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EXPLORING POPULATION DYNAMICS OF THE ASIAN AMBROSIA BEETLE XYLOSANDRUS CRASSIUSCULUS (SCOLYTIDAE: COLEOPTERA) AND CULTIVAR RESISTANCE IN PAKISTANI MANGO ORCHARDS

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ABSTRACT

The bark beetle, *Xylosandrus Crassiusculus*, poses a significant threat to mango orchards in Pakistan. The population buildup of this noxious pest is responsible for mango sudden death disease (MSDD) within the country. Therefore, the current research was designed to observe the population dynamics and cultivar resistance of the bark beetle in the major mango-growing areas, namely Sanghar, Matiari, Tandoalhyar, and Mirpurkhas districts of Sindh, which were selected for the study. From each district, four mango orchards were randomly selected. Each orchard comprised 1000 trees, covering a total area of 12 acres. From each orchard, 20 mango trees were randomly investigated. Bark beetle damage was assessed by measuring perimeter square sections (15.24 cm long) of stems at the attack site, designated as a sampling unit. The maximum population was recorded in Tandoalhyar and Mirpurkhas compared to the other districts of Sindh. Correlation results regarding the mean population of the bark beetle showed a positive relationship (r = 0.59, 0.70, 0.63, and 0.73) between temperature and the mean beetle population. Conversely, the relationship between relative humidity and the mean population was negative (r = -0.51, -0.58, -0.33, and -0.41) with significant differences at ($P < 0.05$) in all four selected districts. The highest disease severity (25.98%) was recorded on the Sindhri variety, while the lowest disease intensity (8.2%) was found on the Began Pali varieties. Based on the current findings, it is recommended that mango growers closely monitor their orchards by regularly observing the trunks from April to June for bark beetle infestations. In case damage symptoms appear on the mango trees, an integrated approach should be implemented for effective orchard management.

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INTRODUCTION

Mango (*Mangifera indica* L., Anacardiaceae) is globally recognized as the King of Fruits in tropical and sub-tropical regions worldwide (Masood et al., 2010). Many biotic and abiotic factors adversely affect the yield (both quality and quantity) of mangoes in Pakistan (Jiskani et al., 2007; Nasir et al., 2014; Fateh et al., 2022; Kiran et al., 2022; Shahbaz et al., 2023). Mango Sudden Death Syndrome (MSDS) is one of the serious threats to the mango industry (Khuhro et al., 2005). In Sindh, the production of mango trees has been decreasing due to the attack of insect pests such as the mango mealybug

(*Drosicha mangiferae*), mango hopper (*Idioscopus clypealis*), midge (*Erosomya indica*), scale (*Aulacaspis tubercularis*), fruit fly (*Bactrocera dorsalis*) (Brown et al., 2006), and the mango bark beetle, *Xylosandrus crassiusculus*, (Stebbing), which frequently attacks mango trees in Pakistan (Saeed et al., 2011).

Bark beetles are highly dangerous pests of orchards and forest trees worldwide. Currently, more than six thousand species of bark beetles have been recorded in tropical and sub-tropical regions globally (Kazmi et al., 2005). A survey conducted by Khuhro et al. (2005) revealed that many high-yielding mango cultivars are affected by the Asian ambrosia beetle *X. crassiusculus* (Scolytidae: Coleoptera) in the Sindh Province. The bark beetle is responsible for mango sudden death disease (MSDS) in mango orchards, ultimately leading to a decline in mango cultivation (Qureshi et al., 2021).

For population buildup, dispersal, and development, favorable temperatures are required (Ranger et al., 2010). High or low temperatures adversely affect the biology of the beetles (Werle et al., 2012; Steininger et al., 2015). The successful propagation of the ragweed beetle depends on appropriate temperature, light intensity, wind direction and speed, as all of these factors can affect the female's ability to recognize and orientate stress escapes from a new host, and then fly to the host (Kendra et al., 2012). This phenomenon, known as directional spread, offers the greatest chance for successful colonization (Iqbal et al., 2007). Temperature is important; if it is too cold, the metabolic responses necessary for flight may be impaired (Ranger et al., 2016), and the ectothermic beetles may not be able to adequately operate the flight muscles (Ranger et al., 2013).

Adult emergences mostly depend on air temperature in April-May every year (Mizell and Riddle, 2004). Werle et al. (2012) reported that some previous studies describe an early spring population peak followed by a summer decline, while others include a possible second, late summer peak for southern populations. There is no systematic information on the seasonal abundance of *X. crassiusculus*, apart from a few reports of its population in mango orchards (Khuhro et al., 2005) and host plant communities (Gandhi et al., 2010).

To reduce infestation in mango orchards, proper monitoring is crucial for timely insecticide use, selecting the best location within the nursery and for trees, and developing a push-pull management strategy. Therefore, there was a need to study the seasonal abundance/population dynamics and outbreaks of the bark beetle on mango plants to understand its role in managing this noxious insect pest. This study will also be useful for predicting proper control strategies in Pakistan. The aim of the present research was to monitor the movement of the bark beetle throughout the year under field conditions, assess cultivar resistance, and analyze disease intensity in different mango-growing areas across various districts of Sindh.

MATERIALS AND METHODS

Study area

For the study of population dynamics and cultivar resistance in four major mango-growing areas (Matiari, Tandoalhyar, Sanghar, and Mirpurkhas), orchards were selected from each of these districts. Four mango orchards were randomly chosen. Each orchard was comprised of 1000 trees, covering a total area of 12 acres. Within each orchard, 20 mango trees were investigated. The procedure outlined by Masood et al. (2008) was followed to assess disease severity in the mango trees. Infestation by bark beetles was identified through the presence of pinholes, while characteristic symptoms of MSDD (Masood et al., 2010) were exhibited by diseased trees. Furthermore, the relationship between temperature and relative humidity with the beetle population was explored during this study.

Assessment of bark beetle damage

Bark beetle damage was assessed by measuring perimeter square sections (15.24 cm in length) of stems at the site of attack, which were designated as sampling units. Three samples were taken from the base to the main stem section to estimate the extent of bark beetle damage, based on the number of holes, as described by Lozano et al. (2001). The average number of holes per tree was calculated for each tree species.

Varietal resistance

The aim of the current research was to identify the most resistant and susceptible mango varieties cultivated locally in mango orchards. The survey included widely cultivated mango varieties (Sindhari, Chaunsa, Langra, Saroli, Sonaro, Fajri, Anwar Ratul, and Began Pali).

Data collection and statistical analysis

Temperature and relative humidity (RH) data for the entire year were collected from the meteorological department of the respective districts. All collected data were analyzed using one-way analysis of variance (ANOVA), and the Least

Significant Difference (LSD) test at a significance level of $P < 0.05$ was employed to distinguish means with significant differences, using SPSS version 21 (IBM SPSS). Additionally, the correlation between temperature, relative humidity, and population for all treatments was assessed using XL-STAT version 2019.

RESULTS

Seasonal activity pattern of *Xylosandrus Crassiusculus* in four districts of Sindh province

The population of *X. crassiusculus* was studied across four districts in the Sindh province. The results concerning the monthly mean population of the bark beetle exhibited significant differences across all districts. The highest monthly mean beetle population was observed at 34.5 holes per tree in district Tandoalhyar during the first week of May 2019, when the temperature was 41°C with a relative humidity of 50%. Fluctuations in temperature and relative humidity were noted, with the highest beetle population occurring within a temperature range of 34°C to 36°C in Tandoalhyar district (Figure 1).

The second-highest mean population of bark beetles, with 280 holes per tree, was recorded in Mirpurkhas, following the Tandoalhyar district. This occurred when the temperature reached 41.30°C, and the relative humidity was recorded at 47.9%. The bark beetle population began to decrease, reaching 40 beetles per tree in the month of September as temperatures dropped (Figure 2).

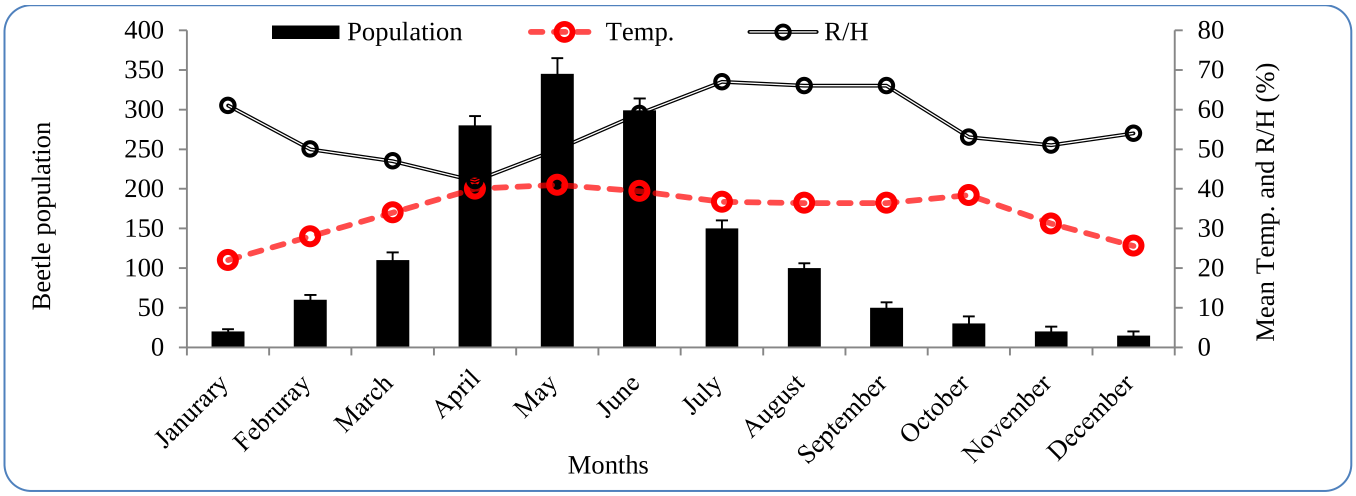

Figure 1: Mean Population of *X. crassiusculus* in district Tandoalhyar.

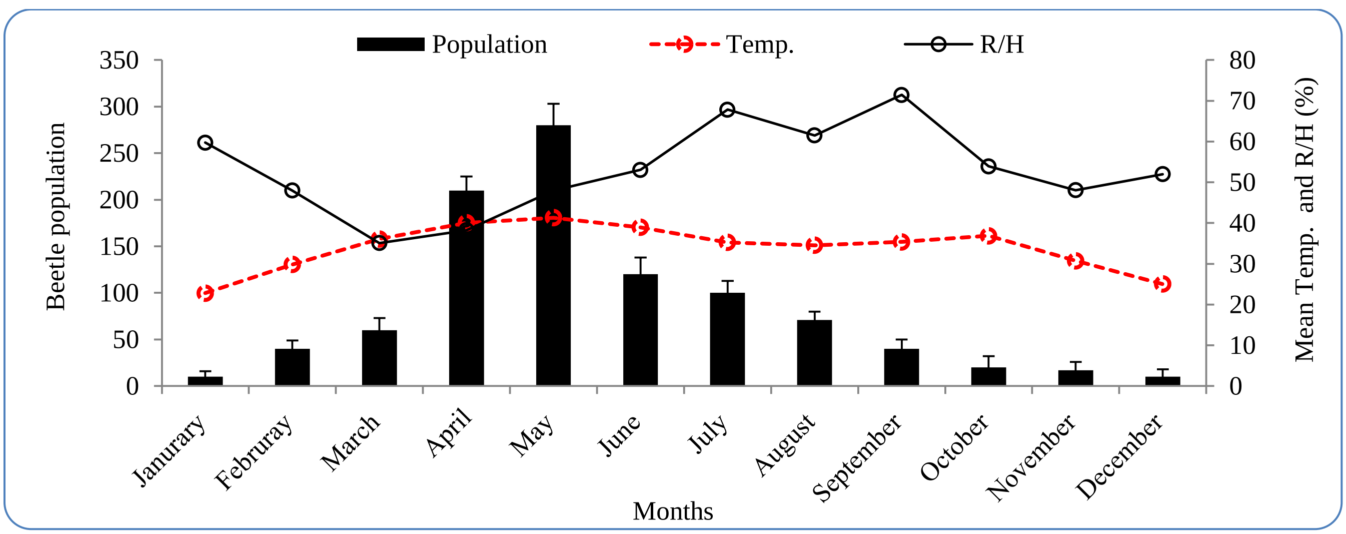

Figure 2: Mean Population of *X. crassiusculus* in district Mirpurkhas.

A similar trend in the beetle population was observed in Sanghar, where the highest average population of 220 holes per tree was recorded in the month of May, with a temperature of 40.0°C and a relative humidity of 51%. The population started to decrease from the last week of August, reaching 50 holes as shown in Figure 3. Likewise, the maximum mean beetle population in the Matiari district was observed in the month of May, with 150 holes per tree. However, the population decreased to 89 holes per tree in July as depicted in Figure 4.

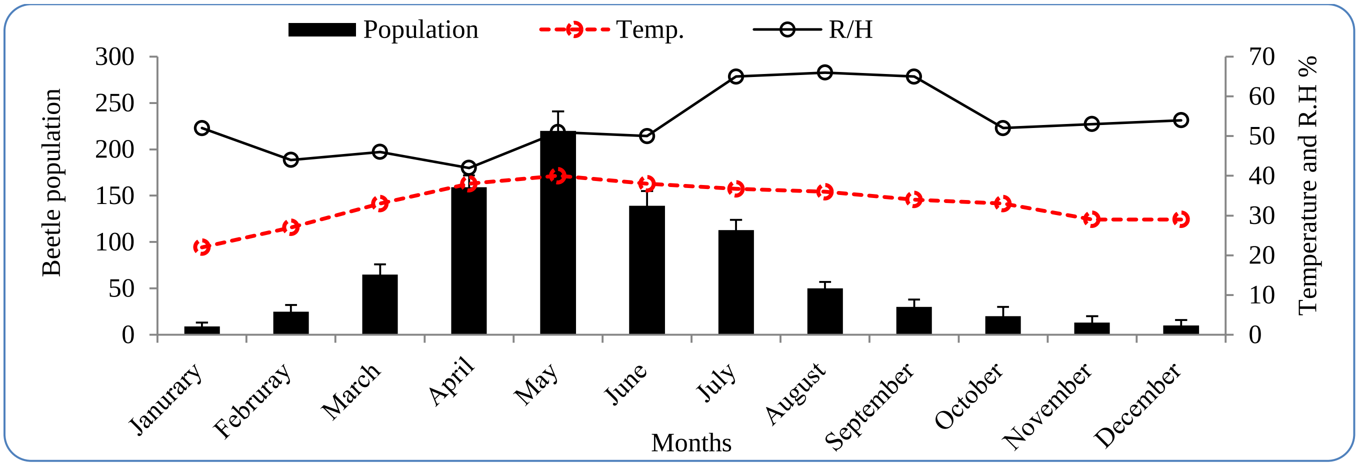

Figure 3: Mean population of *X. crassiusculus* in district Sanghar.

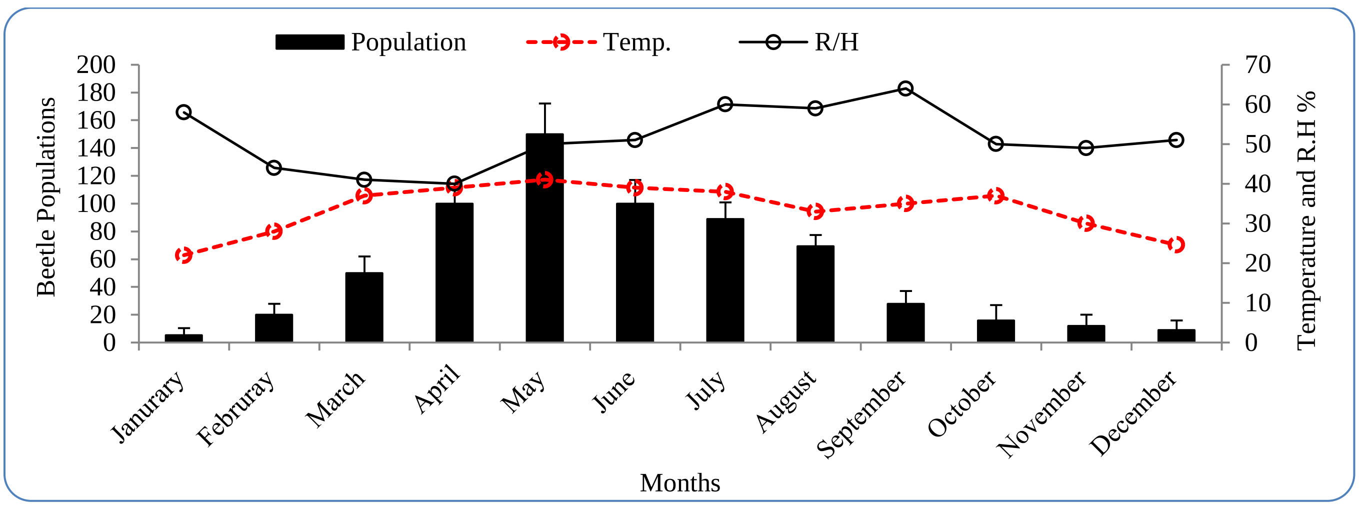

Figure 4: Mean population of *X. crassiusculus* in district Matiari.

Relationship of abiotic factors with beetle population in four districts

Temperature positively correlates with beetle population in all four districts (r = 0.59, 0.70, 0.63, 0.73) with significant differences at $P < 0.05$. However, the relationship between relative humidity and mean population was negative, showing significant differences (r = -0.51, -0.58, -0.33, -0.41) in Tandoalhyar, Mirpurkhas, Sanghar, and Matiari, respectively, at $P < 0.05$ (Table 1).

Disease severity on mango varieties

During the survey, the Sindhri variety was severely affected (25.98%) by the beetle population, followed by Chaunsa (19.52%), Langra (16.63%), and Sarloi (13.52%). On the other hand, the minimum disease intensity was observed in Began Pali (8.2%), followed by Sonaro (9.54%) and Anwar Ratol (9.63%), indicating higher tolerance to the disease (Figure 5).

District wise damage severity

The highest overall damage severity among all the surveyed districts was recorded in Tandoalhyar (37%), followed by Mirpurkhas (27%) and Matiari (20%). In contrast, the lowest damage severity was observed in Sanghar district (16%) as shown in Figure 6.

Table 1. Correlation matric between mean beetle population in study area and abiotic factors.

Districts	Factors	R	R^2	S.E	P value
Tandoalhyar	Temperature	0.59	0.61	0.30	0.0083
	Humidity	-0.51	0.70	0.09	0.6893
Mirpurkhas	Temperature	0.70	0.65	0.15	0.0012
	Humidity	-0.58	0.50	0.03	0.7411
Sanghar	Temperature	0.63	0.59	0.26	0.0265
	Humidity	-0.33	0.49	0.02	0.3781
Matiari	Temperature	0.73	0.55	0.11	0.0026
	Humidity	-0.41	0.31	0.06	0.9875

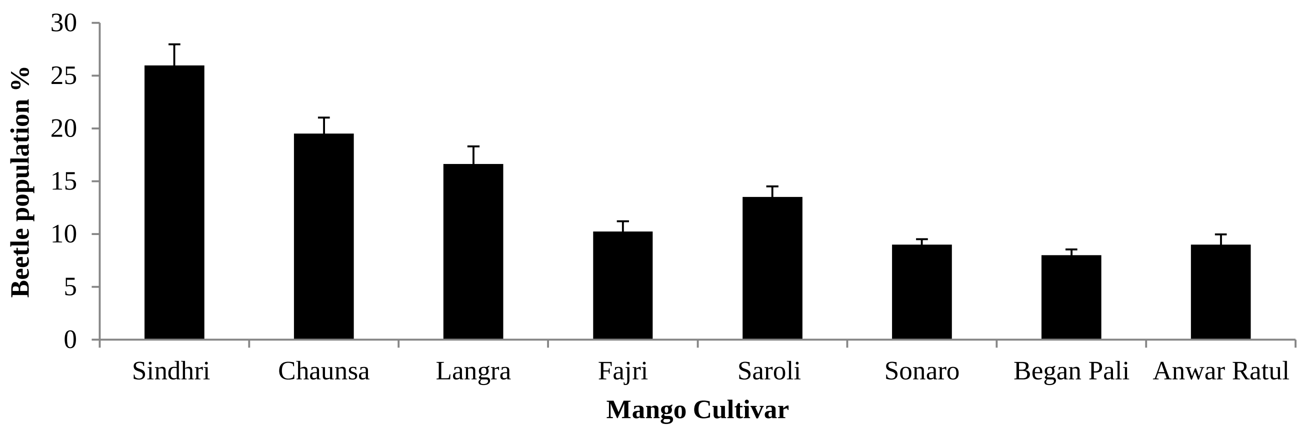

Figure 5. Disease severity (%) on different mango varieties.

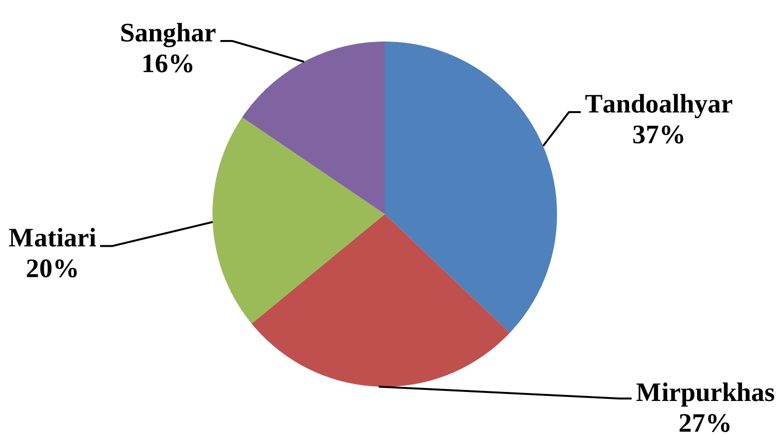

Figure 6. Disease intensity in different districts of Sindh.

DISCUSSION

The population dynamics and disease severity of the bark beetle are significantly influenced by abiotic factors such as temperature and relative humidity. This population trend was observed from March to the end of August during the current study. Bark beetle populations were found to be high in all surveyed areas, with Tandoalhyar and Mirpurkhas districts being heavily infested by this noxious pest compared to districts Sanghar and Matiari.

Changes in the mean population of the beetles in the study area could be attributed to variations in temperature and relative humidity, as suggested by our correlation analysis, which indicated that temperature strongly favored beetle population buildup. The highest mean beetle population was recorded from April to July in all districts, with the population observed to decrease from the month of August in all districts. A study by Qureshi et al. (2021) found that bark beetles are most active in March, and the months of May to August are crucial for their dispersal, movement, and causing MSDD in mango trees (Ranger et al., 2016). Additional evidence supporting our results indicates that the movement of bark beetles starts at the end of March and continues until April, remaining active until August to September (Masood et al., 2010).

Due to its consistent association with diseased trees and favorable temperatures, the beetle can serve as a vector for fungal spores causing sudden mango disease (Al-Adawi et al., 2006). The results of the present research indicate that the beetles are less active from the months of November to February, a finding consistent with Carrillo et al. (2014) and Masood et al. (2009), who noted minimal activity of *Hypocryphalus mangiferae* (Stebbing) during the November to February period (Lieutier et al., 2004). Previous studies support our findings, showing that many other bark beetle species also go into hibernation during oviposition periods and disperse once temperatures increase in May-June (Lieutier et al., 2004; Kazmi et al., 2005). Similar activity patterns have been observed in apple, eucalyptus, and palm trees (Lieutier et al., 2004).

During the current study, *X. crassiusculus* was predominantly found on diseased mango trees, in line with previous documentation by Saeed et al. (2011). Regarding disease severity, the highest disease severity was recorded in Sindhri, followed by Chaunsa, Langra, and Sarloi. These four varieties were the most susceptible to the disease. Conversely, minimum disease intensity was observed in Began Pali, followed by Sonaro and Anwar Ratul, all of which were found to be more tolerant to the disease. Similarly, Masood et al. (2012) assessed the damage caused by bark beetles in six mango varieties based on pinholes and found that not a single variety was resistant to this noxious bark beetle.

CONCLUSIONS

Based on the current study, it can be concluded that the highest monthly mean beetle population was observed in Tandoalhyar district, followed by Mirpurkhas, Sanghar, and Matiari. The correlation analysis indicated a positive relationship between temperature and the mean beetle population in all four districts. Conversely, there was a negative relationship between relative humidity and the mean beetle population, with significant differences observed. The highest disease severity was recorded in the Sindhri variety, followed by Chaunsa, Langra, and Sarloi varieties. On the other hand, the lowest disease intensity was found in the Began Pali variety.

Taking into consideration the findings of this study, it is advisable for mango growers to closely monitor their mango orchards. Regular observation of the trunks during the months of April to June is recommended to detect bark beetle infestations. In the event that damage symptoms appear on the mango trees, an integrated approach should be implemented for effective orchard management.

AUTHORS' CONTRIBUTIONS

KHQ conceived the idea, executed experiments, collected and arranged the data; AWS analyzed the data, wrote up the manuscript; AGL designed the experiments and guided the first author; MUNR analyzed and explained the metrological data; JMM compiled the results and proofread the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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