\%$. Infestation of *Saissetia oleae* on the branches was at the level of $17.5 \pm 1.4\%$. The high level of infestation of *E. olivina* on shoots shows that this pest prefers to infest shoots of higher plant parts which contain apical meristems of actively growing plant parts. Feeding of this pest on young shoots affects plant's vigor.

Table 3: Comparative infestation intensity of major olive insect pests under field conditions.

Olive insect pest	Damage parameters	Infestation (%)
<i>Bactrocera oleae</i>	Fruit infestation (%)	$15.8^{ab} \pm 0.7$
<i>Prays oleae</i>	Fruit/flower damage (%)	$10.5^b \pm 0.9$
<i>Euphyllura olivine</i>	Shoot infestation (%)	$21^a \pm 1.7$
<i>Saissetia oleae</i>	Branch infestation (%)	$17.5^a \pm 1.4$

Mean values followed by different letters indicate significant differences based on Tukey's HSD test at $P \leq 0.05$.

Influence of Insect Pest Infestation on Physio-Morphological Attributes of Olive Tree

The presence of insects negatively impacted the morphological and physical characteristics of the olive plants compared to the control plants. Plants infested with insects showed a decrease in vegetative growth as well as leaf development and ultimately, affected the plant's ability to conduct photosynthesis. This shows that the feeding activities of insects on the plant negatively impacted the plant's physiology.

Plant Height (cm), Leaf Area Index and Chlorophyll content (SPAD)

The control plants (healthy) had the highest recorded plant height at 251.3 ± 2.03 cm as shown in (Table 4). Plants infested with insects had decreased height growth. *Bactrocera oleae* had the least height reduction at 244.3 ± 1.45 cm. Plants infested with *Prays oleae* had a height of 238.0 ± 1.73 cm. The least height plant was observed in plants infested with *Euphyllura olivina* at 224.0 ± 2.31 cm. Plants infested with *Saissetia oleae* had a plant height of 230.0 ± 2.65 cm. It is expected that reduced height growth is due to reduced transportation of nutrients, reduced photosynthetic activity, and diversion of plant growth resources toward stress responses.

Moreover, Insect-infested olive plants exhibited a significant decline in leaf area index than healthy plants (Table 4). The control plants (healthy) recorded the maximum LAI (3.30 ± 0.06). Leaf expansion and canopy development was inhibited by the presence of pests. Among the studied pests, *Bactrocera oleae* had the least effect on LAI (3.05 ± 0.03) while the least values were recorded for the nymphs of *Prays oleae* (2.82 ± 0.04) and *Saissetia oleae* (2.52 ± 0.04). The greatest effect on LAI was caused by nymphs of *Euphyllura olivina* (2.10 ± 0.06). The decrease in LAI is an indication of reduced vegetative growth, and decrease in area of leaves available for carrying out the process of photosynthesis due to the feeding of pests.

However, insect infestation had negative effect in chlorophyll accumulation of olive leaves (Table 4). SPAD values indicate the control plants had a higher chlorophyll content (58.0 ± 2.1) than the other treatments. Among the insect treatments, *Bactrocera oleae* showed comparatively higher chlorophyll content (52.0 ± 0.6 SPAD). The chlorophyll content of the other treatments showed a decreasing trend and was 48.0 ± 1.2 SPAD for *Prays oleae*, 43.7 ± 1.5 SPAD for *Euphyllura olivina*, and 39.3 ± 2.4 SPAD for *Saissetia oleae*. The decrease in SPAD values for the treatments indicate pest-related stress and effects on plant physiology, especially loss of chloroplast activity and efficacy in the plant's ability to conduct photosynthesis.

Table 4: Influence of insect pest infestation on plant height of olive tree Leaf Area Index and Chlorophyll content (SPAD)

Insect Pest	Plant Height (cm)	Leaf Area Index	Chlorophyll content (SPAD)
Healthy control	$251.3^a \pm 2.03$	$3.3^a \pm 0.06$	$58.0^a \pm 2.1$
<i>Bactrocera oleae</i>	$244.3^b \pm 1.45$	$3.05^b \pm 0.03$	$52^{ab} \pm 0.6$
<i>Prays oleae</i>	$238^c \pm 1.73$	$2.82^c \pm 0.04$	$48^{bc} \pm 1.2$
<i>Euphyllura olivina</i>	$224^e \pm 2.31$	$2.1^e \pm 0.06$	$43.7^{cd} \pm 1.5$
<i>Saissetia oleae</i>	$230^d \pm 2.65$	$2.52^d \pm 0.04$	$39.3^d \pm 2.4$

Mean values followed by different letters indicate significant differences based on Tukey's HSD test at $P \leq 0.05$.

Influence of insect pest infestation on yield attributes of olive tree

Olive trees infested with insect pests had decreased values for yield-related attributes in comparison with control plants. Decreases in yield components were the result of the overall effect of pest feeding on plant and crop growth and development.

Fruit number/tree and

The control plants produced the most fruit ($2,176.7$ fruits tree⁻¹) (Table 5). The number of fruits produced was lowered as a result of each of the pest infestations. The highest level of fruit loss was associated with *E. olivina* (1525.0 fruits tree⁻¹), followed by *S. oleae* (1633.3 fruits tree⁻¹) and *B. oleae* (1711.7 fruits tree⁻¹). The infestation of *Prays oleae* reduced fruit loss (1815.0 fruits tree⁻¹). Generally, the results indicated that a decrease in the reproductive success of olive plants is due to pest infestation.

Fruit yield (Kg tree⁻¹)

The healthy control plants (49.0 ± 2.65 kg tree⁻¹) had the highest recorded fruit yield (Table 5). Plants in insect-infested treatments had lower fruit yields. Of these treatments, plants in the *Prays oleae* treatment had the highest fruit yield (41.0 ± 2.08 kg tree⁻¹), followed by *Bactrocera oleae* (38.33 ± 2.85 kg tree⁻¹), and *Saissetia oleae* (35.0 ± 1.73 kg tree⁻¹) treatments. The treatment with *Euphyllura olivina* had the greatest fruit yield reduction, with a yield of (30.7 ± 0.67 kg tree⁻¹).

Table 5: Effect of olive insect pest infestation on fruit number per tree and fruit yield of olive plants.

Insect Pest	Fruit number/tree	Fruit yield (kg/tree)
Healthy control	2176.7 ^a ±43.3	49 ^a ±2.65
<i>Bactrocera oleae</i>	1711.7 ^{bc} ±34.7	38.33 ^{bc} ±2.85
<i>Prays oleae</i>	1815 ^b ±37.5	41 ^{ab} ±2.08
<i>Euphyllura olivina</i>	1525 ^c ±43.3	30.7 ^c ±0.67
<i>Saissetia oleae</i>	1633.3 ^{bc} ±49.1	35 ^{bc} ±1.73

Mean values followed by different letters indicate significant differences based on Tukey's HSD test at $P \leq 0.05$.

Discussion

The current study used Negative Binomial regression to analyze seasonal changes in the population of four economically important olive pests: *B. oleae*, *P. oleae*, *E. olivina* and *S. oleae*. The study also used correlation analysis to analyze the abundance of these pests and the influence of climate on olive plant physiology and yield. The analysis of pest abundance and their relation to climate helped understand when and why there were fluctuations in olive yield. The study identified the biological needs and phenological stages of the olive plant that affected pest species and how the interaction of pest species with the olive plant influenced the pattern and extent of the pest species. Thus, based on biological needs and synchronization with the phenological stages of the olive plant, pest species demonstrate seasonal variation in their population. It was observed that *B. oleae* was found to be relatively inactive during winter and early spring, and gradually increased during the summer months. Populations peaked in October. This activity was associated with fruit ripening and maturation of the olive crop. Results of this study agree with earlier studies that suggested that the population of the olive fruit fly is largely influenced by the availability and the stage of ripening of the olive fruit. In the Eastern Mediterranean, *B. oleae* attack olive trees and other hosts in the region during the fruit maturation and crop ripening season. *B. oleae* infestation declines during the winter months (Ordano et al., 2015). Podgornik et al. (2013) suggested that the abundance of the olive fruit fly during a given season is largely controlled by the annual precipitation levels and the extreme low temperatures of the season, particularly the summer and winter months. In the current study, positive relationships between *B. oleae* and average monthly temperatures were reported, and a negative association was found between average monthly precipitation and *B. oleae*. It was postulated that the lack of correlations between the average monthly precipitation and temperature and *B. oleae* was likely due to the use of monthly averages. Moreover, In prior findings, the results of this study also indicate that the population dynamics of *P. oleae* are synchronized with olive phenology, especially the stages of flowering and fruit development (Sylvestre et al., 2014). Likewise, recent studies also indicated that thermal conditions influence the development of *P. oleae* and that there is an optimal temperature range beyond which the performance of the organism declines and is negatively impacted (El Aalaoui & Sbaghi, 2026). These results of the present study indicate that low correlation between monthly temperatures and the levels of attack by the pest do not indicate thermal independence. However, the peak of *E. olivina* in this study was associated with vegetative growth, emergence of shoots, and development of reproductive organs. Seasonal changes of the *E. olivina* population were reported by Guessab et al. (2021), who indicated that the olive psyllid population increased in spring because of the presence of young plant tissue, which is needed for feeding and psyllid reproduction. The decrease in *E. olivina* population in summer is attributed to psyllid reproduction over-maturation and thermal limitations. It was reported that psyllids lay eggs in the immature ovules of spring and the developing embryos are negatively impacted by heat (El Aalaoui et al., 2025). These findings showing similarity with current results. Moreover, in another study population growth of *S. oleae* showed a gradual increase throughout the summer, and the highest population levels of the growing season in late summer. This gradual increase and dependence on warmer temperatures for population establishment and development is a characteristic of scale insects. Similarly, increases in black scale populations in olive orchards have been reported (Ilias & Hammadi, 2017). Similar seasonal behavior of black scale populations was reported in Egypt (Mesbah et al., 2020). Compared to the other studies pests, *S. oleae* was most influenced by low temperatures. Low temperatures during the winter may negatively influence survival and development. However, recent research has shown that low and high temperatures during the night enhanced survival and development of *S. oleae* (El Aalaoui et al., 2025). However, relationship between pest abundance and abiotic factors was considering the limits of the current study, lack of correlation between abiotic factors and pest damage may be attributed to the inability of the study to capture all relevant environmental factors. It is widely recognized that biotic factors can influence the population density of insects. Depending on the type of insect and the factors influencing it, density may be affected by various factors including temperature, humidity, and presence of competitors, predators and parasitoids. It can be suggested that the relationships may not be linearly correlated by monthly averages. There are several pest modelling studies where linear relationships between abiotic factors and pest density have been reported only after using nonlinear functions or advanced modelling techniques. In ecological studies, where count data are predominantly clumped and over-dispersed, species abundance may be modelled using negative binomial regression, which is more appropriate than Poisson regression in absence of adequate evidence to support the other way (Erdoğan

et al., 2017). Therefore, failure to incorporate nonlinear functions to capture complex interactions between pests and environment may account for the absence of significant relationships in the current study. And in another findings the effects of pest infestation on olive physiology and yield were observed where the findings of this study indicate that Olive plants infested with insects had adverse effects on plant height, leaf area index, chlorophyll content, and fruit yield and number. Variations in growth performance of infested plants indicate feeding activities of olive pests adversely affected the normal development of plant vegetative structures and reproductive organs, and impacted the photosynthetic activity of the plants. Among the studied insect species, *E. olivina* had the most adverse effects on the physiology of olive plants, which might be due to the insect's direct feeding activities on young shoots and inflorescences. *E. olivina* has been reported to have negative effects on the vegetative and reproductive organs, and yield of olive plants (Guessab et al., 2021; El Aalaoui et al. 2025). *Bactrocera oleae* had less effects on vegetative parameters of Olive plants in this study, but larvae of this species feed on olive fruits, resulting in premature fruit drop (Paredes et al., 2015), and lowering the quality of the olive fruits (Ordano et al., 2015). *Prays oleae* infestation causes a reduction in the yield of olive plants due to feeding on different parts of the plant (El Aalaoui et al. 2025). *Saissetia oleae* infestation also adversely affected olive plants due to reduced plant vigor and honeydew sooty mold production (Mesbah et al., 2020).

Conclusion

Olive (*Olea europaea* L.) is an important fruit crop, while sustainable of this crop is adversely affected by various insect pests. It was concluded from the current findings that variability in pest populations is due to complex interactions of biology of the pests, olive crops and phenology of the crops. Variability in climatic conditions of the study site was not strongly related to variability of pest populations. Pests negatively impacted the olive crop by reducing plant height, leaf area, and chlorophyll content as well as number of fruits and olives. The greatest impact was caused by *E. olivina*. Shoots infested by this pest also had the lowest yield of olives. Other pests evaluated also negatively impacted the olive crop by reducing height and reduced yield. The results confirm that development and implementation of pest monitoring programs and phenology-based pest management programs improve the productivity of olive crops. These programs not only help to control pest populations, but also improve crop sustainability in semi-arid regions.

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